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Outline for a German Strategy for Artificial Intelligence

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Executive Summary

Numerous countries like China, France and Japan have declared Artificial Intelligence (AI) a key technology and announced comprehensive plans to promote research and development in AI. The German government has also begun to work on an AI strategy and just published a first blueprint with the core themes. In this paper, we argue that such a strategy needs to be broad and comprehensive, focusing on the development of an internationally-competitive AI ecosystem in Germany.

A strong AI ecosystem is characterized by strong networks between science, economic actors (big companies and startups alike) and society at large. Innovations arise in particular from close exchanges and collaboration between researchers, developers, universities, companies, investors and startups. To promote such an ecosystem, a wide range of different political measures on different levels have to be integrated into a broader, comprehensive strategy.

This paper discusses the central building blocks of an AI ecosystem in Germany, and offers concrete ideas and recommendations for an AI strategy based on this ecosystem approach.

1. AI research: Compared to other countries, Germany is lagging behind in research expenditures and must drastically increase them. Research support needs to be open to different technological approaches within AI. It also needs to be more agile to better react to emerging trends and new opportunities in AI research. Better work conditions overall are needed to compete for the best AI talent worldwide as well as clear benchmarks to measure progress in AI research.

2. Development of AI competencies across society: We do not only need top research. We also need broadly distributed AI competencies in society. Thus AI should not only be taught in computer sciences, but core AI modules should also be integrated into engineering and natural science programs, and be taught at schools of applied sciences.

3. Data as a basic resource for AI development: A strong AI ecosystem needs data for research and for the development of AI applications in industry, particularly with regard to deep learning (DL). This dimension of the ecosystem needs far more attention in Germany. Possible approaches to mobilize data for AI include the development of data pools and

more advanced methods of anonymizing or synthesizing data. It is hard to compete with the big Internet platforms from the United States and China in terms of quantity of data. Instead, special emphasis on machine data, quality of data and alternative approaches to AI that can work with little data could be the cornerstones of an alternative path to a strong AI ecosystem.

4. Infrastructure demands for AI: Deep learning requires not only huge amounts of data but also great computing power. A national AI strategy would address the question of how we can ensure middle- and long-term access to the most powerful processing hardware possible for German AI research and applications.

5. AI development and AI application in the economy: The German economy and industry already struggles with digitalization. AI exacerbates this issue because it represents the next step of digitalization. Small- and medium-sized businesses in Germany, known as the Mittelstand, especially need support. This support could be, for example, through state-funded AI laboratories, in which companies can experiment with AI with little risk and at low costs. Mobilizing venture capital through public funds and providing better incentives for AI investments represent two more critical challenges.

6. Societal dimension of AI: The ethical and regulatory questions regarding AI need to be openly discussed and require input from many different stakeholders in German society. Here, we already see numerous initiatives and approaches, representing the topic's arrival on the political agenda. However, more has to be done to make AI competencies and technologies more familiar within society.

7. A national AI strategy in an international context: Germany can only succeed in the international competition in the long-term as part of an EU-wide approach. Striving for cooperation with France offers the chance to push for a comprehensive European AI strategy. Germany, and Europe as a whole, have to become more conscious of their strategic interests in AI and act accordingly.

A German AI strategy should focus on the ecosystem approach and propose concrete ideas and recommendations. The strategy also needs to address how we can identify and, if possible, measure how the strategy is being implemented, and how the AI ecosystem in Germany is developing. There are many important indicators that policy makers should consult in order to

evaluate the effect of their actions: the attractiveness of German institutes and universities for leading international AI researchers, the number and quality of AI patents, achievements in publishing and visibility at the most important international AI conferences, venture capital investments, the founding of firms, or the number of companies with strong AI competencies and their growth. The good thing is that Germany does not have to start from scratch; numerous countries have already published national AI strategies in which many good ideas can be found. Now is the time for Germany to follow suit. Only then can Germany become a leader of AI development.

Contents

1. Introduction

Artificial Intelligence (AI) is the key technology of digitalization. The digital transformation will produce huge amounts of data. Without automated processing and analysis systems, this data can't be used productively. As a result, AI is the key technology of the digital transformation. Promoting the development and application of this technology will become central to the societal, economic and political challenges of the future.

AI holds huge potential for solving important societal problems. The federal government envisions a society in its high-tech strategy "that confronts modernity in an open-minded manner and is enthusiastic about future technologies and innovations."[1] In accordance with this vision, the use of technology to address important societal problems and challenges should take center stage. AI offers huge potential to solve a myriad of problems. Climate change (energy efficiency), medicine (new diagnostic possibilities) and transportation systems (more efficient logistics chains and intelligent mobility solutions) are just a few frequently-cited examples. There are, however, many other areas of application. Administrative and security agencies could also benefit from AI applications. In general, AI offers huge potential for improving the allocation of scarce resources and the promotion of a more sustainable economy.

AI will become a decisive factor for the economy. Today, digitalization already affects existing supply chains and puts traditional economic sectors under pressure. AI will only further increase this pressure to transform because data alone is of little use. New added value will only come about in combination with intelligent systems of analysis. The most effective and efficient data processing technologies will therefore have a competitive advantage in the market. At the same time, a lack of competence in these key technologies threatens the competitiveness of previously successful companies in

1 Bundesministerium für Bildung und Forschung/Federal Ministry of Education and Research (BMBF) Division Innovation Policy Issues, "The new High-Tech Strategy Innovations for Germany", Federal Ministry of Education and Research, 2014. https://www.bmbf.de/pub_hts/HTS_Broschure_Web.pdf.

both the medium- and long-term. Whether industry or the service sector, no branch can escape this megatrend.[2]

The global race for the development of AI is already well under way. The significance of AI as a key technology is globally recognized. The enormous investments of large technology companies in the USA and China underscore that this is more than hype surrounding the newest technological trend. In China, AI has become a high political priority. In its AI strategy, China's leadership formulated ambitious and concrete goals: catch up to the USA by 2020, overtake the USA by 2025, and become global leader in the field by 2030.[3] Numerous other countries – such as Japan, the USA, Canada, South Korea, France and Finland – grapple with the significance and implications of AI in white papers and strategic processes. The European Commission recently called on EU Member States to develop national action plans, and for collective action on the EU level. Germany must confront these international developments and develop its own national AI strategy in turn.

