Value and Impact through Synergy, Interaction and coOperation of Networks

of AI Excellence Centres

GRANT AGREEMENT NUMBER: 952070

Deliverable D2.4 Report

Towards classification of European AI research & innovation topics

Project title	**Value and Impact through Synergy, Interaction and coOperation of Networks of AI Excellence Centres**
Grant Agreement number	**952070**
Funding scheme	**H2020-ICT-48: Towards a vibrant European network of AI excellence centres, CSA**
Start date of the project and duration	**09/2020 - 08/2024 (48 months)**
Project coordinator name	**University of Leiden**
Deliverable number	**D2.4**
Title of the deliverable	**Towards classification of European AI research & innovation topics**
WP contributing to the deliverable	**WP2-Mobilizing the European AI community**
Deliverable type	**Report**
Dissemination level	**Public**
Due submission date	**31 August 2022**
Actual submission date	**17 August 2023**
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Internal reviewers	**ULEI – Technical compliance** **Executive Board – Formal review**

History of changes		
When	**Who**	**Comments**
15-8-2021	Claudio Lazo (TNO), Tjerk Timan (TNO)	Initial structure, based on the project proposal and results from the initial literature review on roadmaps.
1-2-2023	Claudio Lazo (TNO), Kristina Karanikolova (TNO)	Document further developed after several NoE consultations.
24-2-2023	Claudio Lazo (TNO), Kristina Karanikolova (TNO)	Document improved based on internal review with Joachim de Greeff, Géraud Guillioud and Freek Bomhof
16-3-2023	Claudio Lazo (TNO), Kristina Karanikolova (TNO)	Document improved based on formal and technical review from project partners
10-5-2023	Kristina Karanikolova (TNO)	Changes made based on review by Executive Board, including shifting the AI topics classification to AAAI AI Topics (under AI technology category).

Confidentiality	
Does this report contain **confidential** information?	Yes ☐ No ☑
Is the report **restricted** to a specific group?	Yes ☐ No ☑ *If yes, please precise the list of authorised recipients*:

Contents

Executive Summary

This document describes the classification of topics developed in VISION CSA. The classification methodology, limitations, topics and logic are presented. Examples of activities from the Networks of Excellence from the ICT-48 EU call are also provided. Although other classifications are also possible and existing, this classification aims to facilitate a common language among research, policy and broader stakeholders for the contemporary EU AI landscape on trustworthy AI.

List of Abbreviations

AI	Artificial Intelligence
AAAI	Association for the Advancement of Artificial Intelligence
ADRA	AI, Data and Robotics Partnership
AI4Europe	A European AI On Demand Platform and Ecosystem
AI4Media	A European Excellence Centre for Media, Society and Democracy
CLAIRE	Confederation of Laboratories for Artificial Intelligence Research in Europe
EBDVF	European Big Data Value Forum
EC	European Commission
EIT	European Institute of Innovation & Technology
ELISE	European Learning and Intelligent Systems Excellence
GDPR	General Data Protection Regulation
HumanE-AI-Net	HumanE AI Network
ICT-48	H2020-ICT-48-2020, Towards a vibrant European network of AI excellence centres
IJCAI	International Joint Conference on Artificial Intelligence
NoE	Network of Excellence, by default referring to an ICT48 consortium
R&I	Research and Innovation
SME	Small or Medium Enterprise
TAILOR	Foundations of Trustworthy AI - Integrating Reasoning, Learning and Optimization
TNO	Toegepast Natuurwetenschappelijk Onderzoek, Netherlands Organisation for applied scientific research

1. Introduction

1.1 Setting the scene

Artificial Intelligence (AI) has been rising to the top of many technology agendas and strategic action plans in roughly the last five years[1]. Where the technology domain of AI has a long and broad history in science and in certain application domains, the rise of both pervasive digital services and widely expanded infrastructure, many forms and types of AI are now able to go from lab-setting and small-scale proof of concept to large scale experimentation and implementation in a multitude of sectors and, in general, in daily life. In many digital systems, AI is already a core element. With increased attention for AI, increased investments and strategies are also observable – especially in EU policy[2]. The way in which strategies and their actions and investments (in knowledge, infrastructure, testing facilities, data, etc) are being shaped and organized, varies widely - globally and per country as well as in granularity. While strategic policy documents may refer to objectives and principles at the *macro* level, action plans of individual organization might address more concrete, tactical steps at the *meso or micro* level (see Figure 1.1). Thus, strategic documents and messages from the different societal levels may have different granularity. This may create challenges in communication and in creating a common vision towards future developments.

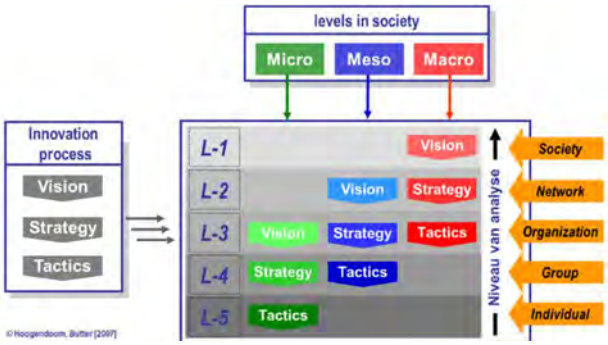

Figure 1.1: Visions, strategies and tactics are usually defined at different societal levels (source: TNO)

A common language is therefore needed to facilitate the discussion among actors at different levels and to make a connection among the policy plans and existing activities. One way to develop a common language is connecting and exemplifying links among various topics – a classification. This is expected to contribute to peer exchange, information dissemination, and orchestration of efforts, to use resources wisely and to develop capabilities to steers and shape the direction of this technology.

1.2 Towards an aligned classification: objective and overall structure

This deliverable presents a first attempt made in the VISION project to help align the language in the research and innovation community on trustworthy AI. This has been done by mapping overarching EU strategic AI topics to (key) activities of the four AI networks of excellence (NoEs) working on trustworthy AI.

[1] See among others the EC communication (2018), "Artificial Intelligence for Europe", COM(2018) 237 final; EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final; Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B., AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of artificial intelligence, EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163.;

[2] See for instance the strategic priorities set in the Digital Europe Programme on capacities development in five priority areas, one of which is AI (The Digital Europe Programme | Shaping Europe's digital future (europa.eu))

The classification follows the main policy priorities set out by the European Commission: to develop an AI ecosystem or trust and ecosystem of excellence in Europe. Development of both strategic priorities is supported by and requires research and knowledge development on particulate AI topics. To enable the distinction between the various and continuously developing list of AI research topics on the one hand and the horizontal enablers used in supporting the EU AI ecosystem, the suggested classification distinguishes among two main groups (see **Error! Reference source not found.**):

- **AI research topics** – for this group, it was decided to use an existing classification that is well known in the international AI research community - the AAAI AI technology classification. To illustrate the relevance in the European AI R&I community, several examples of the NoEs research areas are included, showing how research within these AAAI areas are progressing.
- **AI ecosystems and framework condition topics** – subdivided to the objectives of building an *ecosystem of trust* and *ecosystem of excellence*. These cluster topics and activities that strengthened the framework conditions, methods and enablers needed to support adoption, application, trust and legal and operational framework for AI (loosely following the EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020)).

Ultimately, both sides need to be developed and are interconnected. Further, the two sides of the classification are also connected to four top-level goals:

1. *European brand of AI*: AI that reflects the EU values as well as "our values and fundamental rights such as human dignity and privacy protection"[3];
2. *Europe as AI powerhouse*: Europe becoming the trusted digital leader in a fierce global competition, focusing on industrial competitiveness through leveraging AI, while the technology is also considered "critical enabler for attaining the goals of the Green Deal"[4];
3. *Data-agile European economy*: A common approach to large enough scale and scope, as well as to address potential fragmentation of the single market[5];
4. *Advance knowledge on AI*: furthering the research and knowledge on AI and addressing key societal and policy questions[6].

The developed classification and mapped links can act as a shared language. This – in the opinion of the authors - is useful for:

- Connecting activities to strategic EU policies and objectives;
- Positioning the activities of the NoEs;
- Explore strategic directions, by mapping connection among topics;
- Find others acting within a certain topic;
- Compare work within a certain topic by providing a scope of the discussion;
- Easier to describe pathway to impact in future proposals.

[3] EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final, p.2
[4] Ibid
[5] Ibid
[6] See EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final, pp. 5-6.

