DISCUSSION

On the Development of AI in Germany

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Abstract
The article gives a brief account of the historical evolution of Artificial Intelligence in Germany, covering key steps from antiquity to the present state of the discipline. Its focus is on AI as a science and on organisational aspects rather than on technological ones or on specific AI subjects.

Artificial Intelligence, or AI, is on everyone's lips today. Not in my wildest dreams could I have imagined this when I began to familiarize myself with this field more than 50 years ago in Munich. As far as I know—and otherwise I should actually know—I am the oldest living scientist in Germany who was already doing research in AI at that time, i.e. before 1970.

To avoid discrepancies in the reader's and my conceptions about the term AI, let me first explain what I mean by it. In a rough classification, the world seems to consist of three clearly distinguishable phenomena: physical, biological and informational/psychological/intelligent (IPsI). Accordingly, there are three natural sciences representative of these phenomena: Physics, Biology and IPsI science [7, 8]. For each of these there is a cluster of more specific sciences closely related to the representative one, such as Chemistry belonging to the Physics cluster and dealing with specific physical phenomena, viz. the chemical ones. What I call IPsI science here did not exist as a natural science until the middle of the last century, because the material to be studied was not tangible or visible, ie. not accessible by experimental means. Although you may be able to read a person's anger from his or her face or behavior, it is not possible to grasp the phenomenon anger as such and in all its many aspects in this way. The same applies to intelligent performance in humans and also in animals or plants. It was only by way of the development of the universal computer in the middle of the last century that such phenomena became formalizable and manipulable and, as a result, experiments in this area became possible. This is how an IPsI natural science

in the true sense of the word could emerge in the first place, since experiments validating theories are indispensable ingredients of any natural science. The value of any science is undisputable since only through a deeper and firmly grounded understanding can we reach a better world.

The credit for this historically unique scientific innovation undoubtedly goes to the founders of Artificial Intelligence (AI), who from the beginning had an IPsI science in this general sense in mind [21]. For these reasons, I understand AI in this general sense as a representative natural science, here for clarification also called IPsI science, and only secondarily as a technology resulting from this scientific discipline, namely the extremely rich and promising AI technology. Accordingly, the focus of this note is on AI as a science rather than on the technology resulting from it.

These explanations make it clear that there is still a considerable lack of consistent designations in the AI environment. The underlying natural science, which is also referred to here as IPsI science, has not yet been given a generally accepted name, apart from the ambiguous "AI". An earlier proposal for this, namely "Intellectics" [4], has apparently not been sufficiently well received. Presumably, first of all the general understanding must grow that this is indeed a new and representative natural science of a rank analogous to Physics and Biology.

From the point of view of the history of ideas, this new natural science did not fall from the sky in the middle of the last century. Rather, the underlying idea has a tradition that goes back centuries and even to antiquity. This is not the place to go into this tradition in more detail, so I will limit myself to a simple listing of some of the important milestones in it, mainly those concerned with logic considered fundamental in this context by the present author.

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The following names are worth mentioning, each with brief comments:

- *Aristotle* (384–322 B.C.): He represents the pinnacle of the ancient schools of thought.[1] In his Organon [2] the first foundations of a formal logic are laid, which is called syllogistics and consists of logical rules (syllogisms, figures) about (atomic) statements (called categorical judgements). Through his work, a first basis was created for the formalization and experimental realization of logical reasoning today.

- Gottfried Wilhelm *Leibniz* (1646–1716): "… deserves to be ranked among the greatest of all logicians" [19], p. 320. His opus includes extensive work on logic within the Aristotelian tradition. His insight into the fundamental importance of formal reasoning became fruitful only two centuries later. Inspired early on by the Ars Magna of Raymond Lull and the Computatio sive Logica of Thomas Hobbes, he later envisioned a mechanization of thinking that would include, on the one hand, a lingua philosophica or characteristica universalis, i.e. a universal language in which all available knowledge could be precisely formulated in an encyclopedic manner, and, on the other hand, a calculus ratiocinator, i.e. a calculus for rationally reasoning about statements in this language, then, he prophesied, disputes could be settled simply by calculation: *calculemus*, that is, let's figure it out ([20], pp. 64, 184, 200).