Developing and funding a strong AI ecosystem must take center stage in a national AI strategy. Germany can profit in many respects from the new opportunities presented by the development and application of AI-driven technologies. For this purpose, we need a strategic approach in which an AI-ecosystem takes center stage. Individual research initiatives or the targeted funding of specific technological approaches are neither adequate nor expedient. One cannot predict how AI research will develop in the next five to ten years. As such, an AI strategy should not focus on individual research approaches and applications, but rather on the development of a dynamic and diverse AI ecosystem. In such an ecosystem, different technological approaches of AI should compete with one another. This German ecosystem should have international networks in order to develop synergy and react dynamically to new developments. It is characterized by a healthy mixture of collaboration and competition. Such an ecosystem is the best response to to the "brain drain," the exodus of prominent AI experts abroad, as dynamic ecosystems attract the best researchers from around the world.
The following paper focuses on designing and funding such an ecosystem, in which ethical questions surrounding AI are also discussed. To that end, there are already numerous initiatives and approaches that will be named, but not

2 Jacques Bughin et al., "Artificial Intelligence: The Next Digital Frontier?", McKinsey Global Institute, June 2017. https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx.

3 Sophie-Charlotte Fischer, "Künstliche Intelligenz: Chinas Hightech-Ambitionen", Center for Security Studies (CSS), February 2018. http://www.css.ethz.ch/ueber-uns/css-news/2018/02/kuenstliche-intelligenz-chinas-hightech-ambitionen.html.

be discussed in detail. This discussion is undoubtedly important; however, it is not the focus of this paper. Instead, this paper highlights the key elements of a strong AI ecosystem that an AI strategy needs to address. As such, this paper makes no attempt to comprehensively and exhaustively discuss the political and societal dimensions of AI. Instead the focus lies on the research, economic and educational policy measures that must be considered for the development of a strong AI ecosystem.

Europe's vision of a "third path" must be simultaneously concrete and broad in scope. Whenever AI is discussed in Germany and Europe, policy makers point out the importance of a "third path" that differs from both the state-capitalistic approach of the Chinese AI strategy and the market-driven approach of Silicon Valley. This "third path" must be built on our values. However, concrete ideas on what such an European AI approach should look like have been lacking. Ethics and regulation alone will not be enough to compete internationally. Europe must also include industry and research in its approach to become a global competitor.

An AI strategy has to critically reflect on past shortcomings and define criteria for future success. The strategy should not only be looking ahead, but must begin with an honest analysis and discussion of Germany's weaknesses in the development, design and application of this technology. A strategy should consider both economic and societal implications of AI, as well as envision Germany's role in an international - and especially European - context. An AI strategy has to define milestones that include concrete, relevant and measurable benchmarks.[4] We need indicators that exhibit how the development of an AI ecosystem in Germany is advancing, and, when appropriate, in which sectors it falls behind. This will require the development of new indicators as the data currently available is not sufficient. Otherwise, policy makers will not be able to assess progress and make informed decisions.[5]

Broadly understanding AI as a technology. Among experts, definitions of AI are controversially discussed. As a scientific discipline, AI denotes a research area developing methods to train computers (or machines) to perform acts of intelligence of which only humans were previously capable. This pa-

4 This could include the amount invested in research funding (in comparison to other countries) or an increased turnover of domestic AI-companies, as well as other indicators (e.g. international patents, accepted papers for competitive conferences).

5 The "AI Index" could serve as a model, released in November 2017, see https://aiindex.org/2017-report.pdf.

per examines the increasing capabilities of computers to perform acts of intelligence, such as decision making, assessment, and behavior.

2. Framework for AI research

Research and innovation are catalysts of a strong AI ecosystem in Germany. Therefore, public funding for fundamental research, training of skilled workers and support for the use of AI in the economy and society through effective transfer measures is required.

Germany recognized important trends in AI research too late, despite its traditional strengths in fundamental AI research. Over the last few years, political forces and research policy reacted too slowly to new approaches. As a result, Germany became a straggler. In Germany, development in machine learning is less dynamic compared to other countries. Germany must also catch up in the commercialization of AI applications and their use in the economy.[6] With few exceptions, many large companies in Germany still have yet to develop actionables for integrating AI into their research strategies.

A lot of top AI talent is moving abroad (brain drain). Large technology companies like Amazon, Google, Microsoft and Facebook operate research and development departments that are highly attractive for researchers, particularly for postdocs who were previously employed at universities and public research institutions in Germany. Working conditions resemble those of public research in terms of academic freedom, but salary and working conditions are often disproportionately more attractive. A key challenge for German policy makers is to make universities and public research institutes more attractive to top researchers.[7]

6 See Commission of Experts for Research and Innovation (EFI) (ed.) (2018): Report 2018, EFI, Berlin. (Chapter B3). https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Summary_2018.pdf (English summary) or https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Gutachten_2018.pdf. (full report, German).

7 See "Transkript des Hintergrundgesprächs: Deutschland im globalen KI-Wettbewerb", Hintergrundgespräch in der Stiftung Neue Verantwortung (SNV) mit Damian Borth, Direktor Deep Learning DFKI, March 5, 2018 (german). https://www.stiftung-nv.de/de/news/transkript-zum-hintergrundgespraech-deutschland-im-globalen-ki-wettbewerb oder Bernhard Schölkopf, "Kybernetische Revolution", Süddeutsche Zeitung, March 15, 2018 (german). http://www.sueddeutsche.de/politik/aussenansicht-kybernetische-revolution-1.3907249.

Vector Institute

The Vector Institute at the University of Toronto is an independent, non-profit institute with the ambition to attract the best AI researchers in the world. It has a strong focus on deep learning, offers attractive positions for professors and doctoral candidates, and also addresses the commercial application possibilities of this technology. To date, the Vector Institute has received the equivalent of 131.2 million euros in public and private funding. Geoffrey Hinton is the Vector Institute's scientific advisor. Hinton works for Google in the field of neural networks and is considered the intellectual father of deep learning, along with Yoshua Bengio (McGill University) and Yann LeCun (Facebook). The Vector Institute plays a central role in positioning Toronto as one of the leading AI and advanced technology locations in North America.