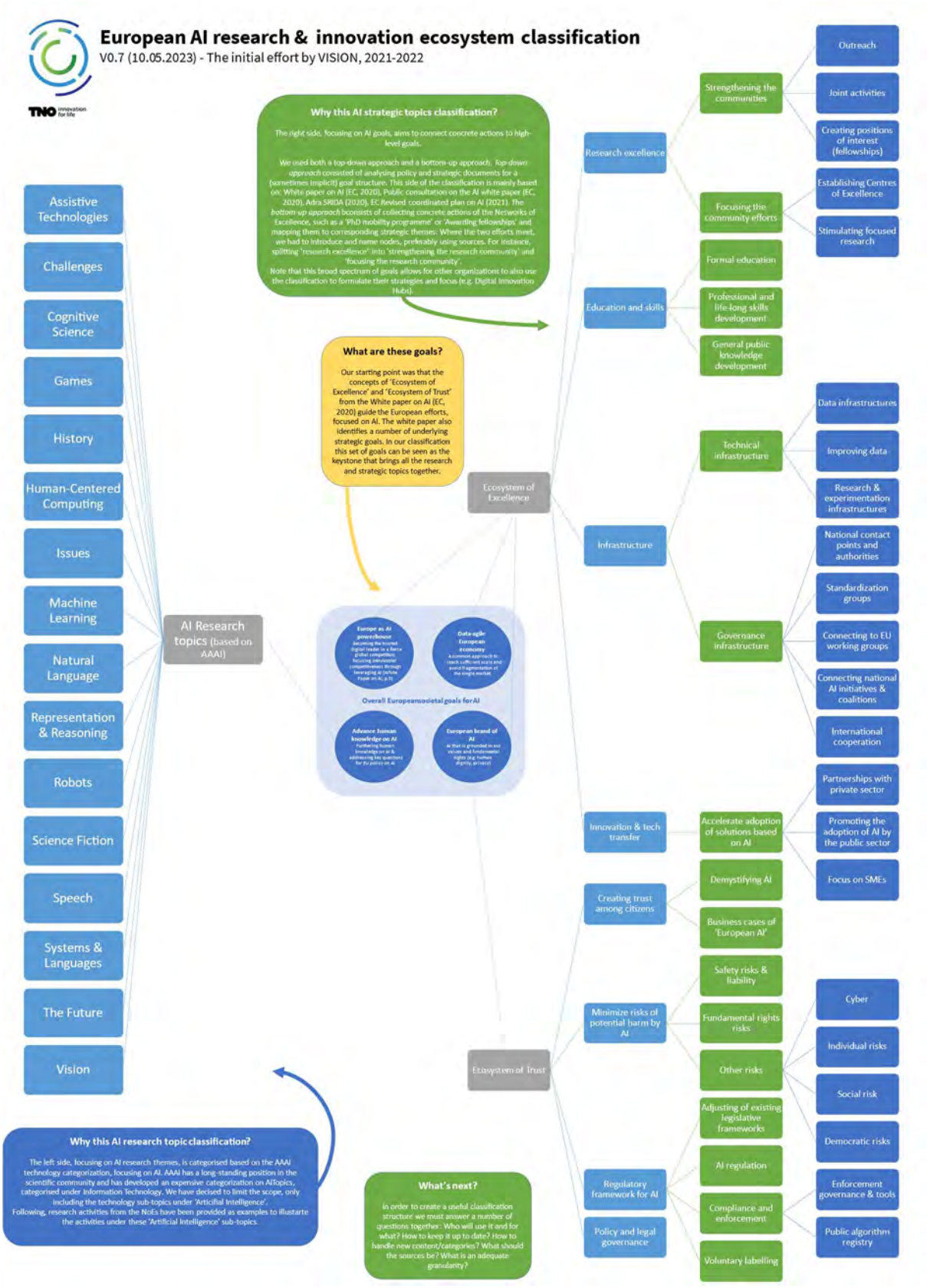

Figure 2 Overall categorization and connection among the topics (source: Vision 2023)

1.3 Methodology

To construct the classification, the VISION team has followed a structured and iterative process combining literature review, consultations with the NoEs and broader community. Each of the individual steps are outlined in more detail in Figure 1.3.

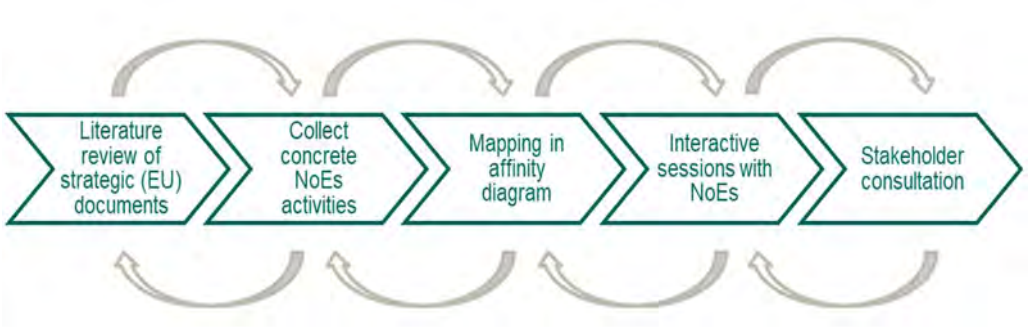

Figure 1.3: overview of the methodology

To facilitate the development of a common framework of discussions, an attempt has been made to categorize the high-level goals and related activities from the different stakeholders in the AI research and innovation ecosystem.

We have used both a top-down approach and a bottom-up approach. The top-down approach provided the broader structure of the classification and is based on literature review of several policy and strategic documents, including, but not limited to: White paper on AI (EC, 2020), Public consultation on the AI white paper (EC, 2020), Adra SRIDA (2020), EC Revised coordinated plan on AI (2021). Further, the AI research topics of the NoEs have been classified building on the JRC AI Watch (Samoili et al., 2020) taxonomy to provide an independent structure and align with European policy and research. This was later extended with research topics from the NoEs and several external European networks[7].

The bottom-up approach consisted of mapping concrete (planned) activities of the NoEs and connecting these to the related policy/strategy area identified in the top-down approach. This has been done in interactive sessions as well as through extracting information from the strategic roadmaps from the NoEs, websites and publicly available documents. In total thirteen meetings took place among the NoE representatives and the VISION team:

- Four individual online meetings with each of the NoEs to present the structure and receive feedback;
- Three joined workshops with representatives from each of the NoEs (incl. ELSA and euROBIN);
- Three presentations / workshops aimed at the larger AI and data community;
- Two community workshops where the NoEs were present (in addition to other stakeholders);
- A concept board to collect inputs was also opened for at least 4 weeks, and the results have been incorporated in the EBDVF report[8].

[7] ADRA, AI4EU, CLAIRE, BDVA/, ELLIS, AI-DIH-Net

[8] The report has been published on the VISION website: https://www.vision4ai.eu/report-ai-topics-categorization/ The report has been published on the VISION website: https://www.vision4ai.eu/report-ai-topics-classification/

Where the bottom up and the top-down classifications met, we introduced and named nodes, preferably using sources (conference categories, other strategic documents). It should be noted that the mapping meant that some new nodes were added, some topics were merged, or others split. Therefore, the classification presents a new merge of topics. At the same time, working with the broader common policy goals provides a broad mission that allows us and the community to align, relate their own activities to the mapping and even focus activities.

Additionally, following the co-clustering of topics with the NoEs, public consultations on the structure were used to gather feedback from the broader community via two community workshops (in 2021 and 2022) as well as a session in the European Big Data Value Forum in 2022.

1.4 Limitations

It should be noted that this is **only one attempt**. Others have also attempted to cluster, map, and categorize the different (research) AI topics (on national and EU level)[9]. For instance, during this project, but after the development of a classification, the EIT 'Creation of a taxonomy for the European AI Ecosystem' (EIT, 2021) has been published. While the EIT mapping presents some commonalities, both initiatives have apparently been working parallelly without being aware of the fact. Therefore, this VISION output can be seen as contribution to the field but further alignment with the community (including in policy) would be needed to ensure that the classification is adopted.

Furthermore, this classification should be seen as only **one part of community building and development of the ecosystem**: The NoEs each have developed a strategic roadmap outlining the needs, progress and way forward for AI R&I and a way to proliferate these new technologies to society. While VISION initially was tasked with a development of a strategic common roadmap/paper, the activities have been restructures and an integrated strategic roadmap is currently under development under the leadership of TAILOR and ELISE. Still, a detailed analysis has been conducted to understand the plans and roadmaps of the NoEs and work towards creating a common classification of Trustworthy AI topics has rendered interesting discussions among the four NoEs as well as the broader AI community.

1.5 Structure of the document

To present the results, the document is structured along the two main 'sides/sub-categories' of the classification. Chapter 2 outlines the overarching topics and activities related to the development of the framework conditions and boosting the ecosystems of trust and excellence. Where possible, examples of the NoEs activities are provided as inspiration for the reader. Chapter 3 dives deeper into the AI research topics and how these correspond to topics identified by the NoEs. Lastly, Chapter 4 aims to draw some overarching conclusions and topics for further research based on the classification exercise and consultation meetings with the stakeholders.

[9] From conferences like AAAI Conference key words, to research papers such as the JRC AI Watch. Defining Artificial Intelligence key words, to various reports and papers such as the EIT Creation Of A Taxonomy For The European Ai Ecosystem.

2 Strengthening the AI ecosystem of trust and excellence: proving common goals and framework for AI activities

2.1 European AI Ecosystem goals

The European Commission[10] postulated two concepts that aim to support the general development, application, adoption and (regulatory) framework surrounding the various AI (and complementary enabling) technologies: 1) creating an Ecosystem of Excellence, and 2) an Ecosystem of Trust. We may look at the goals of the ICT-48 projects through the lens of these two ecosystems, as they align well.

2.2 AI ecosystem and topics classification

An **'Ecosystem of Trust'** sets out the legal framework and boundary conditions to minimize risks for the application of AI. As such, the topics contribute to addressing risks, increasing trust, and adherence to European principles and protection of rights. The eight topics discussed by the EC white paper on AI (2020) (based also on the High-Level Expert Group), have been further clustered merging a few topics related to the regulatory framework and enforcement, labelling, etc. Further, based on discussions in the consultations, and for completeness to address the trust building, we have added a category on creating trust in society by better understanding. Thus, the proposed classification results in four major categories:

1. *Trust by citizens* to use or be subject to AI applications;
2. *Regulatory framework* that structures and sets the boundaries for use AI and impact on the areas thus contributing to the trust in AI;
3. Methods and safeguards to *minimize the risks* of any potential harm;
4. *Policy and legal governance* distinguishing among compliance, certification, division of responsibilities among national and EU policy and legal development.

The topic **'Ecosystem of Excellence'** is more focused on the enablers that connect the different types of actors, at different geographical levels and different application domains to facilitate the development, deployment and uptake of AI[11] across the whole value chain. The ecosystem of excellence aims to align efforts and thus advance the knowledge/expertise on AI research and innovation, support the adoption and development of a data-agile European economy and ultimately ensuing that Europe becomes a trusted AI powerhouse on global level[12]. Adapting and clustering the eight topics outlined by the EU White paper and looking into already planned activities of the NoEs, we differentiate among the following 4 topics:

1. *Research excellence* developed via the research on various AI topics (see next chapter) as well as activities to strengthen the connection among research communities and focus efforts;
2. *Education and skills* which include efforts supporting for professional, academic/formal and general education and upskilling;
3. *Infrastructure* referring to the development and exploitation and use of technical and research infrastructure and a related access to/ governance of infrastructures to connect the different initiatives, operational levels and interconnected topics to reduce fragmentation and leverage on knowledge sharing on EU and – where appropriate – international level;

[10] EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final

[11] Ibid

[12] EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final, pp. 2-3

4. *Innovation and tech transfer* which groups activities supporting the adoption of AI research and solutions.

