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1.1 RECOMMENDATIONS FOR ACTION

1.We need more clarification about the interdisciplinary scope of digital methods and AI-applications in the different classes and disciplines of our Academy which supports new cooperation and transdisciplinary innovation.
2. But, the ecological, economic, and societal balance of digital tools with environment and infrastructure, i.e. their ecological, economic, and societal effects is decisive to achieve a more sustainable world.
3. Therefore, besides concrete technologies, the importance of ecological, legal, and ethical standards and norms has to be taken into account.
4. Besides established IT-tools, new promising technologies such as Artificial Intelligence (AI) should be developed and applied to enhance Europe's position in a worldwide competition of innovation.
5. Our Academy should concentrate the expertise of its members in the research on intelligent systems and machine learning with applications in, e.g., medicine, engineering sciences, robotics, and smart homes to sharpen the profile of the Academy.
6. In times of pandemic, the national health systems must become more efficient by digitalization and AI.
7.Finally, digitalization and AI should aim at sustainable innovation (e.g., renewable energy, "green" and circular economy) and service systems for society.
8.Digital sovereignty and human autonomy are in the best of European philosophical and educational traditions as well as with the leading values of the European Academy.

1.2 BACKGROUND

In our recommendations we focus on the **potentials of digitalization** as one essential step towards achieving a more sustainable economy, culture, and society. Europe is in a worldwide competition with, e.g., the world powers USA and China. In order to be able to comprehensively understand the potential of digital technologies, their modes of action and their interdisciplinary interaction in socio-technical application contexts must be systematically investigated. Hereby, any socio-technical advances must be accompanied by appropriate communication strategies, since they must be broadly (i) accepted by society and (ii) transferred into business models to ensure their extensive implementation.

Concerning AI, we can identify the following steps of development: According to Alan M. Turing (1950), a system is called "*intelligent*" if, roughly speaking, it cannot be distinguished from human answers and problem solving ("*simulation game*"). Initially, AI was based on rules and formulas of symbolic logic, which were translated into suitable computer programs (Robinson 1965). ***Rule-based knowledge***, however, never fully captures the intuitive skill of an expert. Skill is based on learning in diverse experiences. Learning from data is studied mathematically in statistical learning theory (Vapnik 1998). Its algorithms underlie modern ***machine learning*** (Schölkopf/Smola 2002). The strong computational capacity of computers and databases in recent years has made it possible that machine learning with large data masses can now also be realized technically and has led to new breakthroughs in AI application in robotics, industry, economy, and societal infrastructure (Mainzer 2019).

But how safe are AI algorithms of statistical learning? In practical applications, learning algorithms refer to neural network models, which are themselves extremely complex (***Deep Learning***) (Schmidhuber 2015). They are fed with huge amounts of data and trained. The number of parameters required for this explodes exponentially. Therefore, verification of computer programs is a crucial demand of software engineering (Mainzer/Schuster/Schwichtenberg 2021). **Responsible AI** is a challenge not only for the EASA experts of technology and engineering, but also for ethics and humanities. Finally, for an AI algorithm to be useful, understood, and believed by the human expert, it should be transparent (the model is actually described by the human), interpretable (after training, the human can view and understand the model itself), and/or explainable (usually interpreted to mean that the learned model will produce statements or visualizations to demonstrate how it made decisions). **Explainable AI** is thought of as the third wave of artificial intelligence.

Future trends of AI were identified in "*A 20-Year Community Roadmap for Artificial Intelligence research in the US*" (Computing Community Consortium (CCC) and Association for the Advancement of Artificial Intelligence (AAAI) 06.08.2019). Recently, these tendencies were also highlighted in the "*German Standardization Roadmap on Artificial Intelligence*" edited in 2020 by a High Level Expert Group of German ministries, in which the EASA-president was a member and contributor (Wahlster, Winterhalter 2020).