An internationally-comparable evaluation of public AI research expenditures is not yet available in Germany. Budget figures for AI research were first provided in a response by the government to an inquiry from the parliament[8]. The assessment showed that the federal government funded AI research with 500 million euros over the last 30 years. Current funding measures include some 77 million euros for machine learning research (2017 to 2021), as well as 30 million euros for institutional funding of the German Research Center for Artificial Intelligence (DFKI) (2018 to 2022). AI has been and will continue to be funded – presumably at a noticeably smaller scale – through further technology programs.[9] Due to classification reasons, there are no exact numbers available. However, AI is not and never has been the focus of these measures. Currently, it is assumed that yearly funding from the federal government totals about 27 million euros for the period 2018 until 2021.[10] This is on top of the funding measures from the federal states, the German Research Foundation (DFG), and private foundations such as the Volkswagen Foundation.[11] It is also worth noting the federal state of Baden-Württemberg's funding for its flagship initiative "Cyber Valley"of 100 million euros

8 See "Konkrete Ziele und Vorhaben der Bundesregierung im Bereich Künstliche Intelligenz", Drucksache 19/1982 Deutscher Bundestag, May 2, 2018 (German). http://dip21.bundestag.de/dip21/btd/19/019/1901982.pdf.

9 According to the Federal Government, this involves "PAiCE – Digitale Technologien für die Wirtschaft", „Smart Data Smart Service Welt I und II" as well as the completed programs „Autonomik für Industrie 4.0" and „Trusted Cloud". All of these programs do not have a strict focus on AI which is why they cannot be seen as a forsightful approach to AI-sponsorship. The „PAiCE"- program, for example, has a budget of 50 Mio. Euros, but key words such as „Artificial Intelligence" or „machine learning" are not mentioned in the description of the funded topics.

10 Overall 107 Mio. Euros for approximately 4 years. Calculating personnel costs of 80,000 Euros per person, this equates about 335 researchers.

11 See Commission of Experts for Research and Innovation (EFI) (ed.) (2018): Report 2018, EFI, Berlin. (Chapter B3). https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Summary_2018.pdf (English summary) or https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Gutachten_2018.pdf. (full report, German).

over the next few years, which stands out among funding at the state level.[12]

It's highly likely that research funding for AI in Germany at the moment is less than that of comparable countries like Great Britain and France. While the exact financing volume of AI research is difficult to determine due to classification problems, it is safe to say that the German government currently spends less for AI research than Great Britain or France.

Even fundamental AI research can have immediate applications. As such, state-funded AI research should always be accompanied by transfer-measures and the promotion of commercial spin-offs. AI research can be elementary while still opening up new possibilities for applications. If potential uses are clearly identifiable for industrial applications (as in the sector of autonomous driving), they must be taken into account when funding application-oriented projects. However, many possible uses of AI are still unknown. As such, it would be detrimental to constrain funding through federal and state governments only to the area of previously-known potential use-cases and applications. Instead, we also need to remain open to the potential application of AI in sectors (for example, in agriculture) that were previously unconsidered.

ELLIS Initiative

The ELLIS Initiative was initiated with an open letter from leading European AI scientists in April 2018. Its vision is a European research alliance for learning and intelligent systems (European Lab for Learning & Intelligent Systems), where the best European scientists work and cooperate closely with researchers from industry. The initiators envision more transfer of technology between leading European research laboratories, industry and clusters of linked startups. The research alliance (devised as an intergovernmental organization) strives to be at the same level as leading global AI research institutes like Berkeley, Stanford, Carnegie Mellon and MIT. A European Ph.D. program integrated into the initiative is supposed to offer highly talented young scientists new research perspectives in Europe. The initiators of ELLIS seek 100 million euros per new location and an annual budget of up to 30 million euros, similar to the scale of a Max Planck Institute.

The deep-learning approach that's been intensively pursued over past years isn't the only research field, but it should remain important in the medium-term. Research policy – as with other policy areas – struggle with identifying long-term tech trends and developing research programs accordingly.

12 See "Daheim im Innovationsland: wie baden-württembergische Hochschulen und Forschungseinrichtungen zu Innovation und Zukunftsfähigkeit beitragen" Drucksache 16/2161, State Parliament of Baden-Württemberg, May 31, 2017 (German). https://www.landtag-bw.de/files/live/sites/LTBW/files/dokumente/WP16/Drucksachen/2000/16_2161_D.pdf.

Current deep-learning methods are energy and data intensive. Around the world, alternative approaches such as one-shot learning are being developed. The best approaches will likely result from competition among research efforts. Therefore, it's important to organize the allocation of state AI research funding according to competitive criteria. However, particularly attractive research approaches have to be pursued with sufficient intensity.

Research policy has to be more agile, and the flow of information between research policy makers, researchers and the business community has to be improved. In the future, new trends in research can appear suddenly. For example, the success of deep-learning technology – a subcategory of machine learning – was difficult to foresee. It was made possible first by the availability of mass amounts of data and then by the application of graphics processors.[13] In the future, policy should react more quickly to such developments, and research funding should be able to adjust accordingly.[14]

In addition to basic research, research policy should focus more on the establishment and promotion of ecosystems and their national and international connections. In such ecosystems, research findings can be easily translated into new product and service offerings in a market-oriented manner. The venture-capital sector can play an important role in bringing about new forms of collaborations and investments. In order to advance such collaboration, institutions for the promotion of entrepreneurship and the development of networks between researchers, investors and business leaders are crucial. The goal is not to turn top AI researchers into entrepreneurs – on the contrary, the different actors in the ecosystems (established companies, startups, venture capitalists, business angels) have to be brought together for close cooperation. In mentoring programs can help doctoral candidates to connect with the business and investment community early on. Good conditions for the founding of startups are particularly important to attract researchers who come to Germany from countries with vibrant startup scenes (USA, GB, CN).

13 See the advancements in the field of Computer Vision by the so-called AlexNet. It describes a certain architecture of an artificial deep neural network (Convolutional Neural Network), https://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf. This ist he first attempt to combine two graphicboards to train neural netwoks. See also the pioneer work in the field of handwriting recognition of Yann LeCoun et al. http://yann.lecun.com/exdb/publis/pdf/lecun-01a.pdf.

14 The agency for leapfrogging innovations („Agentur für Sprunginnovation") which is currently set up could serve as an important instrument to detect promising topics for funding earlier than before.