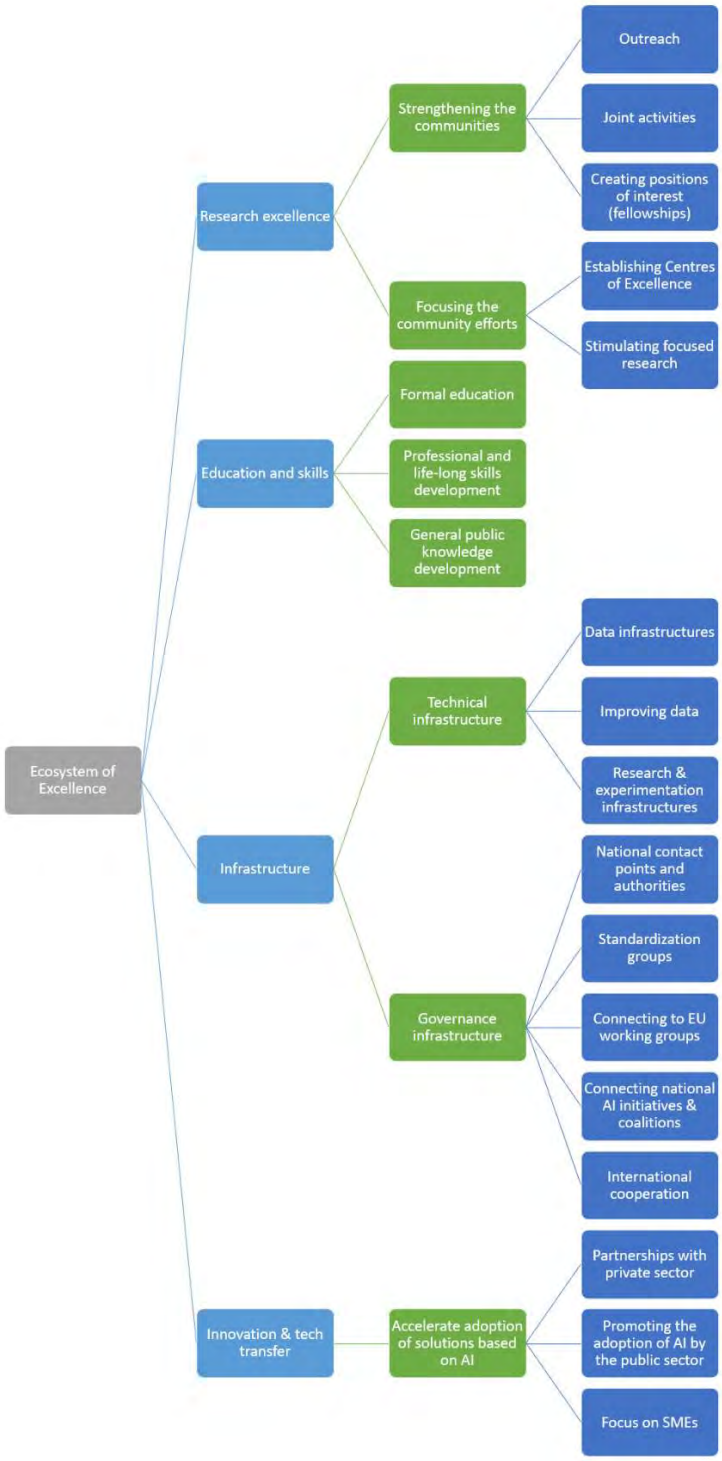

Figure 2.1: Ecosystem of Excellence

Looking at the connection between the two objectives (developing ecosystems of excellence and trust), one can relate the ecosystem of excellence to developing the methods and activities to progress the advancement of AI, while the ecosystem of trust provides the regulatory framework and boundary conditions to these.

2.3 Ecosystem of Excellence

Given that the NoEs represent research and innovation actions with a focus on the development of new knowledge, research and innovation, the framework condition activities in the development of an ecosystem of excellence are very much relevant. Further, this classification allows for other initiatives (more focused on deployment) to be mapped in the future (e.g. consider quadruple helix collaborations (like DIHs), the support activities offered in the AI on Demand platform, innovation actions as well as industrial activities along the whole value chain, etc). In the sections below, next to the structure, some examples of NoE activities are provided to illustrate the point and inspire the reader[13].

2.3.1 Research excellence

Actions may fall under two categories: **strengthening** or **focusing** the R&I communities. In addition, the NoEs are also contributing to academic and applied research and innovation; in particular AI research topics, which are discussed in detail in the next chapter.

[13] Note that the examples are in no particular order and do not imply ranking of the practice. The examples are also based on public documents and selected from the team drafting the deliverable.

Strengthening the R&I communities

In addition to the research activities (Chapter: AI technology research topic landscape), the R&I community is mainly strengthened via *community engagement*. In essence this means actions to stimulate interaction among researchers and in connection to industry, provide opportunity for R&I exchange among peers and leveraging on each other's strengths and expertise. The following types of community engagement are distinguished among:

- *Outreach* to promote results and to engage a larger ecosystem. Specific activities differ per stakeholder or network with examples ranging from actively engaging with AI-on-demand platform, publishing in journals, organizing conferences, etc.
- *Joined activities* to connect the academic and research progress to the needs across different topic groups as well as to link to industrial actors, relevant societal and policy stakeholders and their needs. (Cross-) topical exchanges, challenges, workshops (including industry), theme development workshops, community events, open days, etc are some examples where the NoEs and stakeholders have collaborated. Hackathons, competition, exchange and mobility programmes are also used to connect researchers and innovators across borders and around particular challenges.
- *Creating positions of interest*, such as e.g. joint PhD supervision, fellowships etc., are planned and can be used to further strengthen the research capacity in Europe.

The ICT 48 Networks of excellence are all engaging in activities to promote the potential and new research of the networks. It should be noted that while the bottom-up activities collected are somewhat research biased (due to the NoE nature of targeting upstream activities as Research and Innovations Actions), communication with and collecting of insights from other stakeholders are also used. Theme Development Workshops is one example of a mechanism through which a balanced exchange between industry, academia, and other stakeholders is organized around cross-cutting AI themes for ICT-48.

Focusing the efforts of the R&I community

Focusing actions is allows to pool resources and efforts to advance research in specific sectors and or technologies. The objective is to align (research) roadmaps, exploring potential collaborations, while also allowing for specialization. The VISION classification distinguishes among two actions contributing to this goal:

- *Establishment of AI Centres of Excellence* for specific expertise (AI lighthouses). The EC is supporting the establishment of such centres with the Horizon Europe programme and the NoEs themselves represent the research networks of excellence. The NoEs also contribute to the knowledge development and future strategic planning with identification of key topics. Centres of excellence focused on research are also supported with efforts to support infrastructures (see below) such as Testing and Experimentation Facilities.
- *Stimulating of focused research* (e.g. open calls for research, within specific themes or answering specific questions).

Example of an activity in 'Research Excellence':
Research agendas: addressing both the specific NoE areas and towards a joined strategic agenda
Network:

- ***Led by*** Tailor, ELISE, with support of VISION
- **Contributions from** AI4MEDIA, HUMANE-AI, and connections to ELSA and euROBIN

Activity done:
Each of the Networks of excellence has developed a research agenda that points to current and future research and innovation topics in their particular fields. See here for AI4Media, Humane-AI, Tailor, ELISE research agendas and roadmaps. As all the networks are contributing to the AI research excellence in Europe, the NoEs have also expressed willingness to collaborate and explore the possibility to developed a joined strategic research agenda, identifying higher-level conclusions, research and ecosystem needs, and research topics and in this way position the individual research topics, support the ecosystem, and the EU policy-makers. Tailor and ELISE have agreed to take the lead in the activity with support from VISION and contributions from all. For more details see report from second ICT-48 Community workshop organized by VISION4AI in Nov. 2022.
Contributing to/ Perceived added value: The individual research agendas and the expected joined agenda contribute to the focusing of the R&I activities to contribute to excellence in research. The process of exploring a joined research agenda on the other hand contributes to strengthening of the communities by establishing connection and joined activities among different communities.

2.3.2 Education & skills

The need to support understanding, talent and skills development in digital technologies to meet current shortage[14] and future needs has been emphasised by several industries, publications, policies and programmes. The EC AI white paper exility addresses the need for an aligned strategy among the Member States and on EU level, a prominent recent policy tool has been launched with the Digital Europe Programme and the €580 million budget for digital skills over an approximately 7 year period (2020-2027).[15] Further examples also include the AI-on-Demand Platform which The EU Member States also cooperate and in professional life-long learning and training, formal education (in schools and universities), general promotion of learning on a topic in AI. It should also be noted that skills development can go beyond the topic of AI or digital skills in general.

As skills and training are increasingly becoming a prominent policy objective, in the VISION classification, we have decided to distinguish among three different types of skills support:

- *Formal education*, including school and university education programmes (focused more on future workforce capacity training) as well as supporting activities. The NoEs and VISION for instance collaborate on The International AI Doctoral Academy (see below for AIDA).
- *Professional and life-long skills development* related to upskills, reskilling, and professional development activities such as courses or on the shop-floor training for the existing workforce, knowledge exchange programmes, etc.
- *General public knowledge development* on certain topic open to different parts of society such as introductory courses, videos, online lectures/short introductions, etc.

[14] See for examples the EC White Paper on AI (p. 6),
[15] Digital Europe Programme I Digital Skills and Jobs Platform (europa.eu)

Note that some activities in these categories might also contribute to additional objectives such as creating understanding and trust in AI, dissemination, as well as supporting the technology adoption but these are more secondary benefits.

Example of a practice supporting 'Education and skills':
International AI Doctoral Academy (*AIDA:* www.i-aida.org*);*
Network: AI4MEDIA, Vision, Humane-AI, ELISE, Tailor
Activity done:
The ICT-48 Networks of Excellence - AI4MEDIA, Vision, Humane-AI, ELISE, Tailor - and Vision have joined forces (under the co-leadership of AI4MEDIA and VISION) and started a joined initiative to coordinate the PhD/postdoc AI and training activities among the members. In this way, AIDA is expected to not only become a reference point with an overview of resources but also offer knowledge and expertise and thus attracting (PhD) talent in Europe and supporting the capacity and expertise across Europe. The initiative already includes a number of programmes, courses and an AIDA PhD curriculum.
Contributing to/ Perceived added value:
The AIDA initiative connects the different AI research networks in Europe and presents an easy-to-navigate overview of resources and activities. The AIDA courses – having been identified in the framework of the AI networks of excellence in Europe – also benefit from the AIDA seal of quality for courses, and access to a wide range of professors and experts across Universities and Research organizations in Europe. In the end, the efforts, materials, courses, etc, contribute to the capacity and expertise development in Europe.

2.3.3 Infrastructures

The classification distinguishes between **technical infrastructure** and **governance** of infrastructure as noted by the EC AI white paper. Access to and development of infrastructures (data and computing infrastructure) are essential to support excellence in Europe[16]. Further, coordination among the EU and Member States activities to ensure access, building scale as well as regional engagement (see EC 2021 Revised coordinated plan on AI)[17]. Both elements are needed in order to facilitate the further progress, experimentation and collaboration across the EU AI ecosystem.