- George *Boole* (1815–1864): He succeeded for the first time in developing a logical calculus [10] which was suitable also for mechanization and led to the construction of a logical machine as early as 1869 ("a machine capable of reasoning") ([18], p. 60). In formalizing this calculus, he oriented himself to the standard arithmetic; in addition, he ensured that the four basic statements of Aristotelian logic could be expressed.[2] All in all, he succeeded in doing what Leibniz had already tried to do, but had got stuck in his attempts. The result contains the central parts of what is now well known as propositional logic or Boolean algebra.

- Gottlob *Frege* (1848–1925): "… the deductive system or calculus which he elaborated is the greatest single achievement in the history of the subject. … Frege's

Begriffsschrift is the first really comprehensive system of formal logic. … Frege's work … contains all the essentials of modern logic, and … 1879 is the most important date in the history of the subject. … use of quantifiers to bind variables was one of the greatest intellectual inventions of the nineteenth century. … his achievement was so great that a large part of what comes after can be reviewed most conveniently in relation to his work." [19], pp. 435, 510ff. To this high assessment of Frege's work, especially of his Begriffsschrift [16] there is nothing to add. Frege explicitly referred his logical system to Leibniz's vision of a characteristica universalis and a calculus ratiocinator. After more or less superficial embellishments carried out in the meantime, it provides diverse and fundamental services as the Predicate Logic that is well known and widely in use today. The formal techniques developed by Frege in this work provided the decisive material, which later found important applications in all formal languages, especially in programming languages. As Leibniz predicted, the modern computer now allows nonnumerical problems to be solved computationally, which was previously only possible for arithmetically formulated problems.

- Alan Mathison *Turing* (1912–1954): He was the first to work out an exact description of a universal calculating machine [25], the basic tool not least also for AI. In addition, he exerted a decisive influence on the development of AI especially through his paper [26]. But Konrad *Zuse* is also worth mentioning here, both in terms of computer development and AI ([6], p. 88ff; [12], pp. 231f, 385f, [28, 29]).

The emphasis on logic in the presentation of this tradition corresponds to its outstanding importance for AI as well as for the development of the universal computer in general [13]. Even in the title of his fundamental work Turing explicitly mentions a central problem of logic, the Entscheidungsproblem (decision problem), around which some of the work of a number of logicians after Frege such as Hilbert, Gödel and many others revolved. The cited papers by Zuse also deal explicitly with the automation of mathematical proofs formalized in logic and with his Plankalkül designed as a logic programming language. Most importantly, the idea of universal computing, by which the entire development of computers was triggered, as well as the very concrete switching logic in computers, are clearly rooted in logic.

A more comprehensive presentation of the history of ideas precursors to AI would include further influences from Philosophy (eg. logical empiricism, Wittgenstein, Carnap), Psychology (eg. Wertheimer, Selz), (Neuro-) Physiology (eg. Helmholtz, McCulloch, Pitts), Linguistics (eg. von Humboldt) etc. ([1], [5, 6], p. 88ff).

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[1] A more detailed coverage would, for example, mention the importance of the Pythagorean school which pioneered in dealing with abstract objects and in logical reasoning, see eg. [14].

[2] The four basic forms of general statements in Aristotelian logic are usually denoted by A, E, I, and O. For example, A is a statement of the form: "every man is mortal". In abstracted form A reads as "every X is Y" and is formalized by Boole in quasi-arithmetic terms as $x(1-y) = 0$. Correspondingly for E, I, and O.

As the quintessence of this brief historical outline, we note that these fundamentally new scientific discoveries in the areas of universal computers and logical calculi amounted to truly radical changes in the previously prevailing patterns of thought. The absorption of such innovations in the scientific community and beyond is a complex, very lengthy process, which has not yet been scientifically explored with the AI methods developed from these key findings. For AI methods can be used to formally characterize an individual's linguistic, conceptual ideas about this world, whether scientific or generally educated, as well as his or her assessments and aspirations [23] and then, on such a scientifically precise basis, specify the changes required for this absorption and the psychological forces which try to undermine those changes (which, for example, Th. Kuhn did not even attempt to do).