The *European Lab for Learning and Intelligent Systems* (ELLIS) aims at enabling Europe to shape how machine learning and modern AI change the world. Following this line, the *European Commission's High Level Expert Group on Artificial Intelligence* recently suggests the following definition of today's AI ("*A Definition of AI: Main Capabilities and Scientific Disciplines*"):

"*Artificial Intelligence (AI) refers to systems designed by humans that, given a complex goal, act in the physical and digital world by perceiving their environment, interpreting the collected structured or unstructured data, reasoning on the knowledge derived from this data and deciding the best action(s) to take (according predefined parameters) to achieve the given goal. AI systems can also be designed to learn to adapt their behavior by analyzing how the environment is affected by their previous actions*."

AI opens new avenues to various aspects of **sustainability and interdisciplinary applications**: In the European Academy of Sciences and Arts, we should support interdisciplinary activities in, e.g., medicine and life sciences, natural and engineering sciences to promote transdisciplinary innovation. In humanities and arts, digital tools and AI are exciting topics since many years. In ecology, e.g., drones or sensor-based monitoring can be applied to assess the condition of plants in a more economic and ecological way. In production, energy consumption can be reduced through networking and robotics (Haddadin 2021). Product life can be extended by means of predictive maintenance. In a circular economy, recycling and waste management are great challenges. AI can improve the identification and sorting of waste. For building efficiency and energy management, AI offers improved system control, regulation of heating, cooling, and ventilation systems. In short: Machine learning should help to accelerate and optimize supply chains and help circulate products, components, and materials to enhance a sustainable world.

Medicine and healthcare: The medical field, and more broadly healthcare, presented important, human-centered, challenges to Artificial Intelligence from the early days of the field, while new challenges continuously arise in the current era (Combi and Pozzi, 2019). ***Medical expert systems*** contributed in a significant way to the development of AI in medicine, both methodologically and application wise. Digitalizing human expertise in computer-based systems exhibiting problem-solving competence comparable to that of human experts, that could converse intelligently with their users, handle uncertainty and vagueness, understand and reason with notions of time, given that time is of the essence in many clinical domains (Combi et. al, 2010), explain their recommendations, and learn and adapt through their own experiences, are by no means easy tasks to model. With medical advances people can now live longer, but what matters equally is the quality of life of elderly people. AI can assist in providing healthy living and active aging, in giving the means for effectively managing patients with chronic disorders, in facilitating remote care, even in providing cognitive caregiving (automatic) agents to the elderly and chronic patients. It is also possible to talk about personalized or precision medicine. AI, possibly combined with physics-based modeling, can also be used to design sensors for effective health monitoring in clinics, assisted living facilities and in homes

Digitalization of medical expertise: Nowadays, evidence-based approaches to medical problem solving are a strong paradigm that could alleviate the bottlenecks associated with the digitalization of human expertise (availability, subjectivity, laboriousness regarding knowledge/model acquisition, etc.) but biases in the data and other data related caveats trigger ethical considerations. However, with massive data readily available, there is a motivating paradigm shift in every corner of healthcare, since there are unprecedented opportunities to analyze and extract useful information from diverse, distributed and heterogeneous data repositories so as to make more informed clinical decision making and enhance the efficiency and performance of healthcare systems.

Machine learning in diagnostics and therapy: Recent advances in machine learning and analytics can help reduce diagnostic and therapeutic errors that are inevitable in human clinical practice, improve the understanding of disease mechanisms and facilitate clinical decision support. It also transforms how medical research is conducted, and how healthcare is managed and delivered in a cost-effective manner. The deployment of such models in clinical practice provides proof of concept and projects future utility in general medical practice. If medical analytics for healthcare intelligence is to serve the good of society at large, in an ethically accepted and inclusive manner, it should be able to unravel potential biases in the data and to ensure the inclusiveness and validity of the adopted data. It should also address issues of explainability (Guidotti et. al., 2018), human-machine interaction, confidence and trust, learning from small data and combining knowledge-based AI and machine learning (Chen et. al., 2021).