Technical infrastructures

Technical infrastructures are important to enable access, connection, storage, use of data across Europe. Different instruments could be envisioned (also seen from various EU and national policies)[18]. As a consequence, we distinguish among:

- *Data infrastructures* which focuses on enablers to collect, share and use data sources. Here activities related to interoperability, standards, ecosystems are relevant. Examples of initiatives include the data spaces,[19] GAIA-X, exploring models to share data, open access, etc.;

[16] EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final, p.8
[17] And especially proposals I and II (pp. 13, 20 among others) of European Commission (2021) , "ANNEXES to the Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Fostering a European approach to Artificial Intelligence", 21.4.2021, COM(2021) 205 final
[18] See for instance Digital Europe and Horizon Europe programmes that differentiate among research and adoption and also consider ecosystem initiatives emerging from member states and then spreading across Europe (e.g. GAIA X).
[19] DSSC – Data Space Support Centre

- *Improving data* cluster is focused on the data quality, access rights, reference dataset, training data sets, ownership, privacy, etc. Connected are topics on fairness of access to certain data, legal obligations in anonymity and traceability, accuracy and representation of data sets, etc.;
- *Research and experimentation infrastructures* topic refers to the availability of underlying infrastructures for research, development but also experimentation and where needed demonstrations. There are a number of examples of such infrastructures on regional and national level and connections are made on EU level, e.g. European HPC Centres supporting and providing computing power[20], the AI testing and experimentation facilities (TEFs)[21], but also university, RTO, industrial facilities supporting related technologies like cybersecurity, robotics, quantum, etc.

Governance/political infrastructures

This category mostly focuses on the alignment at the different levels of governance needed to enable access the infrastructures, invest in new ones, ensure the coordination and exchange, connect different initiatives and generally ensure a level of coordination on EU level to enable the ecosystem of excellence. The following types of governance structures are distinguished among:

- Alignment with *national contact points and authorities* in order to coordinate activities, ensure representation, support synergies, economies of scale and provide a joined end-goal;
- *Standardization groups* to explore and prepare for future standardization (requirements) in different sectors and enable connectivity but also the pooling of expertise from difference disciplines, backgrounds and interest to drive adoption of ethical, technological, societal interest also on international level;
- *EU working groups* enabling the co-development and again connection between the national and EU level on particular topics – these could be working groups organized by the Member States, STOA, JRC, EP, EC, etc and could contribute towards strategy, policy, legislation development. Many of the public-private-partnerships also organize working groups among stakeholder types;
- *Connecting to national AI initiatives & coalitions* has also become more important with various partnerships, public-private networks and alliances operating on national level and with the potential to benefit from exchanging information or initiating bi/multilateral collaborations. The EU AI Watch platform for examples can be seen as a first step towards mapping of policies and the AI landscape in Europe. Other examples are initiatives like the AI-on Demand platform, or meeting forums such as conferences, brokerage events, consultations;
- *International cooperation* refers to efforts to collaborate and agree with international partners on how to ensure trustworthy AI application, joined principles, stimulate policy, industrial and stakeholder exchange. Here activities such as contributions to international organizations such as OCED, UN on the collection of data on implementation, use, policies supporting AI adoption can be mentioned.

Example of a practice contributing to "Infrastructures":
Micro project: "Collection of datasets tailored for HumanE-AI multimodal perception and modelling"
Network: HumanE-AI
Activity done:

[20] EU HPC Centres of Excellence (hpccoe.eu)
[21] Testing and Experimentation Facilities (TEFs): Questions and answers | Shaping Europe's digital future (europa.eu)

The supported micro project provided rich labelled data with actions at different levels with an updated Opportunity dataset (OPP++). The project is expected to later be continued with a machine learning challenge.

Contributing to/ Perceived added value:

The Humane-AI strategic research agenda has identified the need to support the ecosystem with a research methodology connecting different disciplines and addressing human centric AI. In addition, it is pointed that there is a need "to provide tools and **infrastructure such as data sets**, evaluation scripts, repositories, base line evaluation sets and benchmarking support" (p.15 of Humane-AI D6.1). To that end, some of the supported micro projects have explored the development of sufficiently labelled training data (and data sets). The Micro projects in Humane-AI support the collaboration of two or more partners over a short period with the objective to produce a tangible outcome. For more, see HumanE AI Network -Strategic Research Agenda, p.15, 23.

2.3.4 Innovation, technology transfer & knowledge transfer

This category relates to activities supporting the adoption and transfer of knowledge from research to innovation and finally solutions for end users. Looking at the different EU instruments (HE, DEP), public-private-partnership objectives, the EC AI white paper and the related public consultation, the following sub-topics can be distinguished:

Accelerate adoption of solutions based on AI

- *Partnerships with private sector,* to connect research, public sector societal objectives and private sector interests and needs enabled via the public-private partnership ADRA, EDIHs, but also the different national PPPs, sectorial groups, strategic regional/national networks, etc. Collaborative projects (for R&I), joined strategy building, demonstrators and use case promotion are further examples of partnership with the private sector;
- *Promoting the adoption of AI by the public sector*[22] connects to the public authorities as an end user and the particularities related to that: impact on citizens, reliability, impact of the decision making, legacy systems, etc. Activities may be connected to different levels: developing AI solution for smart cities, municipalities using AI solutions, data-driven policies, etc.;
- *Focus on SMEs* has been added as a separate category to reflect the greater focus on support (financially, with tech and non-tech support and even connections) of SMEs and scale-ups in Europe to adopt digital technologies, experiment and start the process towards adoption. The support to SMEs for uptake was also noted in the EC public consultation for the white paper, noting that 86% of SMEs having indicated that support for collaboration with larger companies and academia are important and 73% indicating raising awareness of benefits of AI as important. The role of the Digital Innovation Hubs in supporting adoption of AI in SMEs was also recognized[23]. Examples of activities could be open calls for AI projects, demonstrations, examples of potential in different sectors, researcher consultations/ in-residencies etc.

Example of a practice: ELISE ***Example of a practice contributing to "Innovation, tech & knowledge transfer":***

[22] EC (2020), "WHITE PAPER: On Artificial Intelligence - A European approach to excellence and trust", COM(2020) 65 final, p.8.

[23] See European Commission (2020), "Public consultation on the AI White Paper: Final report November 2020", p.6 on the role and important tasks of DIHs.

Cascade-funding for SME projects (ELISE Industry (elise-ai.eu))
Network: ELISE
Activity done:
ELISE has so far run two open calls for cascade funding where SMEs could receive a budget of 60.000 EUR and academic mentoring to develop a project contributing to a challenge identified by the partners. The projects were focused on developing novel services or applications of AI.
Contributing to/ Perceived added value:
The activity contributes to the industry-academic collaboration as well as to the technology and knowledge transfer of research to industry (for more information see the link above).

2.4 Ecosystem of Trust

As the Networks of Excellence coordinated and supported by VISION are all contributing to the (research) development of trustworthy AI, the regulatory framework and supporting trust building activities are directly relevant. While in the EC white paper, the topic is mostly focused on risks mitigation and creating a legal framework, in the public consultation on the white paper[24], an interesting divergence exists in how the different stakeholder types (academia, private sector, citizens) perceived the need for a legislative framework. This divergence, coupled with comments from different VISION consultations on the need to improve understanding of opportunities and limits of AI, and in order to introduce completeness with active contribution to trust, a category on 'creating trust' was introduced. The other three sub-categories cluster some of the topics presented by the EC white paper, which can provide a framework to position various activities. Below, each of the categories is further explained and examples from activities provided.

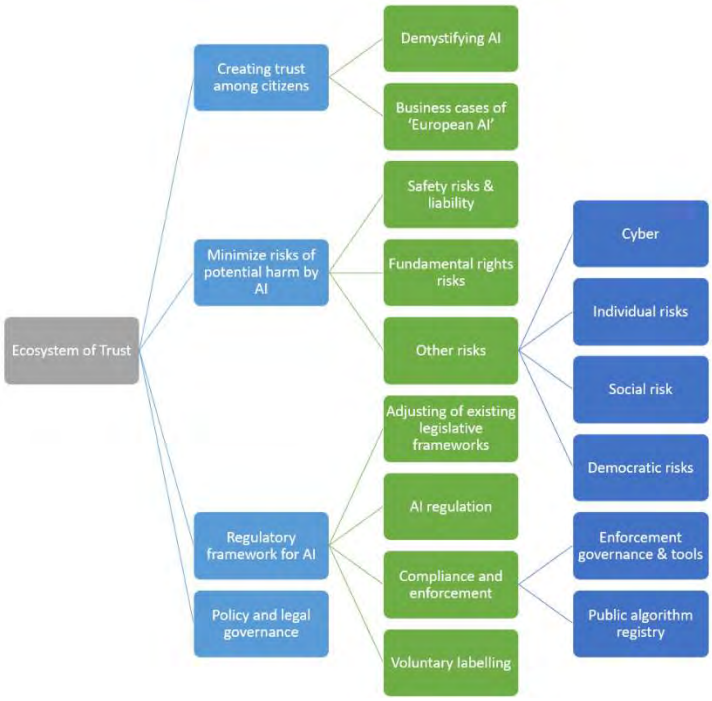

Figure 2.2: Ecosystem of Trust

2.4.1 Minimize risks of potential harm by AI

The two main risks that AI poses and identified in the EC white paper and public consultation are breach of **human fundamental rights** and **safety risks**[25].

Safety risks & liability

AI is anticipated to impact different sectors, services and products and as the safety risk (personal or product safety) materializes, the applicable regulatory and liability regime needs to be clarified.

[24] https://digital-strategy.ec.europa.eu/en/white-paper-artificial-intelligence-public-consultation-towards-european-approach-excellence-and
[25] EC 2020 White paper on AI (p.10); and the EC 2020 public consultation on the white paper (p.7).

Discussions, working groups, study of safety risks are expected activities. While safety and liability risks might not be explicitly relevant for the centres of excellence, the academic and research objectives of the 4 NoEs do not exclude the topic and connects to advancing knowledge on the human-cantered and trustworthy AI application. Other projects and studies in particular sectorial or specific application studies have also examined the topic, e.g. in studies of autonomous driving, AI in medical/healthcare[26], and more.

Fundamental rights risks minimization

The topic related to protection of fundamental rights and minimizing risks of decimation, bias, ethical use of AI. There are many possible activities: when it comes to research efforts and collaborations, many EU projects, including among the NoEs, working on topics such as robustness, fairness, privacy. Further, various projects have developed methodologies and support in ethical evaluations[27], and support intermediaries like DIHs may help in bringing these risk assessment methodologies into practice.