Special programs designed to recruit foreign and German researchers who are employed abroad need to be developed. New approaches are needed which go beyond activities like GAIN.[15] In this way, research policy could financially support winning back or winning over prominent researchers, for example, within the scope of a "100 returnees program" for the benefit of German universities. Here, the sector of AI research and other strategically significant fields of research should be given priority.

3. Promote Training of AI Competencies

A strong AI ecosystem stands out not only for its cutting-edge research, but also for broady distributed competencies in research, development and applications of AI systems among the workforce. Building up a well-functioning AI ecosystem is not only about the funding of cutting-edge research, but also about integrating basic AI training across Bachelor's and Master's programs in engineering and natural sciences as well as courses in basic AI at technical universities.

The number of well-trained AI experts has to be increased. It's necessary to further expand existing degree programs, as well as to establish new degree programs. Moreover, central AI competencies should be integrated into both STEM (Science, Technology, Engineering, and Mathematics) and humanities disciplines.[16] There is already a notable lack of skilled specialists in scientific areas that implement AI applications. Moreover, there is increasingly steeper competition between research and the private sector for well-trained AI workers. The federal states need to expand the teaching and research capacities of universities in the short-term by increasing the number of faculty.

German universities are lacking strategies to make AI processes useful outside of core subjects (computer science, statistics). German universities need to integrate AI competencies into a wide range of degree programs and disciplines beyond computer science and statistics. An example of good practice is the initiative of the Massachusetts Institute of Technology (MIT),

15 The German Academic International Network (GAIN) is a network for German researchers working in North America who consider returning to Germany. https://www.gain-network.org/de/ueber-uns/mission.

16 This allows academic breakthroughs in disciplines that seem unrelated at first. Two examples in the field of human medicine illustrate this: Classification of skin cancer with Deep Machine Learning (https://www.nature.com/articles/nature21056) and the evaluation of cardiovascular risk factors by using Computer Vision, (https://ai.googleblog.com/2018/02/assessing-cardiovascular-risk-factors.html).

in which new research approaches in one discipline are transferred and shared with a wider range of other academic disciplines.[17]

Technical universities could play an important role as hubs for knowledge transfer, especially in regard to the application of AI in business contexts. Several approaches of AI research are already fit for use, but require adjustment and customization to be applied to particular fields. Schools of applied sciences can make valuable contributions to the task of providing comprehensive AI skills, and can provide consultations and knowledge-transfer regionally, especially for medium-sized businesses. A specific support program initiated by the federal government could help technical universities to develop stronger AI capacities to fulfill this role.

Specialists with broad expertise (what we call AI architects) across business units are currently needed to drive forward concrete application projects in industry. In many companies, AI projects can't get out of the pilot phase. This is not necessarily due to a lack of specialized skills, but rather often due to the lack of experienced "architects" who are able to integrate AI strategy, methodology, concept-development, implementation and communications strategy across different business units.We need to define and design the profile of so-called AI architects and develop respective education and training programs. These AI architects could fill the current gap of stewards of AI projects in companies.

Primary students should already start acquiring digital competencies. Computer science courses in Germany are only required in four federal states, and not until secondary education. Compared to students in other countries, German school children interact with technology and data too late in their education.[18]

4. Data as the raw material of AI development

A strong AI ecosystem is built on the foundation of a sustainable data infrastructure. Generation of and access to data are central requirements for the build-up, growth and prosperity of a strong AI ecosystem. The availability of data generally leads to a demand for automated analysis systems. For this

17 See Peter Dizikes, "Institute Launches the MIT Intelligence Quest", MIT News February 2, 2018. http://news.mit.edu/2018/mit-launches-intelligence-quest-0201.

18 See Commission of Experts for Research and Innovation (EFI) (ed.) (2018): Report 2018, EFI, Berlin. (Chapter A4). https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Summary_2018.pdf (English summary) or https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Gutachten_2018.pdf. (full report, German).

reason, large technology firms like Facebook, Google, Amazon and Alibaba are leading the world in the development and application of AI. Therefore, an AI strategy also requires a data strategy.

Europe cannot win the AI competition for the largest data sets. Europe and Germany cannot beat other global players in the AI competition in the race for data. Other countries and global tech companies simply pursue very aggressive data strategies. In addition, outside of the EU and apart from data pertaining to EU citizens, these data policies do not fall under the General Data Protection Regulation (GDPR). Given these constraints, Germany should concentrate on efficient depersonalization processes, high quality of data, and efficient data exchange, including standardization. Semantic interoperability, for example, is necessary for data exchange: This means that all participants of the data exchange need to have the same understanding of the data. AI systems which operate with low amounts of data should be given particular consideration in funding and access to data compared to the "data-hungry" machine learning approaches, such as the use of neural networks for deep learning.

Concrete measures for accessing and using data should account for different legal standards regarding personal and anonymous data. It's mandatory to design the availability and use of personal data to conform with the GDPR. Access,availability, as well as a high quality of data, are central factors for success in the international competition for AI development. Moreover, the importance of the physical location for saving data should not be underestimated; geographical proximity reduces latency periods wheng database queries are made. These factors must be considered when developing strategies for data accessibility and the utilization of data.

Concrete measures for implementing data pools are necessary. Such measures have to be developed with consideration of data protection and competition law. An AI strategy has to name the necessary means and processes with which data in the future can be exchanged on the basis of existing laws and regulations. Particularly machine-to-machine communication in industry which generates huge amounts of non-personal data should be cultivated for AI development.

Germany has to invest more in the development of more efficient anonymization and depersonalization techniques. The AI strategy should fund more research into processes that can be implemented for data pools in compliance with the GDPR. Cryptographic verification processes of data origin and integrity, as well as formal privacy guaranties, fall into this area. A particular-

ly interesting approach is the synthesis of individual-level data, an approach used by statistics authorities for years.[19] Throughout the development of AI, synthetic data will eventually be used successfully for training purposes; labeled datasets are particularly important here.[20]

Data pools need better economic incentive structures. Data pools are being discussed as an approach to increase the availability of data. The relevance of data pools for companies is very much dependent on the quality of the data. The principle of reciprocity could help to resolve free-rider problems[21] (this means database queries and access only for those who also submit data). For decades, this principle has proven effective for credit bureaus, since it reduces problems with freeriders. In general, we need better interconnectivity of existing projects, reference architectures, and data infrastructures.[22]

Potential impact on competition needs to be taken into account when designing data pools. When developing data pools, possible abuses of such pools to undermine competition must be taken into account. It's important to consider the use of data pools for collusion or coordination between companies. It needs to be prevented that companies use data exchanges to reduce market and price uncertainty. The development of concentrated market structures deserves special attention whenever dominant providers access data and refine their own datasets.