Digitalization, AI, renewable energy, and green economy:

The Covid-19 pandemic, which has affected the entire planet with tragic effects and, due to inertial pressure, seems destined to continue, has not only had severe effects in terms of general mortality, but has also generated catastrophic economic and social consequences in many countries of the world. The first sectors identified as deserving immediate support because of their potential to drive recovery are digitalization and the "green" economy. In programmes of European governments, the "digital revolution and the green economy" (M. Draghi) are top priorities for the strategic interventions to be implemented with the European Recovery Plan funds. Together with the expert group "Environment and Energy", this expert group should elaborate strategies for a digital management of renewable energy in a green economy. If appropriately matched by public support for smart, intelligent and effective forms of mutual interaction, digitalization and the green economy can be decisive in the post-pandemic recovery. A fundamental contribution to scientific progress will come from progress in AI, a tool designed to support human intelligence, which will be able to accelerate and improve the process of widespread digitalization hoped for by many governments. In the field of AI, as in vaccine research, there should be no excessive room for the isolationistic tendencies that have always damaged science.

Digitalization and AI as a sustainable innovation portfolio

Future technologies are like shares betting on the future [1]. For this purpose, the advantages and disadvantages of e.g. solar and wind energy, hydropower, hydrogen, nuclear and fusion energy must be weighed against each other for Europe and combined in a "hybrid" energy system in order to orient the European innovation portfolio towards a sustainable future. As with an equity portfolio, diversity ensures resilient beha

vior in an innovation portfolio, in order to be able to react flexibly to the risks of the future and to recover overall in the event of selective setbacks.

As in the energy issue, digitalisation must not be based on a single solution, but rather the entire technological potential must be bundled in an innovation portfolio. Therefore, classical digitisation and artificial intelligence [2] together with future technologies such as neuromorphic computing (following the energy-saving mode of natural brains) are being investigated as well as quantum computing, quantum communication and quantum technology [3]. For this purpose, advantages and disadvantages of digital and analogue technologies must be weighed against each other for Europe and combined in a "hybrid" IT and AI, so that this European innovation portfolio is also oriented towards a sustainable future together with the energy issue.

An innovation portfolio is composed of basic, bridging and future technologies that change in the short and medium term and need to be replaced by new ones. An innovation portfolio is therefore dynamic and must be constantly shaped. Methodologically, this is done by drawing on the mathematical theory of complex systems and non-linear dynamics, which can be used to model complex systems and networks in nature, the economy and society and which the author has been working with for decades [4]. On this basis, chaos and risks become assessable in early warning systems and convertible into strategic action.

AI and robustness/resilience/zero-fault systems: Many critical industrial applications require an absolute level of safety and confidence. The fault is not an option in primary structures as they would immediately result in the loss of the application and human lives. The mathematical foundations and limitations of AI still need to be clarified. Coordination of AI with more classical but robust techniques to achieve redundancy and safety in these systems will be a growing field, and a lot has to be developed in the way we develop that synergy.

AI and Data limitation & AI versus technical expertise: AI has been performing extremely well today in fields with large data corpus. Many critical industrial applications are either unique and with a few instances only. To overcome this from a technical point of view, such systems are designed today using a pyramidal approach (lab-scale, semi-structures, structures). Extreme sparsity of data is compensated by a sequential upscaling approach, which would be a challenge in AI. There are some reflections to be done about what industrial fields could, by essence, not be a good fit for an AI-based approach. This is important as the extension of AI in “technical engineering” groups might come with a progressing weakening of the knowledge of these persons in their respective scientific field. While this could be an option in fields where AI performs well, it would be avoided in fields where it can by essence not perform, to avoid a loss in competitiveness there.

AI and robotics at home: What is the impact of AI at home, and how are its inhabitants benefiting from AI in this time and era? AI-empowered technology in the home can be focused on two dimensions: management of the home (including smart devices and domestic robots) and knowledge enrichment (including information gathering and question answering, e.g. via chatbots) (Santos and Toni 2021). Domestic robots are robots that can autonomously perform household chores in domestic environments, e.g. cleaning, butlering or shopping. Special kinds of domestic robots, referred to as ‘assistive’, can support independent living of users (e.g. elderly or disabled). The last decade has witnessed a hive of activity in the design and realization of domestic robots in general and assistive robots in particular. But how much AI is used in these domestic robots? Some of the research challenges addressed by academics in AI to support domestic robots are:

a. Empowering domestic robots with the ability to decide which actions to perform, by reasoning as to which tasks they contribute to.
b. Equipping domestic robots with human-friendly interactive features.
c. Empowering domestic robots with cognitive abilities.