Other risks

We further distinguish among the following other types of risks (also identified through the EC white paper and via the public consultation):

1. *Cyber risks* connected to cybersecurity, cyber threat;
2. *Individual risks*: privacy risks, personal security risks, mental health risks, loss of control or choice;
3. *"Social" risks:* risk of discrimination, differentiated pricing, profiling, risks to people with disabilities;
4. *Democratic risks*: filter bubbles, financial detriments, interference in political processes, manipulation, risk to democratic oversight, freedom of speech and the challenge with misinformation.

As with the risks above, many different activities could be connected: from studying the potential risks on AI application (in particular area/sector), to connecting a fragmented ecosystem to increase (good) practice sharing, collection of use cases, evaluation and mitigation strategies, improving explain ability of AI, etc.

Example of a practice: Media AI Observatory (for more details see: AI4media project)
Network: AI4MEDIA
Activity done:
The network has conducted a detailed analysis on EU regulatory landscape – including the AI and data regulatory package, safety & liability regulations, etc. – and their impact on the media sector. As such the analysis aims to provide an overview and is a first step towards and AI observatory that can support the media sector stakeholders as well as act as an overview of activities.
Contributing to/perceived added value:
Providing an overview and connections among various legal and policy objectives and analysis of impact on a particular sector. The activity naturally also supports understanding of the regulatory framework as well as understanding and trust among citizens.

[26] Artificial Intelligence and Liability in Health Care (case.edu)
[27] See for example the SIENNA project addressed ethical issues in three new and emerging technology areas: human genomics, human enhancement and human-machine interaction. For more information: SIENNA legacy - SIENNA (sienna-project.eu)

2.4.2 Regulatory framework for AI

Providing, enabling AI development and at the same time ensuring a reassuring legal framework is at the core of the EU ecosystem of trust – it sets the requirements for the use of AI in Europe. As with the EC white paper (2020) and the public consultation on the said paper, several elements can be outlined as sub-objectives:

Adjusting existing legislative frameworks, related to policy and regulatory awareness and activities to evaluate and if needed update existing legislation to address possible risks of AI. Here, policy recommendations to address risks are identified according to the previous category via legislative or regulatory mechanisms are examples of activities. Further, analysis and support to (industrial and private) stakeholder on the inter-connection among AI requirements, robustness, privacy, etc. and a particular second framework (e.g. liability) are examples of activities.

AI regulation setting out horizontal rules and compliance requirements has been a key activity on EU and national level. With the proposed AI Act[28], a flurry of opinions, publications, reactions and assessments have emerged, including among the NoEs, which can not only contribute with research on the topic but can also bring together and inform, consult their stakeholders[29]. Looking at the AI regulation, there are a number of sub-topics where the EU AI ecosystems can contribute, including:

- Clarification of scope and definitions - non-binary distinction (low/high risk), exceptional instances clause, promotion of the trustworthy principles (and further development in technology application) to allow for the certification. Further research and development of benchmarking tools, impacts and auditing of continuously evolving AI algorithms is expected to continue in future years;
- Regulatory sandboxing to support innovation and experimentation. Other examples are the open calls for developing solutions in collaboration with research and industry.

Compliance and enforcement

Connected to AI regulation, compliance and enforcement – on EU and national level – remain a topic of discussion and research. The regulations and expected compliance burden could (and have) prompted activities among the broader AI community related to explaining, educating, systemizing, awareness creating among societal stakeholders. The following sub-categories can be distinguished with regard to compliance (based on EU policy and white paper):

- Research and develop enforcement governance & tools related to continuous / self-assessment / independent bodies, guidelines, etc.;
- Public registry of standardised validation datasets as a way to support continuous validation as noted in the EC public consultation to the AI white paper.

[28] Proposal for a Regulation Of The European Parliament And Of The Council Laying Down Harmonised Rules On Artificial Intelligence (Artificial Intelligence Act) And Amending Certain Union Legislative Acts, Com/2021/206 Final

[29] See for example F. Naretto (2023) "Imagining The Landscape After The AI Act", Tailor online publication, here.

Voluntary labelling (non-high risk applications), including research on the (unintended) impacts of voluntary labelling systems, involvement of different societal groups (e.g. via consultations, workshops, etc), are possible examples of activities.

Example of a practice: Tutorials on "Legal Protection by design" (15 December 2020, Online) and "The proposal for an AI Act" (26 June 2021, Online)
Network: Humane-AI
Activity done:
One of the topics addressed by the project relates to legal and ethical bases for responsible AI. In this context, two tutorials have been developed that discuss the AI act and the concept of legal protection by design. The relevant materials can be found here.
Contributing to/perceived added value:
The tutorials present a position and research on the topics and support stakeholders (e.g. developers and computer scientists or internal partners) in better understanding the proposed AI Act and the GDPR, thereby contributing to the understanding, connections among legal instruments, tools available.

2.4.3 Policy and legal Governance

This category relates to the governance in the policy development and legal systems on national level and alignment and overview on EU level. The AI Watch and OCED provide overview of policies and with AI Act regulation, alignment on EU level can be expected.

Example of a practice: Plan for close collaboration between research, policy-makers and legal experts to support development of explainable AI solutions.
Network: ELISE
Activity done: As part of their AI Roadmap (2021), ELISE has prominently included the role of alignment with social interests (see third pathway). One aspect of this is to engage and collaborate with policymakers as well as experts from legal and social fields to ensure adherence to legislation, possibilities and challenges in various sectors (e.g. healthcare) and support AI 'explainability' (see ELISE SRA (2021), p. 6, 12, 24, among others).
Contributing to/perceived added value: Further alignment of relevant stakeholders (connecting technology development and research with policy, legal and social actors).

2.4.4 Creating trust among citizens

For completeness, we have added the subgoal of 'creating trust among citizens', as it is a more direct method of creating trust, rather than minimizing risks. This sub-category consists of:

Demystification of AI, related to activities explaining to the general public knows what AI is and what it is not, explaining what the limits of AI are and what it implies, what are opportunities, use cases, blogs, etc. This demystification topic was mentioned in the ICT-48 community workshops and the BDVF consultation.

Business cases of European AI, relates to the connection with industry and exploring how data access, availability, (new) business models and distributing value in the ecosystem. The SRIDA by ADRA[30] also note the need to support EU economy to unlock and benefit from developments in AI, data and robotics.

Example of a practice: Tailor's Handbook of Trustworthy AI ***Example of a practice contributing to "Creating trust among citizens":***
Tailor's Handbook of Trustworthy AI
Network: Tailor
Activity done:
To support the better understanding on challenges and developments on the topic of trustworthy AI, TAILOR has developed a hand-book that supports users – predominantly researchers and students – in familiarizing themselves with the dimensions of trustworthy AI and current developments. The handbook acts like a "wiki" page and is also expected to be connected to tutorials and teaching materials.
Contributing to/perceived added value:
The handbook can be seen as a contribution to the better explain the dimensions and risks and understanding of trustworthy AI, thus demystifying the concept.

[30] Zillner, S., Bisset, D., Milano, M., Curry, E., García Robles, A., Hahn, T., Irgens, M., Lafrenz, R., Liepert, B., O'Sullivan, B. and Smeulders, A., (eds) (2020) "Strategic Research, Innovation and Deployment Agenda - AI, Data and Robotics Partnership. Third Release." September 2020, Brussels. BDVA, euRobotics, ELLIS, EurAI and CLAIRE

3 AI technology research topic landscape

3.1 Different classifications and their limitations

As the main goal of the ICT-48 projects is the stimulation of excellent AI research, an analysis of research themes and topics is meant to help the NoEs in finding commonalities and to better position themselves in the landscape of relevant scientific disciplines and research topics. Moreover, it provides a classification that can be high-level enough for non-technologists, such as policy makers, to connect to AI research niches.

Different classifications of AI (research) topics exist. In the deliverable the AAAI key words are used as these have been highlighted by researchers as an established classification. Initially, this classification was based on the AI Watch taxonomy[31] to better represent the connection to the policy thinking but a strong preference for an established research classification was expressed in the last phases before submitting the deliverable. The rationale is that established research classifications like AAAI offer a recognized and quite detailed topic mapping, thus allowing for a more detailed analysis (than the broader topics) while also ensuring continuity, thus limiting the development of yet another AI technology topic classification.

Before we continue to point to some examples of research areas by the NoEs for particular topics, we outline some of the advantages and characteristics of existing classifications.

The AI Watch taxonomy

The AI taxonomy, proposed by the Joint Research Centre as a definition of AI "to be used as a basis for the AI Watch monitoring activity" is focusing on techno-economic analysis.[32] The AI Watch taxonomy has been constructed through a rigorous process and based on existing scientific AI taxonomies: AITopics[33], Association for the Advancement of Artificial Intelligence (AAAI) and International Joint Conferences on Artificial Intelligence (IJCAI), the High-Level Expert Group on Artificial Intelligence (HLEG) and European and member state reports. Furthermore, it has been complemented through topic modelling using NLP, and integrated, based on the HLEG definition and keywords to describe sub-domain categories such as 'Computer vision'. The definition distinguishes between core AI topics – referring to fundamental goals of AI – and transversal AI topics, such as application or ethics, which are common to all identified domains.[34]

[31] Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B., "*AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of artificial intelligence"*, EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163

[32] Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B. (2020), "*AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of artificial intelligence"*, EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163 and Samoili, S., Lopez Cobo, M., Delipetrev, B., Martinez-Plumed, F., Gomez Gutierrez, E. and De Prato, G. (2021), "AI Watch. Defining Artificial Intelligence 2.0", EUR 30873 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-42648-6, doi:10.2760/019901, JRC126426, p7.

[33] aitopics.org

[34] Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B., "*AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of artificial intelligence"*, EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163

The JRC classification offers a quite balanced interdisciplinary classification, focused on policy monitoring. Yet, while it builds on existing classifications, based on recommendations from researches in the field (in the VISION partnership), it was decided to proceed with a more technology focused and established classification.

The International Joint Conference on Artificial Intelligence (IJCAI)[35]IJCAI is a non-profit corporation with two divisions: Conference and Journal division. The initiative is focused on Artificial Intelligence, including promotion and dissemination in view of its scientific and educational objectives. The organization has organized IJCAI conferences since 1969 (not every year).[36] The calls for papers usually provide guidance on eligible topics, spanning a broad range of AI developments or areas with intersection with AI.[37]

Association for the Advancement of Artificial Intelligence (AAAI)

AAAI is focused on the scientific ecosystem, contributing to further research, understanding and responsible use of Artificial Intelligence.38 The non-for-profit organization organizes conferences, workshops, symposia, awards grants and scholarships, and publishes quarterly magazine and series of proceedings. The AAAI is recognized among the scientific community and has published a categorization of AI Topics (official publication of AAAI), where publications can be filtered on numerous criteria, including 'technology' and 'industry'. Over 494148 publications are classified.39 The AITopics (on AI technology) were used to describe the technology topics and give examples of the NoE research.