The infrastructure for data pools could be financed through tiered-pricing for accessing data. Economic theories particularly those backed by strong empirical evidence, should be used for the design of data pricing and monetization incentives for data pools. Different levels of data quality could serve as differentiators for pricing schemes (real-time vs. noisy data).[23] It is also worth considering whether large companies should pay comparatively more for data (for example on the basis of sales-based pricing) in order to promote competition. Pools could fund themselves through tiered-pricing schemes,

19 Jörg Drechsler and Nicola Jentzsch, "Synthetische Daten: Innovationspotential und gesellschaftliche Herausforderungen" Stiftung Neue Verantwortung (SNV), May 2018 (German). https://www.stiftung-nv.de/sites/default/files/synthetische_daten.pdf.

20 "Improving the Realism of Synthetic Images", Apple Machine Learning Journal, Vol. 1, Issue 1, July 2017. https://machinelearning.apple.com/2017/07/07/GAN.html.

21 Nicola Jentzsch, "Financial Privacy – An International Comparison of Credit Reporting Systems", Springer-Verlag, 2007, Heidelberg.

22 Examples for this are e.g. Rat für Sozial- und Wirtschaftsdaten (Council for Social and Economic Data), Smart Data 4 Mobility, Smart Data Web or the Industrial Data Space at the Fraunhofer-Institute.

23 Different methods of depersonalization can achieve different levels of noise or coarseness.

and perhaps even cross-subsidize fundamental research[24] or environmental-protection applications.

The access and use of data pools must be tied to verifiable legal and ethical requirements. An example of such conditions are written, pre-defined optimization goals of data analysis. Such goals establish the necessary compliance with GDPR and reduce legal uncertainty for companies.[25] Companies that don't follow defined goals could be sanctioned through exclusion from pooling mechanisms and public naming and shaming.

Data pools only work with high data integrity and data security. Companies would not share data in pools that cannot guarantee the security of the data, and no company would use data from pools where integrity is not guaranteed. Therefore, data pools require strict IT security specifications that prevent unauthorized access, use, or manipulation of data. Repeated contamination of datasets through antiquated, faulty, or manipulated data has to be punishable. Security standards and the quality of information should be permanently tested and adjusted according to new risk scenarios.

Industrial Data Spaces

An example of an architecture for a secure exchange of data is the Industrial Data Space created and run by 12 Fraunhofer Institutes with the participation of industry. The Industrial Data Space is a referencing architecture which not only enables the cross-sector exchange of data, but also the combination of these data in different value-creation networks. Application scenarios (for example in logistics and mobility) are being piloted in the initiative, which has been institutionalized as a non-profit organization.

The German AI strategy should address the problem of missing incentives in the open-data sector as quickly as possible. According to the most current directive on continued use of information in the public sector (PSI Directive), public-sector data should be made available to the public for free.[26] On the one hand, this means that very large companies can also access these

24 This could be applicable to research that promotes mechanisms of exchange in a privacy protection conform manner, as mentioned in the text.

25 This could be designed similarily to the current initiative „Registered Reports". It allows researchers to register their ideas for future research and protocols with scientific journals. See Elisabeth Pain, "Register your study as a new publication option", Science, December 15, 2015. http://www.sciencemag.org/careers/2015/12/register-your-study-new-publication-option.

26 The release of data in „parastatal" institutions is being discussed within the examination of the PSI-guide lines.

resources for free. On the other hand, administrations lack incentives regarding the improvement of data quality and the investments in making them publicly available. Free resources can also lead to disincentives in the marketplace. This should be taken into consideration. Open data from the public sector, especially in the transport or smart-city sectors, are very important for the development of artificial intelligence.

With the GDPR, we're at the beginning, not the end, of a debate over regulatory data-protection standards for AI. Privacy is important in a democratic society. The GDPR sets important standards in this regard. However, GDPR is not clear about the scope of its application to automated analysis and decision-making systems. Legal clarity is urgently needed, especially in regard to broad clauses with unclear meaning. The effectiveness of GDPR and the related compliance costs require ongoing monitoring. If negative implications or undesirable effects of GDPR are observed, there needs to be openness for the discussion and adoption of respective adjustment. This applies to insufficient protection standards, as well as counterproductive regulations that bring about high costs while at the same time contributing little to better protection of personal rights.

5. Infrastructure requirements for AI

A strong AI ecosystem needs access to the hardware necessary for the development and use of the technology. A global race for hardware needed for AI is well underway. As is the case in software, compared to China and the USA, Germany and Europe are currently trailing behind. A national AI strategy must thus consider access to critical hardware. Given the deterioration of transatlantic relations and the rise of trade conflicts, the challenge of how Germany can guarantee medium- and long-term access to the hardware components of this key technology becomes an issue of high strategic importance.

At the moment, deep learning (DL) is one of the most promising approaches in AI. In addition to its hunger for data, DL requires powerful hardware. The neural networks of automated systems are being trained with huge amounts of data.[27] Special chips – so-called graphic processing units (GPUs) – that deliver the necessary processing power are being used in the development

27 AI- Developers who work in image recognition are more and more reliant on images and videos in 4K or UltraHD resolution. These files are significantly larger than lower resolution files and will therefore create additional data growth which makes a higher computing power unavoidable.

of AI. The advantage of a graphics processor over conventional chips lies in the large, parallel chip architectures that can simultaneously compute multiple tasks. The global GPU market is dominated by US producers, but they are currently facing increasing competition from China.[28] Chinese chip producers, startups and technology companies have begun building their own hardware components and have made remarkable progress in GPU production over the course of only a few years.[29] European companies also exist in this domain,[30] but are very few compared to American and Chinese technology companies, and especially startups. A truly competitive European chip producer – especially compared to American hardware companies – currently does not exist.

The supply of GPU computing power increasingly relies on cloud modules as hardware-as-a-service offers. Google offers its GPU hardware (tensor processing units, TPUs) as the supply of computing power for machine learning (ML) processes over the Google cloud platform. ML developers are able to apply for TPU contingencies. Nvidia also offers some cloud solutions with respect to its GPU hardware. The desired computing power is available through Nvidia "on-demand" on the largest cloud services.[31] Amazon offers a similar service. European companies that use ML applications are already dependent on these cloud-based services today. This is not an issue as long as the computing power over cloud systems remains accessible and affordable.

28 Examples for US-american chip producers and tech companies who develop their own competences in this field: Nvidia, Google, Xilinx, fast.ai, Intel, AMD, Qualcomm, IBM, Amazon_AWS, Microsoft, Apple, Facebook.

29 Examples for chinese chip producers and tech companies who develop their own competences in this field: Cambricon Technologies, HiSilicon (HUAWEI), DeePhi Tech, Horizon Robotics, Bitmain,ThinkForce Electronic Technology, Aliyun, Alibaba Group, Tencent Cloud, Baidu, Baidu Cloud, HUAWEI Cloud.

30 Especially Dutch companies (NXP Semiconductors N.V., STMicroelectronics N.V) und britische (ARM Ltd., Imagination Ltd), a German manufacturer (videantis GmbH) and numerous european Startups (Graphcore – UK, Kalray S.A. und GreenWaves Technologies – France und AImotive – Hungary). It should be noted that in the Startup sector as well, most GPU-Startups are US-american.

31 aws, Microsoft Azure, Google Cloud Platform, IBM Cloud, Oracle Cloud Infrastructure.

Access to critical technology using ZTE as an example

In April 2018, the US Department of Commerce halted exports of American chip, optics, storage and antennae technology to ZTE as a punitive measure. It had previously determined that ZTE had not only inappropriately responded to US measures imposed for violations of Iranian sanctions, but had also lied to US authorities. The export ban cut ZTE off from important technology needed for the development of 5G and hit the Chinese telecommunications supplier very hard as a result. President Trump politicized the punitive measures when he placed them in the context of the trade conflict with China. It's therefore not only an example of the huge effects of export controls on key technologies, but also an alarming warning sign that technology exports could be employed as leverage in future trade conflicts. Given the reliance of the EU on US technology, ZTE serves as a wake-up call regarding the EU's vulnerability in this respect.

Technology companies can gain competitive advantage through on-demand GPU architectures. Tech companies do not only offer researchers access to very valuable data but also to the best hardware infrastructure. This is one of the reasons tech companies are so attractive to university researchers.

It's possible for large technology companies to use their own GPU infrastructures. These large hardware architectures are very expensive and cannot be easily replicated on the same scale as competing companies and startups. This gives the large tech companies with their own hardware not only an advantage in the development of new AI business models, but also in the further exploration and development of AI.

6. Promote AI development and AI use in the economy

Next to research, the economy is the driving force of the AI ecosystem. The large internet platforms currently lead in the development and application of AI. In the course of the digital transformation of the economy, the importance of AI as a key cross-sector technology will grow even further. To remain competitive, businesses across the board need to analyze the impact of AI, in particular regarding their core business areas. Based on this analysis they also need to identify new opportunities and to invest in the competencies of their workforce accordingly. Here, policies should especially concentrate on putting companies in a position to succeed: from the training of skilled workers and the development of sustainable data infrastructure to regulatory framework and research funding. At the same time, the development of competencies and the use of AI in companies is an important building block for a strong AI ecosystem that German policy must prioritize. As is already

the case in the digital transformation, small and medium-sized businesses are particularly vulnerable to the threat of falling behind.

Special laboratories (labs) should be established for small and medium-sized enterprises (SMEs) in which companies can gain access to AI technologies and experiment with them. The SMEs that are so important to the German economy are currently lagging behind in the digital transformation. AI threatens to amplify this deficit. Therefore, the AI strategy has to specifically address SMEs and include measures that enable them to access this key technology. To this end, experimental spaces and labs should be created where SMEs can experiment with the use of AI without incurring huge costs and risks.

Digital innovation hubs of the EU

In April 2016, the European Commission brought the European Network of Digital Innovation Hubs (DIH) into being. DIH supports small and medium-sized enterprises (SMEs) in making their business and production processes, products or services more competitive with the help of digital technologies. They support SMEs financially and technologically in trying out and developing new innovations that are application-driven. Moreover, they provide them with test and experimentation rooms at many locations. For example, the DIH at the Scuola Supperiore Sant'Anna, Pisa university functions as a Robotics Innovation Facility (RIF) within the ECHORD++ project (The European Coordination Hub for Open Robotics Development). As a Digital Innovation Hub, the university houses a test farm that can put application-driven robot technology for SMEs in the agricultural to the test. Technology transfer from the university to the private sector within such test environments should be promoted more aggressively .an alarming warning sign that technology exports could be employed as leverage in future trade conflicts. Given the reliance of the EU on US technology, ZTE serves as a wake-up call regarding the EU's vulnerability in this respect.

The American approach of competitively-organized funding for research and innovation could be a model. In the United States, the relevant federal departments have founded agencies that request startups and companies to develop specific technologies and products through bidding. The applying firms then enter into rigorous competition with one another. Only companies with the most convincing business models and technologies receive funding. This is how innovative companies were supported during their founding and growth phases over the years.

A gap in venture capital still exists and must be quickly closed. Investments and venture capital are lacking in Germany for greater commercial development of AI systems and their use. The improvement of investment incentives - as well as a strengthening of public venture-capital funds with a specific focus on AI - could make an important contribution here. However, publicly financed institutions like the KfW development bank would have to reconsider their strategy and make more investments in the seed and growth phases. Large German companies and industry also need to massively increase their investments into AI.

Exit options need to be strengthened. German economic policy should be especially geared toward supporting the development of new independent companies. Successful German and European firms are currently being acquired very early on by established foreign investors. This creates the risk that added value will not remain in Germany in the long-term.

Promote cooperation between companies and research. Government funding for the development of prototypes should be tied to potential, as well as indicators for concrete application and commercialization. Companies should – according to the model of the American STTR (Small Business Technology Transfer) project – also be permitted to use university research institutions for the further development of their prototypes. Clusters arise concurrently in both the medium- and long-term from the interplay of innovative companies, universities and spin-offs.

7. Societal dimensions of AI

A strong AI ecosystem includes public debates on the societal and ethical questions associated with the technology. Europe is based on strong legal frameworks and values. Therefore, the societal and ethical debate surrounding AI does not have to begin at square one. Rather, the government should closely monitor that the development and use of AI does not conflict with existing laws and values. The use of the technology has to comply with our values and legal frameworks, not the other way around. In those cases in which AI raises new questions and poses new conflicts, we have to openly discuss and address them.

The value dimension of AI is already on the societal and political agenda. Ethical questions surrounding AI are already being broadly discussed in society. The use of AI algorithms and automated decision making was a central

theme at this year's re:publica conference in Berlin. The Bertelsmann Foundation has started a project focusing on ethical questions around the use of algorithms. And with the founding of Algorithm Watch, there is a new NGO in Germany that is focused on the societal and ethical implications of algorithms and AI. Through the platform "Learning Systems," the Federal Ministry for Education and Research (BMBF) is also supporting a broad exchange about the potential and societal questions surrounding this new technology. The governing coalition has agreed to appoint a special committee of parliamentarians and experts that, is supposed to address ethical and societal questions around AI, as well as its economic potential. The EU has also not been idle and created a high-level expert group on AI to discuss ethical and regulatory challenges around AI.

AI Now & OpenAI

The independent AI Now Institute located at New York University explores the societal implications of artificial intelligence within four primary topic areas: Rights and liberties, labor and automation, bias and inclusion, as well as safety and critical infrastructure. At the same time, it functions as an intersectional hub for leading experts within the topic area of societally relevant AI implications. The non-profit organization OpenAI – brought into being with 1 billion dollars from Elon Musk – commits itself to the exploration and development of more secure and powerful AI (Artificial General Intelligence). Moreover, OpenAI informs policy makers about the economic opportunities and socio-political risks of (more powerful) AI. The principles of the OpenAI charter (https://blog.openai.com/openai-charter/) can provide important approaches.

Requirements for transparency and verifiability of AI systems can be found in the GDPR. The importance of a high degree of transparency and verifiability in the operating modes of AI systems receives strong emphasis in the societal debate. Legal experts are currently discussing whether Articles 13-15 of the GDPR establish a so-called "right to explanation" – a requirement for companies to explain the logic of automated decision-making systems to those subjected to them – and how it should be understood and applied.[32] This debate is closely linked to critical ethical and regulatory questions of AI, which must continue to be studied and widely discussed by researchers. But also questions of good design and quality criteria for AI systems that are compatible with our values require further interdisciplinary research and

32 Andrew D. Selbst und Julia Powles, "Meaningful Information and the Right to Explanation", International Data Privacy Law Vol. 7(4), November 30, 2017. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3039125.

broader societal and political discussion.

Optimize data use and privacy: AI developers can implement legal requirements and ethical principles directly into code. Advancing the development of AI in Germany is important from societal and ethical perspectives as well, since legal standards and ethical principles should be already considered during development and roll-out of AI systems. Verifiable requirements concerning transparency, information efficiency, formal privacy guarantees and the integrity of AI could also become features of AI development that distinguishes Germany and Europe internationally. Germany, however, is currently lagging behind in these areas of research. This must change urgently.

Societal fears about the effects of AI on the labor market have to be taken seriously. It is not just ethical questions that take center stage in the societal discourse surrounding AI. The effects on the labor market, as well as the displacement of human labor through automation, also shape the public debate. This was already seen the middle of the 1970s with the introduction of robotics and mainframe computers in industry. Since then, the effects of automation technologies on the demand for labor in Germany have been heavily disputed among researchers. German employees have been displaced from their traditional fields through the application of robots in industry.[33] Unlike in the US, however, they often find employment elsewhere within the same plant, which more often than not is accompanied by a decrease in wages. The use of industrial robots in German industry thus contributes to the decline in wage shares.[34]

There are no reliable medium and long-term predictions about the labor market effects of AI. The investigation of labor market effects through the use of AI is indeed just beginning,[35] but two essential observations can already be made. First, many experts who research AI or invest in AI companies fear powerful negative effects on employment.[36] Even researchers from the robotics sector estimate that the automation potential of AI is higher than

33 Daron Acemoglu and Pascual Restrepo, "Robots and Jobs: Evidence from US Labor Markets", MIT Economics, March 17, 2017. https://economics.mit.edu/files/12763.

34 Wolfgang Dauth et al. "German Robots – The Impact of Industrial Robots on German Workers", Institute for Employment Research (IAB), 2017. http://doku.iab.de/discussionpapers/2017/dp3017.pdf.

35 Ajay K. Agrawal et al., "The Economics of Artificial Intelligence: An Agenda", Economics of AI Conference (presented on November 13/14, 2017). http://papers.nber.org/books/agra-1.

36 Olivia Solon, "Alibaba founder Jack Ma: AI will cause people 'more pain than happiness'", The Guardian, April 24, 2017. https://www.theguardian.com/technology/2017/apr/24/alibaba-jack-ma-artificial-intelligence-more-pain-than-happiness; Kai-Fu Lee, "Tech companies should stop pretending AI won't destroy jobs", MIT Technology Review, February 21, 2017. https://www.technologyreview.com/s/610298/tech-companies-should-stop-pretending-ai-wont-destroy-jobs/.

that of robots.[37] Second, labor market researchers tackling the effects of AI are asking the same crucial questions as researchers dealing with the automation potential of robotics: could AI-based business models create enough new jobs to compensate for those that have been lost?[38] At this point in time, it is impossible to know.

Policy should focus on what it can control. Education and upskilling are areas where the government can make particularly significant contributions. Furthermore, more funding is necessary to research the question of which branches and career groups will be particularly affected by AI. Policy makers need to consider far-reaching socio-political actions in these sectors in order to reduce (with federal support) the disruption of the labor market caused by AI. The Federal Ministry of Labor and Social Affairs (BMAS) should promote discourse about effects and solution strategies within the context of the debate about the future of work. In doing so, it can build upon the green- and white-book process of "Labor 4.0" from the past legislative period. The Federal Ministry of Education has also already launched initiatives in this space with the platform "Learning Systems" and the research program "work environments."

Expand access to AI: AI should not be a technology of academic elites. The societal dimension should not be limited to discourse alone, but also allow citizens the most direct access to AI as possible. Such access can be supported, for example, through online knowledge platforms and the development of simple AI demonstration prototypes in schools and hacker spaces. As such, awareness and understanding of the use of AI can be borne into society at large. This democratizes access to AI.[39] The technological change associated with AI will only be accepted, if society as a whole is widely integrated and involved.

37 Observation at the Life & Robotics Symposium, organized in Heidelberg by Springer Nature, October 2017: https://www.springernature.com/gp/researchers/campaigns/life-and-robotics?utm_medium=spredfast&utm_content=SpringerNature_SN+Robotics&utm_source=twitter&utm_campaign=SpringerNature_&sf123025051=1. This is seen as a result of the fact that current inventions in the field of robotics differ tremendously to industry robots that have been employed in the 1980s. Current developments in robotics are aiming to create Co-Bots – collaborative robots that are equipped with tactile sensors and therefore able to safely work collaboratively with humans.

38 Daren Acemoglu & Pascual Restrepo, "Artificial Intelligence, Automation and Work", MIT Economics, January 4, 2018. https://economics.mit.edu/files/14641.

39 The British consumer organization „Which?" uses machine learning to deliver estimates for future price developments in 18 different categories of products. This enables consumers to detect the best point in time to buy a certain product. As presented at the KNIME Spring Summit 2018 in Berlin: https://www.knime.com/about/events/knime-spring-summit-2018-berlin.

A strong AI ecosystem needs to involve citizens. In many companies, the archetype of the "data citizen" is already being discussed and realized. Doing so involves the undertaking of granting all interested personnel (tiered) access to data and to the company's analysis tools. This endeavor should be a guiding principle for German society and considered in a national AI strategy. As such, the funds mobilized in an AI strategy should not be limited to cutting-edge research, cooperation between the economy, and research and venture capital. Rather, funds should also be earmarked for the development of platforms, and for tools through which citizens can get easy access to AI technologies and experiment with them.

8. Think internationally about the national AI strategy

A German AI ecosystem alone is too small. Germany can only survive the international competition with China and the USA by adopting a European approach. Combining the efforts of EU Member States and the common internal digital market have to be part of Germany's AI strategy.

A German-French AI initiative can become an important catalyst for the European approach. The European Commission has called on Member States to make a joint effort to promote AI. But EU-wide coordination will take time. A German-French initiative, by contrast, could be drawn up much faster and thus serve as catalyst for EU-wide efforts. The German coalition agreement proposes research cooperation in AI with France. The French government is highly interested in cooperation with Germany. Now it is time to translate the good intentions into concrete French-German cooperation.

The French AI strategy

At the core of the French AI strategy is the report "For a Meaningful Artificial Intelligence," presented by Cédric Villani in March 2018. Under the leadership of the renowned mathematician and member of the French Parliament, the so-called "Villani Mission" surveyed leading AI experts from around the world and conducted town halls and public events about AI all over France. The over 200-page Villani report presents a comprehensive vision for the use and potential of AI without neglecting ethical and societal challenges and risks. The report contains concrete measures and ideas about how the development of AI in France can be funded and for which societal uses the technology can be employed. The high priority President Macron attributes to AI is reflected in his numerous speeches and contributions to debates on the subject. The AI strategy not only promoted a clear position of the French government on the subject, but also contributed to a broad social discourse on AI and positioned France internationally as an attractive location for AI development and research.

The key elements of the national AI strategy also need to be taken to Brussels. Many of the points listed here aren't only relevant for Germany, but also for a European approach. Whether data pools, SME funding, or ethical questions, Germany should engage the EU on central points of its national AI strategy.

Europe has to have a discussion about the protection of its own interests regarding key technologies like AI. The USA, China, Russia and many other countries are trying to protect strategically important technology companies from foreign takeovers. The EU can no longer afford to not engage in this discussion. If countries like China do not give European companies fair market access and severely limit the takeover of their own firms, Chinese companies should not receive open access to European advanced technologies. European cutting edge technology research and companies need better protection against industrial espionage, especially from cyberspace. To this end, better specifications for IT security have to be applied for particularly critical projects.

9. Conclusion: The ecosystem approach has to take center stage

The German government should put the promotion of a strong AI ecosystem at the center of its national AI strategy. The ambitions of German policy have to go beyond individual research programs. Since AI is a field of paramount importance, development and application of this technology must be sustainably funded and propelled forward. This requires a comprehensive approach that encompasses all of the central building blocks of a flourishing AI ecosystem as presented. Ultimately, the strategy will have to be measured against the actual progress in the development of such an AI ecosystem. Thus, an AI strategy needs clearly defined indicators and benchmarks that capture the differing dimensions of a strong AI ecosystem to measure its strength and development over time.

There is a lot of talk about "brain-drain" of leading AI researchers from Germany abroad. Simply spending more on AI research will not reverse this trend. Only a strong ecosystem will attract the best researchers and developers in the medium- and long-term. The ability to bring top international experts to Germany is therefore an essential indicator of the international appeal of the German AI ecosystem. There are other important indicators that policy makers should consult in order to evaluate the effectiveness of their measures: the number and quality of AI patents, publications in leading journals, and visibility at the most important international AI conferences, venture capital investments, the founding of firms, and the number, diversity, and growth of companies with strong AI competencies. Germany does not have to start from scratch; quite a few countries have already developed and published national AI strategies in which many good ideas can be found. Now it is time that Germany finally follows suit. Only then will Germany be able to go from lagging to leading in AI.

About Stiftung Neue Verantwortung

The Stiftung Neue Verantwortung (SNV) is an independent think tank that develops concrete ideas as to how German politics can shape technological change in society, the economy and the state. In order to guarantee the independence of its work, the organisation adopted a concept of mixed funding sources that include foundations, public funds and businesses.

Issues of digital infrastructure, the changing pattern of employment, IT security or internet surveillance now affect key areas of economic and social policy, domestic security or the protection of the fundamental rights of individuals. The experts of the SNV formulate analyses, develop policy proposals and organise conferences that address these issues and further subject areas.

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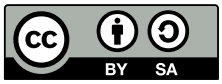

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