Besides, several technological advances in recent years have empowered a transition to the use of AI for the management of the home. These advances include a variety of connected devices, such as smart sensors, smart actuators and smart meters, which all be embedded in the home to identify and “optimize” human activities.

What has AI done and could do for our homes? The digital era of smart homes is already here. We can foster some of the benefits it brings and change whatever needs to be changed. This will require close- knit collaboration between computer scientists and engineers on one hand and philosophers, psychologists, social scientists and legal experts and policy makers on the other.

AI and new engineering approaches such as soft robotics: While AI could not be applied to some fields as described above, there are synergies with some new trends in engineering such as Soft Robotics. In these approaches, the initial paradigm is that systems initially made of multiple junctions between rigid parts (classical robots) can be replaced by monolithic systems made of soft matter with complex kinematics. The control and task-oriented learning of these robots are perfect for applying an AI framework. This is probably an important playground for the EU in the future.

Digital sovereignty and human autonomy: Given that intelligent systems are transforming our lives, AI is just as much a new frontier for ethics and risk assessment as it is an emerging technology. There are many questions related to the development of AI in society that need to be answered, and the responsibility lies with all stakeholders – companies, associations, governments and the public. The European Commission has taken a step forward and the High-Level Expert Group on AI published the Ethics Guidelines for Trustworthy Artificial Intelligence on 8 April 2019.

But it is not enough to start with a “deficit consideration” of humans with respect to machines. The point rather is the human ability of self-control, steering, autonomy, close to Kant’s idea of “Mündigkeit” (Hemel (2020). The idea of “human autonomy” or “human self-control” or “digital sovereignty”, combined with “digital fairness” should be such a starting point. In a certain way, this is very much in line with the best of European philosophical and educational traditions as well as with the leading values of the European Academy.

Digitalization, AI and Cultural Heritage for Europe: Everything in the World (e.g.science, technology, household, health, heritage, economy) is transforming into a digital process with a multiple product outcome. One such field is *Cultural Heritage* (tangible and intangible). From 3D configuration of ancient artifacts to applying artificial intelligence to shed new light on how we perceive the lineage of humanities, cultural heritage is headed toward a digital future. Only 15% of the world’s cultural heritage is currently available in a digitalized format (https://amt-lab.org/blog/2020/3/a-digital-future-for-cultural-heritage).

Digitalization uses 3D scanning to create a digitized heritage that is less vulnerable to damage and has more room for the public to access and interact with; also uses accelerated laser scanner to make digital copy of cultural heritage and employs cyber tools to locate, excavate, document, analyze, disseminate the cultural product, via Cyber-archaeology the digital simulation of the past (Terras, M. (2015). "Cultural Heritage Information: Artefacts and Digitization Technologies" In Chowdhury, G. and Ruthven, I. (2015). "Cultural Heritage information: Artefacts and Digitization Technologies", London: Facet. p. 63-88).

Artificial Intelligence (AI) is another useful tool for preserving ancient human ingenuities from natural conditions and human activities. It can help to facilitate a more rapid process of tracking a cultural heritage’s lifespan and the type of measures that should be taken to guarantee its existence into the future. The dependence of digital transformation on AI is of utmost importance as it can help culturalists, archaeologists, historians, archaeometrists, museologists, scientists, that study ancient cultures, to accelerate their Digitization processes.