3.2 AI technology topics: some examples from the NoEs

As seen above, there are many examples of classifications of AI topics. To simplify the process, given the long-standing position of the AAAI in the research society, and to respond to preference from practitioners, the approach was moved from

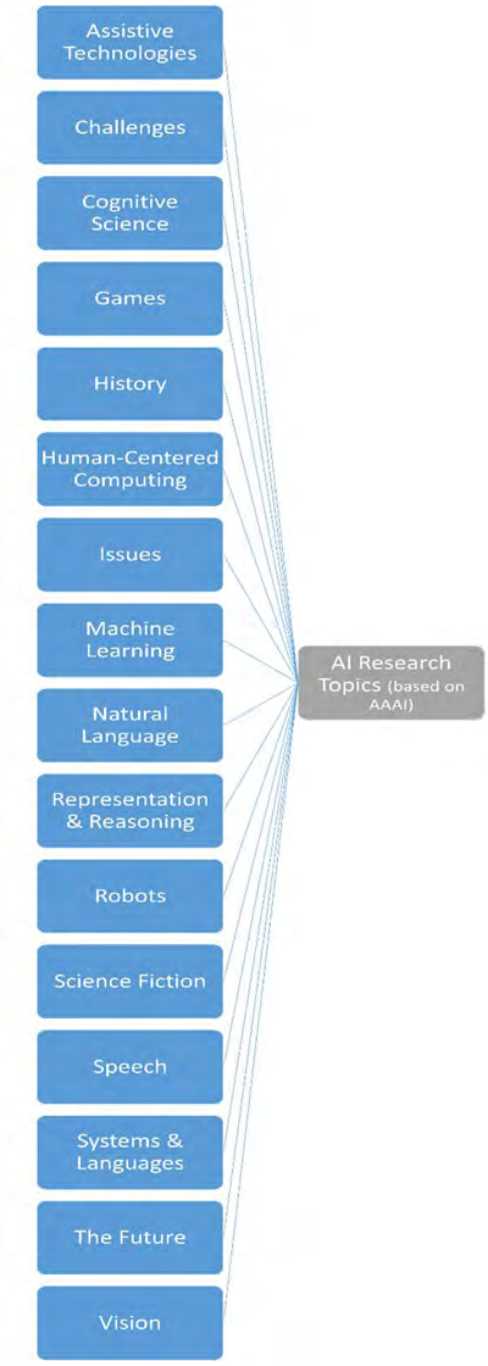

Figure 6: Research topics overview (based on AAAI, Artificial Intelligence technology category)

[35] The International Joint Conference on Artificial Intelligence (n.d.-a), 'Welcome to IJCAI | IJCAI', last visited 10 May 2023..
[36] About IJCAI | IJCAI
[37] For an example see the 2022 edition of the IJCAI Joined Conference in Vienna: IJCAI-ECAI 2022 (ijcai-22.org).
[38] AAAI Association for the Advancement of Artificial Intelligence, (n.a), 'About the Association for the Advancement of Artificial Intelligence (AAAI)', last visited 10 May 2023.
[39] AAAI, AITopics, last visited 10 May 2023.

the JRC to the AAAI classification.[40] AAAI includes 36 technology categories under the umbrella of Information Technologies. One of these categories is 'Artificial Intelligence'. In this deliverable, we have decided to only use include and discuss in detail, the category 'Artificial Intelligence' and its underlying technology sub-categories. While other technology topics might are undoubtedly relevant and very much connected to AI (e.g. 'game theory', 'human-computer interaction', 'modelling', 'data science', etc), the authors have decided that the 'Artificial Intelligence' category sufficiently reflects the focus of VISION and provides a convenient scoping mechanism.[41]

In the next sections, we will outline some examples from the NoEs conducting research on AI topics. This is by no means an exhaustive list – there are many more topics that the NoEs cover and naturally there are also other actors in the ecosystem, who focus on AI research. Yet, the section aims to illustrate what the topics refer to and how these could be addressed.

3.2.1 Assistive Technology

The topic relates to assistive technologies where AI systems, possibly in combination with other technologies such as robotics, can support people with specific needs.[42] Many research sub-topics are included under this category (e.g. motion studies, speech to text technologies, etc.).

While assistive technology might not always be referred to, the NoEs have recognized the importance of AI as a tool to support accessibility to content for various groups,[43] collaborations where research towards AI solutions with societal need – like healthcare - are emerging,[44] accessibility and explainability,[45] etc.

Example of a research area: *Reflexivity and adaptation in human-AI collaboration*
Network: Humane AI Net
Research goal: Humane AI Net aims to work towards new methods for meta-reasoning between the developed AI solutions and the involved human with responses adapted to and co-adapted with the human to ensure relevance and suitability.
Contributing to/ Perceived added value:
Core objectives of the adapted research direction are to work on the methodology and routine, the trustworthiness and creating mutual understanding.
The project has already supported micro-projects on the topic ("Adaption of ASR for Impaired Speech with minimum resources (AdAIS)" and "Learning Individual Users' Strategies for Adaptive UIs"). (HumanE-AI-Net Strategic Research Agenda (2022), p. 26)[46].

[40] Note that AAAI also published key words lists related to the conference submission of papers. As these change from year to year, we have decided to instead use the official AI Topics list.
[41] For full list of categories under Information Technology, see the AAAI AI Topic list, here.
[42] Assistive Technologies | AITopics
[43] See for example, F. Tsalakanidou (2020), "AI technologies and applications in media: State of Play, Foresight, and Research Directions", AI4Media, D 2.3, p.58.
[44] See for example, ELISE Consortium (2021), "Creating a European AI Powerhouse: A Strategic Research Agenda from the European Learning and Intelligent Systems Excellence (ELISE) consortium", May 2021, p. 32
[45] See for instance Paul Lukowicz (2022), "D6.1 Strategic Research Agenda" HumanE AI Net, p. 26 and M. Milano and M. Schoenauer (2022), "Strategic research and Innovation Roadmap, version 1.0", Tailor, Deliverable 2.1, p. 8.
[46] Paul Lukowicz (2022), "D6.1 Strategic Research Agenda", HumanE-AI-Net - hereafter referred to as HumanE-AI-Net Strategic Research Agenda (2022).

3.2.2 Challenges

While no specific definition of the subtopic is found, as the name suggest, the topic encompasses a variety of sub-topics related to the challenges of research, development, deployment, use of AI.

In essence, each of the Networks of Excellence are addressing current and upcoming challenges. The NoE research agendas and strategic documents, as well and the Joined SRA, also outline future research topics to address needs and changes. The below example provides only one such illustration.

Example of a research area: *Affective analysis*
Network: AI4Media
Research goal: "*The development of artificial intelligence systems that would be able to model people's goals and intentions and be able to assist them in achieving them*". "*There are still numerous challenges that need to be addressed in the future"*: Affect modelling across cultures; Dataset bias and inconsistent annotations; Class imbalance; Design choices in multimodal affect recognition; Context modelling; and Causality.
Contributing to/ Perceived added value:
"*Affective Computing is computing that relates to, arises from or deliberately influences emotion or other affective phenomena. One of the incentives of such research is the creation of empathetic machines, i.e. machines that understand and interpret a human's emotional state and adopt their behaviour to give responses corresponding to our emotions and moods*" (F. Tsalakanidou (2020), "D2.3 AI technologies and applications in media: State of Play, Foresight, and Research Directions", AI4Media – hereafter referred to as AI4Media SRA (2020), p.194).

3.2.3 Cognitive science

Cognitive science connects AI to various other areas related to mind and intelligence, turning into a multidisciplinary topic encompassing study areas from philosophy, to AI, and anthropology. The topic includes the following subcategories: child development, cognitive architectures, creativity and intelligence, emotion, neuroscience, problem solving, simulation of human behaviour. This AAAI classification uses the definition of Paul Thagard 'Cognitive Science'[47].

Example of a research area: *Natural intelligence*
Network: ELISE
Research questions/goals:
"*Advance the science of artificial intelligence by better understanding the intelligent behaviour of living systems and how this emerges*". (p.17)
Contributing to/ Perceived added value:
Contributing to explainability and transparency, AI ethics and societal impact. "Studying the intelligent behaviour of animals and humans can give insights into how the field of artificial intelligence could develop and the tasks that intelligence machines could help solve. […] It could further lay foundations for advances in computational psychiatry." (ELISE SRA, 2021, p.34)

[47] Cognitive Science | AITopics

3.2.4 Games

Games relates to studying and further developing the ability to reason and 'skills' such as pattern recognition, alternatives selection, learning based on experience, etc.[48]

Example of a research area: *AI for Games*
Network: AI4Media
Research questions/goals: how can connecting or combining different fields - game playing, content generation, and player modelling – support more complex tasks and move towards research on general game AI beyond playing.
Contributing to/ Perceived added value:
AI for games is one of the application areas explored by the AI4Media SRA (2020). The paper notes that while there has been significant progress in various aspects such as playing, modelling, generating, most of the research is very specific. This has prompted to call for research on general game AI to improve applicability (e.g. of a method in another game) and in terms of AI solutions capabilities. In the next couple of decades, the paper predicts that the community will observe "integration of existing foundation models into games and the rise of game-based models" (from AI4Media SRA (2020), pp.293-295).[49]

3.2.5 History

While no specific definition is provided in AAAI website, looking at published articles, the topic relates the historical development and implications on AI (including more current events).

In their future looking research agendas and strategic documents, the NoEs do reflect on previous and current state-of-play for many of the topics. This often serves as a way to base expectations or needs for future research areas. Yet, the history of AI is not a particular research topic for the future.

3.2.6 Human-Centered Computing

While AAAI does not provide a specific definition, the topic can be connected to to the interactions among humans and computing or intelligent systems.[50]

Example of a research area: *Human-in-the-loop machine learning, reasoning and planning*
Network: HumanE-AI-Net
Research questions: *(not specified)*
Contributing to/ Perceived added value:
"*A core concern is the use of hybrid incrementally modifiable representations in joint human-machine learning and planning. One example from reinforcement learning is to learn an intelligible abstraction of the state-space (the world) and the possible transitions, and then learn a reward function over this abstract model*" (from: HumanE-AI-Net Strategic Research Agenda (2022), p.16).
Further, HumanE-AI-Net has developed a hierarchical framework that outlines the different research topics (and challenges) related to collaborative AI systems (see: HumanE-AI-Net Strategic Research Agenda (2022), p.7).[51]

[48] Games: Overviews | AITopics
[49] AI4Media_D2.3_Roadmap_final.pdf
[50] See for instance in CDW (2022), "What is Human-Centered Computing and Why It Matters", accessed 10 May 2023, available here; or the University of Copenhagen (n.a.), "Human-Centred Computing", accessed on 10 May 2023, available here.
[51] HAI-Net-Deliverable-D6.1.pdf (humane-ai.eu)

3.2.7 Issues

The AAAI category includes a number of challenges such as: Social & Ethical Issues, Turing's Test, Philosophy, Arguments Against AI, Social Issues.