In the present case, only a few individual scientists succeeded in this absorption initially. Among them, John McCarthy took the initiative to call some of these like-minded people together for the legendary Dartmouth Conference of 1956, which has since been regarded as the beginning of AI in the original sense of this term, and at which the first outlines of an emerging new science were worked out.

Since Germany at that time was bled dry both intellectually and materially by the Nazis and the war, a corresponding initiative did not exist in this country until almost two decades later (see below). Nevertheless, during these two decades, there were a number of individual scientists from different disciplines, who in the form of an "Invisible College" ([1], p. 61) engaged in AI topics. The scientific and technological preoccupation in the context of the new type of computers was nevertheless looking for organisational places to settle, for which German researchers were offered the alternatives DMV, GAMM and NTG (each explained subsequently), depending on their orientation [11], p. 141f.

For a long time, not even Mathematical Logic, let alone AI or Computer Science, found a home in the "Deutsche Mathematiker-Vereinigung (DMV)" (German Mathematicians' Association) founded in 1890. The "Gesellschaft für Angewandte Mathematik und Mechanik (GAMM)", founded in 1922, on the other hand, was very early on open to the new computer developments—but unfortunately to these more or less exclusively. As an exception, at GAMM's first meeting after the war, taking place 24 Sept. 1948, Konrad Zuse spoke about a new type of computing machine under the title "Über den Plankalkül als Mittel zur Formulierung schematisch kombinativer Aufgaben" [11], p. 142, [28].[3] His work on AI at that time—namely his Plankalkül based on

"Aussagen- und Prädikatenkalkül der Logistik" (ie. on propositional and predicate logic) and its application to theorem proving and chess—was born, so to speak, in the distress of the time around 1945, when he could not immediately resume his computer development with the necessary means. Afterwards he devoted himself again with full power to the further development and marketing of his computers and was unfortunately lost for AI as a result. Other personalities of the GAMM, such as Armin Walther (Darmstadt), who was the chairman of the Fachausschuß Rechenmaschinen (technical committee for calculating machines) at that time, are not known to the author to have had any interest in topics beyond computer development and towards AI.

Surprisingly, the fields of signal, message, and information processing were the obvious places to settle for German researchers interested in AI. These areas were and are represented in the "Nachrichtentechnische Gesellschaft (NTG)" (today: Informationstechnische Gesellschaft ITG). NTG was founded in 1954 as the first of the professional societies associated within the "Verband der Elektrotechnik Elektronik Informationstechnik e.V. (VDE)". In the absence of a successful absorption of the radically new findings described above (universal computers and logical calculi), an organisational and conceptual framework was chosen within more familiar terrain, albeit under the new designation *Cybernetics*, as it were, as a unifying "umbrella science". This was understood to mean the field of development and application of "novel communication and control systems" or "the theory or technology of communication, communication turnover or the systems providing it" [15], p. 9. The aim of the anthology quoted here was to provide "basic knowledge of the principle and application of these new types of machines" [15], p. VII. Although in it at least the term Turing machine is casually mentioned in the context of the described circuit algebra ([15], pp. 10,42), [25] is not even quoted, let alone any of the other fundamental work on logic described above. This misguided and distortingly narrowed view explains to some extent why Cybernetics was later completely displaced by the well-founded AI and Computer Science.

Among the scientists represented or cited in this anthology, Karl Steinbuch deserves special mention. For example, his Lernmatrix was far ahead of the international competition (keyword: perceptron) for a certain period of time. Other names include Max Bense, Winfried Görke, H. Henkel, A. Reichling, Helmut Schnelle, Spiros Simitis, Gerold Ungeheuer and Heinz Zemanek. Among the AI topics

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[3] For whatever reason neither the meeting nor the talk are listed on the GAMM website https://www.gamm-ev.de/index.php/de/tagungen/jahrestagung.html (accessed 9.3.2020).

covered are learning methods, language translation, speech generation, as well as medical and legal applications.

In the developments that followed, the international influences are unmistakable. It became apparent—easily apparent to the government—that the German data processing industry (AEG Telefunken, Siemens, Zuse) had fallen behind the American competition, which, represented by IBM Germany, Standard Elektrik Lorenz (belonging to the American ITT) and Control Data Corp. (CDC), dominated the German market anyway. This is why the government had used money to "persuade" the universities to act. In 1967, for example, the Federal Government set up the so-called "Fachbeirat für Datenverarbeitung" (FDV) as an advisory body to oversee the "Programme for the promotion of research and development in the field of data processing for public tasks", the first data processing programme. The following twelve persons belonged to this body [22], p. 22f): (1) Prof. Dr. Klaus Samelson (Direktor des Rechenzentrums der TH München), (2) Prof. Dr.-Ing. Heinz Unger (Direktor des Instituts für angewandte Mathematik der Universität Bonn), (3) Dr. Christian Fritzsche (Leiter der Abteilung Halbleiterphysik am Institut für Elektrowerkstoffe der Fraunhofer-Gesellschaft in Freiburg), (4) Dr. Hans Joachim Stuckenberg (Leiter der experimentellen Elektronikgruppe beim Deutschen Elektronensynchroton DESY in Hamburg), (5) Prof. Dr.-Ing. Robert Piloty (Direktor des Instituts für Nachrichtenverarbeitung der TH Darmstadt), (6) Prof. Dr.-Ing. Wolfgang Giloi (Direktor des Instituts für Informationsverarbeitung der TU Berlin), (7) Diplom-Ingenieur Meisel (Fernmeldetechnisches Zentralamt in Darmstadt), (8) Dr. rer. nat. Horst Springer (Direktor des Forschungsinstituts für Funk und Mathematik in Werthoven), (9) Prof. Dr. Karl Heinrich Weise (ordentlicher Professor für Mathematik an der Universität Kiel), (10) Prof. Dr. Wilhelm Krelle (Direktor des Instituts für Gesellschafts- und Wirtschaftswissenschaften der Universität Bonn), (11) Klaus Schneider (Direktor der Zentralstelle für maschinelle Dokumentation in Frankfurt), (12) Prof. Dr. Helmar G. Frank (Direktor des Instituts für Kybernetik an der Pädagogischen Hochschule Berlin). On the recommendation of the government, the following areas of application should be represented in the FDV: (1) data processing in industrial administration, (2) data processing in steel production and rolling mill technology, (3) data processing in chemical process engineering, (4) data processing on numerically controlled machine tools and transport equipment, (5) data processing in power plant technology and electrical power transmission, (6) data processing in aviation.

In addition, the ad hoc committee "Einführung von Informatik-Studiengängen" (Introduction of Computer Science Study Programmes) of the BMWF (sic—Federal Ministry for Science and Research) was established in 1968, to which the following persons belonged[4]: Robert Piloty (Institut für Nachrichtenverarbeitung der TH Darmstadt), Friedrich Ludwig Bauer (Mathematisches Institut und Rechenzentrum der TH München), Johannes Dörr (Institut für angewandte Mathematik der Universität des Saarlandes), Theodor Einsele (Institut für Datenverarbeitung der TH München), Wolfgang Giloi (Institut für Informations-verarbeitung der TU Berlin), Wolfgang Händler (Institut für mathematische Maschinen und Datenverarbeitung der Universität Erlangen-Nürnberg), Ulrich Kulisch (Rechenzentrum der Universität Karlsruhe), Klaus Samelson (Mathematisches Institut und Rechenzentrum der TH München), Bodo Schlender (Institut für instrumentelle Mathematik der TU Hannover), Karl Steinbuch (Institut für Nachrichtenverarbeitung und Nachrichtenübertragung der Universität Karlsruhe), Heinz Unger (Institut für angewandte Mathematik der Universität Bonn), Karl Heinrich Weise (Mathematisches Seminar der Universität Kiel), Horst Herrmann (Institut für Rechentechnik der TU Braunschweig), Walter Knödel (Lehrstuhl für instrumentelle Mathematik der Universität Stuttgart), Alfred Lotze (Institut für Nachrichtenvermittlung und Datenverarbeitung der Universität Stuttgart), Fritz Reutter (Institut für Geometrie und praktische Mathematik der TH Aachen).

Not a single one of the 28 persons (and others in subsequent committees) mentioned (some of them twice) could show even a hint of scientifically proven expertise with regard to the radically new findings described above, with the only conceivable exception of Steinbuch, who, however, had maneuvered himself into a rather weak position due to his identification with Cybernetics and, as an isolated individual, could of course not influence all the other members enough towards a major change of their minds. Their expertise was limited to computer construction and programming technology and the obvious or already established applications of the new type of computer, whose delayed development in Germany now had to be urgently pushed ahead. With this staff and their successors, who were responsible for the allocation of considerable resources and for reaching fundamental decisions, the further development of computer science as a subject without any consideration of AI was shaped for years to come (so that now in AI, just as in computer technology, one fell behind again considerably). For example, the founding of the "Gesellschaft für Informatik e.V." (GI) in 1969 does not signal any reference to AI. Nor did the 13 subject areas of the Überregionales Forschungsprogramm (ÜRF, Supraregional Research Programme) established in 1972, nor the recommendations for a Studienmodell (study model) contain any reference to AI. Nevertheless, for obvious reasons of content, not least the

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[4] All members were Professors with a PhD, for which reason the repetition of "Prof. Dr." in front of each name is omitted in the listing.

use of computers, there was practically no alternative for AI researchers to joining Informatik (Computer Science) as their disciplinary home.

Especially the younger scientists had to realize from the reading of scientific journals and conference proceedings that the development of AI outside of Germany had progressed relatively rapidly. In 1959, for example, the First International Conference on Information Processing (IFIP) was held in Paris, and in 1962 the second was held in Munich. Even back then, it already held technical meetings on AI topics. This was followed in 1969 by "The First International Joint Conference on Artificial Intelligence (IJCAI)" in Washington DC and in 1971 by the second one in London, ie. at the same time as the two German bodies mentioned above were active, which nevertheless excluded AI topics from their decisions entirely. The members of the "Invisible College" were further stimulated in their work by the associated publications accessible in German university libraries. Some of them gained additional experience through stays abroad, such as Wolfgang Bibel, Christian Freksa, Bernd Neumann, Michael Richter, Jörg Siekmann, etc. So, at the beginning of the 1970s, AI researchers were already active at a number of German universities and research institutions [1], p. 61ff. The resulting gap between the establishing Computer Science and the members of the "Invisible College" inevitably had to lead to an increasing alienation, which unfortunately also resulted in scientifically unfounded and grossly unequal treatment with regard to publication possibilities, research funding and positions for the scientists concerned ([3], p. 326ff).

These developments therefore prepared the ground for Gerd Veenker's initiative to invite all those interested in AI to a meeting in Bonn on February 18, 1975,[5] which today is regarded as the beginning of the institutionalization of German AI, reported in detail in [1, 5]).[6] Veenker had already become a professor in Bonn and a member of the "Sachverständigenkreis ÜRF" in 1972, and in this capacity, he had probably felt his isolation among his Computer Science colleagues at first hand, which perhaps also motivated his

initiative. Important components of this institutionalization were the following.

- A circular letter (Rundbrief) started in 1975 and distributed on a regular basis, which after a few years was already sent to about 400 and in 1984 to 1150 ([1], p. 117) recipients free of charge and which, after a series of intermediate stages over the decades, finally evolved into the now internationally renowned journal KI.

- An annual meeting starting with the one mentioned above and followed by a second one in the same year during the GI annual conference in Dortmund, which is still held today as the annual German Conference on Artificial Intelligence. In addition, a number of meetings and workshops on specific topics of AI have been established. From the very beginning, these two components—the newsletter and the meetings—have promoted the community and networking of those interested in AI, as well as the personal and professional exchange among them. The AI community was open to all interested parties without restriction. If some scientists, such as neuroscientists, felt that they did not belong to it, it was their personal decision and cannot be considered a failure of the community.

- International networking of the leading German AI researchers, who soon exercised influential functions both at the European (EurAI) and the international (IJCAII, AAAI, IFIP) level. A highlight was the organization of the IJCAI-1983 in Karlsruhe with 1500 participants, which made the importance of the field visible to German Computer Science.

- The foundation 1975 of the Fachgruppe KI within the Gesellschaft für Informatik (GI) as well as of the Subcommittee AI within the GI Fachausschuß 6 "Digitale Verarbeitung kontinuierlicher Signale" (Digital Processing of Continuous Signals) which in terms of personnel established a connection with the earlier activities of an AI flavor previously mentioned under "Cybernetics". In the context of a restructuring within the GI in 1983, AI was promoted to the highest structural level as Fachbereich 1 "Grundlagen der Informatik und Künstliche Intelligenz" (Foundations of Computer Science and Artificial Intelligence), and in 1989 even a separate Fachbereich 1 "Künstliche Intelligenz", ie. with the special number 1, was established, which visibly documents the rank achieved in the meantime.

- The Frühjahrsschule Künstliche Intelligenz (KIFS, Spring School for Artificial Intelligence), first held in 1982, attempted to compensate for the lack of AI contents in teaching at German universities, which had arisen due to the one-sided occupation of the above-mentioned ad hoc committee in the courses of study in Computer Science and had been largely maintained until then.

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[5] The author does not have access to a list of the participants in this meeting, which would be very desirable for the historical record. According to [1], p. 75) between 30 and 50 people were present. In the documentation [27] published after the meeting with 9 contributing authors neither names nor number of participants are mentioned. In the Foreword, Veenker refers to the research in AI in the Anglo-Saxon countries and to Nilsson's presentation at the IFIP Congress 1974 in Stockholm.

[6] In [9] a detailed analysis of the development of AI research at the TUM is given. There, also research topics are discussed, an issue not covered in the present note.

- Financial research support primarily by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), and since the 1980s also by ministries, the EU Commission and companies. Special mention should be made of the ESPRIT project at the European level, which was initiated in 1983, of the several hundred millions DM in funding provided for Information Technology by the BMFT in 1984, with which collaborative projects between universities and industry were promoted, and last but not least of the Sonderforschungsbereich (Collaborative Research Center) 314 "Künstliche Intelligenz – Wissensbasierte Systeme" (Artificial Intelligence—Knowledge-based Systems), which was established by the DFG in 1985 and financed with about 20 million DM.

In the wake of the Fifth Generation Computer Systems Conference held in Tokyo in 1981, AI became the focus of political attention on a broad national and international level. Thus, in the 1980s with respect to AI it was repeated what we have described in relation to data processing in the 1960s. The associated funds in the aforementioned funding pools changed attitudes towards this discipline and its representatives, who could no longer complain about a lack of reputation and research funds. With the decisions they had made since 1975, German AI researchers had positioned themselves so well in time that they were able to derive full benefit for their subject and for themselves from this focus. In Germany, this led to the establishment of a number of AI professorships (under a number of different names) at many German universities and, in 1988, to the founding of the "Deutsches Forschungszentrum für Künstliche Intelligenz" (DFKI, German Research Center for Artificial Intelligence), which today has more than 1000 employees. In addition, AI centres were also established in four federal states, although these no longer have any visible existence today.

Up to now, the description of the development has concentrated exclusively on the Federal Republic of Germany (FRG) and ignored the one in the German Democratic Republic (GDR). The development there is described in detail in [1], p. 85ff, [5], which is why I will limit myself to a few remarks here. In the 1980s, in my functions, for example as President of EurAI, I myself was often in a number of countries of the then "Eastern Bloc", including the GDR. From the encounters there, I learned that even in the GDR, the focused scientific contents did not differ fundamentally from those in the West. However, due to governmental planning regulations, repressions, tutelage and spying, scientific productivity, especially in a pioneering discipline like AI, was significantly less scientifically productive than in West Germany, let alone in the Anglo-Saxon countries. Above all, it had not been possible to form an AI community beyond the "Invisible College", which could have competed with that in the FRG. For this reason, the integration of East

German AI scientists within the AI community that had previously emerged in the Federal Republic of Germany, was carried out without any significant difficulties after the fall of the Berlin Wall, in so far as this was at all possible after examination of their political background.

Although with a considerable delay in each case, the establishment of Computer Science and AI in Germany can be considered a success. Some of the scientific as well as applicational and technological contributions in AI coming out of Germany are indeed remarkable. Nevertheless, it cannot be overlooked that the scientific as well as the economic success is comparatively limited. Only a few scientific results from Germany are truly outstanding in an international perspective. Similarly, the international market is dominated by computers of all sizes as well as integrated AI products (smartphones, search engines, provider platforms on the net, etc.), offered primarily by American (Apple, Google, Amazon, Intel, etc.), but increasingly also by Chinese (Alibaba, Huawei, etc.) giants, which the German and European economies have little or nothing to oppose.

It would have to be investigated in more detail which mechanisms have led to this superiority. One thesis could prove true: our country is no longer a too conducive home for the really great scientists of the rank of Einstein, Gödel, Zuse, McCarthy, etc. nor for their minor variants in all areas of society. At least until the nineteenth century, this was clearly different, of which capital we all still live in Germany today. I think in view of our future well-being it would be worthwhile to find out the reasons for this adverse change and its underlying structure. For if this thesis were correct, it would also explain why these decades of delays in the establishment of Computer Science and AI had to occur in the first place.

Even after the establishment of AI in Germany, its scientific prosperity in this country during the so-called AI winter in the years after 1990 in my opinion remained limited. Only now, when the whole world is talking about AI, the Germans are again loudly involved, but unfortunately again only under pressure from outside. In the spirit of "better late than never", the current strategic efforts of the Federal Government[7] and of some German federal states, as well as the intended alliance with France in the field of AI, are only to be welcomed.

A leading role in scientific development, which, as history teaches us, pays off economically in the long term and sustainably, obviously requires a more conducive environment for the country's outstanding creative minds, in addition to other important conditions. Above all, it is important to recognize these minds as such and then to grant them a

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[7] See https://www.bmbf.de/files/Nationale_KI-Strategie.pdf (accessed 26.12.19).

protected freedom and an appropriate appreciation, which in my view is obviously not sufficiently given in our time of excessive grant applications and democratically watered down evaluation procedures [17]. In addition, we need the courage to initiate promising research projects, even if their success does not appear assured from the outset.

I cannot see that such a lighthouse project is currently taking place anywhere in our country. For example, we are only partially up to date with the latest topics such as learning algorithms based on neural networks and their applications, in comparison with our competitors and as far as I can judge. Even when it comes to autonomous driving, the Californian company Waymo, with its autonomous Jaguar i-Pace for example, is—after more than a decade of development and testing—already way ahead of the companies in Germany which boasts itself as a car country. It is simply not enough to run after the trends that have already been set in motion internationally.

In this sense, at the end of these personal assessments I refer once more to the "fundamentally new scientific discoveries in the areas of universal computers and logical calculi" discussed at the beginning. Computer development is most likely far from complete. New computing concepts (quantum computers, biologically inspired computing like DNA computers, etc.) could open up completely new possibilities—see also [24]. Even with the logical calculi, which have remained unrivalled in their fundamental importance to this day, we are far from having reached the end of their development. Germany can build on a long tradition in this area in particular. So here, for example, there would be opportunities to once again take the lead ahead of everyone else. A lighthouse project around the latter topic would then perhaps in the foreseeable future lead to the scenario foreseen by Leibniz, in which it simply says: calculemus.

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