AI **-** the upcoming digital milestone, and Digitizing Education, offer a Value creation in Digitization and produces a new wave of opportunities in art and cultures. In order to be successful and fruitful, adopting AI

(& robotics) in the digital transformation of a cultural material or archaeological problem, one needs the concept, the interest from the scientist. This is of critical importance as it will help generate the momentum needed to go the Institutional inertia for a fast and accurate problem solving (University, Museum, Laboratory) for e.g. environmental reconstruction, artifact reconstruction, clustering/classification of objects, aDNA sequencing and classification, reassembling of scattered artifacts, color identification, attribution of works of art to authorship/composer, remote sensing reconnaissance and more.

Thus: AI with Digitalization use algorithms to run image processing to detect signs of damage, provide future guidance for repairs and maintenance, helps to analyze and reconstruct data with machine learning/robotics, and coalescence fragmented data input (scrips, images, material culture, videos, etc) into useable knowledge.

Artificial Intelligence (AI) and Cultural Heritage (CH) are two topics that have piqued the interest of both scientific and cultural organizations in recent years due to the potential for interactions and aggregations among the many participants in these fields. The dual subjects identify responsibilities and connects them to places where research and new technology might provide paths and competitive solutions for integrating tourism and culture with business and the market and sustainability (see for sustainability: Liritzis & Korka, 2019; for AI and CH, Bordoni et al., 2016; see also: the european project EUROPEANA data model; https://pro.europeana.eu/the-europeana-website/about-europeana-eu, where they are a mechanism that helps heritage institutions structure metadata related to heritage objects; and university efforts: https://www.lboro.ac.uk/research/ias/events/2022/march/aiculturalheritage/).

AI is propelling us to the future of the Past, boosts the deciphering of ancient languages, restores Ancient Text using Deep Learning, Decodes epigraphic marks, provides automatic identification of images of artifacts, and Automates 3D digitization procedures, helps to perform Chemical-physical analysis of artifacts and monuments, Detects unknown Cultural Heritage through AI (aerial photography, geophysical prospection in 2D and 3D), recognizes ancient structures through a machine learning algorithm arrive at a learned model. AI in present in detecting changes of National cultural heritage inventories (due to climatic or other anthropogenic causes), and bridges with exponential technologies and their pervasiveness (including 3D printers, drones, robotics, blockchain, VR and AR, massive digitalization) (see Traviglia 2020; Liritzis & Korka 2019; Levy & Jones 2018).

In all AI applications in cultural heritage, freedom of speech must be maintained while preventing huge misinformation and rising repression on the internet, social media, and mainstream media, as well as the manufacture of old tales.

Freedom of expression needs however to be protected, be it from abuse of technological developments, attempts to muzzle dissenting voices in a society or misuse of the freedom of expression to foster divisive narratives, deceiving, and intolerance and hate. Here AI and Ethics should apply wise power to harmonically marginalize such noisy factors.

Artists, experts, cultural professionals, and digital culture creations are frequently the ones who hint at problems, spell out uncomfortable truths, speak the unspoken and make the unseen visible - using artistic and cultural means and creating spaces for societal debate within and beyond the mainstream bodies of political discourse and in social media. (CoE 2020)

We believe that AI "*…..will allow quick access to enriched cultural information, which can serve equally well for cultural and social ends, education, tourism, and possibly for historians or anthropologists. Indirectly the citizens can benefit from better public services, when these are based on the insight that the richer metadata we produce offers – such as web accessibility for the visually impaired or narratives that can expose social injustice or integration and gender issues through cultural heritage corpora and help create a more tolerant European identity*". (Maria-Cristina Marinescu, Project coordinator; A SAINT ON A BIKE TO TRAIN AI (https://www.timemachine.eu/how-artificial-intelligence-can-help-the-cultural-heritage-sector-saint-george-on-a-bike/)

At any rate in the history of art, archaeology, anthropology one must remember that technology is just a tool and in itself does not deliver higher competence, especially regarding deontology of expressing past reality, yet it satisfies to a high degree of fidelity the current needs.

Thus, three measures may raise the chances that AI will preserve and reflect our shared cultural legacy, and so our humanity. *Preserve and digitize, engage politicians, Diversify AI's educators.* Our motto here may be*: "Don't Build AI Without Humanity's Cultural Heritage".*

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