The category can be seen as quite broad but it is also relevant for the issues of trustworthiness and how to support the trust, understanding and compliance of AI with various social, legal and ethical norms. There is significant variation in research themes across the NoEs: 'Trustworthiness' to 'legal and ethical basis for responsible AI', 'human- and society-centred AI', 'human oversight'. Two examples are provided below.

Example of a research area: *Legal and ethical bases for responsible AI*
Network: HumanE-AI-Net
Research questions/goals:
"*The overall goal is to boost research aimed at developing methods and methodological guidelines for the entire lifecycle of the AI system: design, field validation with stakeholders (simulations, sandbox), deployment and feedback through continuous oversight*".
Contributing to/ Perceived added value:

- "*Ensuring that design processes result in systems that are robust, accountable, explainable, responsible and transparent*
- *Ethics for designers: and making sure that those developing AI systems are aware of their role and impact on the values and capabilities of those systems*
- *Methods to elicit and align multi-stakeholder values and interest and constraints capable of balancing societal and individual values and rights*
- *Methods to integrate and validate a combination of different possibly conflicting values (Design for Values), describe dilemmas and priorities, and integrate them into the computational solutions*
- *Compliance with laws and regulation and with guidelines for ethical AI*
- *Explainable AI systems in support of high-stakes decision making (e.g., in health, justice, job screening)*
- *Feedback methods to inform policy makers and regulators on missing elements in current regulations and practices*".

(from: HumanE-AI-Net Strategic Research Agenda (2022), p. 35)[52]

3.2.8 Machine Learning

Machine learning discusses the ability of systems to automatically learn, adapt and improve as well as the laws that rule the whole learning process.[53] Over 20 sub-topics are included under machine learning, including but not limited to: neural networks, statistical, inductive, supervised learning, etc.

Example of a research area: *Geometric deep learning*
Network: ELISE
Research questions/goal: *'"Improve the performance of deep learning algorithms in non-Euclidean spaces, and in so doing identify new applications, efficient implementations and symmetries in data that can be used to advance the use of deep learning methods*". (from: ELISE SRA (2021), p. 34).
Contributing to/ Perceived added value:

[52] HAI-Net-Deliverable-D6.1.pdf (humane-ai.eu)
[53] Machine Learning | AITopics, see also Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B. (2020), "*AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of artificial intelligence*", EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163, p12.

"The development of deep learning methods that perform well on non-Euclidean data could unlock further applications in a range of domains, including a variety of scientific disciplines, such as protein folding in the study of disease and treatment" (from: ELISE SRA (2021), p. 34).

3.2.9 Natural Language

Natural Language refers to the interaction and communication between computer systems and people.[54] The topic is interdisciplinary, connecting areas like natural language, cognitive science of human understanding of science, AI.

Example of a research area: Natural Language Processing
Network: ELISE
Research questions/goals: the objective of the research programme is to "*build systems for general-purpose natural language understanding and generation*". (from: ELISE SRA (2021), p.36)
Contributing to/ Perceived added value:
"*Advances in natural language processing already support the operation of digital assistants, machine translation services, and information extraction from different documents. Further advances could help democratise access to AI – enabling easier interaction with digital services across groups in society*" (from: ELISE SRA (2021), p.36).

3.2.10 Representation and reasoning

According to AAAI classification, this refers to the methodologies on representing knowledge (e.g. planning& scheduling, ontologies, etc) and/or the reasoning on a particular issue (e.g. abductive, analogical, meta reasoning, etc). For more sub-topics and description on the Representation and reasoning topics, please see the AAAI Topics website.

The topic is also prominent in classifications used by the AI Watch, referring to roughly the same point: the way in which machines represent knowledge, convert data into knowledge, or deduce facts from data sources.[55]

Example of a research area: *Deciding and learning how to act*
Network: TAILOR, WP5
Research questions: "How does an AI agent decide and learn on how to act?''
Contributing to/ Perceived added value:
"*Research in this area aims at empowering the agent with the ability of deliberating on how to act in the world in an autonomous fashion without the direct intervention of humans. Crucially, empowering an AI agent with the ability to self-deliberate its own behaviour carries significant risks of the agent getting out-of-control, hence this ability must be balanced with safety*" (TAILOR Strategic research and Innovation Roadmap – D2.1 (2022), p.16).

3.2.11 Robots

This topic (in the context of AI) refers to the intelligent processing needed for movement, handling and manipulating objects. The topic includes different types of robot applications (e.g. home,

[54] Natural Language | AITopics
[55] Salatino, A. A., Thanapalasingam, T.,Mannocci, A., Birukou, A., Osborne, F. & Motta, E. (2020), "The computer science ontology: A comprehensive automatically-generated taxonomy of research areas". Data Intelligence 2(2020), 379-416. doi: 10.1162/dint_a_00055, p.12.

workplace robots, autonomous vehicles) and processes like locomotion, manipulation, planning & actions.

Example of a research area: *Robot learning: closing the reality gap*
Network: ELISE
Research questions/goals: The second pathway in the ELISE SRA aims to support the performance in deployment. One element of that pathway is to **"**Create robotic systems that can interact intelligently with the world around them by combining robot learning approaches with machine learning methods, such as reinforcement learning; and information systems that can better understand human behaviour" (from: ELISE SRA (2021), p.6).
Contributing to/ Perceived added value: the topic contributes to improvements in deployment and is connected to AI integration, explainability and transparency, trustworthiness and certification. And how robot agents can perform reliably (from: ELISE SRA (2021), pp.18-19).

3.2.12 Science fiction

The topic refers to future looking, curiosity-driven, possible visions for scientific progress and their impacts.[56]

As the topic is quite broad and future looking, it is difficult to give a particular example of the research agendas of the NoEs. Yet, it should be noted that many of the articles connected to AAAI 'science fiction' category relate to possible impacts and explainability of the potential of AI.

In that sense, all the networks are active to a certain degree – all the research agendas are future-oriented and explore the impact and need for explainability in society, industry, policy. As an example, Humane-AI-Net is exploring the societal impact of AI;[57] TAILOR has explored the possibilities of AI application in different sectors such as 'AI for the future healthcare' theme-development workshop;[58] ELISE is also researching in the area of AI ethics and societal impact and developing application for societal needs like climate change;[59] AI4Media has noted the need to further explore the impact of AI for publishing, including the need to put the needs of users and communities in the centre and develop algorithms to support them,[60] etc.

3.2.13 Speech

The topic relates to speech recognition, understanding and synthesis.[61]

Example of a research area: *'*Cross-modal and multimodal representation, indexing and retrieval'
Network: AI4Media
Research questions/goals: how to develop, train and optimize models for multi-modal data
Contributing to/ Perceived added value: ***"****An efficient solution for audio-visual speech recognition, benefiting from both modalities, would allow to convert the speech in videos (interviews on TV, conferences, etc.) into a huge amount of textual content, a lot easier to search into and retrieve information from it. […] By a simple text query a user could find/retrieve all relevant multimedia content no matter the available modality****"* (from AI4Media SRA (2020), p.180).[62]

3.2.14 Systems and Languages

The topic encompasses the overall context within which AI systems are developed and operate, including hardware and operating system, programming languages, and applied architectures for reasoning and representation (e.g. distributed, problem independent or problem-specific).[63]

Example of a research area: *AI at the Edge*
Network: AI4Media
Research questions/goals:
"Existing research to support AI on the edge can be roughly categorised into three directions, which differ in their degree of autonomy: On-device inference, Distributed learning, Decentralized learning".
Contributing to/ Perceived added value:
"An increasingly popular alternative to centralised data processing that addresses these concerns is to perform in-device data processing and employ privacy-aware communication schemes between devices that do not expose internal user data. Additional perks of this approach include robustness against downtime of centralised infrastructure (e.g., the 2021 Facebook outage had serious ramifications around the globe and the ability to deploy software and its accompanying AI to places with limited or restricted internet"(AI4Media SRA (2020), p. 156).[64]

3.2.15 The future

This category relates to the future development of AI.

The research agendas of all NoEs are all looking towards future research trends and needs based on current status. As such, many topics can be included as examples. Below, an example from each NoE provided highlighting some AI paradigms.

Example of a research area: *Compositionality and automated machine learning (Auto-ML)*
Network: HumanE-AI-Net
Research goal: "To develop a theoretical framework for compositionality that could inform practical algorithms that can guide and to some extent automate composition of relevant sub-systems, perhaps developing an auto-compositionality theme." (p.19)
Contributing to/ Perceived added value:
"Enable the combination of symbolic and statistical AI methods and further extend them with theoretical models that allow continuous adaptation. A core goal devising methods for automating the development, deployment, and maintenance of AI systems that are performant, robust, and predictable, without requiring deep and highly specialised AI expertise" (HumanE-AI-Net Strategic Research Agenda (2022), p. 19).

Example of a research area: *Bioinspired learning*
Network: AI4Media
Research questions:
i) "Is it possible to build an artificial neural network that has the same cognitive pattern and behaves in the same way as the biological human visual system?
ii) Can we design a smarter artificial neural network by exploring diverse neural network topologies that exist in the human brain?
iii) Is it possible to enable the artificial network to have a similar continual learning ability as a human?"
Contributing to/ Perceived added value:
"Bringing more neural realism into deep networks and reducing the differences between the artificial and biological neural networks" (AI4Media SRA (2020), p. 166).[65]

Example of a research area: *Machine learning for earth and climate sciences*
Network: ELISE
Research questions/goals:

[56] Science Fiction | AITopics
[57] Paul Lukowicz (2022), "D6.1 Strategic Research Agenda" HumanE AI Net, p. 33.
[58] M. Milano and M. Schoenauer (2022), "Strategic research and Innovation Roadmap, version 1.0", Tailor, Deliverable 2.1, p. 27, available here.
[59] ELISE Consortium (2021), "Creating a European AI Powerhouse: A Strategic Research Agenda from the European Learning and Intelligent Systems Excellence (ELISE) consortium", May 2021, pp.30-31.
[60] F. Tsalakanidou (2020), "AI technologies and applications in media: State of Play, Foresight, and Research Directions", AI4Media, D 2.3, p.306.
[61] Speech | AITopics
[62] AI4Media_D2.3_Roadmap_final.pdf
[63] Systems & Languages | AITopics
[64] AI4Media_D2.3_Roadmap_final.pdf
[65] AI4Media_D2.3_Roadmap_final.pdf

To create "AI tools that can contribute to humanity's response to the climate crisis, increasing understanding of climate extremes, changes to earth systems and potential areas for intervention".
Contributing to/ Perceived added value:
"Tackling climate change will require insights into the ways in which human actions are changing the Earth's atmosphere and the impact of these changes on local conditions. Machine learning can be deployed in earth and climate sciences to better understand the interactions between people and the planet" (ELISE SRA (2021), p. 34).

