KONRAD ADENAUER STIFTUNG

Comparison of National Strategies to Promote Artificial Intelligence

Part 1

Cambrian

www.kas.de

Imprint

Editor:
Konrad-Adenauer-Stiftung e. V. 2019, Berlin

Authors:
Dr. Olaf J. Groth, CEO & Managing Partner
Dr. Mark Nitzberg, Principal & Chief Scientist
Dan Zehr, Editor-in-Chief

Tobias Straube, Project Manager and Senior-Analyst
Toni Kaatz-Dubberke, Senior-Analyst

Cambrian LLC, 2381 Eunice Street, Berkeley CA 94708-1644, United States
https://cambrian.ai, Twitter: @AICambrian

Editorial team and contact at the Konrad-Adenauer-Stiftung e. V.
David Gregosz
Coordinator for International Economic Policy,
Department for European and
International Cooperation
Konrad-Adenauer-Stiftung e. V.
Branch Office: Klingelhöferstraße 23
10785 Berlin
Post: 10907 Berlin
T +49 30 / 269 96-3516
F +49 30 / 269 96-3551

[Note: This English-language version was translated from the original publication in German.]
Cover image: © PhonlamaiPhoto/fanjianhua (istockphoto by Getty Images)
Images: © p. 11: Paulo Silva, © p. 18: Yiran Ding, © p. 24: Susan Yin,
© p. 29: Léonard Cotte, © p. 34: Johny Goerend, © p. 39: Yeo Khee / unsplash
Design and typesetting: yellow too Pasiek Horntrich GbR
The print edition was produced in a carbon-neutral way at Druckerei Kern GmbH,
Bexbach, and printed on FSC-certified paper.
Printed in Germany.
Printed with the financial support of the Federal Republic of Germany.

ISBN 978-3-95721-548-2

Comparison of National Strategies to Promote Artificial Intelligence

Part 1

Dr. Olaf J. Groth, CEO & Managing Partner
Dr. Mark Nitzberg, Principal & Chief Scientist
Dan Zehr, Editor-in-Chief

Tobias Straube, Project Manager and Senior-Analyst
Toni Kaatz-Dubberke, Senior-Analyst

Table of Contents

Preface

Technologies can rarely be reduced to their mere commercial added value.
The history of the Industrial Revolution teaches us that nation states have always endeavored to build or maintain political supremacy through pioneering economic achievements. In the age of digital upheavals, multiple disruptions and immense acceleration, this dictum still applies.

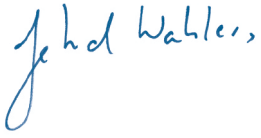
The topic of "artificial intelligence" plays a special role here – a technology that is currently being discussed worldwide and increasingly applied. As with any new technology, both the Cassandrian pessimists (such as Steven Hawking or Elon Musk) and the progress optimists (Mark Zuckerberg, Eric Schmidt or Bill Gates) contribute their theses on the future development of humanity. They widely vary from dark dystopia to paradisiacal future prospects.

Let us hope that the recently appointed Enquete Commission of the German Bundestag will counter an agitated and possibly overheated debate with sober stocktaking. Germany's AI strategy, which is expected by the end of the year, must define quantifiable goals and concrete measures, which will then be vigorously implemented. The political crash barriers necessary for the use of automated machine learning need to be established.

Other countries are well ahead in this respect. They have long since defined AI strategies, developed business models and subjected ground-breaking applications to initial practical tests. Therefore, it is worth taking a close look at how other economies are dealing with the digital revolution: What regulatory framework conditions have they defined? How do they implement policy strategies and programs to create new industrial policy facts?

With this two-part publication, the Konrad Adenauer Foundation intends to give a comparative overview of the AI strategies of major national economies in order to provide food for thought and inspire the German debate. We believe: "Tech is politics" – and politics and civil society should give this more attention and discuss this more vigorously.

I hope you find this publication an inspiring read.



Yours
Dr. Gerhard Wahlers

Dr. Gerhard Wahlers is Deputy Secretary General and Head of the Principal Department for European and International Cooperation of the Konrad-Adenauer-Stiftung.

Background and Definitions

Artificial intelligence: rapid developments and designs of the initial conceptual AI frameworks.

In July 2018, the German government published a key issues paper for the German Artificial Intelligence (AI) strategy, in which they acknowledged: "Artificial intelligence has reached a new stage of maturity in recent years and is becoming a driver of digitization and autonomous systems in all spheres of life."[1] The document urged the state, society, the economy, the government, and science to consider artificial intelligence in depth and deal with its opportunities and risks.

A comprehensive German AI strategy will now be developed by the end of November and its results presented at the Digital Summit in early December. The aim is to prominently embed the topic of AI in the digital policy of the Federal Government. In this way, Germany is catching up with a large number of countries that in recent years produced extensive initiatives for AI strategy and processes.[2]

These strategies are motivated by remarkable progress in the research and application of AI systems, many based on Machine Learning (ML) techniques – particularly Deep Learning (DL) and the variety of neural network designs that DL experts have created.

The global relevance of AI technologies is demonstrated by their prominent representation on this year's international agenda – from the Munich Security Conference in February, to the presentation of the EU Commission's[3] AI paper in April, and to the joint AI declaration in June from the G7 countries in Canada ("Charlevoix Common Vision for the Future of Artificial Intelligence").[4]

The role of Artificial Intelligence as a potential key technology of dystopian future concepts, social control, and autocratic world power fantasies is also finding its way further into public debate. This overview, however, focuses on the analysis of AI frameworks in six countries and how they deal with the revolutionary potential of Artificial Intelligence.

How this report defines Artificial Intelligence:

„In the broadest sense, artificial intelligence is the ability of machines to learn, to think, to plan and to perceive (i. e., the qualities that we primarily identify with human cognition). This ability is achieved by digital technologies or hybrid digital-physical technologies, which imitate the cognitive and physical functions of humans. For that purpose, AI systems do not only process data, they recognize patterns, draw conclusions, and become more intelligent over time. Their ability to adopt and refine newly developed skills has improved significantly since the turn of the century. This also means that what is referred to as AI changes with each major technological breakthrough, and the definition must therefore be periodically adjusted."

1 Cf. German Federal Government, Key Points of the Federal Government for an Artificial Intelligence Strategy (July 2018), https://www.bmbf.de/files/180718%20 Eckpunkte_ KI-Strategie%20final%20Layout.pdf.

2 To this end, see the OEZE overviews, for example, http://www.oecd.org/going-digital/ai/initiatives-worldwide/, Future of Life Institute, https://futureoflife.org/ai-policy/, the Smart Data Forum, https://smartdataforum.de/ en/ services/international-networking/international-ai-strategies/, Charlotte Stix, https://www.charlottestix.com/ ai-policy-resources, und Tim Dutton, https://medium. com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd, all last retrieved on 17.9.2018.

3 Cf. European Commission, Artificial Intelligence for Europe (April 2018), http://ec.europa.eu/newsroom/dae/document. cfm?doc_id=51625

4 See Canadian G7 Presidency, Charlevoix Common Vision for the Future of Artificial Intelligence (June 2018), https://g7.gc.ca/wp-content/uploads/2018/06/ FutureArtificialIntelligence.pdf.

Summary

The race for world leadership in Artificial Intelligence (AI) technologies has begun. Since the publication of the Obama government's AI strategy in 2016, other countries have looked for ways to promote research and development (R&D), to encourage commercialization of AI and to catch up with the leading AI nation, the USA. The following summary describes the findings from the analyses of the first six countries (USA, China, Great Britain, France, Finland and South Korea). These six countries comprise Part One of a 12-country study for the Konrad Adenauer Foundation. Some of the key findings include:

Vague and inconsistent AI definitions: In the strategies compared, there are very different definitions of AI – and in some cases no definitions at all. The only thing they have in common is an understanding of AI as a driving force in the digital revolution, which involves both potential and risk in terms of social, economic and, to some extent, security policy. Accordingly, they often leave aside any existing sector or digital strategies. An AI strategy should therefore be preceded by a definition of AI concepts, and it should not be too specialized – instead conceived of and anchored in a cross-sector approach.

Lack of target systems: The strategies are predominantly formulated in general terms. Their partially vague objectives relate to different levels of impact, which will make it more difficult to control their implementation and measure their success. China, for example, measures the economic strength of the AI industry, among other metrics, while the UK sets targets for the number of future doctoral candidates. A future AI strategy should be based on a system of measurable targets that take into account the complexity of a holistic German approach. This is necessary to understand whether the strategy leads to the desired effects. At the same time, it needs a mechanism that allows for the observation of global AI trends and the measures used by other countries, especially as these effects are still unfolding. In this way, the German strategy could be adapted and globally integrated.

AI superpowers vs. "fortress countries": In the US and China, the leading AI countries, the dynamics of AI development are largely determined by the private sector, particularly young companies and Internet companies with global operations. While the trend in the United States is towards further deregulation, China is seeing tendencies towards increased state control of the large technology companies. Neither of these currents will slow down the worldwide distribution of their AI products. In the countries of continental Europe, which are focused more on science and the protection of the individual, there is a lack of such global players. This is partly due to a very high degree of skepticism towards digital technologies and a resulting protective stance in policy-making. Their support is aimed at the development of research networks, open data pools and technology transfer to the established manufacturing industry and SMEs, but not at creating a global, formative voice. In contrast to the USA, where the permeability between business and science has grown over the past ten years, the success of European attempts to achieve this permeability is very limited, let alone attempts to scale it. Therefore, to have a constructive voice on the world stage, a strategy must point out ways to trigger a more-effective exchange between the separate fortresses of science and business and then project that economic power globally.

AI in production 4.0 vs Digital Society 5.0: In East Asia, the Fourth Industrial Revolution (South Korea) and Society 5.0 (Japan) are considered the inevitable next stages in human development, in which AI will influence all spheres of life. This results from a constellation of specific economic growth targets and demographic limitations and is facilitated by a focus on research, commercialization and rapid scale-up of AI applications.

In contrast to that, Europe risks focusing too closely on manufacturing aspects, despite further specializing in basic research and the concept of industry 4.0. To understand the upcoming cognitive age and actively shape it, a digitally strong, qualified and young population is needed as a "home base." For this to succeed in Europe, the mainstream society must open itself toward the potential of this technology, both critically and constructively – but quickly, above all.

Ethics and human orientation as strategic strengths of the Europeans: Although ethical issues are discussed in different social forums in China and the USA, the topic is not given any high priority by the respective governments. This creates the space for Europe to take the lead on the issue of ethical AI, as has been attempted by French President Macron. While Britain has taken the initiative in developing an international AI governance architecture faster than France, the Brexit movement has weakened the country's ability to project these developments. One of Europe's challenges stems from the fragmentation of their internal data market, which potentially could comprise 500 million inhabitants. In addition, the calls for ethical design of AI have hardly been accompanied by concrete suggestions or strategies. To help shape future innovation of cognitive machines for both the European digital market and for other economic regions, it will be necessary to think outside the box and beyond the basic data-protection regulations. The European and German ethics and their sense of responsibility can be conveyed more easily through digital economic power.

Lack of computing capacities as a strategic weakness: While the availability of data and training of specialists are promoted by many strategies as a prerequisite for AI research and commercialization, only in a few cases is there also a focus on the expansion of domestic computing capacities (the exceptions are South Korea and China). The current global trade conflicts show that availability of powerful chips or access to cloud-based computing power is a strategic necessity. Compared to the US and East Asia, the European countries are not competitive in this field.

Ecosystems as a strategic asset: To develop higher quality AI solutions and implement them into the international dialogue, Europe will need experienced investors and an agile legislature in addition to its researchers, talented developers and strategic entrepreneurs. While these parties provide the fertile ground for successful commercialization of AI in the USA and China, Great Britain is the only European country beginning to succeed in this respect. In France or Germany, the small number of AI startups bears witness to the fact that such ecosystems are not yet thought through and supported to the extent necessary. A strategy must create incentives for the parties involved to be willing to locate in Germany and establish platforms for their exchange.

The countries at a glance:

USA: The most influential publications on AI, an estimated 3,000-plus doctoral students in the field each year, about 1,400 AI startups, seven of the world's ten largest technology companies, and the cooperation between universities, public authorities and companies that has grown over the last 40 years – this combination of factors is the reason the U. S. holds global leadership in AI. In view of the increasing competition, especially from China, and the strategic relevance for the economy and society, the Obama administration has also presented the world's first national AI strategy.

The Trump government has yet to produce a national strategy, as called for by US Secretary of Defense Mattis. In addition to funds from the private sector, basic research receives funding through a key part of the government's annual AI R&D budget (1.3 billion Euro). In addition, funding from individual departments also supports AI development, with the Department of Defense alone spending 6.3 billion Euro (2017). What is more, Washington supports the commercialization of AI by reducing and removing regulatory barriers. However, it remains to be seen, whether the America First immigration policy inhibits the country's ability to attract AI experts from around the world. And it remains to be seen how differ-

ent initiatives from the executive and legislative branches will form and shape new AI strategy.

China: The country has set out a three-step plan to become the world's leading AI nation by 2030, and it is the only country to set measurable macroeconomic targets for this purpose. More than 700 million Chinese internet users and growing groups of high-performance hardware and technology companies – which have become serious competitors to American firms because of the protected domestic market – combine to create the optimal conditions for this strategy. Although the country still lags the US in basic research, training of qualified specialists, the number of AI startups and internationally enforced patents; the developments in recent years leave no doubt that China is catching up. Beijing has announced spending of 16.4 billion Euro to promote the microchip industry alone, and at the sub-national level a single city (Tijian) has set up a fund of 12.8 billion euros for AI promotion. With the *Thousand Talents* scheme, Beijing wants to bring back highly qualified Chinese expatriates. However, despite the massive deployment of resources, scientific breakthrough cannot be planned, particularly not in the weak field of basic research. In addition to financial resources, favorable academic frameworks are require, and developing of them takes time. What is more, export of AI products developed under Chinese data protection standards is encumbered by strict regulations in Western countries.

Great Britain: At the beginning of 2018, the British government and the private economic sector agreed to jointly promote R&D and the commercialization of AI with 1 billion Euro. The agreement is based on the country's strengths: British AI research is very influential internationally, and nowhere else in Europe are there more AI startups concentrated in one place than in London. At the same time, the government has set the foundation for the development of ethical guidelines for AI, including the establishment of a Centre for Ethics and an international AI Ethics Conference planned for 2019. However, the commercialization of research, as expressed by the small number of patent publications, among other factors, is considered a "historic weakness." It is still unclear how the country will continue to attract scientists and entrepreneurs after Brexit, and how it will compensate for its loss of influence in the EU. What is clear, however, is that the UK is currently expanding their technological cooperation with the US. After Brexit, other European countries will have to do without the Anglo-Saxon approach.

France: Macron has formulated a leadership claim by striking the balance between the Chinese and American strategies, and basing it on European values. The French president reckons his country's greatest advantage in AI development to be in the centralized structure and organization of the political system. In the areas of health, mobility and defense, the relevant ministries are using strategies and resources to stimulate AI applications. However, it is questionable whether innovations can be centrally controlled in the long run, because success in AI requires a broad spectrum of experiments in various fields of application. A striking trend is the small number of French institutes and teaching staff that actively conduct research in areas directly related to AI (Great Britain has almost eight times more, Germany about four times more), as well as the lack of cooperation between academia and industry. Planned centers of excellence will help bring together scientists to work with users in projects and scenarios that are, to a certain extent, autonomous. And, at the same time, new rules established by Macron will allow researchers to work concurrently in the academic and private sectors. About 30 public institutions have set up branches around the Startup Campus "Station F" in Paris to advise startup companies on legal issues while learning what new AI developments might mean for the country. A network of voluntary AI experts ("AI reserve") is to advise the state on the procurement of technologies and support cyber security.

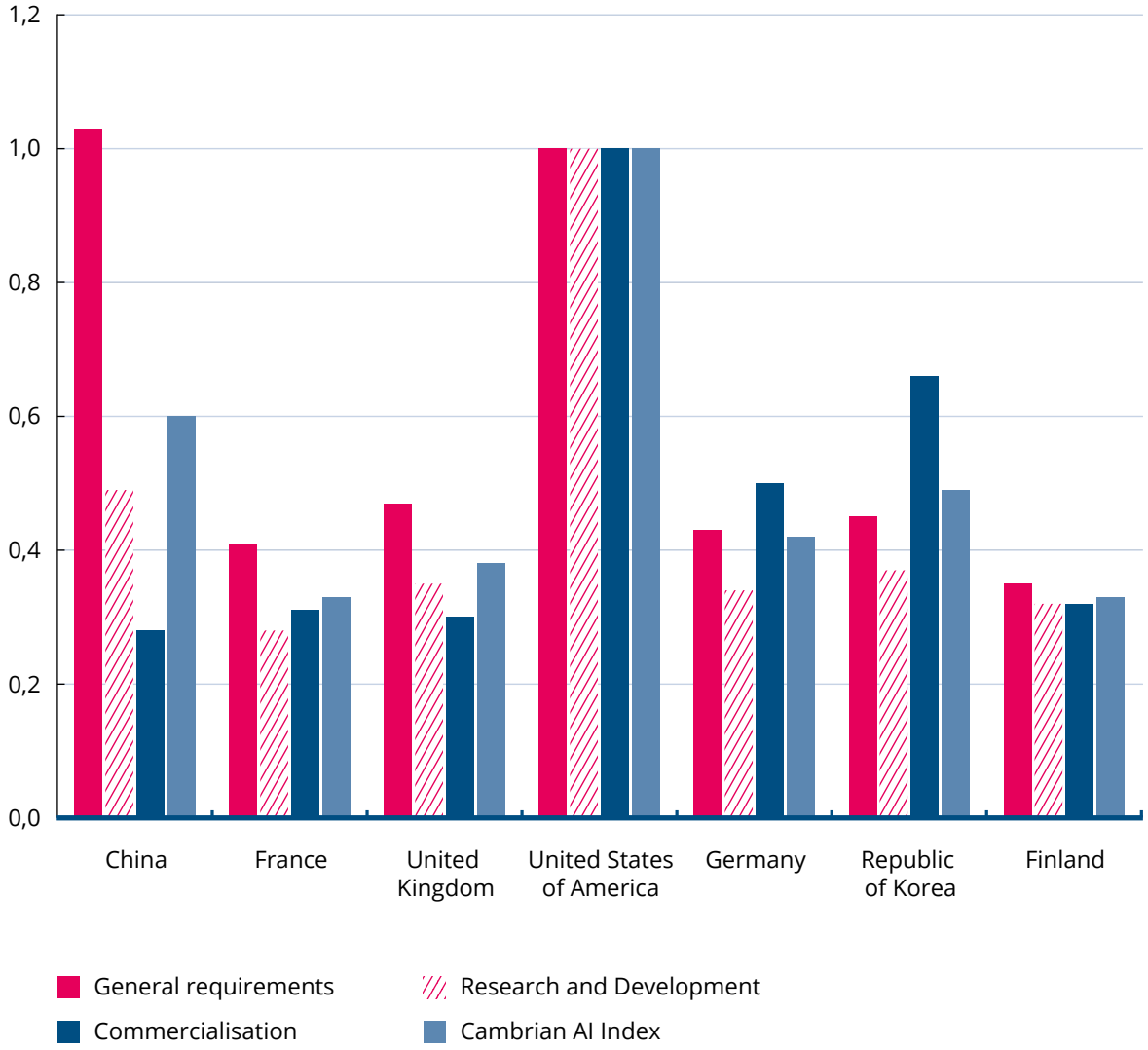
Finland: In Helsinki, it is clear that the big strings in AI development are pulled elsewhere. The country's data pool and market cannot keep pace with the big AI players. Thus, the focus is entirely on AI application and cooperation between business, science and administration – by topic across separate domestic and European ecosystems. The

major part of the funds made available for the field are aimed at the promotion of a small but growing AI startup scene and the adaptation of traditional industries to AI through research subsidies. One interesting feature is "Innovation vouchers," which enable companies to purchase expertise from other firms or researchers and use it to develop and test new ideas. Commercial potential for AI beyond Finland's borders is available in the health sector, based on the Finnish genome project "FinnGen" and in cooperation with IBM Watson Health. Another niche is the development of a protocol for international data exchange (IHAN), similar to the IBAN protocol for bank transfers. Among the countries examined, Finland is the only one to submit its own government document that's specifically dedicated to work and ethics in the AI age. And it intends to keep those regulations adaptable, so it can adjust to all the potential opportunities for making AI usable.

South Korea: In Seoul, AI technologies are considered to be part of an inevitable "fourth industrial revolution," similar to German industry 4.0. Based on the economic model of export-oriented industrial production, which has been very successful to date, the focus is on the promotion of strategic hardware and AI applications. The Moon government has good preconditions on which it can build toward competing with the larger AI players. South Korea is already in third place in filing the most AI patents, behind the USA and China. Around 1 billion Euro have been made available to be spent on brain research, the findings of which are expected to lead to the next breakthrough in the field of neural networks. To enable faster commercialization of AI applications, "transitional licenses" are intended to allow companies to develop their products to market maturity while government approval procedures are still in progress. This could take place, for example, in the large-scale, networked tech parks (e. g. "Innopolis"), where AI research is being conducted right next to industrial sites. The data and knowledge obtained there will then be shared with startups and SMEs to help them develop new services and technologies. To promote early commercialization of knowledge closely in line with research, more than 80 universities grant their students absence periods of up to four semesters to take care of their startups. The best among them are determined through national events that prepare them for international competition and help them build an international profile. So far, there are hardly any AI startups, and large corporations such as Samsung prefer to buy innovation abroad.

Cambrian AI Index ©

This analysis assessed countries on base indicators that incorporate a country's AI preconditions, the research and development environment and the degree of AI commercialization. To integrate these indicators and to determine the AI position of a country, the Cambrian AI Index was developed. The index is limited by proxy measurements for which reliable and comparable data are available at this early stage of the AI application.[5] There was no weighting of the data.



5 Cf. Methodology of the Cambrian AI Index chapter

United States of America
Defending the global AI leadership position

- World leader in AI due to established cooperation structures between government, the private sector and universities: The state's funding is focused on basic research, while the private sector concentrates on application research.
- Public funding schemes focus their efforts on the contextual adaptability of AI (what is referred to as the "third wave")
- Ethics has no great significance under Trump

I.) Introduction

In 2016, the National Science and Technology Council (NSTC), on behalf of the Obama government, developed the USA's first AI strategy, which is considered a blueprint for other countries, e. g. China.[6] In addition to assessment of the interdependencies and implications of AI, automation, and economics[7] the "National Strategy Plan for AI Research and Development" postulates the defense of the country's AI leadership position as well as the courageous vision of "a future world where AI is safely deployed for all members of society."[8]

The fact that the AI is considered a priority of the Trump government "since the first day" is emphasized by the current Deputy Chief Technology Officer Michael Kratsios.[9] In contrast to that, Tim Hwang, former Google employee (global public policy for AI and Machine Learning), gave a reminder at the beginning of 2018, saying "we are still waiting for the White House to provide a strategic direction."[10] General tendencies of this unfolding development have been noticeable since May 2018: the focus is on strengthening the environment for research and development (R&D); supporting American workers; reducing "innovation inhibitors;" and enabling industry-

specific AI applications.[11] So far, however, no documented national strategy from the new administration is discernible.[12]

II.) Requirements for AI

After China and India, the USA has the most internet users with 246 million (2016)[13] providing potential data for AI. The data pools of some technology companies are even larger. Facebook alone has more than two billion users every month.[14] There is a need for improvement in the quality and availability of public-sector data, with the US ranking third among this study's six countries on the Open Data Barometer behind Europe (in the comparison set).[15] The AI leadership position of the USA also becomes evident in supercomputers and semiconductor manufacturing,[16] as well as AI talents. The USA has the world's largest pool of young researchers with an estimated 10,000 master's and doctoral students graduating each year from computer science departments with active AI research initiatives.[17]

III.) Institutional framework

Ethics – New government, new priorities: Since the inauguration of the Trump government, ethical issues have apparently no longer played a major role in the White House AI strategy.[18] The strategy of the Obama government included requirements for more transparency in AI-supported decision processes and suggestions for ethical governance architectures, such as a two-step monitoring architecture for both the operational and the ethical and legal evaluation of AI applications.[19] However, in documentation from the AI summit held in May 2018, these issues are no longer mentioned. The summit materials merely contain potential negative consequences for employees.[20] Although AI-related ethics is not publicly discussed by the Trump government, the authors of this study know from discussions with senior officials in departments and agencies that the issue remains an important consideration. Furthermore, in addition to work by non-governmental organizations and companies, Congress has addressed the ethical implications of AI.

The US private sector has traditionally played a central role in the research, development and commercialization of new technologies. This is underlined by milestones such as: 1) Kinect (Xbox 360 games console from Microsoft 2010), which is the first to translate body movements into the virtual world of gaming with the help of a 3D camera and infrared sensor; 2) the IBM-AI Watson, which won the panel game Jeopardy against professional players in 2010; and 3) the victory of Google's AI AlphaGO over Go grand master Lee Sedol. Against the background of this private economic dynamic, the government's role is limited, with the White House merely acting as a coordinator.[21] Kratsios, Chief Technology Officer at the White House, says that „the frontline of AI policy lies with federal agencies."[22] The most important authorities with regard to AI promotion are: the Department of Commerce, the Energy Department, the Department of Defense (including the Defense Advanced Research Projects Agency, or DARPA), the National Science Foundation (NSF), and the Intelligence Advanced Research Projects Activity (IARPA), a research organization to support the intelligence services. Leaders from are to be given a seat on an AI committee, which was announced at the May 2018 AI Summit to improve coordination and advise the White House.[23] The legislative branch deals with AI in a largely independent fashion from the executive powers. At the end of 2017, the Representative John Delaney in his *Future of A. I. Act* called for the establishment of an „Advisory Council for the Development and Implementation of AI" at the federal level to advise the Commerce Department and Congress and to deal with AI-related issues, including the USA's competitiveness, implications for the labor market, ethical aspects and international cooperation.[24] The law had yet to be passed as of July 2018. Recently, Elise Stefanik, member of Congress, also introduced a legislative initiative to fill the gap in a coherent national strategy.[25]

IV.) Research and Development

With investment of approximately 445 billion Euro (2016)[26] by the private sector (62 percent), the government (25 percent), private universities (four percent), and civil society, the USA is world leader in terms of total R&D spending.[27] The private sector's share of such funding is increasing in the US, but it still lags the private-sector percentages in China, South Korea and Germany. However, the volume and ratio of investment for AI-specific R&D funding is unclear. In 2015, government investments in *unclassified* R&D (i. e. not considered secret) were 950 million euros,[28] according to Obama government strategy documents. The Trump government announced a 40 percent increase to 1.3 billion Euro in May 2018, "in addition to the substantial *classified* investments in defense and intelligence."[29] However, no figures are available for this.

In the research fields of *computer vision, machine learning, data mining, and natural language processing,* the USA are in the lead. Since 2016, the number of institutes actively engaged in research has been at about 126.[30] This is more than the total number of AI R&D facilities in the other examined countries combined. Regarding the number of scientific AI publications, the USA ranks second behind China. However, measured by the influence and impact of the publications (H index)[31] it remains in the lead. According to Chinese scientists, this will not change in the near future.[32]

Fields of research and instruments for advancement of research

Even though the priorities of the Trump government for investments in AI R&D still need to be finalized by the announced committee,[33] one can assumed that the focus will remain on the promotion of basic research rather than applied research.[34] This assumption is supported by the expected annual investments of 90 million Euro in basic research and labor-market research at the interface with AI, as announced in May 2018 by NSF Director Dr. France A. Cordova,[35] and as suggested by the government's R&D funding priorities for fiscal year 2019, which are aimed at early phase and basic research by the federal agencies.[36] This concept is consistent with Obama's policy of using public funds as a complementary means to those from the private sector, which are focus mainly on application-oriented R&D.[37] The Obama administration saw a need for funding of basic research projects in fields such as data analysis, theoretical models for performance efficiency of AI and hardware, and a range of topics dealing with "Interaction between man and AI."[38] (See chart 1).

The Obama administration's strategic plan contained a list of application areas, including agriculture, education, medicine, production, and law, but it did not describe which ones the economy and public sector should support. Only the funding focus on public goods is mentioned, since investments by the private sector cannot be expected due to the lack of commercial benefit.[39]

The AI R&D strategy plan of the Obama government consisted of seven sub-strategies:

1. Long-term investments in AI research
2. Development of effective methods for cooperation and interaction between man and AI
3. Understanding and addressing the ethical, legal and societal implications of AI
4. Ensuring safety and security of AI systems
5. Development of common public data records and environments for AI training and testing
6. Measurement and evaluation of AI technologies based on standards and benchmarks
7. Better understanding of national needs for R&D personnel in AI

The strategic plan closes with recommendations for the development of an implementation plan and preparation of a needs assessment for the labor market.

No explicit focus was placed on *General AI*, a subcategory of AI that would enable a machine to

solve a variety of different tasks, comparable to human cognitive abilities. The authors of the strategy pointed out that "long-term concerns about super-intelligent *General AI* should have little influence on today's policy" and that "the best way to increase capacities to deal with long-term speculative risks is to address the short- to medium-term risks such as security and data protection."[40]

Although the Trump administration's priorities have not yet been determined, according to Kratsios the focus is on applications fields of defense and security as well as economic advancement.[41] The memorandum on priorities in R&D in the 2019 budget, which was addressed to the federal agencies, adds the focus areas of energy and health care to the list of priorities.[42]

As far as the instruments for research promotion are concerned, the USA represents the Anglo-Saxon research model, which is characterized by competition-driven science funding and college/university budgets that are heavily dependent on third-party funding. This is also reflected in the funding programs of the federal authorities and the NSF, which implement the government's research funding. In the fields of computer science, mathematics and statistics, the *Department of Defense (*DoD) and the NSF provided 83 and 79 percent of such R&D funding in 2016.[43] Experts assume that since 2017 the subsidies among the institutions have shifted in favor of the DoD. The NSF was founded in 1950 with the aim of "promoting the progress of science, of supporting national health, prosperity and well-being, to ensure national defence."[44] Support and funding will be particularly provided in the field of basic research in all sectors (except medical research), not by hiring researchers and setting up new laboratories but by financing research at existing institutions. The only priority goal highlighted in the Foundation's Strategic Plan 2018–2022 is a similar market-oriented approach put forward by Kratsios:[45] The "development of public and private partnerships to increase the impact of NSF investments and contribute to the competitiveness and security of the American economy."[46]

One of the most successful research programs of the government is DARPA, an DoD agency that is responsible for inventions such as the Internet and GPS. DARPA divides AI development into three "waves." While previous DARPA AI investments aimed at further development of rule-based AI ("first wave") and statistical learning-based AI ("second wave"), DARPA today focuses on the contextual adaptability of AI ("third wave") – i. e., a theory and application of AI that deals with the limits of the technologies from the first and second waves.[47] The *Artificial Intelligence Exploration* program, which was launched for this purpose in July 2018, allocates funds of up to 800,000 euros in an uncomplicated and quick manner to successful grant applications.[48]

That instrument is part of a comprehensive AI investment strategy at DARPA, which matches the overall effort of the DoD. According to an analysis by market research company Govini, spending on AI, *big data* and *cloud* has increased by 32.4 percent to 6.3 billion Euro between 2012 and 2017. DARPA accounted for 28.5 percent of the investments for the three most critical sub-segments: deep learning, machine learning and natural language processing.[49]

V.) Commercialization

In addition to the globally active "digital barons,"[50] – such as Google, Apple, Facebook, or Amazon, each of which manages enormous financial resources and data volumes – the most (approx. 1,400)[51] and most influential (77 of the Top 100)[52] AI startups are established in the USA. The application areas focus on cyber security, healthcare, marketing and sales, as well as business solutions (see chart 2). The proximity to research and funds has a highly promotional effect on the startup environment. From 2012 to 2016, 17 of the 18 most active and AI-savvy investors in startup ventures were from the U. S. Accordingly, it was there that most AI investments were made in 2016 (62 percent of the global investment volume of around 4.3 billion Euro).[53] However, other countries are catching up. In 2012, 79 percent of the AI deals were

closed in the U. S.[54] Five years later, in 2017, a Chinese company (Bytedance) reported the highest capital (2.68 billion Euro) of the Top 100 startup companies, for the first time.[55] Between 2015 and 2017, an average of 74 percent of the internationally enforceable AI patents originated in the USA *(assignee country)*.[56] However, the number says nothing about the quality of the patented innovations.

Regulation: "The way I think about the regulatory structure for AI, is that a thousand flowers should bloom early in a technology," Obama said in 2016.[57]

Implementation of this is achieved through cautious and incentive-generating state regulation, according to the Anglo-Saxon understanding. The foundation for this is formed by three acts:

(1) The Bayh-Dole Act (1980) allows American universities to exploit intellectual property from government-sponsored research.

(2) The *Small Business Innovation Development Act* (1982) supports small enterprises with commercialization of new technologies, followed by the *Small Business Innovation Research Program (SBIR),* which facilitates technological innovation and participation of small businesses in government R&D activities and subsequent commercialization of such activities.

(3) The *Small Business Research and Development Enhancement Act* promotes scientific and technological cooperation among universities and small enterprises and permits grants for technology transfer to small enterprises. This results in professionalization of the players involved and strong interdependence between universities and industries (second only to Switzerland).[58]

To strengthen knowledge transfer between public institutions, science and other organizations, the Obama government discussed the expansion of a personnel exchange program (see text box). Integration of different perspectives in the development of AI was considered an instrument for risk minimization against discriminatory AI systems.[59]

The ***Intergovernmental Personnel Act Mobility Program*** provides for the temporary exchange of personnel among governments, colleges and universities, Indian tribal governments, government-funded R&D centers, and eligible organizations. The Obama strategy saw this as an opportunity to promote knowledge transfer and thus ensure effective regulation of technologies such as AI.

To adequately promote AI commercialization, the Trump administration considers the reduction and elimination of innovation-inhibiting factors its most decisive action.[60] For example, it considers it necessary that states and municipalities to have permission to carry out innovative drone operations, which so far have been banned by federal aviation authorities.[61] The development of more effective regulation for autonomous driving is also seen as a core issue, because the first countries or regions to adopt an effective regulatory framework for autonomous driving can expect to benefit from investments made by vehicle manufacturers and providers of intelligent infrastructure and other support services, regardless of their respective stage of development in AI. As early as in 2017, the Department of Transportation published an update of the 2016 *Federal Automated Vehicles Policy*, which provides developers of automated vehicles with non-regulatory guidance for safe integration of driverless vehicles in the United States.[62] Moreover, in April 2018, the National Food and Drug Administration (FDA) approved the first AI-based medical diagnostic device.[63]

However, other government regulations, especially immigration regulations, weaken the leading position of the USA. The *Center for American Entrepreneurship* has found that 43 percent (2017) of the Fortune 500 entrepreneurs are immigrants or children of immigrants.[64] The consequences of immigration policy can be seen in the example of Sara Sabour, a young Iranian researcher at Google who was denied a US visa and therefore moved to Toronto, together with Geoffrey Hinton, a leading Google AI expert.[65]

The public sector as users of AI: The strategy documents do not only consider the public sector as a promoter and investor, but also as a user and beneficiary of AI. The USA ranks second in the world (behind the United Arab Emirates) in the procurement of advanced technology by public institutions.[66] During Obama's presidency, the volume of public procurement was identified as an opportunity to create incentives for the development of ethically correct, transparent, and fair AI by setting appropriate targets.[67] Even if the management agenda of the Trump government does not explicitly include AI, it still represents a central pillar for increasing the efficiency of public administration.[68] Sharing of public data will be given a central role to promote AI applications outside the public sector. In addition, the *General Services Administration* (GSA) is conducting pilot programs using AI, including a tool predicting expected compliance with rules and regulations, which is planned for this year's production in Cloud.gov.[69]

Another concrete example is DIUx, which was founded in Silicon Valley in 2015 and represents "an agile government entity" that provides capital to companies in order to solve national defense problems."[70] Investments are made within 90 days in the form of so-called pilot contracts, lowering the hurdles for possible follow-up contracts.[71] Although integration of DIUx-funded innovations into the DoD proves to be difficult and the cultural divide between the military and Silicon Valley can occasionally encumber cooperation, the DoD also plans to hold on to DIUx under Trump.[72]

6 Metz, 2018
7 White House, 2016a; White House 2016b; White House 2016c
8 White House, 2016b: 8
9 Kratsios is considered a key figure in technology policy, especially as the appointment of Kelvin Droegemeier as scientific advisor to the government and head of the Office of Science and Technology Policy (OSTP) of the White House is still pending (Reardon, Witze, 2018).
10 Metz, 2018
11 White House, 2018b
12 Dutton, 2018; Sputnik, 2018
13 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)
14 Statista, 2018a
15 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)
16 124 of the top 500 supercomputers 2018 are operated in the USA, six of them are among the top 10 (Top500.org, 2018). In addition, American companies, between them, generate the highest sales of semiconductors compared to the industrial sales of other countries. The EE Times also assumes American companies to dominate the global FPGA chip manufacturing market in 2016 (Dilien, 2017).
17 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)
18 White House, 2016a; Shepardson, 2018
19 White House, 2016b: 26–27
20 White House, 2018d
21 Coldeway, 2016
22 Metz, 2018
23 White House, 2018d: 7
24 115th Congress, 2017
25 Stefanik, 2018
26 All foreign currency amounts mentioned were converted into euros and rounded up or down (exchange rate as at 30 August 2018) for the purpose of standardisation
27 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)
28 White House, 2016a: 25
29 White House, 2018d: 5; Corrigan, 2018
30 CS Ranking, 2016–2018 (cf. Methodology of the Cambrian AI Index)
31 SJR, 2017 (cf. Methodology of the Cambrian AI Index)
32 Groth, Nitzberg, 2018: 159.
33 Shepardson, 2018
34 Corrigan, 2018
35 NSF, 2018b
36 White House, 2017a: 1–2
37 Ibidem
38 White House, 2016b: 16–17
39 ibidem: 6–7, 15
40 White House, 2016a: 7–8
41 Metz, 2018
42 White House, 2017a: 1–2
43 NSF, k. D.
44 Ibidem
45 World Economic Forum, 2017: 303 (cf. Methodology of the Cambrian AI Index)
46 NSF, 2018a: 28
47 Launchbury, k. D.
48 FBO, 2018
49 giovini, n. D.:1
50 Cf. Groth, Nitzberg, 2018
51 Asgard Human Venture Capital/Roland Berger, 2018: 8–9 (cf. Methodology of the Cambrian AI Index)
52 CB Insights, 2017b (cf. Methodology of the Cambrian AI Index)
53 Ibidem
54 Ibidem
55 CB Insights, 2017b (cf. Methodology of the Cambrian AI Index)
56 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index)
57 Dadich, 2016
58 World Economic Forum, 2017: 303 (cf. Methodology of the Cambrian AI Index)
59 White House, 2016a: 17, 27
60 White House, 2018b
61 White House, 2017b
62 NHTSA, 2017
63 FDA, 2018
64 Buchanan, 2017
65 Metz, 2017
66 World Economic Forum, 2017: 303 (cf. Methodology of the Cambrian AI Index)
67 White House, 2016a: 34
68 White House, 2018a
69 White House 2018: 6
70 DIUX, k. D.
71 Ibidem
72 Simonite, 2017

China

Catching up and overtaking – with massive capital investment

- The Chinese strategy is the only one of the compared documents that contains measurable economic goals and benchmarks
- Efforts to centralize AI support and funding and to control the use of AI
- Promotion of AI basic research through new institutes and apprenticeships and the recruitment of researchers through the *Thousand Talents* program
- Training in what is referred to as "AI+" professions that overlap with AI
- Development of thematic innovation platforms in cooperation with technology companies

I.) Introduction

The government in Beijing considers AI to be a "strategic opportunity" to lead the country into a knowledge-based economy. The strategy published by the State Council in July 2017 plans implementation of this in three steps:

- Catch up with the leading AI nations by 2020 and create an AI industry worth 19 billion Euro and related industries worth 126 billion Euro;
- Become the world leader in AI by 2025 and increase the value of the AI industry to 51 billion Euro and related industries to 635 billion Euro;
- Achieve supremacy by 2030, with an industry worth130 billion Euro and the related industries worth 1.2 trillion Euro.[73]

At the moment, the strategy still reads like a "wish list for Santa Claus"[74] and contains only few concrete proposals for achieving the established objectives. However, experts say the visions could become reality because of the country's size and ability to experiment.[75]

Much like the *One Belt, One Road* megaproject,[76] investments in AI are aimed at global influence, although there are many domestic policy motivations as well. Similar to South Korea, the victory of Google Deep Mind's "AlphaGo" in the Chinese game Go is considered a "Sputnik" moment in China, as evidenced by the sudden post-match increase in search queries for "Artificial Intelligence" on Baidu (the equivalent of Google in China).[77] In addition, a study by the McKinsey Global Institute calculated that half of the country's economic activities could be automated.[78] In addition to risks for the labor market, AI offers the opportunity to keep production levels stable despite an ageing population. The exploding costs of health care could also be reduced, corruption could be combated more efficiently and a more effective transport system could be established.[79]

II.) Requirements for AI

Apart from India, no other country can match the enormous data volume of the estimated 730 million Chinese internet users.[80] It must be noted that China ranks last among the six included countries in terms of the availability and quality of public data (19.64 out of 100 points).[81] However, this is compensated by the data pools of the large Chinese technology companies, which are filled by one billion users per month through Facebook competitor WeChat alone.[82] In addition, the state system allows the government to collect and use data much more systematically than in the USA, for example. Paired with the highest number of top supercomputers (208/500)[83] and the largest estimated talent pool after the US,[84] China has the best basic prerequisites to further expand its global position in the field of AI. As for strategic weaknesses, a lack of cutting-edge semiconductor products was revealed in 2015, when the US government banned chip manufacturers from selling semiconductors to China.[85]

III.) Institutional framework

Ethics, a topic of secondary but growing importance

In China, data protection and the ethical implications of AI have so far lagged the economic considerations. AI laws, regulations, ethical standards and security controls are going to be established in a step-by-step manner, but only from 2020 onwards (to be fully in force by 2030). The *Social Credit System* planned for 2020, for example, serves more to control society and avoid political and social conflicts than to protect data. Also, the last paragraph of the *Public opinion guidance* strategic plan does not leave any doubt that intentions are to control public opinion. Still, ethical questions are gaining in importance among experts, as revealed by discussions about "moral machines" and stronger controls that arose from a report by the Tencent Institute.[86]

The national AI plan of the State Council carries much weight in centrally controlled China, especially as it fits perfectly into the "Chinese dream" of Xi Jinping. The document not only systematizes promotion and funding of AI, which has already been laid out in various strategic plans,[87] it also reorganizes institutional responsibilities at national level. AI-related strategies, such as the "Internet Plus" plan and the "Three-Year AI Implementation Plan," are accounted for by the State Commission for Development and Reform, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the *Cyber Space Administration of China*.[88] The AI plan of the State Council, on the other hand, provides for the establishment of a new office managed by the Ministry of Science and Technology, which will be responsible solely for implementing the strategy.

This corresponds to a general tendency towards centralization, as shown by the government's attempts to control domestic technology companies (cf. Commercialization chapter).

IV.) Research and Development

Although R&D spending in 2016 was only around 2.1 percent of GDP, in absolute terms China spends the most money on R&D worldwide after the US.[89] Similar to South Korea, more than three-quarters of research investments are made by companies, which leaves the conclusion that there is a general dominance of applied research. The boundaries between business and government are not altogether clear, so it must also be assumed that the economic objectives of the AI strategy will be achieved through government support for research and development. In relation to the overall population, the number of scientists is comparatively low,[90] and there's also a lack of AI researchers. Since 2016, about 271 scholars have been performing active research in the fields of AI, computer vision, machine learning, data mining, natural language processing and robotics. They're at eleven institutes with an estimated 800 doctorate students per year.[91] And while the *McKinsey Global Institute* assumes that there are more institutions (30 instead of 11),[92] these figures are still too low to fulfil the requirements to achieve leadership in AI research. Measured by the number of scientific AI publications, the country has already achieved global leadership (in 2017, with 11,383), but the impact of such publications lags that of the American and British researchers, and in the country achieved only sixth place in the field of statistics and probability.[93] The high number of publications in relation to the rather low influence leads to the conclusion that there is less scientific innovation.

Fields of research and instruments for advancement of research

The status as one of the "leading global AI hubs"[94] is mainly the result of private investments in application-oriented R&D, which resulted from the government-promoted rapprochement of universities and companies since the 1980s. As part of the reform and open-door policy, the universities were granted greater autonomy and public funding was cut in order to stimulate the acquisition of third-party funds, which led to a concentration on commercialization. As a result, however, "The priority of pursuing rapid economic benefits, social capital and hierarchical status has reduced the incentives for researchers to undertake long-term basic research."[95] In response to this weakness, the AI strategy intends to fund basic research in various theoretical areas.[96] Another dimension the strategy uses to define focus areas is technology systems.[97] In order to advance these areas and systems, new institutions, courses of study and doctoral programs are going to be established, although without defining any specific objectives. Like the technology companies,[98] the government wants to address the lack of talent and has thus initiated the *Thousand Talents* program as early as 2008. It is intended to bring back renowned Chinese scientists, academics and entrepreneurs living abroad and to facilitate international experts' access to Chinese research institutions. Reduced bureaucracy and financial incentives have already lured many talents back – albeit not the "best of the best."[99] Researchers who have done their PhD degrees in the USA hardly come back and, if so, only do so on a temporary basis. The framework conditions for research are more important than the financial incentives. Alibaba, SenseTime and other technology companies are reacting to the double problem of a shortage of skilled workers and inadequate basic research in a rather pragmatic manner, setting up their own billion-dollar research laboratories in the USA.[100]

On the labor and talent front, the government also plans to support both educational institutions and companies in training the workforce and promoting young talent. And it has expanded training of Chinese students and workers to strengthen what it refers to as "AI+" (see text box).

In this manner, China is following an approach similar to the Japanese under what they call Digital Society 5.0.

By **"AI+" professions** the government means professional fields in the areas of economics, social affairs, management, or law at the interface with AI. To achieve this, the strategy provides for a stronger combination of training in AI and mathematics, computer science, physics, biology, psychology, sociology, law and other disciplines.

The army has also become aware of the disruptive potential of AI to gain a decisive advantage over competing powers. Much like DARPA in the USA, it promotes application-oriented R&D on intelligent and autonomous unmanned systems, AI-enabled data fusion, information processing and intelligence analysis, war games, simulation and training, defense, offense and command in information warfare, as well as AI support in planning, command and decision-making.[101]

V.) Commercialization

The enormous size of the internal market holds great potential for the expansion of AI applications. The Chinese "digital barons" – including Baidu, Alibaba and Tencent (see chart 3) – are already capitalizing on this advantage.[102] At the same time, the country is home to the second largest number of AI startups worldwide (383), behind the USA,[103] eight of which CB Insights considers to be among the most influential.[104] In 2017, China accounted for the world's highest share of equity financing in AI startups (48 percent versus 38 percent in the USA),[105] as well as the AI startup that collected the most venture financing worldwide.[106] The positive developments are also reflected in an explosive increase in patent publications, in particular for the keyword of *deep learning*.[107] According to this, China is eight times greater than the USA (see chart 4). However, an in-depth analysis (chart 5) illustrates that only a very small proportion of the Chinese patents have an international equivalent, which would make the patents enforceable outside the country. (Between 2015 and 2017, an average of just 1.3 percent of Chinese AI-related patents had international equivalents, compared with 74 percent for the USA.[108]) Against the background of this imbalance, the question arises as to how the country will make use of its constantly growing global influence to help shape the international patent regime, or to build up its own regime of institutions, for which there are already precedents.

Regulation: With stronger control mechanisms – through party committees in companies, for example – the government intends to increase its influence on the tech giants.[109] Chinese companies still enjoy great advantages over global competitors due to the protected market. However, questions remain about their ability to commercialize internationally, since their AI applications are based on culturally, linguistically and geographically bound data, the limits of which are also set by the "Chinese Intranet."[110] In addition, there is growing awareness and regulation of data protection (such as the DSGVO) in the U. S. and Europe, which will make it more difficult for Chinese companies to export their AI products developed under domestic data protection standards[111] or to collect data in these markets and to exploit them using Chinese procedures.

The government is expected to promulgate more regulations and laws to protect intellectual property and establish standards for autonomous driving, service robots and safety management, according to a January 2018 white paper from the Chinese Institute for Standardization of Electronics (CESI).[112] In order to help shape the development of a global *governance* structure for AI, the country is already active in an AI subcommittee of the International Organization for Standardization.[113]

To promote an intelligent economy and further strengthen the collaboration between R&D and applications, the strategy provides measures to support new AI industries, modernize existing industries, establish AI innovation guiding lights and develop AI-innovation platforms.[114,115] In addition, pilot projects are planned to open up access to government data and set up AI *open source* hardware and software infrastructure platforms. Although the strategy on how platforms should work remains vague, there are examples already available: Alibaba Cloud's *"City Brain"* AI platform, which aims to create "smart cities"; a "smart" public health service on Tencent's AI platform; and autonomous vehicles on Baidu's Apollo platform.[116]

The public sector as users of AI: In addition to the *social credit* system noted above and the different AI platforms the state uses, the defense sector is particularly important. With regard to commer-

cialization of military AI applications, China has an advantage over the USA. The Chinese model of civil-military fusion stands in sharp contrast to the cultural resistance the Pentagon encounters in *Silicon Valley*. The greater cooperation between the private and public sectors will be helpful in realizing and implementing the required applications in the fields of *big data, cloud-computing,* AI and other cutting-edge technologies for the development of a joint mission control system.[117]

The government also looks at the wider context of public goods to create markets for AI applications, doing so in areas where it sees high demand. The Chinese government currently ranks tenth in the world in the procurement of advanced technologies.[118]

Infrastructure and financial support: Parallel to these efforts at the national level, cities and provinces (e. g. Beijing, Shanghai and Tianjin) are developing their own AI plans and strategies. In January 2018, the city of Beijing announced the construction of an AI park for roughly 1.8 billion Euro to promote research and commercialization through startups in partnership with foreign universities. The new AI Park will focus on attracting companies in the fields of *big data,* biometric identification, *deep learning* and *cloud computing*.[119] Shortly afterwards, the city of Tianjiin announced plans for a roughly 12.8 billion Euro fund for investments in the AI industry and higher education.[120] This sum alone is about eleven times greater than the total volume of deals in the British AI sector. Among other things, scientific institutions will receive around 3.8 million Euro when they settle in Tianjin.

The national government also established a separate industrial investment fund of 15 billion Euro to support the semiconductor industry, supporting the development of advanced manufacturing processes, mainly through foundry services, and to encourage creation, growth or mergers of companies.[121,122] As a result, the construction of ten new semiconductor plants and *foundries* was planned for 2016 and 2017.[123] These developments are noteworthy, as traditional computer architectures are reaching their limits for the use of AI. Advanced materials technology is therefore considered to be the "key to opening up the commercial value of AI."[124]

73 New America, 2017 (translation of the *Next Generation Artificial Intelligence Development Plan*)

74 Webster, Creemers, Triolo, Kania, 2017

75 Metz, 2018

76 Economist, 2018: 13–18

77 Ding, 2018: 20

78 Barton, Woetzel, Seong, Tian, 2017: 1

79 Webster, Creemers, Triolo, Kania, 2017

80 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)

81 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)

82 Statista, 2018

83 In the Top 10 of the Top 500 only 2 super computers are from China (Top500.org, 2018), (cf. Methodology of the Cambrian AI Index)

84 CS Ranking, 2016–2018 (cf. Methodology of the Cambrian AI Index)

85 Barton, Woetzel, Seong, Tian, 2017: 8

86 Ding, 2018: 30

87 13th five-year plan for the development of the national strategic and emerging industries (2016–2020), "Internet Plus" and "Three-Year AI Implementation Plan" (2016–2018)

88 Ding, 2018: 14

89 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)

90 1096 per million inhabitants (UNESCO, k. D.), (cf. Methodology of the Cambrian AI Index)

91 CS Ranking, 2016–2018 (cf. Methodology of the Cambrian AI Index)

92 Barton, Woetzel, Seong, Tian, 2017: 8, 15

93 SJR, 2017 (cf. Methodology of the Cambrian AI Index)

94 Barton, Woetzel, Seong, Tian, 2017; Ding, 2018: 25

95 Chen, Sanders, Wang, 2008: 10

96 *Big data intelligence theory; Cross-media sensing and computing theory; Hybrid and enhanced intelligence theory; Swarm intelligence theory; Autonomous coordination and control, and optimized decision-making theory; High-level machine learning theory; Brain-inspired intelligence computing theory;* Und *Quantum intelligent computing theory.*

97 *Knowledge computing engines and knowledge service technology; Cross-medium analytic reasoning technology; Key swarm intelligence technology; Hybrid enhanced intelligent new architectures and technologies; Autonomous unmanned systems intelligent technology; Virtual reality intelligent modelling technology; Intelligent computing chips and systems;* and *natural language processing technology.*

98 Chou, 2018; Marr, 2018; MIT, 2018

99 New York Times, 2013

100 Shu, 2017; MIT, 2018

101 Horowitz, Kania, Allen, Scharre, 2018

102 French, 2018

103 Asgard Human Venture Capital/Roland Berger, 2018: 8–9 (cf. Methodology of the Cambrian AI Index)

104 CB insights, 2017b (cf. Methodology of the Cambrian AI Index)

105 Varadharajan, 2017: 31

106 CB insights 2017b (cf. Methodology of the Cambrian AI Index)

107 Number of patent publications shown for a keyword search "Deep Learning" in title or abstract of a patent (www.epo.org). However, the number of patents is not indicative of their quality.

108 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index). In the Cambrian AI Index we work with the internationally enforceable patent numbers, as this is globally accepted procedure to date. We point out, however, that strategically motivated readers should closely and critically follow the further development of China's internal figures in order to be prepared for potential competition among regimes.

109 Ding, 2018: 18

110 Webster, Creemers, Triolo, Kania, 2017

111 Murison, 2018

112 Luo, Kaja, Karch, 2018

113 ISO, 2017

114 *Smart software and hardware, smart robots, smart delivery tools, virtual and augmented reality, smart terminals, basic Internet of Things devices*

115 *AI Open-Source Hardware and Software Infrastructure and Platforms; Group Intelligent Service Platforms; Hybrid Enhanced Intelligent Support Platforms; Autonomous Unmanned System Support Platforms; AI Basic Data and Security Detection Platforms.*

116 Varadharajan, 2017: 21–30

117 Horowitz, Kania, Allen, Scharre, 2018

118 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index)

119 Reuters, 2018a

120 Reuters, 2018b

121 Foundries are companies operating in the field of microelectronics, manufacturing products in semiconductor plants for other semiconductor companies

122 Ernst, 2016

123 Dieseldorf, 2016

124 Bajikar, 2018;

Great Britain

Outstanding AI science, challenges in commercialization

- Promotion of AI through an agreement between the private sector and the government;
- The Alan Turing Institute is the primary conduit for efforts to promote research and commercialize universities' intellectual property.
- Priority is also given to ethics and AI through a dedicated center and a planned international conference on the development of AI governance standards.
- As a result of Brexit, there are also signs indicating closer cooperation with the USA.

I.) Introduction

With the *AI Sector Deal,* an agreement between the public and private sectors, the British are showing their plans to establish and strengthen the country as a leader in AI. This is one of four deals[125] included in an overriding industrial strategy that pursues the vision of making the United Kingdom the world's most innovative economy, creating good jobs and higher productivity, improving the infrastructure, being the best place for business startups, and ensuring prosperity in communities.[126]

More than one billion Euro will be used to promote education, build infrastructure, create a conducive business environment and establish sites for AI R&D. Of this sum, approximately 673 million Euro comes from newly allocated funds and about 382 million Euro from existing budgets. Both include state, industrial, and university contributions. Another 280 million Euro are intended for "connected and autonomous vehicles."[127] There is no schedule for the provision of the funding.

II.) Requirements for AI

With around 62 million internet users, the country can only draw on a comparatively small pool of private data,[128] but it is the world leader in terms of high-quality public sector data.[129] In addition, internet users are less skeptical about sharing data than their continental European neighbors.[130]

The country also has a good approach to training young AI talent. Since 2016, an estimated 950 master's students graduated annually from institutes that have been actively researching AI-relevant fields.[131] However, with only 22 of the 500 most powerful supercomputers, the country has a strategic disadvantage in terms of computing power,[132] and there is no domestic semiconductor production.

The withdrawal from the EU also means that the country will lose ready access to the common market and the user data of continental Europeans, as well as a direct influence on the orientation of R&D funding priorities within a possible pan-European *governance of* AI in Brussels. In contrast, an agreement concluded with the USA in 2017 paves the way for closer transatlantic research cooperation.[133] Due to the US leadership role in AI, this could generate greater added value for the country than the connection with the EU.

III.) Institutional framework

Ethical AI? The UK lays the foundation and establishes facts

While Macron speaks of Paris as the European center of ethical AI discussions, concrete measures are already being developed in London regarding ways to develop ethical norms for the use and development of AI. The report by the UK House of Lords *(AI in the UK: ready, willing, and able?*) argues that the UK has an opportunity to become the global leader in the development of international standards for AI.

In June 2018, the government formed the Centre for Data Ethics and Innovation Consultation as an advisory body for this purpose.[134] And a global summit on this subject is already planned for 2019. However, Lord Puttnam, a leading British politician, has said the loss of EU integration will weaken the country's influence on ethics and AI globally.[135]

The *AI Sector Deal* was produced in April 2018 under the overall management and guidance of the Secretaries of State for the Department for Business, Energy and Industrial Strategy (BEIS) and for the Department for Digital, Culture, Media & Sport (DCMS), along with AI experts Professor Dame Wendy Hall (University of Southampton) and Jérôme Pesenti (Facebook). The deal will be implemented by the Government Office for Artificial Intelligence, which initiated an AI Council in June 2018 to advise the office and oversee operations.[136] One of the first tasks of the office is to develop implementation plans and success benchmarks for each of the individual sections of the *AI Sector Deal*. In addition to these initiatives, the House of Lords' Select Committee on AI deals with the AI issues in a detailed report (*AI in the UK: ready, willing, and able?*). The report represents the results of a ten-month analysis of the economic, ethical and social impacts of AI innovation and was supported by international interviews, including in Germany and France.

IV.) Research and Development

The country has the best prerequisites for AI-relevant R&D of the six nations considered in this part of the report. While R&D spending as a percentage of GDP ranked last among the six (1.69 percent in 2016) and it ranked fifth in absolute figures behind France and Germany,[137] the output from British AI research is impressive. Between 2016 and 2018, for example, there were about 136 scholars from 15 institutions actively involved in AI research (third place behind the USA and China).

In addition, an estimated 400 PhD students per year are writing their doctorate theses on

research topics related to AI.[138] Although British researchers only contributed around 2,250 publications on AI topics in 2017 (about a quarter of Chinese publications), their influence is at the forefront globally (second place in the H index).[139]

Fields of research and instruments for advancement of research

The Engineering and Physical Sciences Research Council (EPSRC), the central government agency for funding research and education in the engineering and natural sciences has assumed a critical role in the British AI ecosystem. The council is managed by and reports to the Alan Turing Institute for Data Science and Artificial Intelligence, which was founded in 2015.[140] Its tasks include research, advising decision-makers, and development of guidelines to support the justification of AI decisions.[141] As a national organization, the institute can work across multiple disciplines and in partnership with universities, industry and government. This close network between the public and private sectors resembles the pragmatic cooperation approach applied in the USA and distinguishes itself from the rather philosophical and normative orientation of continental European countries.[142]

In its "Ideas" chapter, the AI Sector Deal provides for government research investments amounting a total of 475 million Euro, which will be distributed by the EPSRC. Approximately 47 million Euro of this funding is intended for the Alan Turing Institute, and about 93 million Euro is earmarked for 159 research grants in AI technologies.[143] A detailed weighting of research priorities is illustrated by the distribution of the research funds that was charted out by the EPSRC and the Alan Turing Institute's research focus areas. (See chart 6) According to that and as of September 2018, the EPSRC's financial support focuses on robotics (21 percent), statistics and applied probability calculation (18 percent), information systems (16 percent) and man-computer interaction (12 percent). From a sector standpoint, the plan targets information technology (13 percent); aerospace, defense and marine applications (10 percent); as well as the environment (8 percent). Other sectors include healthcare, energy and the transportation system.[144] The research schemes of the Alan Turing Institute, which are partly financed by private economic partners, cover the areas of policy development, health care, data science in economics, defense and security, data-centered engineering, and data science at scale. The latter represents research on algorithms, such as those deployed in the area of *deep learning*, and the improvement of hardware to increase the speed and efficiency of data-driven computing tasks.[145]

In addition, the Institute supports other stakeholders through partnerships that, among other things, address the challenges of revolutionizing health care; ensuring safe and intelligent technology; security management in an insecure world; understanding the economy; making algorithm-based systems fair, transparent and ethical; developing computers for the next generation of algorithms; using AI in the humanities; and strengthening innovation in the public sector.[146]

In addition to funds for research subsidies, investments in the labor market are also planned. These include setting up a fellowship program at the Alan Turing Institute and increasing the number of publicly supported PhD positions in AI subjects from 200 (2020–21) to 1,000 (2025) annually. About 110 million Euro will be distributed by the EPRSC for doctoral scholarships,[147] supplemented by contributions from the private sector.[148] To increase the pool of future researchers, the government is investing 453 million Euro in mathematics, digital matters and engineering at schools, including the improvement of skills and competences among 8,000 computer science teachers. In hopes of increasing diversity among AI researchers and because of potential Brexit outcomes, the strategy also aims to ease immigration and relocation of foreign AI talent.

V.) Commercialization

Compared to the USA and China, the country's startup scene is only of middling rank, but it leads in Europe. No other European country can claim more AI startups (245), and four of them rank on the list of the most influential AI startups.[149] Also,

several foreign AI pioneers have assured explicit contributions to the *AI Sector Deal*, including Google, Amazon and HPE from the USA, Element AI from Canada, Ironfly Technologies from Hong Kong, and Astroscale from Japan.[150] Contributions by large British companies, on the other hand, are hard to find (Rolls Royce being the notable exception). Great Britain also leads Europe on measures of R&D cooperation between industry and science (worldwide: it ranks sixth).[151] This is having a great effect. More and more companies are founded by graduates and the revenues from commissioned research and the marketing of intellectual property are increasing.[152] However, these positive results still lag far behind expectations. Parliament even speaks of "Britain's historic weakness in commercialization,"[153] a fact also reflected in the small number of AI patent publications emerging from the country.[154]

Regulation: Commercialization can be achieved through selling licenses for intellectual property to existing companies or through the creation of new *spin-out* companies. To facilitate this, many universities have initiated *Technology Transfer Offices*. However, most are not sufficiently efficient due to organizational, academic and cultural restrictions.[155]

The Industry Challenge Fund, an integral part of national industrial strategy, pursues the goal of strengthening science and business innovation. The fund is divided into different support "challenges",[156] three of which are to be financially strengthened by the *AI Sector Deal* – accounting, insurance and legal services "of the next generation" (22 million Euro); "Robots for a safer world" (103 million Euro); and "Data for early diagnosis and precision medicine" (234 million Euro).[157] In addition, university efforts to market their research and innovation in cooperation with companies will get around 280 million Euro per year until 2021. This will be accompanied by a 110 million Euro *Connecting Capability* Fund, which supports universities in pooling capacities and exchanging best practices in commercialization.[158]

Besides the provision of funds for technology transfer, the management of research and innovation is restructured by the Act on Higher Education and Research. This includes foundation of the *UK Research and Innovation* (UKRI) umbrella organization, whose main activity is managing the Industry Challenge Fund and providing companies with a clear understanding of the opportunities arising from the UK research community's intellectual property.[159]

Konfer, an initiative of UKRI, provides the service of innovation brokerage: The online tool (https://konfer.online) was developed to help companies search for researchers, facilities, equipment and financial resources and to create opportunities for universities to find potential research partners.

A new investment fund by the British Business Bank will also be set up to support high-growth companies. Through joint investments with the private sector, a total of around 8.4 billion Euro (including 2.8 billion Euro of its own funding) are to be leveraged. A reform of the *Enterprise Investment Scheme* (EIS) and the *Venture Capital Trusts* (VCTs) was designed to help support more than 7.8 billion Euro of "innovative, knowledge-intensive" investments in fast-growing companies over the next ten years. Similar revisions will make it possible for pension funds to invest in assets that promote innovative companies.[160] These measures are in line with investments in *Tech City UK*, amounting to 23 million Euro to promote the digital economy ecosystem.[161]

The public sector as users of AI: The *AI Sector Deal* also regards the public sector as a driver of innovation and user of AI. According to the *AI Government Readiness Index,* the United Kingdom provides the best preconditions for an AI-driven public administration,[162] but the country only ranks 24th in the world in the procurement of advanced technology for the public sector.[163] Around 22 million Euro will be invested to support technology companies in developing innovative and technical solutions for administration. At the same time, the government wants to make data publically available in order to promote research and new business models in the private sector.[164]

125 The industrial strategy defines AI, clean growth, future of mobility and an ageing society as areas in which the government is considering a future leadership position to be possible (BEIS, DCMS, 2018: 6)

126 BEIS, 2017b: 13.

127 BEIS, DCMS, 2018: 8

128 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)

129 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)

130 Middleton, 2018

131 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)

132 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index)

133 BEIS, 2017a

134 DCMS, 2018

135 Groth, Nitzberg, 2018: 124

136 Hardacker, 2018

137 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)

138 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)

139 SJR, 2017 (cf. Methodology of the Cambrian AI Index)

140 Cambridge, Edinburgh, Oxford, UCL and Warwick. Eight more universities were added in 2018: Leeds, Manchester, Newcastle, Queen Mary University of London, Birmingham, Exeter, Bristol, and Southampton

141 BEIS, DCMS, 2018: 13, 16, 18

142 Groth, Nitzberg, 2018: 316

143 BEIS, DCMS, 2018: 13

144 EPSRC, 2018

145 Alan Turing Institute, k. D.

146 Ibidem

147 BEIS, DCMS, 2018: 16

148 Ibidem: 16–17

149 Asgard Human Venture Capital/Roland Berger, 2018: 8–9 (cf. Methodology of the Cambrian AI Index)

150 BEIS, DCMS, 2018: 14–15

151 World Economic Forum, 2017: 300–301 (cf. Methodology of the Cambrian AI Index)

152 Between 2016 and 17, 4,161 startups by graduates were registered; revenues of around 1,345 billion Euro were generated from commissioned research and almost 167 million Euros from the disposal of intellectual property. These figures are the result of an average annual growth of 8.6 percent in the sale of university intellectual property and a revenue increase of four to five percent from research partnerships, commissioned research and consulting services between 2003/04 and 2015/16 (HESA k. D.)

153 Parliament UK, 2017

154 1.13% in 2015, 1.23% in 2016 and 1.46% in 2017 of the overall AI patents according to *Assignee Country* (M-Cam, 2018), (cf. Methodology of the Cambrian AI Index)

155 RSM, 2018: 5–12

156 Audience of the future, Faraday battery, early diagnosis and precision medicine, healthy aging, health care, next generation services, energy revolution, quantum technologies, robotics, construction & design, food production, creative industries, driverless cars, manufacturing and future materials as well as the National Satellite Test Facility (BEIS, UKRI, 2017)

157 BEIS, DCMS, 2018: 9, 13

158 BEIS, 2018: 17

159 UKRI, k. D.

160 BEIS, DCMS 2018: 20

161 Ibidem: 18, 21

162 Stirling, Miller, Martinho-Truswell, 2017

163 World Economic Forum, 2017: 300–301 (cf. Methodology of the Cambrian AI Index)

164 BEIS, DCMS, 2018: 13, 18

France

Taking the middle course towards leadership

- Network of interdisciplinary AI institutes (R3IA), focus also on niche topics
- Researchers have the opportunity of working commercially for half their time
- “Innovation playgrounds” and startup promotion
- Administration: consulting and learning from “Station F” AI startups
- Network of voluntary experts for consulting and security (“AI Reserve”)

I.) Introduction

For France’s President Macron, AI not only represents a major technological revolution, but “an economic, social and therefore a political one” that he wants to help shape as a chief spokesperson.[165] The French strategy can be described as an “interdisciplinary cross-breed of mathematics, social sciences, technology and philosophy.”[166] In March 2018, Macron presented the strategic cornerstones: Ecosystems comprised of talent, research and an adventurous spirit; open data policies; improved financial and regulatory frameworks; and ethical rules.[167] He underscored the need for European values to represent a middle course between the dominant models from the USA and China. In a speech widely quoted by the media, Macron announced that around 1.5 billion Euro will be available for this purpose by 2022. However, to maintain the “digital sovereignty” of France and Europe,[168] countries will need to cooperate – for example by forming a joint EU research landscape for AI. France will also pursue bilateral agreements with Canada and other countries in hopes of becoming less dependent on the time-consuming cooperation in Brussels.[169] A bilateral cooperation on AI is also planned with Germany.

II.) Requirements for AI

The relatively small population of the country and the correspondingly small volume of potential user data (as ranked among the six countries[170]) leads to low scalability of AI applications. European integration would overcome this. France is increasingly opening state data pools in recent years, a move that has helped it quickly catch up on the *Open Data Barometer*.[171] Of the "Top500" supercomputers, only 18 are in France.[172]

III.) Institutional framework

Since 2016, a number of players from science, politics,[173] and the economy *(France Digitale, ISAI-Fonds*) have started to tackle the topic of AI in France, compiling reports and holding various events. The Ministry of Economy and the Ministry of Education launched the *"FranceIA"* initiative in an effort to compile a national AI strategy. In the report, ten working groups stipulate recommendations for the government on the topics of research, commercialization and social and political framework conditions.[174] It was Macron who first made AI a top priority and commissioned the mathematician Cédric Villani to develop a more comprehensive strategy that takes ecology, ethics and diversity into account.[175] From this, Macron derived the sectors of health, mobility and defense (but not ecology) to be areas of application for his "National Program for Artificial Intelligence."[176] France benefits from centralized structures and organization of its state matters, such as the extensive health database (SDSN). Macron claims that Paris already has an AI ecosystem[177] based on business and science, and he holds centralized decision-making power and direct control over the ministries, unlike in the United States.

Shortly after Macron's announcements,[178] a strategy for autonomous driving was presented and the Ministry of Defense announced an investment of 100 million Euro in AI research and application.[179] About 400 million Euro were made available to form a network of AI research institutes,[180] along with another 180 million Euro earmarked for German-French projects.[181] The main instruments to promote the commercialization of AI are specified in the "PACTE" bill[182] by the Ministry of Economy and Finance.

Ethics in research
The Villani report describes in much detail the ethical problems that may arise from AI, such as the explainability and justification of decisions by machines *(deep neural networks*) and the risk of discriminatory algorithms.[183] Ethical considerations should therefore be integrated as a topic spanning all areas of AI research. At the moment, these considerations are lagging behind practice, but they will be necessary for the acceptance of AI.[184]

IV.) Research and Development

Between 2016 and 2018, only about 17 scholars did active research in AI areas.[185] Their influence through AI-related publications, as measured by the H index, ranks seventh on an international comparison. Their influence is greater in the fields of computer vision, language patterns and statistics, probability calculation and decision science (ranking third).[186] The research landscape is fragmented and the system of funding it is neither efficient nor innovative.[187] Approval of applications takes up to one year, is strongly oriented towards concrete research outputs and has little prospect of success. Unlike in the United States, there is also a lack of large companies involved in financing and carrying out application-oriented upstream research, so that research is mainly state-funded.[188] Due to the lack of "permeability" between the academic and private sectors (lowest of all the countries examined[189]), most French AI scientists prefer to work in Anglo-Saxon systems.[190]

Strategic research fields[191]
In the "upstream research" report by the *FranceIA* working group, the authors identify 36 "disruptive research topics" that they classify into nine major research fields. They

briefly describe their respective research-related challenges: 1) perception (visual, auditory); 2) interaction of man and machine (speech recognition, decision-making aids); 3) big data; 4) justification of AI decisions and actions; 5) machine learning (deep learning, unsupervised learning, incremental learning, reinforcing learning); 6) problem solving (optimization, beyond NP, heuristic/meta-heuristic search, multi-level reasoning); 7) decision, autonomous agents and collective AI; 8) general AI; and 9) ethical and social challenges, acceptance and data protection.[192]

Fields of research and instruments for advancement of research

The main instrument of the AI promotion in the field of R&D is the establishment of a national network of "four or five … independent but coordinated"[193] interdisciplinary AI institutions (RN3IA),[194] each with a separate thematic focus. These are jointly operated and funded by public universities and private companies. Two of these institutes already exist: PRAIRIE and *DataIA* (see text box). The *FranceIA* experts recommended promoting all AI areas equally (see text box).[195]

The Villani report, on the other hand, notes that it's necessary to focus efforts and funding on topics that are currently highly relevant (above all deep learning, big data), but it's also important to ensure the consistent promotion of previously neglected topics (e. g. knowledge representation, semantic web, distributed AI and game theory). The report argues that these topics might already bear "the seed of the next AI revolution"[196] and that research should not focus exclusively on deep learning. Diversity in research is critical in such a young field, and France might be able to "surprise" the AI giants on topics that are currently less prominent[197] – precisely because large American and Chinese companies put their energy into the star topics.

The intention is to attract both domestic and international teachers, faculty, staff and researchers through reduced bureaucracy in the process to approve research proposals and by creating "innovation playgrounds" (cf. Commercialization chapter).[198] Villani suggests that entry-level salaries at universities should be in line with those payed by the tech giants, or at least doubled from their current rate.[199] Macron has not made a statement on that, yet. Another important instrument to support research is the announced consolidation of and broader access to state data pools on platforms that "follow a sector logic."[200] For example, the Ministry of Health is already conducting a feasibility study on the opening of the health data base (SDSN) and its expansion to include clinical data.[201] Other sectors, such as mobility or agriculture, are expected to follow soon, possibly in cooperation with Germany and the EU.[202] Villani also proposes the development of a super-computer specifically for AI, one exclusively available to French researchers and especially to the "3IA" institutes.[203] As an alternative, pooling of computing power through cloud Infrastructures on the pan-European level could also make sense.[204]

Paris Artificial Intelligence Research Institute (PRAIRIE)

The Institute includes CNRS and INRIA, as well as Amazon, Google, Facebook and Microsoft. French industry participants include Suez and PSA.[205] The primary focus has not yet been publicized, but one current initiative (OpenLab PSA) focuses on basic and application research for the automotive industry.[206]

DataIA[207]

Data IA includes Paris Saclay, INRIA and engineering schools alongside private players such as Renault, IBM Research, EDF and Axa. Previously, application-oriented research focused on big data, deep learning, digital trust, transparency and societal issues.[208]

For further allocations of funds from the announced 400 million Euro budget, AI competitions are currently held in the fields of medical diagnostics and the security, reliability and certification of algorithms. These competitions are intended to leverage additional investment from the private sector.[209]

V.) Commercialization

Asgard Capital and Roland Berger have counted 109 AI startups in France, less than half the amount of the UK.[210] Of these French startups, CB Insights identifies one (Shift Technology) among the 100 most influential in the world.[211] Only 3.3 percent of global AI deals were done in France in 2016.[212] Google, IBM, Samsung and other large corporations have opened branches and AI research institutes in the country, but there are no French organizations that could scale up or market AI applications globally.

Regulation: To enhance the permeability between research and commercialization, researchers at public universities will now be allowed to work up to 50 percent of their time as employees or owners of private companies, in addition to their teaching duties.[213] To place experiments in "real life" conditions and thus facilitate innovation, Villani proposes the initiation of "innovation playgrounds" where certain regulations will be temporarily relaxed.[214] The French authority for postal and communications regulation (ARCEP) has already implemented such a system for accessing band frequencies.[215] It is also planned to gradually establish a regulatory framework for autonomous driving by 2022[216] and to regulate predictive algorithms,[217] while a national auditing system is to check the fairness of algorithms through ex post facto evaluations (instead of preventive regulation).[218] At the same time, however, PACTE also envisions the extension of "strategic" sectors in which foreign investments would be subject to state approval.[219] Currently, these would include AI, robotics and large-scale databases, which are considered relevant for "national security" and critical to the country's economy.[220]

The public sector as users of AI: As far as public procurement of advanced technology is concerned, France ranks last among the six countries examined.[221] Within the European public procurement law for awarding contracts, the increased use of "competitive dialogs" with potential contractors would ensure more flexibility in the government's search for useful applications, allowing discussions without the end product having to be precisely defined in advance.[222] In order to have the necessary personnel capacities available in the administrations, the Villani report proposes to establish a joint AI Center of Excellence and an "AI Reserve" – a network of voluntary experts who will advise on the procurement of digital technologies and support the national cybersecurity agency.[223] In an effort to foster 1,000 startups and the jobs they create,[224] 30 public services and authorities have set up offices at the *Station F* startup campus. There, they advise startups on legal frameworks and, in return, learn about the innovations developed there and how they might overlap with state needs.[225]

Financial support for the promotion of companies/startups: To promote "disruptive innovation" in general and AI in particular, a 10 billion Euro "Fund for Industry and Innovation" launched in January 2018 to pay 100 million Euro per year for AI and 25 million Euro per year for nano-electronics.[226] 70 million per year are provided for startups in a more generalized Deep Tech category.[227]

165 Wired, 2018
166 Ibidem
167 Macron, 2018
168 Ibidem
169 Diplomatie Francaise, 2018
170 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)
171 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)
172 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index)
173 OPECST, 2017
174 France Intelligence Artificielle, 2017
175 Villani, 2018
176 Macron, 2018
177 Franceisai.com/research
178 Idrac, 2018
179 Cf. Ministère des Armées, 2018
180 Ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation, 2018a
181 Macron, 2018
182 LeMaire, Gény-Stephann, 2018
183 Villani, 2018: 65, 113ff
184 Ibidem: 65.
185 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)
186 SJR, 2017 (cf. Methodology of the Cambrian AI Index)
187 France Intelligence Artificielle, 2017: 8
188 Ibidem: 10
189 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index)
190 Macron, 2018
191 Ibidem
192 Cf. overview in France Intelligence Artificielle, 2017: 8ff.
193 Macron, 2018
194 Villani, 2018: 10
195 France Intelligence Artificielle, 2017: 10
196 Villani, 2018: 64
197 Ibidem
198 Villani, 2018: 10
199 Ibidem: 76
200 Macron, 2018
201 Ministère des Solidarités et de la Santé, 2018
202 Macron, 2018
203 Villani, 2018: 75
204 Ibidem: 54
205 INRIA, 2018a
206 INRIA, 2018b
207 Dataia.eu
208 DataIA, 2018
209 Ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation, 2018b
210 Asgard Human Venture Capital/Roland Berger, 2018 (cf. Methodology of the Cambrian AI Index)
211 CB Insights 2017b (cf. Methodology of the Cambrian AI Index)
212 CB Insights , 2017a (cf. Methodology of the Cambrian AI Index)
213 LeMaire, Gény-Stephann, 2018: 51
214 Villani, 2018: 47f.
215 ARCEP, 2018
216 Macron, 2018; LeMaire, Gény-Stephann, 2018: 53
217 Villani, 2018: 124
218 Ibidem: 117f.
219 LeMaire, Gény-Stephann, 2018: 61
220 Usine-digitale.fr, 2018
221 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index)
222 Villani, 2018: 39
223 Ibidem: 56ff.
224 Wired, 2017
225 La FrenchTech
226 LeMaire, Gény-Stephann, 2018: 55
227 Ibidem

Finland

On its way to becoming a top user country

- High level of cooperation between industry, research and administration
- Focus on adaptation, application and commercialization (e. g. in the health sector)
- Main sponsor, *Business Finland,* awards "Innovation Vouchers" to companies and others
- Protocol for International Data Exchange ("IHAN")

I.) Introduction

Finland only has about five million inhabitants. There is no world-leading university. The startup scene is modest, albeit growing. And since the Nokia crisis in the early 2010s, it's home to no internationally operating platform companies. "It's clear that the major portion of AI development and innovation will take place outside Finland," according to the "Finland's Age of Artificial Intelligence" strategy paper from October 2017.[228] Nevertheless, it claims to be the "leading country in the application of AI" with its best achieved "when AI aids and supports workers in their daily work."[229] The authors of the strategy, working with former Nokia CEO Pekka Ala-Pietilä focused on three aspects: 1) competitiveness and growth of the private sector through the full exploitation of AI; 2) "high-quality and effective" public services through AI; and 3) adjustment of society to the changes through AI, particularly the preservation of work, health and privacy.[230] Accenture estimates Finland will achieve 4.1 percent growth in its economy due to AI by 2035, making it the economy that stands to benefit most from AI after the US.[231] In comparison to the other cases examined, however, the commitment of around 173 million Euro until 2022 is rather modest, mainly intended for startups and the "renewal" of companies[232] to increase their competitiveness, while very little of the sum is spent to promote basic research.

II.) Requirements for AI

The small population results in the smallest absolute number of Internet users among the countries surveyed and, thus, Finland has smaller domestic data resources.[233] The *OpenData* Barometer in 2016 ranked Finland in 20th place worldwide (first place: Great Britain) for availability of public data,[234] although the country has been pursuing an open data policy since 2013.[235] Finland also has the smallest pool of talent of any of the countries, with an estimated 60 master's graduates in AI areas per year.[236] Of the 500 supercomputers, only one is in Helsinki,[237] and there's no indication that Finland will develop its own chip industry.

III.) Institutional framework

The entrepreneurial and technology-oriented center-right coalition of Prime Minister Juha Sipilä is striving for a "leap in productivity of the public and private sectors" with one of its five focal points of "digitalization, experimentation and deregulation."[238] The AI strategy was commissioned by the Ministry of Economy and Labor and developed by a group of 72 representatives from various ministries, as well as the economy and science. This "steering group" will also be responsible for providing support and consulting for the implementation of the measures proposed, including development of networks around the four sub-groups (expertise and innovation, data and platform economics, transformation of society and labor, and public sector). The study suggests that implementation of the proposals through partnerships between public and private players – a PPP model for "ecosystem policy."[239] The overall responsibility lies with the Ministry of Economic Affairs, where AI is considered one of its "key projects."[240] The Ministry founded *Business Finland* in early 2018,[241] and the organization will channel most of the promised AI investments into application-oriented research, development and commercialization.[242] In addition, the economic and other ministries have presented sector strategies for AI initiatives in climate-friendly energy,[243] digital licensing, and transportation.[244] Support for university research is provided by the national *Academy of Finland.* The Ministry of Local Governments and Public Reform is responsible for structuring and accessibility of government databases.[245] This argues in favor of a pragmatic application approach, which is less geared towards global leadership and more towards an increase and reinforcement of domestic economic power.

IV.) Research and Development

Total investment in research and development in 2016 was around 2.75 per cent of GDP, of which 48 percent was contributed by the private sector and 29 percent by public funds.[246] These are expected to rise to 4 percent of GDP by 2030.[247] Although the country was far behind other industrialized nations in absolute terms with only around 5.7 billion Euro in expenditure (roughly on par with Singapore), in 2016 there were around 7,000 researchers per million inhabitants actively operating in the country, a top figure among the countries surveyed.[248] Nevertheless, between 2016 and 2018, only about eight teachers from the renowned Aalto University were actively involved in AI research and in advising an estimated 20 doctoral students there,[249] the lowest figure of all countries surveyed. The AI publications they produced resulted in few citations and had little impact when compared with other countries.[250]

Fields of research and instruments for advancement of research

In October 2017, Aalto University, the University of Helsinki and the VTT Technical Research Center initiated the Finnish Center for Artificial Intelligence (FCAI). In addition to university degrees, the organization performs research on the basics (see text box) and offers AI courses for schools and companies. New PhD and postdoctoral positions for *Machine Learning* projects have been announced.[251] To make AI easier to understand and more accessible for people in non-technical fields, the center has also founded the *FCAI Society*.[252]

Finish Center for Artificial Intelligence: Includes work in machine learning, deep learning, reinforcement learning and control, data science, distributed systems, human-computer interaction and signal processing. It looks at the application of these technologies in three major areas: 1) AI for areas in which there is hardly any data; 2) development of secure methods (trust and ethics); and 3) mutual understanding between AI and users. Initiatives on autonomous AI, ethical and social aspects of AI, multimedia and computer vision, and industrial AI are being prepared.[253]

FCAI also performs research for applications in health, engineering and natural sciences,[254] which is in line with VTT's market approach. In 2018–2019, the Academy of Finland will provide six million Euro for research in the fields of machine learning, bio-medicine and statistics as part of the "ICT2023"[255] initiative (in partnership with Business Finland), with another 7 million euros between 2018–2021 for "new AI applications in physics and engineering."[256] Another important area of application is outlined in the "Strategic Research Agenda for Finland as a AI Innovation Hub for Health"[257] by the VTT research institute, which is using data from its genome project FinnG[258] for commercial purposes as well.[259]

V.) Commercialization

Around the same time as the global financial crisis, Nokia experienced its own crisis, selling its mobile communications business to Microsoft in 2013 and laying off around half its workforce.[260] As a result, former Nokia employees and researchers set up a PPP network of researchers and companies, called *Allied ICT Finland*[261] (previously, *HILLA Center*). It's organized in ten different ecosystems, including the FCAI, *Internet of Things,* 5G and 6G infrastructure, "smart" machines and production, augmented reality, drones and data analysis.[262] It offers 40 "test environments"[263] for development and commercialization of IT innovation, including AI.

The project is funded by companies and *Business Finland.* Other former Nokia employees have made significant contributions towards a growing startup scene,[264] which has recorded an increase in venture capital investments (in 2017, approximately 350 million Euro). There are 45 AI startups (South Korea has 42), a remarkable number for such a small-population country.[265] However, due to Nokia's troubles and a small number of AI start-ups, Finland is not position well for global commercialization and scaling of AI value chains. Still, it can fill niches in the health sector, ethical AI (see text box) and marketing of "test environments."

Ethics: In addition to the AI, strategy documents deal specifically with the impact of artificial intelligence on ethical issues and general economic and employment trends.[266] A key document recommends plans to establish rules that prevent monopolistic tendencies, monitor technological developments and clarify responsibilities for machine-made decisions, including in the health sector or for B2B applications.[267] The innovation agency SITRA hopes to achieve European and global attention with the development of a **Protocol for International Data Exchange (IHAN)**, analogous to the IBAN protocol for bank transfers. The idea is to create a standardized virtual identification account for everyone, as well "common standards, principles and an administrative model" for centralized administration of these accounts.[268]

Start-ups and small and medium-sized enterprises based in Finland can be supported through six different support programs, with amounts of up to 50,000 Euro if they match the amount through their own services. (See text box on the next page) So-called "innovation vouchers" are of particular interest here.[269] They allow companies to purchase expertise from other companies or researchers to develop and test new ideas. In line with that, startups can support national and international research projects if they work closely with companies. Larger companies can either obtain research loans – half of which cover the development costs

of new products or services – or grants for basic research with a marketing purpose.[270] In both cases, networking with small and medium-sized enterprises and research institutions is required. It should be noted, however, that some have criticized the impact of *Business Finland* on companies' results.[271]

Regulation: Since new technologies often produce unexpected results, it's important to adjust existing regulation patterns after initial experience has been gained.[272] Some legislation has already been adapted to accommodate the academic and commercial use of genome data from the Finnish "biobanks." This helped the SITRA Innovation Fund develop its "ISAA-CUS" project for the collection and coordination of health data.[273] Further legislation on the use of data for AI applications (including transport, forestry and health) is currently being adapted, as well.[274] After initial experience with self-propelled buses on designated roads, more demands for autonomous driving rules have been raised.[275]

One of the priorities of the Sipilä government is increasing the accessibility of public data pools and making them usable for research and, more importantly, for commercial purposes.[276] For example, data from the Ministry of Transport,[277] research data[278] and data from Helsinki[279] are now available, and they will be merged and pooled in the next step. This is already happening on the *Opendata.fi* platform, which has published around 1,300 data sets and various tools for combining them.[280]

***AI Business Program* – support for startups and small businesses**[281]

- Prototype development ("Tempo"): up to € 50,000
- Scaling (*"Young Innovative Company"*): up to € 1.25 million in a three-step mix of *grants* and *loans*
- Entry into export markets ("Into"): up to € 200,000 (50 percent of project costs)
- Expansion into international markets (*"Explorer"*): up to € 10,000
- Experimentation and testing (*"Innovation Vouchers"*): up to € 150,000 over three years (grant)
- *Trade Fair Grant:* up to € 30,000 for groups comprising at least four startups

Additional plans will ease access to the Finnish labor market for talent from outside the EU *(Talent Boost Program)*.[282] Experts who want to found a startup "with high growth potential" in Finland can get a two-year residence permit *(startup permit)*, and their children will get easier access to international schools.[283]

The public sector as users of AI: The Finnish state considers itself a user of AI, especially in the field of digitized administration and health care, even if the administration only ranks middle of the pack in terms of procurement of modern technologies.[284] One pilot project at the Immigration Department – speech recognition on the telephone – includes plans to set up a "network of customer service robots" for all areas of administration.[285] For their own initiatives, public agencies might share up to half the cost of development and testing of "innovative procurement solutions" with *Business Finland*, as long as the solution is jointly developed with service providers and users.[286]

228 Ministry of Economic Affairs and Employment, 2017b: 23

229 Ministry of Economic Affairs and Employment, k. D.

230 Cf. Ministry of Economic Affairs and Employment, 2017b. The strategy specifies measures in a total of eight fields of action: 1.) Increase of the competitiveness of companies through the use of AI, 2.) Effective use of data in all areas, 3.) Ensuring fast and easy AI transfer, 4.) Securing high-grade expertise; attracting high-grade experts, 5.) Brave decisions and investments, 6.) Development of the best public administration of the world, 7.) New models for cooperation, 8.) Making Finland the frontrunner in the AI age.

231 Accenture, 2016: 16

232 Own calculations on the basis of: businessfinland.fi and Academy of Finland, 2017b, c

233 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)

234 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)

235 Ministry of Finance, k. D.

236 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)

237 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index)

238 Government of Finland, 2017: 59

239 Government of Finland, k. D.

240 Ministry of Economic Affairs and Employment, k. D.

241 *Business Finland* is the result of a merger between the former innovation promotion agency Tekes and the former export promotion agency Finpro Oy.

242 Business Finland.

243 Ministry of Economic Affairs and Employment, 2017a

244 Ministry of Economic Affairs and Employment, 2018a

245 Ministry of Finance, k. D.

246 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)

247 Ministry of Education and Culture, 2018: Slide 9

248 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)

249 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)

250 SJR, 2017 (cf. Methodology of the Cambrian AI Index)

251 Finnish Center for Artificial Intelligence, 2018b

252 Finnish Center for Artificial Intelligence, 2018a

253 Finnish Center for Artificial Intelligence, k. D.

254 Ibidem

255 Academy of Finland, 2017b

256 Academy of Finland, 2017a

257 Ahola et al., 2017

258 FinnGen Research Project, k. D.

259 Lähteenmäki, 2017

260 Cf. Financial Times, 2015 and the figures quoted therein by Bloomberg

261 AlliedICT.fi

262 Ibidem

263 HILLA Center, k. D.

264 TechCrunch, 2015

265 Asgard Human Venture Capital/Roland Berger, 2018: 8–9 (cf. Methodology of the Cambrian AI Index)

266 Ministry of Economic Affairs and Employment, 2018b

267 Ibidem: 52f.

268 SITRA, k. D.a

269 Business Finland, k. D.

270 Ibidem

271 Tech Crunch, 2015

272 Ministry of Economic Affairs and Employment, 2018b: 54

273 SITRA, k. D.b

274 Keski-Äijö, 2018

275 SvenskaYLE, 2018

276 Business Finland, k. D.

277 Government of Finland, 2017: 16

278 Finnish Transport Agency, k. D.

279 Open Science and Research, k. D.

280 City of Espoo, k. D.

281 Open Data and interoperability tools, k. D.

282 Ministry of Economic Affairs and Employment(k. D.)

283 Business Finland, k. D.

284 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index)

285 Ministry of Economic Affairs and Employment 2017b: 38f.

286 Business Finland, k. D.

South Korea

Hidden champion of the ”fourth industrial revolution”

- Training of 1,400 AI talents
- Expansion of AI basic research with a focus on brain research
- Techparks (“Innopolis”) for close cooperation between science and industry
- “Electronic persons” and transitional licences in test zones

I.) Introduction

The March 2016 victory of Google DeepMind’s “AlphaGo” over Korean Go champion Lee Sedol was a key moment not only for the Chinese, but for the Korean public as well. Go has held a special cultural meaning for Koreans, and two days after the final game of the match President Park announced her plan to invest about 770 million Euro in AI and accelerate existing plans. According to Park, Korean society can “ironically call themselves lucky that, thanks to the AlphaGo shock, I understood the importance of AI before it is too late.”[287] Even then, however, a Korean AI professional criticized the fact that too much of the promised money was earmarked for industry and too little for universities.[288] At the end of 2016 the Ministry of Science, IT and Future Planning (MSIP)[289] published their master plan for intelligent IT.[290] It identifies AI as a technology that, based on the internet of things, cloud computing, big data and mobile platforms, will “inevitably [and] irreversibly … lead to the fourth industrial revolution.”[291] The vision is that of an “intelligent information society with man at the center.”[292] The government is to assume the role of a partner for “spontaneous innovation in the private sector,”[293] create the social and cultural infrastructure, and strengthen the social safety net.[294] In May 2017, the Moon government underscored Korea’s claim to be one of the world’s leading AI nations with approximately 1.7 billion Euro by 2022.[295] In

return, the government believes that GDP growth of around 360 billion Euro is possible by 2030.[296] The leading sectors of the fourth revolution in which the government will invest are autonomous cars, smart factories, drones and smart cities with smart infrastructure and green energy.[297] Investments will promote an "intelligent infrastructure" to support these initiatives.[298]

II.) Requirements for AI

Although roughly 93 percent of Koreans used the internet in 2016, the country only ranks ninth among the countries surveyed in terms of the absolute number of internet users.[299] The country held one of the top rankings in the Open Data Barometer that same year (fifth place).[300] With an estimated 200 master's graduates per year in subjects closely related to AI, it is roughly on a par with Japan and ahead of France.[301] Korean companies (e. g. Samsung and SK Hynix) are among the global leaders in semiconductor production. In 2017, these companies collectively generated the second-highest revenues in the chip business worldwide, trailing only the USA.[302] At the moment, South Korea operates only seven of the Top500 supercomputers.[303]

III.) Institutional framework

The liberal Moon Jae-in presides over a powerful central state.[304] In September 2017, he initiated the "Committee of the Fourth Industrial Revolution,"[305] which reports directly to him and whose head is the former startup entrepreneur and investor Chang Byung-gyu. The committee includes eight ministries, the presidential secretary for science and technology, various academics, and representatives of Korean conglomerates, startups and media.[306] Chang set out the main task of the committee as the "application of the opinions of the private sector to the policies already adopted by various government departments," with a goal to catch up with China as a competitor.[307]

IV.) Research and Development

Total investment in research and development has posted strong growth in recent years. With a share of 4.24 percent of GDP in 2016, South Korea is among the world leaders in investment rates.[308] Nevertheless, the absolute amount of around 50 billion Euro is comparable to that of France. In 2017, about 745 million Euro were invested in basic research and about 550 million Euro in "promising basic technology" through the National Research Foundation (NRF).[309] The largest investor, however, is the private sector, particularly the large corporations such as Samsung and LG, with a share of around 75 percent. Private companies focused mainly on application- and market-oriented R&D. The density of researchers is at a high level with about 6,900 per one million inhabitants, comparable with Israel and Finland.[310] In AI fields, an estimated 90 doctoral students graduate each year.[311]

Since May 2017, the Korea Advanced Institute of Science and Technology (KAIST) has been operating an AI center that focuses on research in areas such as brain research, machine learning, quantum machine learning, multimodal perception and interaction, natural language processing, emotional intelligence, smart chips for pervasive intelligence,[312] and AI for robotics.[313] The National Institute for Science and Technology in Ulsan (UNIST) performs research on "decision and explainability" for clinical diagnostics and financial transactions. It has been endowed with around 12 million Euro over five years.[314] Pohang University of Science and Technology (POSTECH) conducts AI research in computer science (i. e. machine learning for decision-making and big complex web data).[315] And the renowned "Research Institute for Electronics and Telecommunications" (ETRI) is conducting research in cooperation with the industry, particularly in "hyperintelligent software."[316]

However, scientific publications have had little influence outside Korea so far,[317] and they rarely are produced with international partners.[318] This is partly due to the low level of internationalization of universities and partly due to the fact that research results are often available only in Korean.[319]

Fields of research and instruments for advancement of research

The country's weaknesses mainly relate to a clear underfunding of basic research to date. To counter this, a new proposal aims to have 1,400 AI experts, including 350 researchers, trained and six new AI institutes set up by 2022. Basic research is to be funded above all in the fields of speech and image recognition and brain research, the findings of which will form the basis for the next step in the development of AI (neural networks).[320] The plans intended AI as a technology to produce new insights, which in turn are to serve the further development of AI. Korea's ambitions were made clear with an announced investment of about 1 billion Euro by 2022 and the establishment of a *Korea Brain Research Institute.*[321,322] Application-oriented AI research is also aim to help cut the development cycle of medicines from 15 to seven years.[323] In order to increase the internationalization of Korean universities, the entry requirements for foreign academics have been relaxed.[324] In addition, 3,600 employees are to receive further training in AI through support program until 2022. By 2025, the government wants to consolidate the data pools of all public institutions, make them machine-readable and open them up to developers.[325]

V.) Commercialization

Like Finland, the benefits of AI applications for the economy stand at the forefront of Korean considerations, particularly for the export-oriented industrial production by conglomerates. Korea's economic model, which has been very successful in recent decades, is mainly based on the ability of its conglomerates, such as Samsung, Hyundai and LG, to quickly adapt technological innovations by others, translate them into their own products and bring them to the global market cheaply and in large quantities (i. e. a fast-follower strategy). However, while Korea is one of the most innovative economies in the world, according to Bloomberg,[326] many of its companies are lag China and the USA with regard to AI.[327] To catch up, the conglomerates are investing billions into application-oriented R&D for future technologies, opening research centers around the world and strategically taking over AI startups abroad. Between 2015 and 2017, around 3 percent of all internationally enforceable AI patents came from South Korea, securing the country's third place in our worldwide comparison.[328] However, the internal structures of the family-run conglomerates are organized in a strictly hierarchical and patrimonial fashion. They dominate the domestic market and are very closely interwoven with Korea's politics.[329] The five largest conglomerates together accounted for more than half of the Korean stock market in April 2018, with Samsung alone accounting for around 30 percent.[330] This hinders startups and SMEs, resulting in high costs for innovation or unsustainable efforts to promote innovation.[331] This, in turn, has a detrimental effect on Korea's ability to produce groundbreaking and disruptive technologies. Still, the last 40 years have proven that this has not stopped the growth of the Korean economy. President Moon Jae-in's announcement to reduce the concentration of market power and the power of conglomerates has so far only led to moderate success.[332]

Ethics:
To prevent discrimination and social polarization, political decision-makers need to establish "precise methods for applying and testing ethical standards at an early stage of development"[333] (e. g. with a Technological Consequences Council consisting of representatives from the government, the private sector and civil society). An interesting approach is to have copyright and liability issues controlled by "electronic persons."[334]

Perhaps in response to international criticism from AI researchers about its (apparently discontinued[335]) cooperation with the military company Hanwha, KAIST founded a sub-committee for ethical AI and published a *Code of Ethics for AI* on its website (see Annex, chart 8). [336]

Startup funding: The number of startups is increasing, especially in the IT sector,[337] thanks in part to measures by the Park government,

including tax relief, simplification of merger laws and state funding of startups amounting to 360 million Euro.[338] In addition, more than 80 universities grant their students absence periods of up to four semesters to take care of their start-ups.[339] In the field of AI there were only around 40 startups affected in 2017,[340] none of which was able to gain international influence.[341] Gaining access to angel investment is difficult, and less than 1 percent of startups manage market exits through acquisitions. An IPO takes thirteen years on average.[342] All this results in the well-trained IT staff remaining with the conglomerates.[343] Therefore, the Korean master plan recommends the establishment of an initial fund of 23 million Euro from resources at the Korea Institute of Finance (KIF), gradually increasing that figure by 77 million Euro each year to support startups and SMEs in the field of intelligent IT.[344] Moreover, national events will be used to identify Korean startups in order to prepare them for international competitions (e. g. U. S. Mass Challenge) and build awareness of them outside Korea. It is also planned to expand "hubs for the intelligent IT industry" for startups based on the model of the already existing Pangyo Techno Valley, a kind of South Korean Silicon Valley.

Regulation: The National Intelligent Information Framework Law will extend the existing legal framework. Among other things, it's designed to treat companies' data ownership like property ownership and better protect it against unauthorized access.[345] In addition, safety and test standards are to be established for AI and harmonized with international standards, especially in the medical, automotive and software industries. Autonomous driving (Level Three) should be achieved by 2022, at the latest.[346] At the same time, tax breaks granted in the past for the construction of industrial robots will be reduced until the end of 2019. In the country with the world's highest robot density[347] there is a fear of job losses and thus also tax losses,[348] although the government's AI strategy has the potential to create 600,000 to 800,000 new jobs through "intelligent IT" by 2030.[349] "Monopolistic and (oligopolistic) practice" by platform providers, such as Google, would be minimized through more stringent laws, and data theft by conglomerates from smaller companies will be prosecuted more rigorously.[350]

A system of "transitional licenses" is designed to enable companies to develop their products to market maturity while the state approval procedures are still in progress.[351] This could take place, for example, in large-scale "regulatory-free" or "test" zones needed in the fields of smart cities, robotics and autonomous cars. Once established, these test zones will be interconnected to improve "strategic local industries and to support existing industrial clusters through intelligent IT infrastructure."[352] The data and knowledge gained there will then be shared with startups and small and medium-sized enterprises in order to develop a wider range of new services and technologies.

Support by companies: One of these "test zones" is the Industrial Artificial Intelligence Center[353] at the heavy industry site in Ulsan, which is operated jointly by UNIST, Samsung, EWP and POSCO. It's part of the Deadeok Innopolis, a supra-regional network of companies and research institutes (including KAIST and ETRI, among others). The five announced AI research centers were structured to study the integration of AI into robotics, life sciences, machines and automobiles.[354] Research-based companies settling there will be exempt from tax for three years, receive discounts for electricity and can draw on an investment fund. The proximity to state authorities also simplifies approval procedures.[355]

The Ministry of Industry recently announced some 1.15 billion Euro to be spent over the next ten years on Samsung Electronics and SK Hynix, thus supporting the largest semiconductor producers in the country. The aim is to promote the development of materials for the next generation of microchips, further development of production facilities, and the establishment of production lines for global semiconductor companies.[356]

The public sector as users of AI: For years, South Korea has held a leading international position in digital administration and citizen participation.[357] In terms of procurement of advanced technology by the government, however, it ranks only 32nd worldwide.[358] This is about to change, with AI applications being used in tax and legal consulting, social welfare, health care, crime prevention,[359] as well as in airport security and fighting of forest fires.[360] Military applications are to be used to reduce the number of troops and for improvement of decision-making processes.[361]

287 Park Geun-hye, quoted in: Nature, 2016
288 Nature, 2016
289 The "Ministry of Science, ICT and Future Planning" (MSIP) was restructured in 2017 and renamed "Ministry of Science and ICT" (MSIT).
290 MSIP, 2016
291 Ibidem: Preface
292 Ibidem: 26
293 Ibidem: 62
294 Ibidem
295 Yonhap, 2018a
296 MSIP, 2016: 14
297 Korea.net, 2017
298 Cf. MSIP, 2018
299 World Bank, 2016 (cf. Methodology of the Cambrian AI Index)
300 World Wide Web Foundation, 2016 (cf. Methodology of the Cambrian AI Index)
301 CS Ranking, 2018 (cf. Methodology of the Cambrian AI Index)
302 Statista, 2018 (cf. Methodology of the Cambrian AI Index)
303 Top500.org, 2018 (cf. Methodology of the Cambrian AI Index)
304 Cf. Kim, 2017
305 Korea.net, 2017
306 Organisation and members cf. PCFIR, k. D.
307 Korea JoongAng Daily, 2017
308 UNESCO, k. D. (cf. Methodology of the Cambrian AI Index)
309 NRF, 2018
310 UNESCO, n.D (cf. Methodology of the Cambrian AI Index)
311 CS Ranking 2016–2018 (cf. Methodology of the Cambrian of the Cambrian AI Index)
312 KAIST, k. D.
313 Overview of all research fields, cf. chart 7 in the Annex
314 UNIST, 2017
315 POSTECH, k. D.
316 ETRI, k. D.
317 Measured by the H index, a value of 114, SJR, 2017 (cf. "Methodology of the Cambrian AI Index" chapter)
318 European Commission, 2017
319 Cf. Palmer et al., 2011: 137ff.
320 PCFIR, 2018
321 KBRI, k. D.
322 Business Korea, 2018a
323 PCFIR, 2018
324 Business Korea, 2018b
325 MSIP, 2016: 34
326 Bloomberg, 2018a
327 Business Korea, 2017
328 M-Cam, 2018 (cf. Methodology of the Cambrian AI Index)
329 Cf. Premack, 2017
330 Cf. Bloomberg, 2018b
331 Cf. Council on Foreign Relations, 2018
332 Financial Times, 2018
333 Ibidem: 56
334 Ibidem
335 Walsh et al., 2018
336 KAIST, 2018; see also Annex, chart 8
337 According to Korean government figures, at the end of 2014 there were about 30,000 startups in Korea, of which about 30 percent are are to be found in the area of IT (quoted in: McKinsey, 2015: 8).
338 McKinsey, 2015: 4
339 Ibidem: 12
340 Asgard Human Venture Capital/Roland Berger, 2018: 8–9 (cf. Methodology of the Cambrian AI Index)
341 Cf. CBInsights, 2017b (cf. Methodology of the Cambrian AI Index).
342 McKinsey, 2015: 14
343 KISTEP, 2017: 90 ff.
344 MSIP, 2016: 44
345 Ibidem: 57
346 Cf. MSIT, 2018: 8
347 IFR, 2017 (cf. Methodology of the Cambrian AI Index)
348 Korea Times, 2017
349 MSIP, 2016: 16
350 Ibidem: 45
351 MSIP, 2016: 57
352 Ibidem: 43
353 UNIST, k. D.
354 PCFIR, 2018
355 Cf. Ministry of Knowledge Economy/Daedeok Innopolis/ Daedeok Innopolis Association, k. D.: 26
356 Yonhap, 2018a
357 UN, 2018
358 World Economic Forum, 2017 (cf. Methodology of the Cambrian AI Index)
359 MSIP, 2016: 40ff.
360 PCFIR, 2018: 28
361 Ibidem

Methodology Cambrian AI Index ©

The analysis on which this report is based assessed the countries on the indicators that incorporate the countries' preconditions, the research and development situation, and the degree of commercialization of AI. In an attempt to integrate these indicators and determine the AI position of a country in an international comparison, the Cambrian AI Index © was developed. The Cambrian AI Index consists of the three segments mentioned above, which in turn consist of different components for which one or more proxy indicators have been identified. The methodology had to be restricted to proxy measurements for which reliable and comparable data from different countries were available because the current state of the AI field produces limited measurable outputs. This is likely to change over the next few years, as AI-related continues to develop rapidly.

The values of the different *proxies* are indexed from 0 to 1, with the USA representing the "benchmark" value 1 against which the other countries are measured. (The USA was selected as the benchmark because of its current global leadership in AI.) The mean value of the indexed proxy values of each component is that component's intermediate value. The mean values of all the components of a segment, in turn, results in the total value of the segment. The mean values of the three segments result in the comprehensive Cambrian AI Index. Weighting was not carried out at proxy, component or segment level, because adequate weighting would require well-researched empirical studies, which to date do not exist.

Segment	Component	Proxy	Survey Method/Source
General requirements	**Framework conditions**	**Network Readiness Index Value (2016)** Explanation: The index provides insights about the performance of national economies in the use of information and communication technologies to enhance competitiveness, innovation and well-being. Thus it serves as a proxy for the framework conditions of AI.	Survey based on a scale from 1 (worst) to 7 (best). World Economic Forum: https://widgets.weforum.org/gitr2016/
	Data	**OpenData Barometer (2016)** Explanation: In addition to individuals with internet access and businesses, the public sector is the third important source of AI-related data. The OpenData barometer assesses governments worldwide in their willingness to implement OpenData initiatives. It also measures the impact of OpenData on business, politics and civil society.	The data for the OpenData barometer is collected through expert interviews, self-assessments by governments and secondary data sources. World Wide Web Foundation: https://opendatabarometer.org
		Number of Internet users (2016) Explanation: Internet users are persons who have used the internet (from anywhere) via computers, mobile phones, personal digital assistants, gaming machines, digital television, etc. in the last 3 months. This proxy measures internet users in absolute numbers rather than as a percentage of the population, since the quantity of data is what counts for AI.	World Bank: https://data.worldbank.org/indicator/IT.NET.USER.ZS
	Computing power	**Number of 500 most powerful supercomputers per country (2018)** Explanation: Even if computing power can be used across borders, the availability of supercomputers to cope with large amounts of data and increasingly complex algorithms is a strategic factor for a nation.	The website Top500.org counts and lists the top super computers that are publicly known and commercially available worldwide in semi-annual surveys (June and November). It is possible that military high-performance computers exist which are not known. Top500.org: www.top500.org

Segment	Component	Proxy	Survey Method/Source
		Number of 10 most powerful supercomputers per country (2018) Explanation: The Top 10 of the 500 most powerful supercomputers shows that in some countries, e. g. China, the most supercomputers are installed, but they are not the most powerful.	Top500.org: www.top500.org
		Turnover of leading semi-conductor manufacturing companies in billions (2017) Explanation: Turnover from semicon-ductor companies per country gives information about the dominance and thus innovation power in this industry segment. Even though the production of semiconductors is not indicative of the use of semiconduc-tors, production capacities are a stra-tegic factor for a nation.	**China:** HiSilicon Technologies Uni Group Sanechips Huada Goodix **Japan:** Toshiba Renesas Electronics Sony ROHM Semiconductor **Republic of Korea:** Samsung Electronics SK Hynix **USA:** Intel Micron Technology Broadcom Qualcomm Texas Instruments nVidia Skyworks Solutions SanDisk / Western Digital Analog Devices ON Semiconductor Freescale Semiconductor AMD **Statista:** https://www.statista.com/statistics/271553/worldwide-revenue-of-semiconductor-suppliers-since-2009 supplemented by the evaluations of individual annual financial statements.

Segment	Component	Proxy	Survey Method/Source
		Number of leading semiconductor manufacturing companies (2017) Explanation: Complementing the proxies stated above, the number of semi-conductor companies provides information about the strength of a country's semiconductor environment.	Statista, supplemented by further research (see above)
		Revenues from FPGA chips in million USD (2016) Explanation: Intel and Microsoft are confident that FPG chips will be the dominant AI hardware in the future. A paper recently published by Intel engineers titled "Can FPGAs Beat GPUs in Accelerating Deep Neural Networks" provides some of the technical reasons for this speculation. It should be noted that the industry has developed strongly since 2016 (see chapter on China).	EE Times: https://www.eetimes.com/author.asp?doc_id=1331443 Nurvitadhi, E.; Venkatesh, G.; Sim, J.; Marr, D.; Huang, R.; Ong, J. G. H.; Liew, Y. T.; Srivatsan, K.; Moss, D.; Subhaschandra, S.; Boudoukh, G. (2017): Can FPGAs Beat GPUs in Accelerating Next-Generation Deep Neural Networks? http://jaewoong.org/pubs/fpga17-next-generation-dnns.pdf
	Human resources	**Number of students enrolled in all tertiary education programs, both sexes (2016)** Explanation: AI is considered to be basic research technology, which is why the number of students per country is a proxy for the amount of qualified human resources.	UNESCO: http://data.uis.unesco.org
		Estimated number of Master's graduates in AI-relevant fields, at computer science institutes with actively researching teachers Explanation: Master graduates in the above-mentioned areas provide information on the size of the pool of young talents for AI research and commercialization. In contrast, the index assigns the number of doctoral students to the "Research and Development" segment.	The estimate is based on the number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. In order to determine the annual number of Master's graduates, the

Segment	Component	Proxy	Survey Method/Source
			number of scholars was multiplied by a factor of 7. This factor was determined by Mark Nitzberg, Chief Scientist for Cambrian and Head of UC Berkeley CHAI, on the basis of a random sample survey of top AI research laboratories in the USA (potential regional/national differences were not considered). CS Ranking: http://csrankings.org/#/index?none
Research and Development	**General R&D framework conditions**	**Gross domestic expenditure on research and development in 000 USD (2016)** Explanation: The gross domestic expenditure comprises the R&D investments of the private sector, the government, higher education institutions and civil society. This proxy is presented in absolute terms in USD as opposed to the percentage ratio of GDP to reflect the global and mobile value chains of AI.	The data are available in the respective national currency. For comparability, all values have been converted to USD (average exchange rate of 2016). The 2016 expenditures from Singapore and India are not available, which is why they were projected based on historical values. UNESCO http://data.uis.unesco.org
		Number of researchers per 1 million inhabitants (2016) Explanation: The "density" of researchers is a proxy for the serendipity in research in a country. The importance of serendipity in the field of AI is high, since AI is a basic technology with practically unlimited application areas.	UNESCO http://data.uis.unesco.org
	AI-relevant R&D (Input)	**Number of computer science institutes with actively researching teachers in AI-relevant areas** Explanation: The number of computer science institutes provides information about the size of the relevant R&D ecosystem.	Number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. CS Ranking 2016–2018: http://csrankings.org/#/index?none

Segment	Component	Proxy	Survey Method/Source
		Number of scholars actively doing research in areas relevant to AI Explanation: The number of teaching staff is a proxy for research and training of qualified human resources of a country.	Number of scholars at computer science institutes who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. CS Ranking 2016–2018: http://csrankings.org/#/index?none
		Estimated number of doctorate students supervised by scholars actively engaged in research in AI-relevant areas Explanation: The number of doctorate students provides information about the R&D relevant human resources of a country.	The estimate is based on the number of scholars at computer science institutes in universities who have been actively researching artificial intelligence, computer vision, machine learning & data mining, natural language processing and robotics since 2016, i. e. whose publications have been presented at relevant conferences. To determine the annual number of doctorate students, the number of scholars was multiplied by a factor of 4. This factor was determined by Mark Nitzberg, Chief Scientist for Cambrian and Head of UC Berkeley CHAI, on the basis of a random sample survey of top AI research laboratories in the USA (potential regional/national differences were not considered). CSRanking 2016–2018: http://csrankings.org/#/index?none

Segment	Component	Proxy	Survey Method/Source
	AI-relevant R&D (Input)	**Number of citable publications in the subject area of AI (2017)** Explanation: The number of citable publications in the field of AI provides information about the scientific productivity of a country in the field of AI.	Scimago Journal & Country Rank: https://www.scimagojr.com Cf. the methodology used there
		Influence of publications in the subject area of AI (2017) Explanation: The influence of publications is a proxy for the quality and innovative power of research in the field of AI. It is unknown whether the index takes into account co-authors and their nationality.	The influence of publications is measured on the basis of the H index. The figure is based on bibliometric analyses, i. e. on citations of the scientist's publications. Scimago Journal & Country Rank: https://www.scimagojr.com
Commercialization	**Knowledge and technology transfer**	**Cooperation between universities and industry on research and development (2017–18)** Explanation: This proxy delivers information on the knowledge and technology transfer between universities and the private sector.	Opinion polls among executives: In your country, to what extent do business and universities cooperate in research and development (R&D)? (1 = not at all; 7 = intensively). Weighted average. World Economic Forum: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018
		Public procurement of cutting-edge technology (2017–18) Explanation: This proxy provides information about the incentives that the public sector creates by demand for certain technologies and thus innovations.	Opinion polls among executives: To what extent do government purchasing decisions promote innovation in your country? (1 = not at all; 7 = to a large extent). Weighted average. World Economic Forum: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018

Segment	Component	Proxy	Survey Method/Source
	Patents	**AI patents (with international enforcement expectations) by assignee country in % (average of the years 2015, 2016 and 2017).** Explanation: This proxy provides information on the patent activities of a country's companies. Nevertheless, this proxy is subject to reservation, since the patents are not indicative of the quality of an innovation and are often merely incremental in nature.	Although various sources suggest that China has overtaken the US in terms of AI-related patent applications, most Chinese patents have no international equivalents and are therefore unenforceable outside China. The patents cover AI as well as Machine Learning and Deep Learning. Notice: The process of patent application for patent publication is associated with a considerable time delay, which is why the figures may also vary retroactively. Research by M-Cam: https://www.m-cam.com
	AI startup landscape	**Number of AI startups (2017)** Explanation: The number of AI startups provides information about the diversity of the potentials of AI and the innovative strength of the national economies.	The data collection focused exclusively on startups active in the AI technology industry and ignored companies dealing with other digital topics and technologies. These are startups that produce AI solutions and expressly excludes startups that use existing AI solutions on the market to develop new services or products. Asgard und Roland Berger/Lemaire, A.; Lucazeau, H.; Carly, E.; Romain; Rappers, T.; Westerheide, F. (2018): https://asgard.vc/global-ai
		The 100 most influential AI startups (2017) Explanation: While the above proxy reflects the quantity of AI startups, the number of AI startups in the list of the 100 most influential AI startups per country is a proxy for the quality and future potential of the companies.	The companies were selected from a pool of more than 2,000 startups based on several criteria, including investor profile, technological innovation, team strength, patent activity, financing history, valuation and business model. CB Insights: https://www.cbinsights.com/research/artificial-intelligence-top-startups

Segment	Component	Proxy	Survey Method/Source
		Share of AI private equity deals in all AI private equity deals worldwide (2016) Explanation: This proxy provides information about the countries with the startup landscapes with the highest future potentials in AI as seen by investors.	CB Insights: https://www.cbinsights.com/research/artificial-intelligence-startup-funding
		Number of most active venture capital investors (2012–2016) Explanation: This proxy indicates in which countries the most AI-savvy investors are based and thus have the largest influence in terms of AI startups.	CB Insights: https://www.cbinsights.com/research/artificial-intelligence-startup-funding
	Robotics	**Number of industrial robots installed per 10,000 employees in the manufacturing industry (2016)** Explanation: This proxy provides information about the automation of the manufacturing industry and the consumption and implementation of robot technology, and thus is indicative of the level of experience of the labor market in interaction with machines.	International Federation of Robotics: www.ifr.org
		Number of manufacturers producing service robotics (2016) Explanation: Complementing the proxy, specified above, the number of manufacturers of service robots provides information about the size of the ecosystem in this future technology.	The data only represent the individual figures for the eleven countries with the largest number of such companies. The other thirteen countries in which companies produce service robots have been consolidated in the category “Rest of the world”, with an average of four companies per country. Statista: https://www.statista.com/statistics/658048/service-robotics-manufacturers-by-country

Annexes

Chart 1: Schematic overview of the Obama government's AI strategy [362]

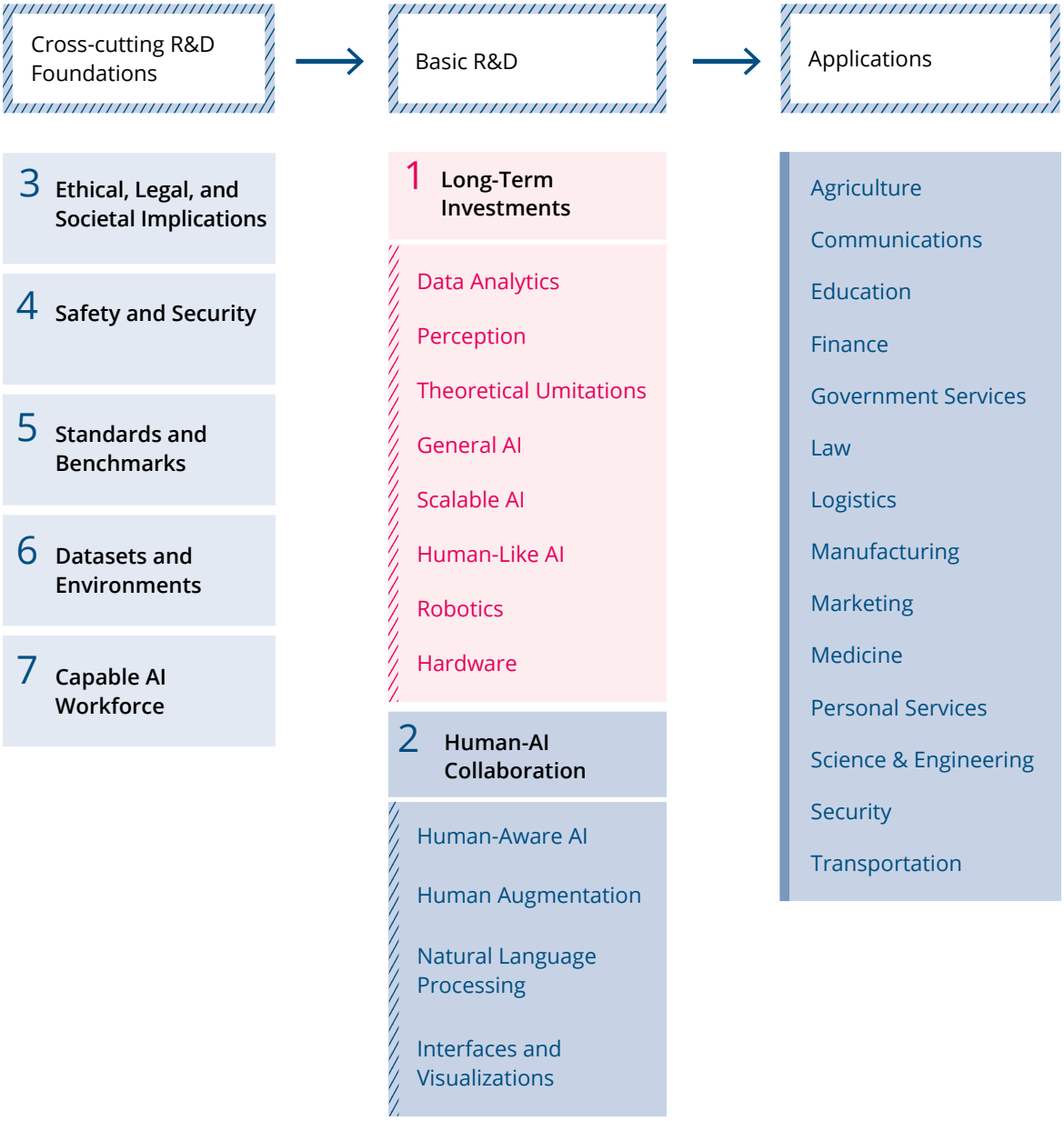


Chart 2: Thematic distribution of American AI startups in the Top 100 of 2017 [363]

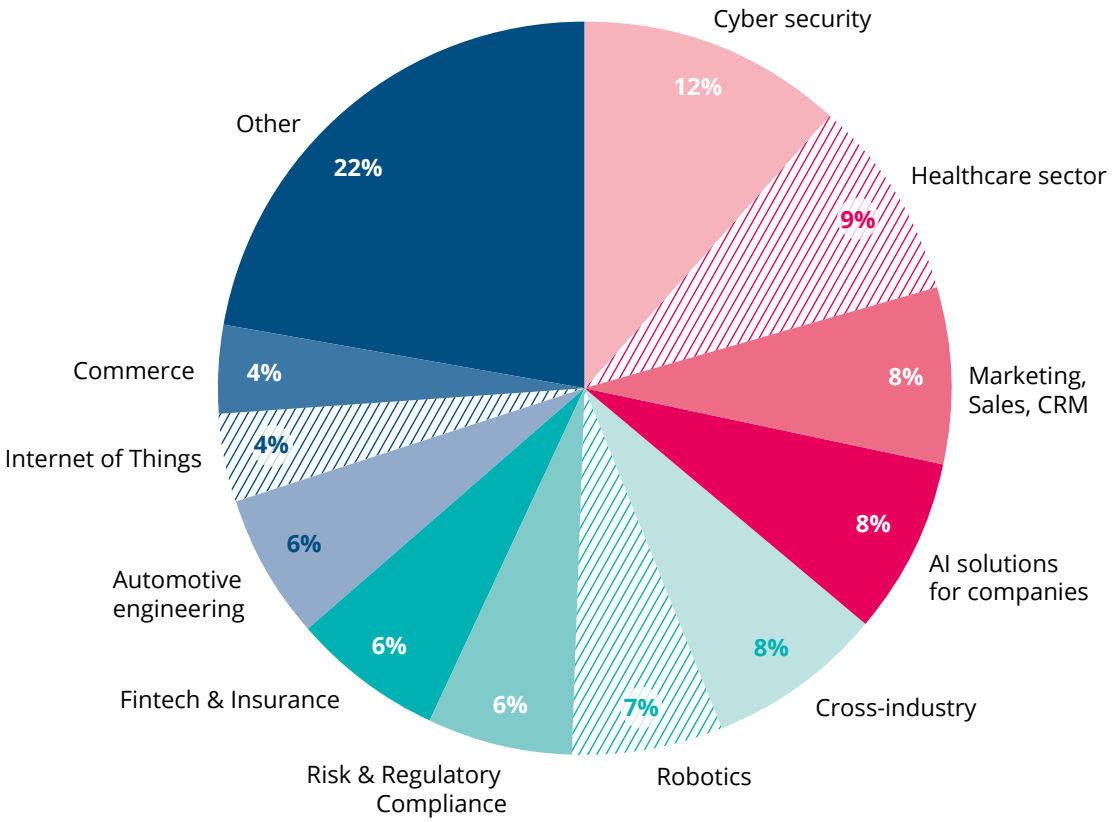


Chart 3: The most valuable Top 20 technology companies (29/05/2018) [364]

Pos.	Company	Country	Market value in billion USD
1	Apple	USA	924
2	Amazon	USA	783
3	Microsoft	USA	753
4	Google Alphabet	USA	739
5	Facebook	USA	538
6	**Alibaba**	**China**	**509**
7	**Tencent**	**China**	**483**
8	Netflix	USA	152
9	**Ant Financial**	**China**	**150**
10	Ebay	USA	133
11	Booking Holdings	USA	100
12	Salesforce.com	USA	94
13	**Baidu**	**China**	**84**
14	**Xiaomi**	**China**	**75**
15	Uber	USA	72
16	**Didi Chuxing**	**China**	**56**
17	**JD.com**	**China**	**52**
18	AirBnB	USA	31
19	**Meituan-Dianpin**	**China**	**30**
20	**Toutiao**	**China**	**30**

Chart 4: Patent publications for Machine Learning and Deep Learning (by country code) [365]

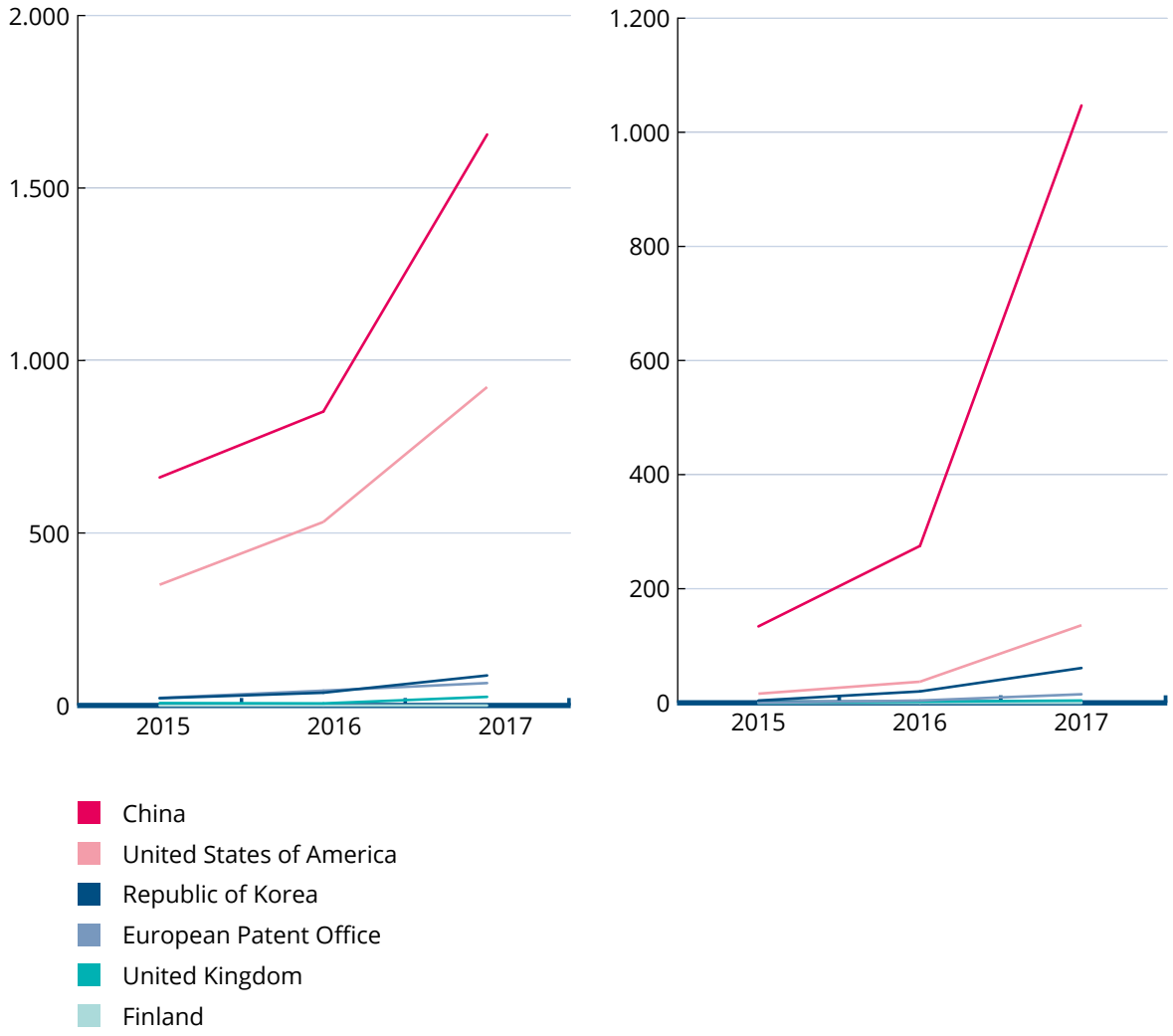


Chart 5: Patent publications on AI, Machine Learning and Deep Learning (including international equivalents) [365]

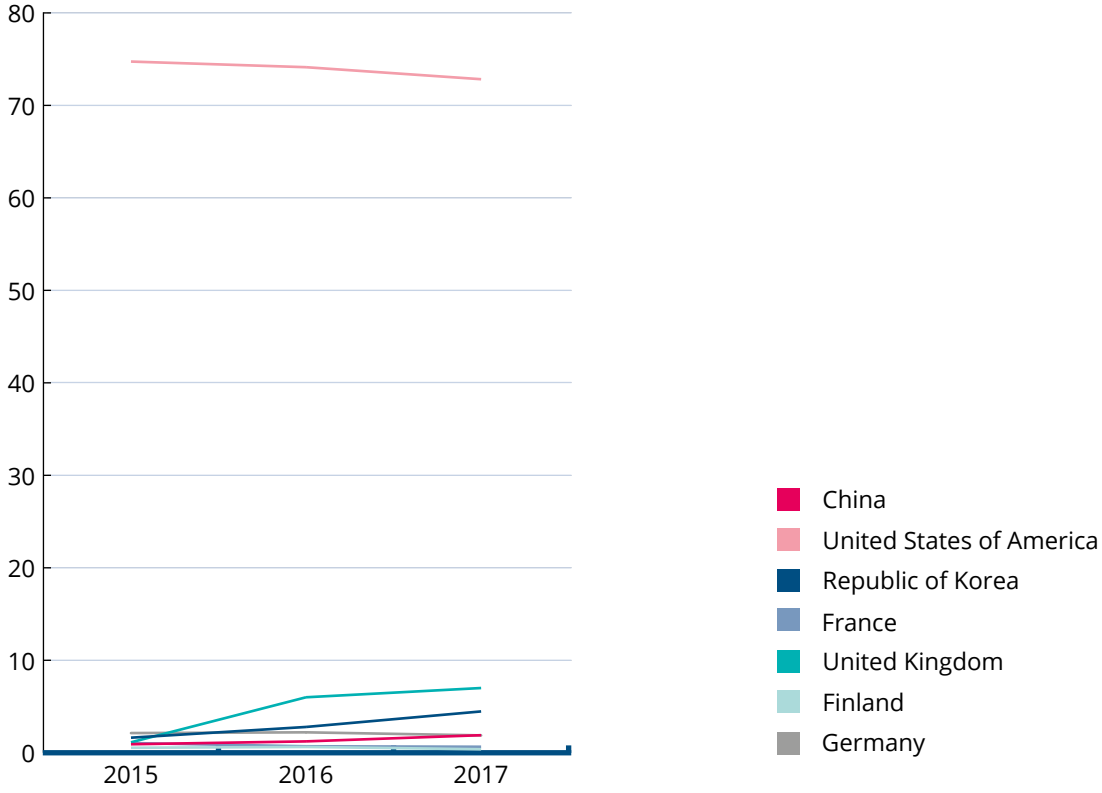


Chart 6: Distribution of EPRSC research grants by topics (as of 09/2018) [366]

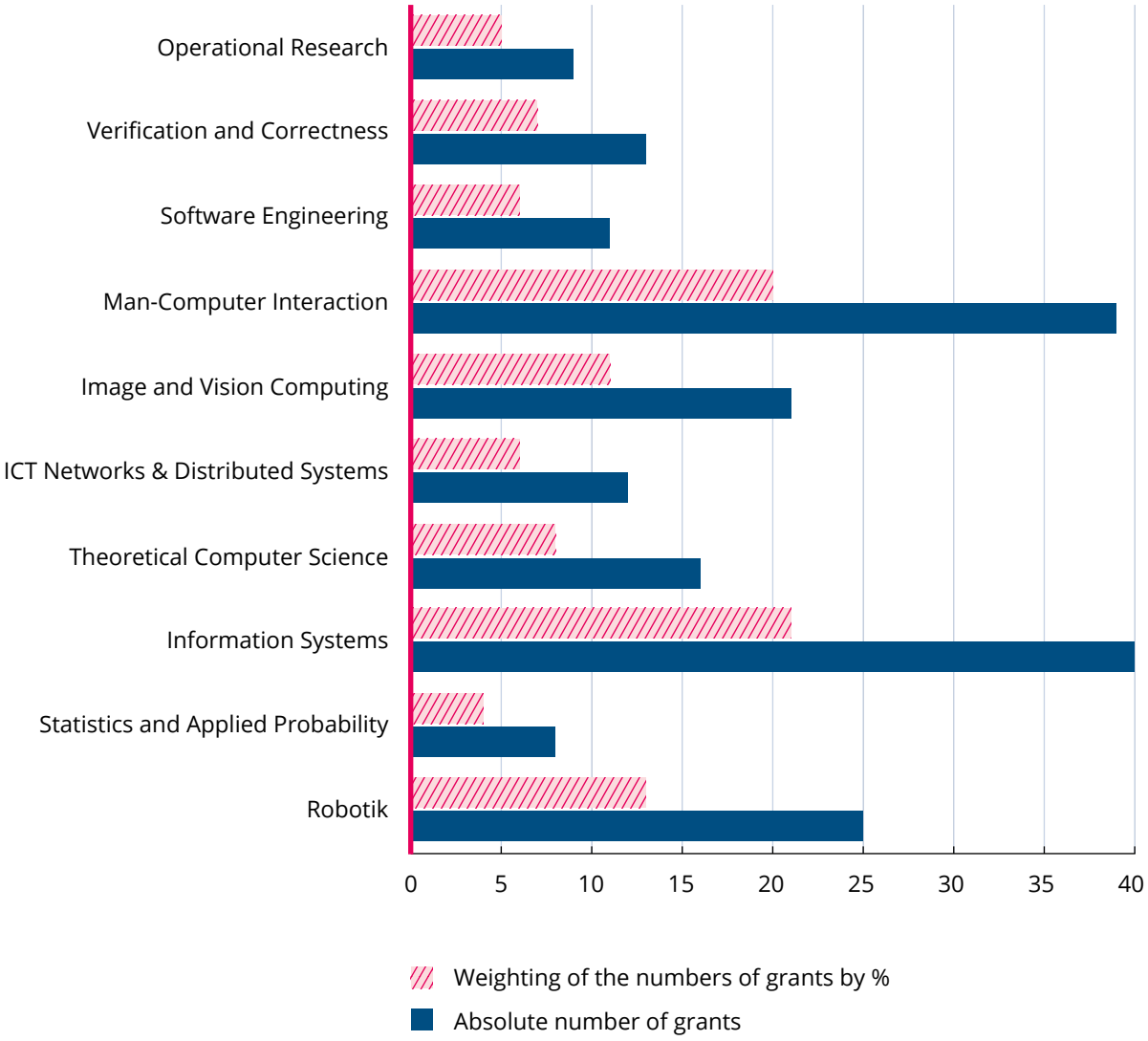


Chart 7: Research areas of the Korea Advanced Institute of Science and Technology [367]

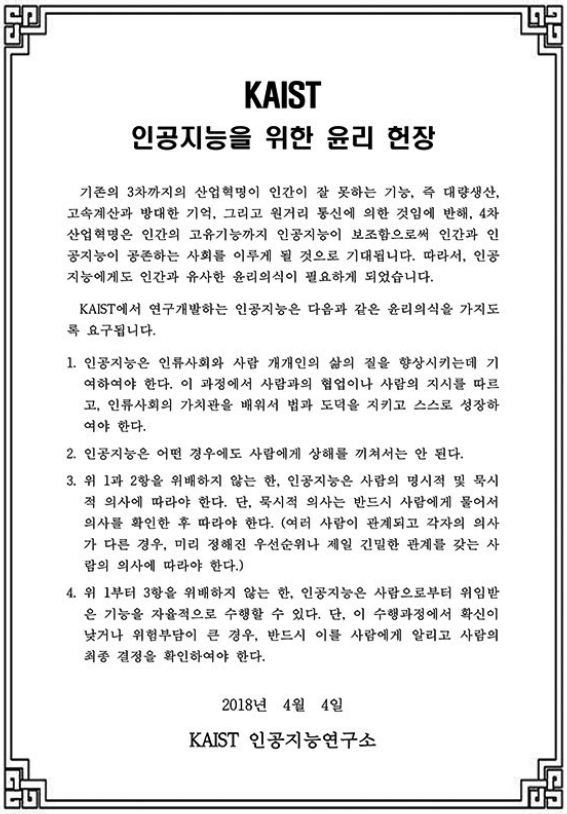
"AI Fundamentals" (22 researchers)	
Brain Science and Engineering	› Study to understand how the human brain works › Study to create machines exhibiting behavior comparable to those of humans
Machine Learning	› Artificial neural networks › Deep learning › Inductive logic programming › Bayesian networks › Reinforcement learning › Representation learning › Sparse dictionary learning › Genetic algorithms › Rule-based machine learning
Multimodal Perception and Interaction (audio/visual/text)	› Visual representation and recognition › Video captioning › Speech recognition/understanding and synthesis › Tactile perception › Multimodal integration of text, visual, auditory and tactile information
Natural Language Processing, Understanding and Generation	› Visual representation and recognition › Video captioning › Speech recognition/understanding and synthesis › Tactile perception › Multimodal integration of text, visual, auditory and tactile information
Emotional Intelligence	› Facial emotion recognition › Speech emotion recognition › Text emotion recognition › Multimodal emotion recognition › Ethics intelligence

"KI Robotics": AI for Robotics (7 researchers)	
research programmes	› Cooperation between Multiple Robots Based on Task Planning › Development of a Mobile Robot Platform › Development of a Learning Algorithm for AI

"AI Emerging" (15 researchers)	
Brain AI Interface (BAI)	› Non-invasive BCIs › Electroencephalography (EEG)-based brain-computer interfaces › Neurogaming › Brain to AI (brain science based AI study) und AI to Brain (AI based brain study)
Smart Chips for Pervasive Intelligence	› Hardware acceleration techniques (e. g., FPGA and ASIC) for neural and machine learning paradigms › Neuromorphic implementation › Learning on chips for regression, classification, feature learning and sparse coding › Approximated and incremental computing hardware for machine learning › Smart chips and hardware implementation for auditory systems › Smart chips and hardware implementation for visual systems
Quantum Machine Learning (QML)	› Quantum-enhanced machine learning › Quantum learning theory › Classical learning applied to quantum systems › Fully quantum machine learning

"AI Applications" (32 researchers)	
research areas	› Intelligent agent services › Intelligent robot/drone/self-driving car › AI based solutions for natural science and engineering problems › AI based medicine and healthcare › AI based design of new material and composition › AI based management, economics and finance analysis › AI based environment and atmosphere prediction system › AI based music technology
Applications/Use-Cases	› AI based Medical/Healthcare › Intelligent Urban Robotics › IoT based Intelligent Companion › AI based new material design and composition › AI based Chemistry › AI based nuclear fusion reactor diagnosis and control › AI based hazardous situation control › AI based Marine and Atmosphere Prediction System › AI based Management and Economics

Chart 8: *Korea Advanced Institute of Science and Technology: Code of Ethics for AI* [368]



KAIST

인공지능을 위한 윤리 헌장

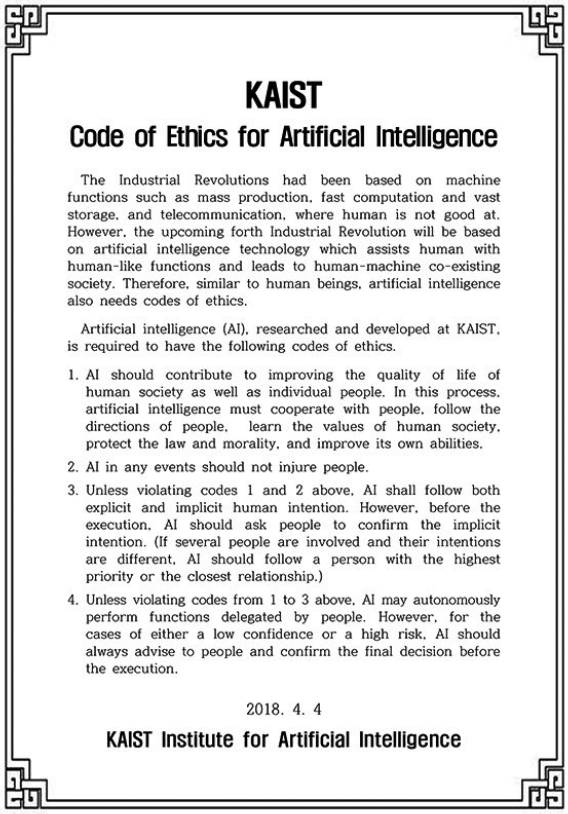
기존의 3차까지의 산업혁명이 인간이 잘 못하는 기능, 즉 대량생산, 고속계산과 방대한 기억, 그리고 원거리 통신에 의한 것임에 반해, 4차 산업혁명은 인간의 고유기능까지 인공지능이 보조함으로써 인간과 인공지능이 공존하는 사회를 이루게 될 것으로 기대됩니다. 따라서, 인공지능에게도 인간과 유사한 윤리의식이 필요하게 되었습니다.

KAIST에서 연구개발하는 인공지능은 다음과 같은 윤리의식을 가지도록 요구됩니다.

1. 인공지능은 인류사회와 사람 개개인의 삶의 질을 향상시키는데 기여하여야 한다. 이 과정에서 사람과의 협업이나 사람의 지시를 따르고, 인류사회의 가치관을 배워서 법과 도덕을 지키고 스스로 성장하여야 한다.
2. 인공지능은 어떤 경우에도 사람에게 상해를 끼쳐서는 안 된다.
3. 위 1과 2항을 위배하지 않는 한, 인공지능은 사람의 명시적 및 묵시적 의사에 따라야 한다. 단, 묵시적 의사는 반드시 사람에게 물어서 의사를 확인한 후 따라야 한다. (여러 사람이 관계되고 각자의 의사가 다른 경우, 미리 정해진 우선순위나 제일 긴밀한 관계를 갖는 사람의 의사에 따라야 한다.)
4. 위 1부터 3항을 위배하지 않는 한, 인공지능은 사람으로부터 위임받은 기능을 자율적으로 수행할 수 있다. 단, 이 수행과정에서 확신이 낮거나 위험부담이 큰 경우, 반드시 이를 사람에게 알리고 사람의 최종 결정을 확인하여야 한다.

2018년 4월 4일

KAIST 인공지능연구소



KAIST

Code of Ethics for Artificial Intelligence

The Industrial Revolutions had been based on machine functions such as mass production, fast computation and vast storage, and telecommunication, where human is not good at. However, the upcoming forth Industrial Revolution will be based on artificial intelligence technology which assists human with human-like functions and leads to human-machine co-existing society. Therefore, similar to human beings, artificial intelligence also needs codes of ethics.

Artificial intelligence (AI), researched and developed at KAIST, is required to have the following codes of ethics.

1. AI should contribute to improving the quality of life of human society as well as individual people. In this process, artificial intelligence must cooperate with people, follow the directions of people, learn the values of human society, protect the law and morality, and improve its own abilities.
2. AI in any events should not injure people.
3. Unless violating codes 1 and 2 above, AI shall follow both explicit and implicit human intention. However, before the execution, AI should ask people to confirm the implicit intention. (If several people are involved and their intentions are different, AI should follow a person with the highest priority or the closest relationship.)
4. Unless violating codes from 1 to 3 above, AI may autonomously perform functions delegated by people. However, for the cases of either a low confidence or a high risk, AI should always advise to people and confirm the final decision before the execution.

2018. 4. 4

KAIST Institute for Artificial Intelligence

362 White House 2016b: 16 (see chapter USA)

363 CB Insights 2017 (see chapter “Methodology Cambrian AI Index”)

364 French, 2018 (see chapter “China”).

365 Based on an online research of patent publications from 2015–2017 (www.epo.org > Espacenet)

366 M-Cam, 2018 (see chapter “Methodology Cambrian AI Index”)

367 See Kaist, 2018

368 KAIST, 2018

Bibliography

Methodology notes for the Cambrian AI Index

C CB Insights (2017a): The 2016 AI Recap: Startups See Record High In Deals And Funding. 09.01. 2017, CB Insights. https://www.cbinsights.com/research/artificial-intelligence-startup-funding/ (retrieved on 12.07.2018)

CB Insights (2017b): AI 100: The Artificial Intelligence Startups Redefining Industries. 12.12.2017, CB Insights. Retrieved from: https://www.cbinsights.com/research/artificial-intelligence-top-startups (retrieved on 12.07.2018)

CSRankings (2018): Computer Science Rankings 2016–2018. http://csrankings.org/#/fromyear/2016/toyear/2018/index?ai&vision&mlmining&nlp&world (retrieved on 10.07.2018)

E EE Times/Dilien, P. (2017): And the Winner of Best FPGA of 2016 is... 06.03.2017, EE Times. https:// www.eetimes.com/author.asp?doc_id=1331443 (retrieved on 10.09.2017)

I IFR (International Federation of Robotics) (2017): World Robotics 2017 Industrial Robots. www.ifr.org (retrieved on 10.07.2018)

M M-Cam (2018): share of global yearly patent breakdown by assignee country (in per cent). The source is not publicly available.

N Nurvitadhi, E.; Venkatesh, G.; Sim, J.; Marr, D.; Huang, R.; Ong, J. G. H.; Liew, Y. T.; Srivatsan, K.; Moss, D.; Subhaschandra, S.; Boudoukh, G. (2017): Can FPGAs Beat GPUs in Accelerating Next-Generation Deep Neural Networks? http://jaewoong.org/pubs/fpga17-next-generation-dnns.pdf

R Roland Berger/Asgard – Human Venture Capital (2018): Artificial Intelligence, A strategy for European startups Recommendations for policymakers. https://asgard.vc/wp-content/uploads/2018/05/Artificial-Intelligence-Strategy-for-Europe-2018.pdf (retrieved on 15.07.2018)

S SJR (2017): Scimago Journal & Country Rank 2017. https://www.scimagojr.com/countryrank.php?year=2017 (retrieved on 17.07.2018)

Statista (2016): Number of service robotics manufacturers of all types in 2016, by country https:// www.statista.com/statistics/658048/service-robotics-manufacturers-by-country/ (retrieved on 19.07.2018)

Statista (2018): Semiconductor supplier ranking: global revenue 2009–2017 https://www.statista.com/statistics/271553/worldwide-revenue-of-semiconductor-suppliers-since-2009/ (retrieved on 17.07.2018)

T Top500.org (2018): Top500 June 2018. https://www.top500.org/lists/2018/06/ (retrieved on 19.07.2018)

U UNESCO Institute for Statistics (k. D.): Education. http://data.uis.unesco.org/ (retrieved on 28.07.2018)

W World Bank (2016): Individuals using the Internet (in per cent of population by 2016). https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=CN-US-FR-FI-KR-GB-AE-RU-IN-SG-JP-CA&name_ desc=false (retrieved on 28.07.2018)

World Economic Forum (2016): Networked Readiness Index 2016. https://widgets.weforum.org/gitr2016/ (retrieved on 09.09.2018)

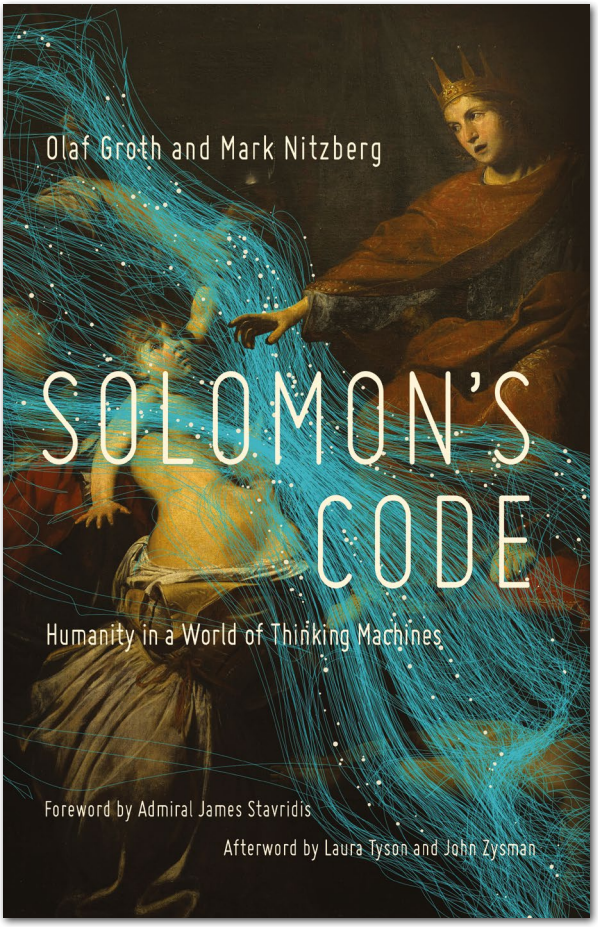
World Economic Forum (2017): Global Competitive Report 2017–18. http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf (retrieved on 25.07.2018)

World Wide Web Foundation (2016): OpenData Barometer. https://opendatabarometer.org/?_year=2016&indicator=ODB (retrieved on 25.07.2018)

Acknowledgements

We would like to particularly thank the team of M-Cam Inc. whose dedication and expertise have added depth to the report by analyzing the patent applications. In addition, we are most thankful to Paula Weise who spontaneously agreed to develop the layout of the report.

“Solomon’s Code” by Dr. Olaf J. Groth and Dr. Mark Nitzberg was published in November 2018:



The Authors

Olaf Groth is Professor of Strategy, Innovation and Economics at the Hult International Business School. He is founder and CEO of Cambrian.ai, Visiting Scholar at UC Berkeley and a member of the Global Expert Network at the World Economic Forum. Olaf is a former corporate manager in high-tech industries who holds a PhD from Tufts University's Fletcher School and has published for WIRED, Harvard Business Review, The Financial Times, and others.

E-Mail: groth@cambrian.ai
Twitter: @OlafGrothSF
LinkedIn: https://www.linkedin.com/in/olafgroth

Mark Nitzberg is head of the Center for Human Compatible Artificial Intelligence at UC Berkeley and director of Cambrian.ai. Mark studied AI at M. I. T. and earned his doctorate at Harvard University. He has led Computer Vision projects for Microsoft and Amazon and built technology companies to help vulnerable populations around the world.

E-Mail: nitzberg@cambrian.ai
Twitter: @Nitz54
LinkedIn: https://www.linkedin.com/in/nitzberg

Dan Zehr is a business journalist whose journalistic fields span most major industries and worldwide regions. His articles have been published in the Austin American-Statesman, the New York Times, the Arkansas Democrat Gazette, the Seattle Times and many other publications. He has received several awards and was a finalist of the Society of American Business Editors and Writers' National Best in Business Award.

E-Mail: zehr@cambrian.ai
Twitter: @DZehr
LinkedIn: https://www.linkedin.com/in/dan-zehr-30bb85

Tobias Straube is a graduate in International Political Management (B. A.) and holds an Executive Master of Business Administration (MBA) from Hult International Business School. He works as a consultant for GIZ GmbH, Germany's leading service provider for international cooperation and sustainable development, particularly in the areas of fund mechanisms, innovation management and entrepreneurship. For Cambrian.ai he was in charge of the preparation of the present study.

E-Mail: straube@cambrian.ai
Twitter: @Tobias_Stra
LinkedIn: https://www.linkedin.com/in/tobias-straube

Toni Kaatz-Dubberke is a graduate of the University of Leipzig and a candidate for the Executive Master of Public Administration (MPA) at the Hertie School of Governance in Berlin. For GIZ GmbH, he currently works as an advisor to the Federal Ministry for Economic Cooperation and Development in the field of urbanization. At Cambrian.ai he works as a senior analyst for this study.

E-Mail: toni.kaatz-dubberke@posteo.de
LinkedIn: https://www.linkedin.com/in/toni-kaatz-dubberke-5a24b1a

The race for world leadership in Artificial Intelligence (AI) technologies has begun. Since the publication of the AI strategy by the Obama administration in 2016, other countries have also started to explore ways to support the research and development (R&D) and commercialization of AI to catch up with the US, currently the leading AI nation. With this two-part publication, the Konrad Adenauer Foundation intends to give a comparative overview of the AI strategies of major national economies to provide food for thought and inspire the German debate. We believe "tech is politics" and our political and civil society should debate this vigorously.

Konrad-Adenauer-Stiftung e. V.