Example of a research area: *Learning and reasoning in social contexts*
Network: TAILOR
Research questions/goal: How do "*we empower individual AI agents to communicate with each other, collaborate, negotiate and reach agreements/consensus and how they coordinate to fairly share common resources, and how they differentiate to accomplish collaborative tasks together*?"
Contributing to/ Perceived added value:
"*When interacting with one or more human agents, software agents or robots need to explain their motives and intended actions and to understand those of their human partners*" (TAILOR Strategic research and Innovation Roadmap – D2.1 (2022), p. 18).

3.2.16 Vision

The topic refers to the ability to process and understand visual data.[66]

Several NoE's focus on this research topic. HumanE-AI-Net is researching multimodal perception and modelling, and ELISE research topic on Machine Learning & Computer Vision – and AI4Media (e.g. with research topics as media or music analysis).

Example of a research area: *Machine Learning and Computer Vision*
Network: ELISE
Research questions/goal: To "*build bridges between classical algorithms and machine learning to unlock further advances in computer vision*".
Contributing to/ Perceived added value:
"*Better connections between the study of classical algorithms and modern machine learning could unlock further advances. In turn, this would enable a range of applications – from autonomous vehicles to video search to robotic navigation – and address important challenges around the trustworthiness and explainability of machine learning methods such as deep learning*" (ELISE SRA (2021), p.37).

[66] Vision | AITopics

4 Conclusion & Discussion

This paper presents the VISION attempt to connect AI topics in a way that connects and helps create a joined language between research and policy. Drawing from the process of developing the classification and the stakeholder consultations, the following observations can be made:

- **Common language is needed** to align not only the developments at the different geographical levels (regional, national, EU, international) but also to allow the different types of stakeholders to position themselves and to understand the position of others.
- AI (research) is developing very quickly – in terms of research, new capabilities, policy and legal framework. There are a number of initiatives working on AI strategic roadmaps as well as various classifications. This naturally supports creativity and innovation. There are also attempts – such as this deliverable – to connect the topics. **Further work is however needed to create an ontology or taxonomy** which also can incorporate dependencies and interconnections. Such an ontology or taxonomy can also contribute to foresight or road-mapping activities. However, this requires acceptance, recognition and consistency in the ecosystem. Consequently, broader stakeholder consultations (than a project or network of projects) are needed, but also alignment of strategic documents, monitoring, etc.
- Trustworthy AI is a vast and highly relevant topic as illustrated by the research agendas by each of the networks of excellence as well as other SRIDAs (e.g. that by ADRA, or individual organizations). **Strategic decisions on prioritization and increase in scale and funding are likely** to be needed to address identified research topics and position EU AI research for the future. The role of policy-makers would be to stimulate these initiatives to connect (already done via diverse partners), identify priority application areas or research areas to structure the future funding, and align it with priorities like resilience, developing a robust structure for trustworthy and explainable technology, creating a regulatory framework, etc.
- Each of the NoEs is working on connecting with society and industrial stakeholders. Various instruments have been used by the NoEs to connect to industry – consultations, joined workshops, etc. These connections are two-folded: industry provides insights on needs, expectations and barriers in particular sectors, while on the other hand research can showcase the opportunities and progress. Yet, the **cooperation and collaboration among research, experimentation and industry overall should be further strengthened** – in practice and on policy level. Possible ways would be to explore how the research outcomes and further plans from RIAs can feed into future AI projects, experimentation facilities and ultimately later on be faster seen adopted by the market.
- The NoEs have contributed to further research and connect the scientific community as well as to **raise public awareness** – via publications, conferences, workshops, etc – on trustworthy AI, ethical, societal and legal impacts. Discussions have indicated that these are very important to demystify and better explain the potential, risks and limitations of AI. Similar efforts are needed in the future with an increased focus on legal framework complexity, tools, guidelines. Further connection with stakeholders might also be needed.

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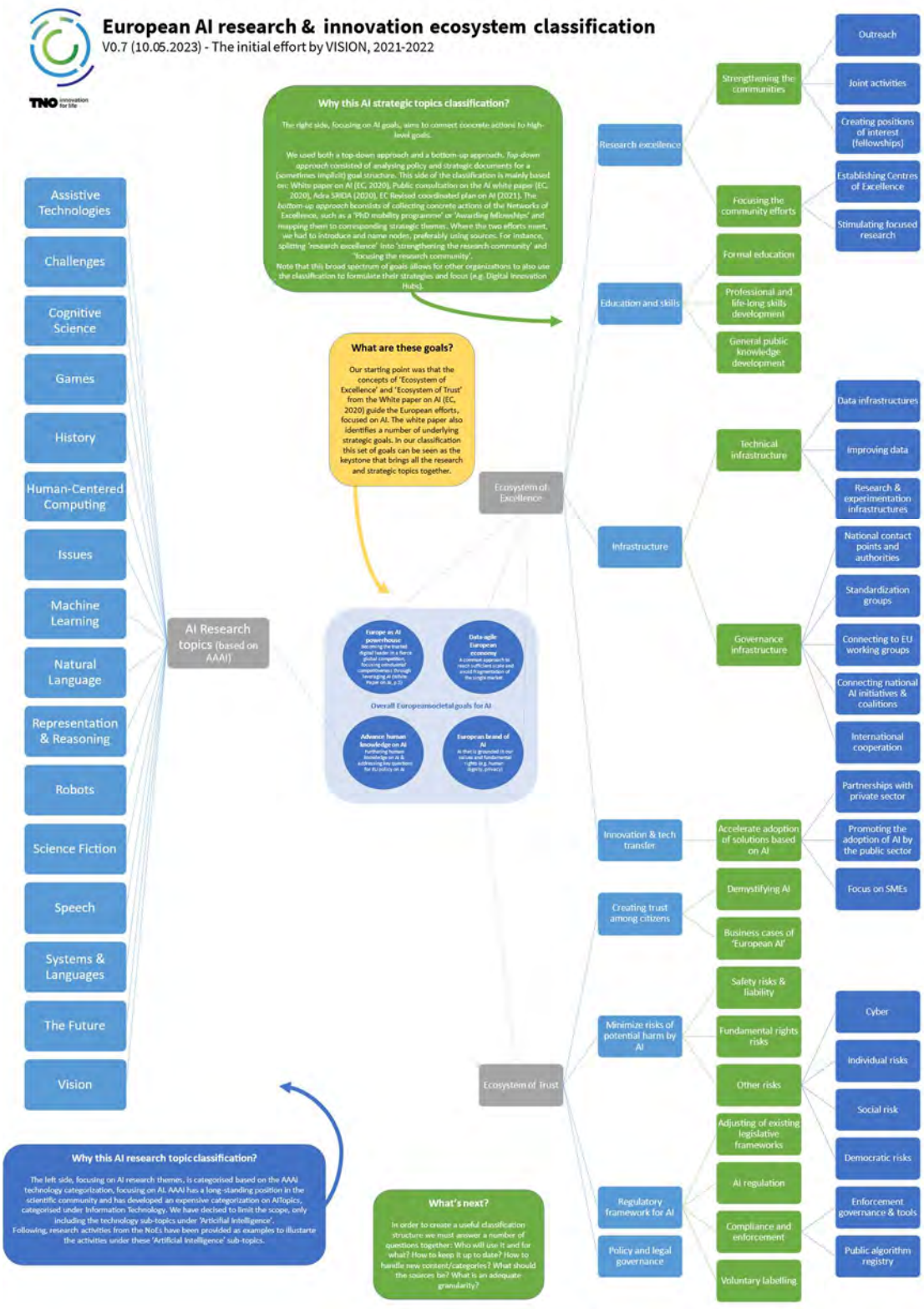
Annexes

Annex A: Vision topics classification

Below, a full overview of the topics classification is provided, including updates to take into account selected comments from the public consultations and shit towards the AAAI Topics categorization. Note that this classification might change in future.



Annex B: Consultations

During the project, we regularly organized moments for feedback on the structures and our plan. In total we have performed 13 consultations of the VISION-WG with the NoEs and external stakeholders.

Consultation	Stakeholders	Summary
21-4-2021	Core team	Initial meeting with VISION team members, including boundary spanning colleagues in TAILOR and HumanE-AI-Net
19-5-2021	Core team	Affinity diagram workshop with the CT, to categorize the AI topics bottom-up
1-6-2021	Task lead, TAILOR editorial board	Participated in the TAILOR roadmapping workshop
30-6-2021	Task lead, NoEs	Presented our progress, the developed structure, and plans at the 1st ICT-48 Community Event
22-7-2021	AI community at large	Presented our progress, the developed structure, and plans at the IDAI 2021 Summer School
7-9-2021 9-9-2021	TAILOR	Hosted two sessions during the joint Theme Development Workshop on *AI in the public sector*
25-10-2021	AI4Media	NoE consultation about the classification
25-10-2021	TAILOR	NoE consultation about the classification
1-11-2021	ELISE	NoE consultation about the classification
11-01-2022	HumanE-AI-Net	NoE consultation about the classification
25-5-2022	External (data & AI community)	Presented the classification at the Data Week
19-10-2022	TAILOR, ELISE, AI4Media, HumanE-AI-Net, ELSA, euROBIN, EC	At the 2nd ICT-48 Community Workshop, the work done so far was presented (SRA, ecosystem mapping and underlying classification structure)
21-11-2022	External (data & AI community at large)	At the European Big Data Value Forum, the classification was presented and feedback was elicited through a workshop format.
21-02-2023	TAILOR	Presented the classification at the TAILOR open meeting

Annex C: Initial mapping

In 2021, VISION performed a mapping of the available information at that point. As several SRAs were not published at that time, this is not completely error free, and the mapping may have changed. This is the left-hand side, containing AI research topics: