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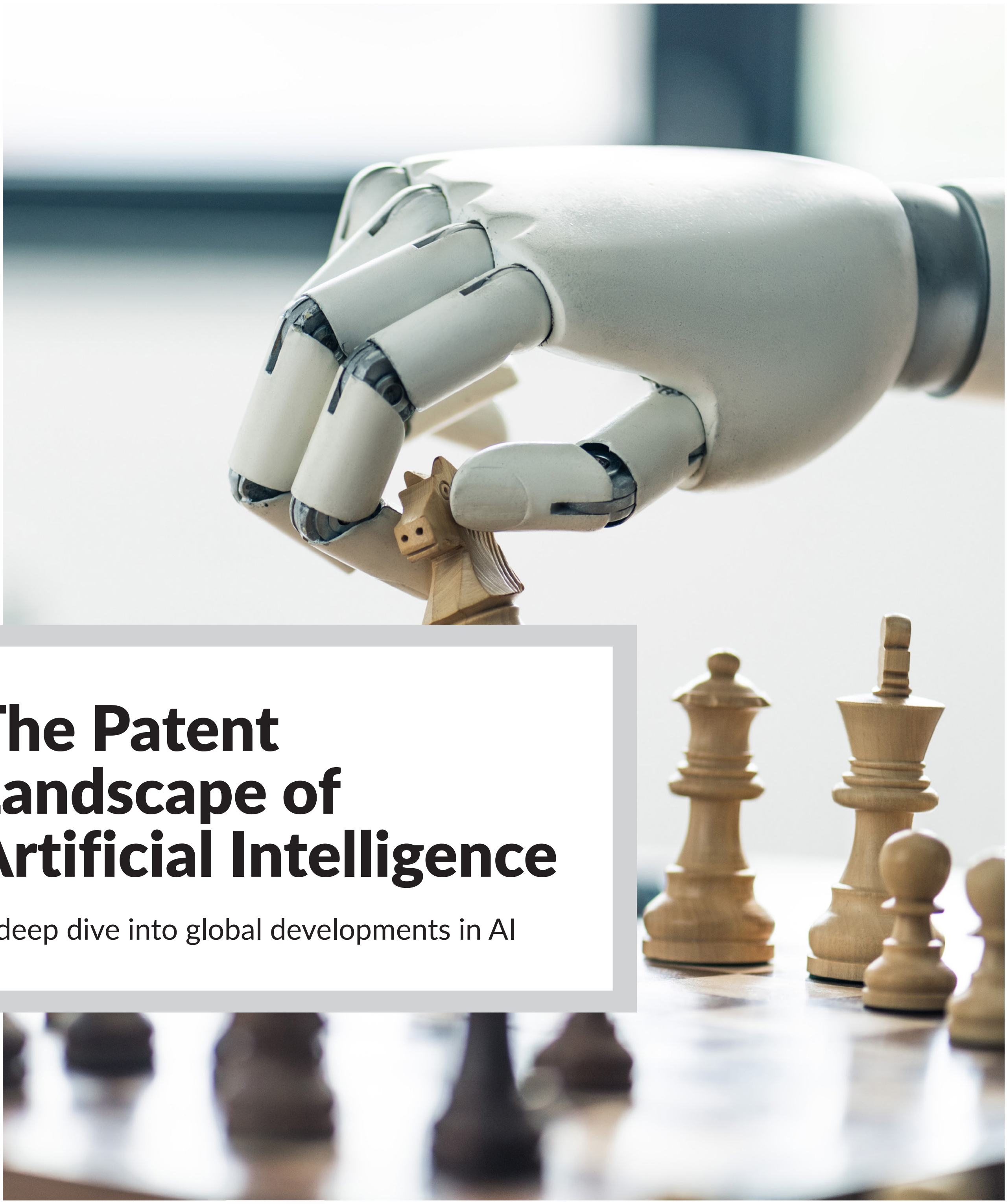

The Patent Landscape of Artificial Intelligence

A deep dive into global developments in AI

Prepared by EconSight

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The Patent Landscape of Artificial Intelligence

Global developments, fields of application, drivers of innovation and world-class research

Executive Summary

This study has been prepared by EconSight in co-operation with the Swiss Federal Institute of Intellectual Property and leading global patent analytics solutions provider PatentSight – a LexisNexis company.

The primary aim of the study is to define the development of Artificial Intelligence (AI) technologies over time. Existing research about the field was found to be lacking in a comprehensive and detailed definition of AI, the scope of the technology and a deeper understanding of its different sub-technologies. Patent Analysis has been used to perform a deep-dive into the year-on-year development of different sub-technologies that fall under the broad scope of this field. PatentSight provided the requisite data and tools in order to perform the study. Using the software, patents belonging to the specific technology field of AI were analyzed. These results are presented and interpreted in this study.

The development of the 3 main sub technologies viz. Machine Learning, Neural Networks and Deep Learning have been analyzed in detail, using patent data from patents that have been filed all over the world under the respective technology classes. The study concludes by providing a detailed understanding of the field, its current stage of development and also a profile on various countries and their endeavors in AI technology.

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1 Key facts at a glance

Comprehensive analysis and evaluation of Artificial Intelligence

The EconSight study was created in cooperation with the Swiss Federal Institute of Intellectual Property and PatentSight. While it shows the development of Artificial Intelligence (AI), the most important research fields and key application areas, it also identifies the world's major global research sites as well as the best companies and research organizations in terms of Artificial Intelligence. From a methodological perspective, this study is based on a comprehensive patent analysis with a new assessment approach that focuses on the identification of world-class patents.

The guiding technology

The number of patents in Artificial Intelligence technologies has more than doubled to 140,000 in the last 3 years and increased tenfold in the last 10 years.

Artificial Intelligence as an umbrella term for sub-technologies

Artificial Intelligence comprises different approaches such as Machine Learning, Neural Networks and Deep Learning, all of which are uniquely identifiable in the patents. Currently, about two-thirds of the AI patents concern Machine Learning, followed by Neural Networks and Deep Learning. The latter is currently the most dynamic approach. All approaches have one thing in common: they are used for new developments in speech recognition, image analysis, character recognition and data analysis.

The seven most important application fields

Public discussions often focus on Artificial Intelligence's future universal applicability with all the consequences for the economy, the state and the society. Today's Artificial Intelligence, however, cannot yet be used universally. It achieves good results particularly in clearly defined and delimited range of tasks, i.e. for a specific application purpose. In numbers, the main applications for Artificial Intelligence currently are in the healthcare sector (2,891 world-class patents), followed by data security (1,935 patents), Industry 4.0 (1,674 patents), mobility (1,600), marketing (1,058), energy (738) and financial technologies (521).

Microsoft: best AI company

The ranking of the top 50 Artificial Intelligence companies is led by five major US IT companies – Microsoft is by far the strongest AI company in the world, with 1,339 world-class Artificial Intelligence patents, followed by Alphabet (901 world-class patents), Intel (409), Qualcomm (353) and Apple (201). There are no European companies among the top 10 and only three companies in the top 50 – Philips ranks at 14th (108 world-class patents in AI), Siemens at 16th (99) and Roche at 46th (50) position.

US companies own 60% of the world-class patents in Artificial Intelligence

US companies are dominating the technology, holding 60% of all world-class patents. Companies from China (9.3%), Japan (10%) and the European Union (8.8%) are on a similar level. Specifically, Chinese companies have doubled their market share to 9.3% in the last three years, while the shares of US and EU companies are declining.

US companies hold more world-class AI patents in Europe than the Europeans themselves

US companies are dominating AI research in other countries as well. In Great Britain, American companies currently hold almost 70% of all patents with a British inventor. In France and Switzerland, they are responsible for 53% of the patents, while in Germany the share of US companies is slightly lower at 33%. For the entire EU, the share of US companies is 50%. Thus, US companies hold more world-class AI patents in Europe than the Europeans themselves. In Japan (7%), China (21%) and South Korea (17%), US companies also provide the greatest research performance of all foreign companies, but the shares are significantly lower.

The top 10 companies already hold more than a quarter of all world-class patents in Artificial Intelligence

Besides the general dominance of US companies, market concentration is also increasing. The share of the top 10 companies in terms of world-class patents is steadily increasing and currently accounts for almost 27% (2018). Five years ago, the share was 19%. A view on the top 50 confirms the rising market concentration: The top 50 AI companies today hold a market share of around 56% (2013: 47%). This means that in a dynamic technology, a market concentration is taking place at the same time – with hardly any European companies taking part.

University research: the US is dominating, China is catching up

The University of California and MIT are leading in this area. However, there are already four Chinese institutes within the top 10. In total, 30 American institutions are among the top 50. From a European perspective, there are only five institutions in the top 50: the universities of Oxford and London as well as the research institutions Fraunhofer, CNRS and CEA. China, on the other hand, is present with a total of 11 universities and research institutions.

Europeans are better positioned in healthcare and mobility applications

Philips is leading in AI healthcare (medical devices) applications, while Siemens and Roche remain in the top 10. European companies are also active in the field of mobility, e.g. vehicles and Smart City. Continental, Here Navigation, TomTom, Bosch, VW and BMW are in the top 50. However, this field of AI mobility application is led by the American companies Intel, Alphabet, Microsoft, GM and Ford. In terms of energy, GE is leading followed by Toyota and Siemens. Bosch, ABB and Schneider Electric are also within the top 50. In Industry 4.0, Emerson Electric is leading followed by Alphabet, Microsoft and GE. Siemens ranks at 9th position – ABB, Bosch and Philips are among the top 50.

Artificial Intelligence in marketing, data security and Fintech without European involvement

Artificial Intelligence in Fintech is completely dominated by the US, while data security and marketing are dominated by US and Asian companies.

2 Introduction

Artificial Intelligence (AI) creates the highest expectations out of the technologies in the current discussion on digitalization. At the same time, it is one of the most polarizing technologies. This has essentially to do with the fact that hardly anyone outside the AI's developmental field understands what is really behind it. Thought through to the end, even the developers themselves might no longer understand why a fully developed universal Artificial Intelligence does the things it does. More about this important point at a later time. Until then, in the words of Arthur C. Clarke, "any sufficiently advanced technology is indistinguishable from magic" fits better with no other technology than with Artificial Intelligence.

Artificial Intelligence is not a mature and "researched" technology, i.e. research is currently at the center of global activities. In addition, AI currently is in an extremely dynamic development phase. This means: Those who achieve the next breakthrough will have a considerable competitive advantage. It also implies that companies and institutions without research activities and a consistent application of the results may lose touch.

This is the starting point of the study. Particularly, it answers the following questions:

- What is Artificial Intelligence and how do sub-technologies such as Machine Learning or Deep Learning differ from it?
- What are the countries in which Artificial Intelligence is being significantly advanced?
- Which companies and research institutions are active in Artificial Intelligence and who is doing world-class research?
- What are the most important application fields of Artificial Intelligence?
- How important are national research locations for the companies compared to international research sites?

The goal of this study is to re-think the topic of Artificial Intelligence, reduce its complexity and provide new data and insights that help to make better classifications and strategic decisions.

This is a publication that makes use of various short studies. It aims to address relevant topics in order to re-think them, thus making a significant contribution to the objectification of discussions.

3 What Artificial Intelligence is

The general expectation towards Artificial Intelligence is that machines are able to perform tasks that require a certain level of intelligence. In the 1950s, rule-based decisions and the automation of processes were at the center of discussions[1] . Today, the term "Artificial Intelligence" refers to applications that mimic human cognitive skills such as solving problems, which in turn require strategic thinking. With this in mind, Artificial Intelligence is aimed to enable software and machines to perform certain human tasks equally well or even better.

Artificial Intelligence is not a technology

This definition of AI is problematic due to the absence of a universally valid definition of intelligence, and because the term describes the technology from a target's perspective: Every step on the way towards Artificial Intelligence must – by definition – measure itself against the goal. Yet, at least in public and media discussions, it fails because of the built-up expectation. It therefore makes more sense to describe Artificial Intelligence as a science or field of study that finds its application in a variety of technologies.

AI definitions change over time

The expectations of Artificial Intelligence are constantly increasing. Much of what was considered unique AI 40 years ago is today's programming standard. Today's navigation software, for example, calculates the shortest, fastest or most efficient route from A to B, makes adjustments based on latest traffic conditions, accepts voice commands and provides route suggestions via voice message. Thirty years ago, these would have been clear indications of AI applications, but today it is referred to as normal or technology standard.

Exorbitant and unfulfilled expectations lead to "AI winters"

Although there has been disagreement on what Artificial Intelligence really is right from the beginning, the expectation of what it is supposed to be has changed significantly over time. Successes in research aroused expectations that could not be fulfilled in subsequent years. Accordingly, in the field of AI research, phases of high research intensity and periods of lower activity (so-called "AI winters") alternated over the decades. Even today, AI performance within a very tight and specific task is often mistaken with basic and comprehensive AI competence.

The past – rule-based AI systems

During the first AI wave, algorithms and software were developed for a specific purpose based on clear logic rules and necessary parameters, which in turn were specified by human programmers. The first highlight of this approach was the powerful chess computer. Even today, the majority of software used worldwide rests on rule-based decisions in the sense of "if this, then that", like the above example of the navigation software.

The disadvantage of such systems is that they cannot adapt to new situations. They cannot draw abstract conclusions, i.e. apply their "knowledge" to other problems or deal with uncertainties. They are therefore not intelligent in a strict sense, although they met the early expectations towards Artificial Intelligence.

Initial euphoria soon gave way to disillusionment and the awareness that comprehensive rule-based Artificial Intelligence required vast amounts of code lines, complex rules and decision trees, but ultimately was unfeasible

1 The term «Artificial Intelligence» has been vastly influenced by John McCarthy at Dartmouth College in 1956 («Dartmouth Summer Research Project on Artificial Intelligence»). Conceptually, Alan Turing is considered the father of Artificial Intelligence with his lecture «Can machines think?» in 1947.

and incapable of meeting the growing demands. Promising alternatives such as the concept of basic learning without explicit programming were already theoretically developed, but could not be implemented without additional technologies.

The present – Machine Learning

The second phase of Artificial Intelligence began around 10 years ago with progresses in other technologies such as the increasing performance capabilities of computers, the rise of the Internet and the possibilities of big data.

Instead of complex rules, example-based learning is at the center of research. The AI software is trained by using sample data until meaningful results for predefined questions are achieved. The larger the amount of data that algorithms can access, the more the AI learns and the better the results. Instead of complex programming guidelines, the AI is fed with data sets with correct results, from which the algorithms create decision models that are applied later on. Machine Learning is particularly suitable for monitoring large amounts of data and identifying similarities. Yet, it relies strongly on extensive data sets for training the software. Insufficient data sets may lead to distorted results, which are very difficult to diagnose and fix because of unclear decision-making.

The most important method currently used in Machine Learning is "Deep Learning". It is based on the functioning of the human brain and complex artificial neural networks. Information is processed and evaluated at the same time and at different levels in a "human-like" manner. Findings, such as identified patterns in data sets, are condensed on multiple levels, linked together and weighted via nodes. AI learns by constantly questioning the knowledge gained and by creating new levels, links and – above all – new priorities with the help of new information. There are a number of levels between the input and the output level, in which learning takes place. Thus, the term "Deep Learning" refers to the vast amount of levels. Due to the significantly increasing computing power of processors, today hundreds of neuron levels or layers are possible.

Artificial Intelligence based on Deep Learning has made significant progress in recent years, especially in facial, object or speech recognition. At the same time, the success of Deep Learning, particularly in complex applications, reveals its major weakness: Although the results are of high quality, the underlying decision-making process are not comprehensible even for AI experts. Compared to first-generation AI, there is no methodology and therefore no dependence on basic rules. Causalities are recognized by the algorithm, but the exact manner in which input is converted into output and data is used to make decisions remains hidden. This leads to a considerable number of unresolved issues, e.g. in terms of responsibility for the results, verifiability of the results and risk minimization in a technical and legal, but also in an ethical and moral sense.

The principles of today's Artificial Intelligence date back to the 1960s

Although artificial neural networks have experienced a dynamic development in recent years, their theoretical foundations were already laid back in the 1960s. Marvin Minsky published his PhD thesis on the "Theory of Neural-Analog Reinforcement Systems and its Application to the Brain-Model Problem" in 1954. In 1960, Frank Rosenblatt first introduced the concept of a perceptron – a simplified artificial neural network. However, after Minsky showed the limits of perceptrons in 1969, this field of research had come to an end for the first time. It was not until 1984 that research by David Rumelhart, Geoffrey Hinton and Ronald Williams was revived with their article on "Learning Representations by Back-Propagating Errors". Here, they introduced a model with multiple levels for the first time, with each corresponding to the perceptron model. This was followed by a decade of extensive research activity and the rise of the term "Deep Learning", however, without any significant results. Only when Geoffrey Hinton and Ruslan Salakhutdinov presented the idea of a step-by-step development of levels in their publication "Reducing the Dimension of Data with Neural Networks" in 2006, the Deep Learning approach could be put into practice along with advances in computing power and data availability on the Internet.

The future – strong Artificial Intelligence

Second-generation AI approaches are extremely specialized. They learn from massive data sets and achieve good results particularly within clearly defined and delimited range of tasks. Although they represent the current state of the art, they remain so-called "weak artificial intelligences", also referred to as "Artificial Narrow Intelligence" (ANI). From a technical perspective, they can be applied to the same problem definitions, but already fail on similar ones – the use for any problem definition, defined as "strong Artificial Intelligence" (AGI, "Artificial General Intelligence"), lies in the distant future. Besides basic requirements for hardware and energy consumption, also the requirements for the necessary software are still too high. Furthermore, it is uncertain whether strong Artificial Intelligence can be deployed on current systems or whether completely new pathways have to be explored, e.g. self-creating and self-modifying codes.

Despite all uncertainties about the approach to be adopted, there is broad consensus on the requirements towards third-generation AI skills. What is needed is the ability to learn autonomously in real time, to generalize, to be able to think abstractly and to use natural language. In this context, capacity for abstraction and adaptability are central objectives, i.e. third-generation AI needs to be able to understand context and meaning, be able to adapt to changing circumstances and behave reasonably in unexpected situations. In short: future AI is expected to include commonsense capabilities.

4 Patent analysis: Approach and procedure

One of the main reasons for the present study is the lack of comprehensive and detailed definitions of Artificial Intelligence as a stand-alone technology. The dynamics of current developments make this definition more difficult and also lead to superficial public discussions that are characterized by fear. Therefore, this study aims to provide a structured basis for analysis and discussion.

In order to portray the development of Artificial Intelligence worldwide, and for a wide range of applications, a patent system is useful. Conventional methods of patent analysis, however, focus only on the number of patents. Furthermore, due to distorting effects arising e.g. from country-specific differences in the patenting systems, usually unsatisfactory results are the consequence. As an example, significantly less research is published in Japan, so that patents are one of only few opportunities for researchers to publish their research results. In China, on the other hand, researchers are encouraged by tax reductions to patent as much as possible in order to increase the relevance of China as a research location. The simple measurement of patent activity with regard to new applications overrates the importance of certain countries and distorts the overall picture. Moreover, there is no classification of the relevance of the particular invention.

New valuation approach for patents with world-class focus

EconSight therefore makes use of a new valuation approach of its cooperation partner PatentSight, one of the leading providers of patent analytics. With this new approach, a weighted and standardized quality assessment of individual patent families (definition of family: "simple family"[1]) is possible for the first time, allowing a comparison to all other patent families worldwide. From a technical perspective, worldwide patent quality is measured by Market Coverage™ and Technology Relevance™. Market Coverage™ calculates the worldwide legal coverage of patent protection by means of extension of the nationalization of intellectual property rights (scope and extension of the patent family) and shows how companies evaluate the significance of their own invention. As patent protection becomes more cost intensive with every country that the patent is covering, a broader international market coverage signals that the patent applicant views his patent as promising (internal assessment). Technology Relevance™, on the other hand, demonstrates how important an invention is in comparison to other patents in a corresponding technology (external assessment), taking into account patent examiners' references and citations. While Market Coverage™ and Technology Relevance™ together constitute the competitive impact of a patent family, the sum of all patent families with their individual impact values results in the Patent Asset Index. This is the valuation of the entire patent portfolio of a company or research institute.

The relative valuation of worldwide patents allows a quantifiable classification into relevant and less relevant patents. Due to this, the distortions within the patent system as described above are evaded. The focus of this study lies upon the top 10% of all existing patents, so-called world-class patents.

Active patent portfolio instead of new applications

In this study, patents are identified and counted according to the concept of "Reporting Date". This means that only active and published patent families as well as patent applications will be included in the analyses. Thus,

1 A simple patent family is a collection of patent documents relating to a single invention with identical technical content. Definition: https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/patent-families/docdb_de.html

only patent families that have at least one valid patent or pending application are counted. The procedure differs from other patent analyses in which e.g. only new patent applications per year are counted or all patents are used including inactive ones. Rather than just measuring the dynamics of developments, the approach used in this study focuses on the absolute size and strength of a patent portfolio at the current time. For example, the deadline for data collection (10 January 2019) includes all issued patents and pending applications published to this date. Furthermore, all active patents from previous years are taken into consideration. As patents in many countries are published after 18 months of concealment, the years 2018 and 2017 are still incomplete. Due to the strong dynamics and the general demand for up-to-date data, these years have been taken into account nevertheless. Accordingly, 2016 is the last complete year.

Inventor's address instead of company seat

Patents are categorized according to the inventor's address. This eliminates distortions by companies that register all patents at their headquarters, even though research has been done somewhere else. In the further course of the study, both approaches will be combined.

A patent is the result of research effort that is usually done by more than one researcher, often by more than one institution and sometimes in more than one country. To respect this effort properly, each researcher involved and each institute specified as the owner is fully assigned the relevant patent. Thus, the research undertaken is considered in the best possible way, however, the number of patents aggregated across all companies and institutions exceeds the total number of patents in total. But since this analysis deals with the relative importance of the players within the technology and the structures as a whole, this distortion is acceptable.

Changes compared to the pre-release

This study was developed over the course of several phases, discussed with external experts and adjusted accordingly. First preliminary data was presented during selected events and workshops in autumn 2018. The data used in the present study differs from the pre-release in some respects, e.g. a refined definition of Artificial Intelligence has been applied. The new definition is broader in order to be able to better identify relevant developments, particularly in terms of application fields. Specifically, the full-text search in the patent data bases was expanded and the data status was updated to January 2019. Due to these optimizations, the number of identified patent families related to Artificial Intelligence has grown from around 90,000 to more than 140,000.

5 Technological definition of Artificial Intelligence

The technological definition of Artificial Intelligence used was created with the support of the Swiss Federal Institute of Intellectual Property on the basis of various international patent classification systems (IPC, CPC). It consists of more than 130 patent classes that have clear references to Artificial Intelligence, Machine Learning, Neural Networks and Deep Learning or which show concrete application thereof. In addition, relevant word concepts, particularly on theoretical principles such as “convolutional neural network” or “restricted Boltzmann machine”, have been applied in class domains such as IPC/CPC G06F (data processing), B25J9 (robotics), G06K9 (pattern recognition), B60W30-40 (vehicle control systems) to complete the data for different applications more broadly. Documentation of selected classes and word concepts for the underlying technology field is available on the IGE’s website.

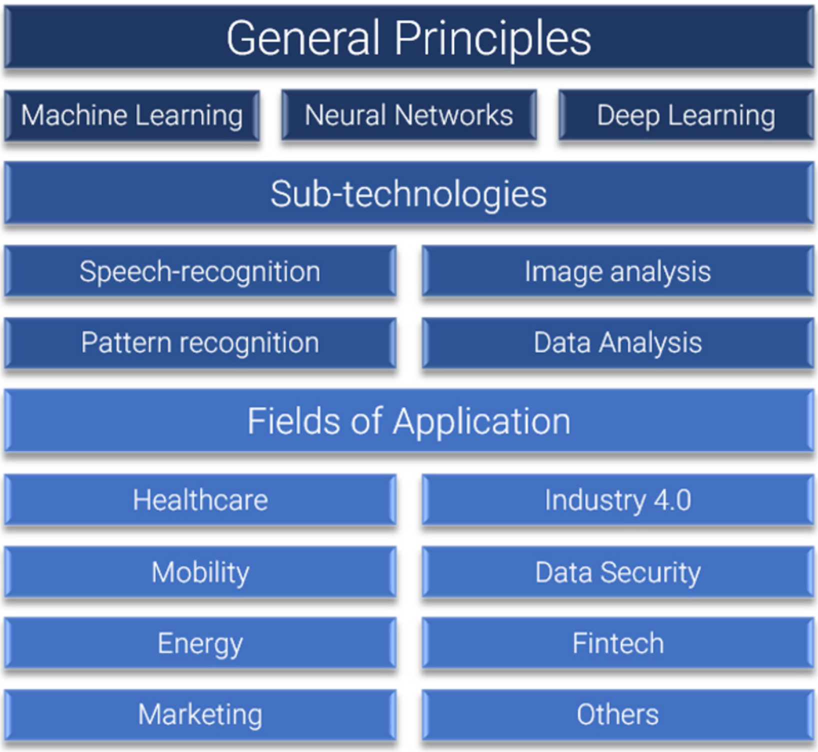
Here, the approach differs from the frequently used standard procedure of describing a technology as selectively as possible and by means of well-defined technical elements. This approach would have shown too much the technology itself rather than the embedding and connection with the surrounding fields.[1]

Artificial Intelligence consists of general principles as well as four sub-technologies: speech recognition, image analysis, character recognition and general data processing. Most of the patent activities take place in these four sub-technologies. Additionally, there are seven major applications of Artificial Intelligence: healthcare, mobility, energy, marketing, Industry 4.0, data security and financial technologies.

In the course of this study, the main application fields of Artificial Intelligence are presented in detail. In addition, there are other fields of application that are about to emerge, but which are already identifiable from a patent perspective. These include legal services, personnel management, warehousing and supply chain management. While 250 patents have been filed in the legal and HR sectors worldwide, supply chain management already counts more than 500 patents, driven particularly by major online retailers such as Amazon. Specifically, developments within the legal and HR sectors should not be underestimated, as high-quality services come into contact with Artificial Intelligence here.

1 Since patents can be assigned to numerous patents classes, and these in turn to different application fields, a patent can be counted several times. In terms of content, this procedure is desired because the competence in fact lies within the technologies. Due to the overlaps, the sum of patents of the individual application areas exceeds the total patent sum by about 10%.

Figure 5.1. Structure of Artificial Intelligence



Source: EconSight, 2019

The above figure shows AI's defined structure. Using the example of the current widely discussed use of AI for the analysis and interpretation of x-ray images, this structure can be depicted as follows: The principle of Machine Learning is used in the field of image analysis for application in medical technology.

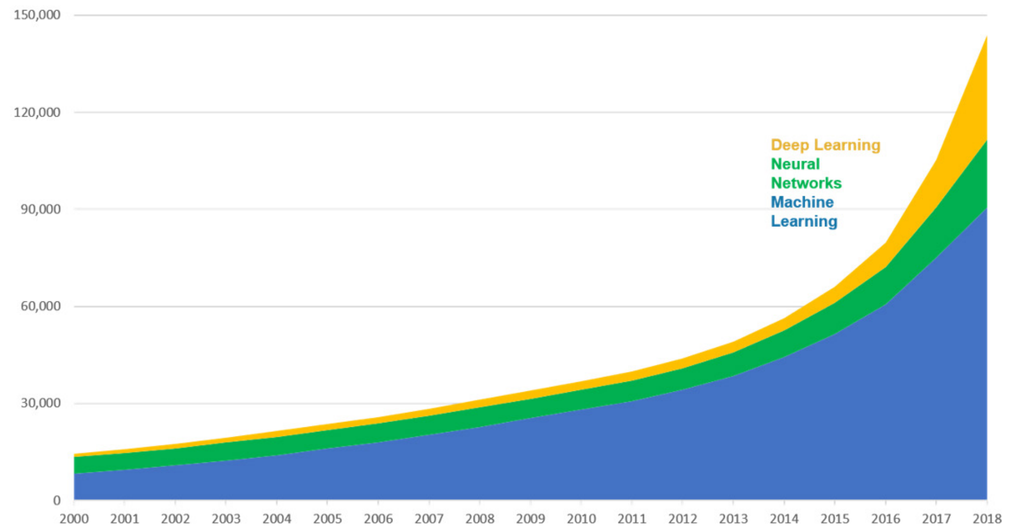
On the whole, around 20% of all patents in Artificial Intelligence are attributable to principles, around 45% to the four sub-technologies and 35% to the application fields. The focus of the analysis lies on the application areas. However, the distribution makes clear that although Artificial Intelligence is very dynamic in the development of concrete applications, basic research is still being conducted in many areas. Failures therefore cannot be excluded and applications can quickly become obsolete by significant new insights into the principles. Correspondingly, the technologies are considerably risky.

6 Global Patent Develpments and Rankings

Global patent developments

The number of active Artificial Intelligence patents[1] has increased tenfold between 2000 and 2018 – from 14,000 to 144,000 patents. A strong development has taken place in recent years. For example, in the past three years the patent volume has doubled.

Figure 6.1. Global patent development in AI and the most important sub-technologies, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

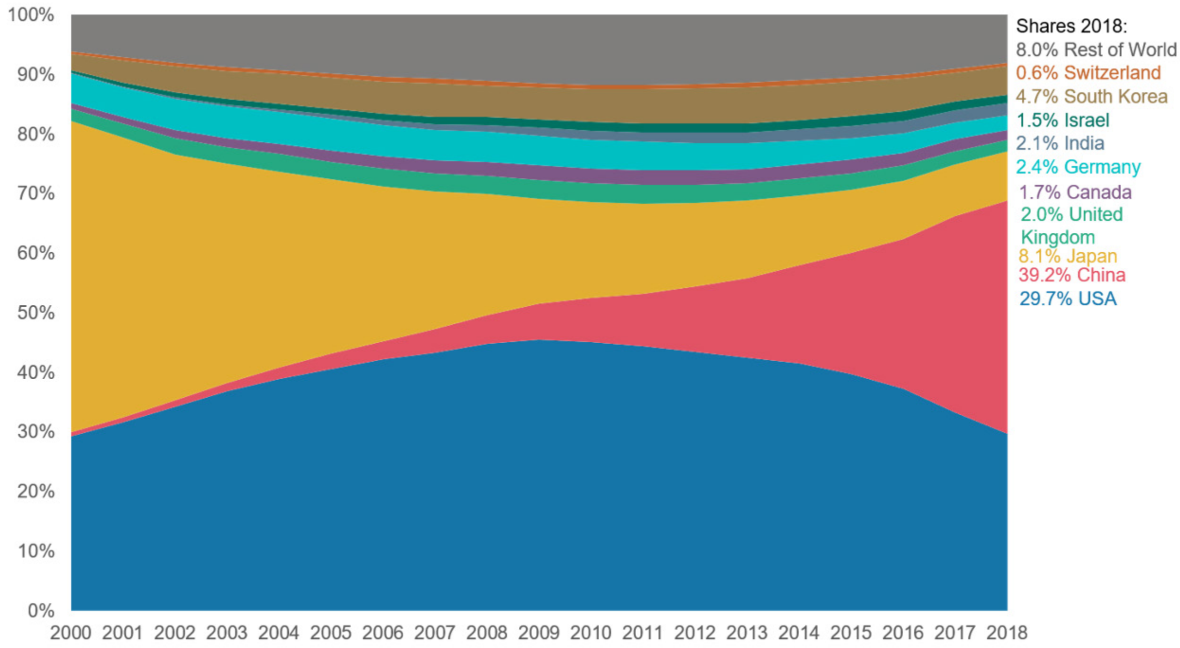
Within Artificial Intelligence, the developments of the following three main sub-technologies can be distinguished:

- Machine Learning applies algorithms to collections of data in order to identify relevant patterns. It is the largest field of research, currently accounting for two-thirds of all AI patents (91,000).
- Neural Networks are machine learning algorithms inspired by the human brain that are supposed to learn from data. A simple neural network consists of an input layer, an output layer and a single hidden layer. With 15% of all patents (21,000), this area of research is currently much smaller.
- Deep Learning is the advanced form of Neural Networks. It consists of more than two hidden layers, each of which analyses, evaluates and condenses data and whose results are serving the subsequent layer as a basis. Deep Learning is currently the most dynamic technology, accounting for around 20% of patents. In the last year, this number has doubled to 32,000 patents.

The development of total AI patents for selected countries shows three distinct phases. At the beginning of the millennium, Japan dominated Artificial Intelligence with more than half of all patents in this technology. In 2003, the US passed Japan and took on the leading position. Last year, after more than a decade of dominance, the

1 Patent data consists of the current patent portfolio as of December 31 of the respective year. The patent portfolio does not only contain the current patent applications, but also all registered and issued patent families from the previous years, which are still valid at the time. Since patents are published with a delay of up to 18 months, the years 2017 and 2018 are still incomplete. Thus, 2016 is the last complete year.

Figure 6.2. Overall development of the patent structure in Artificial Intelligence, selected countries, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

United States was overtaken by China. Meanwhile, 40% of all AI patents come from China.

Chinese dynamics is largely due to specific characteristics of the national patent system. As discussed in the chapter on approach and procedure, Chinese researchers are encouraged by tax reductions to patent as much as possible in order to increase the relevance of China as a research location. To minimize the corresponding distortions (also from other countries), this study mainly analyses world-class patents. Defined as the top 10% of patents in the field of Artificial Intelligence, they allow a better view of the relevant players. The following figure shows a comparison between total patents and world-class patents in Artificial Intelligence.

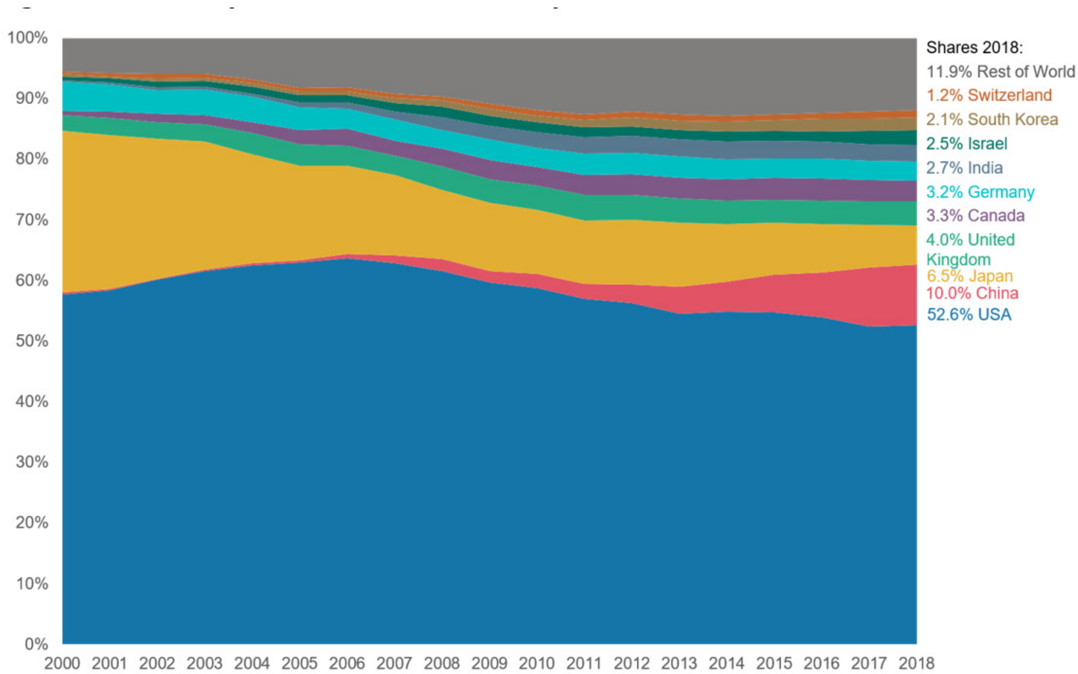
Accordingly, the US leads with more than 50% in terms of world-class patents, while the Chinese shares are reduced to 10%. This puts China in second place in terms of world-class patents, while in terms of total patents it reaches 40%. This structural difference shows that while China is the leader in terms of patents, its patent quality is lagging behind. In other countries, the difference is less prominent. On the whole, China and the US account for more than two-thirds of all AI patents in both comparisons.

The global analysis reveals the dynamic development of Artificial Intelligence, especially in recent years. It also shows the importance and changes in the activities of individual countries, particularly China. The rise of China in the world-class patents reflects the dynamics and increasing quality of China as a research location. However, this figure only shows where the development of the patents has taken place geographically. In the following figures, and especially in the later chapters, the focus is more on who is developing the relevant world-class patents.

Rankings of the best companies and universities

A view on individual companies and research institutions also shows a clear picture. Measured by world-class patents, half of the top 50 companies in Artificial Intelligence come from the USA. Where Microsoft, Alphabet

Figure 6.3. Development of the world-class patent structure in AI, selected countries, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

(Google) and Intel are leading. In total, there are six American companies within the top 10, four Asian companies (Samsung from South Korea, Sony from Japan as well as Tencent and Alibaba from China). Philips is the first European company, ranking at 14th position, followed closely by Siemens.

Overall, the ranking is dominated by IT companies, but also vehicle manufacturers (GM, Toyota, Ford, Honda and Boeing), electrical engineering (among others GE, Sony, Philips, and Siemens) and pharmaceutical companies (Johnson & Johnson, and Roche) are present. It is striking that not a single company specializes in Artificial Intelligence. All companies and institutions are primarily active in other areas and achieve their positioning by linking their core competence with AI.

Table 6.1. The top 50 AI companies and research institutions, sorted by world-class patents, 2018

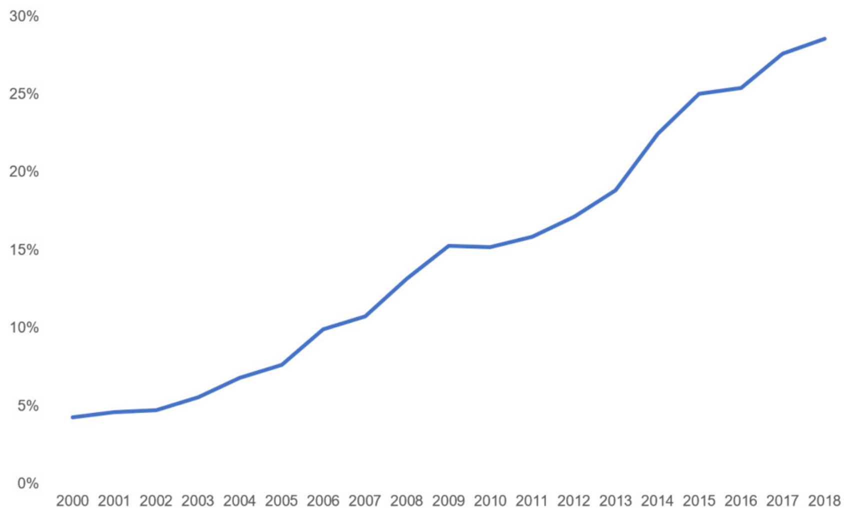
Rank	Name	World-class patents in AI	Total patents in AI	Total patent portfolio	Share of AI patents
1	Microsoft	1'339	4'187	31'804	13.2%
2	Alphabet	901	2'311	22'161	10.4%
3	Intel	409	1'237	34'189	3.6%
4	Qualcomm	353	671	26'762	2.5%
5	Apple	201	444	14'979	3.0%
6	Samsung	198	1'683	99'143	1.7%
7	Sony	186	919	31'399	2.9%
8	Tencent	177	912	16'075	5.7%
9	Alibaba Group	167	744	11'338	6.6%
10	Amazon	159	842	7'878	10.7%
11	IBM	153	4'028	45'824	8.8%
12	Facebook	130	887	4'124	21.5%
13	GE	126	732	38'785	1.9%
14	Philips	108	545	12'877	4.2%
15	Canon	102	942	80'437	1.2%
16	Siemens	99	984	31'453	3.1%
17	LG Electronics	88	300	47'446	0.6%
18	Toyota Motor	85	495	66'805	0.7%
19	Baidu	82	1492	4'570	32.2%
20	Emerson Electric	82	152	4'508	3.4%
21	Hitachi	81	669	74'484	0.9%
22	GM	81	595	19'565	3.0%
23	Honeywell	81	270	15'115	1.8%
24	Panasonic	78	521	78'673	0.7%
25	Verizon	73	759	8'155	9.3%
26	Semiconductor Energy Lab	73	111	8'365	1.3%
27	Nuance	72	434	1'985	21.9%
28	University of California	71	218	6'574	3.3%
29	Cisco	68	418	12'238	3.4%
30	Xerox	64	587	10'422	5.6%
31	Huawei	63	656	53'102	1.2%
32	Xiaomi	61	553	13'673	4.0%
33	Mitsubishi Electric	61	402	56'940	0.7%
34	Nokia	60	398	21'802	1.8%
35	Magic Leap	59	62	229	27.1%
36	NEC	58	997	33'257	3.0%
37	Accenture	57	333	1'722	19.3%
38	Ford	55	295	17'544	1.7%
39	Rockwell Automation	55	183	1'837	10.0%
40	Boston Scientific	55	93	7'196	1.3%
41	Intellectual Ventures	54	300	9'028	3.3%
42	KLA-Tencor	53	108	1'838	5.9%
43	Honda Motor	52	390	31'573	1.2%
44	InterDigital	52	154	7'622	2.0%
45	MIT	51	144	3'291	4.4%
46	Roche	50	106	6'282	1.7%
47	Oracle	48	475	14'228	3.3%
48	Beijing Didi Infinity Technology	48	54	314	17.2%
49	Johnson & Johnson	47	71	11'789	0.6%
50	Boeing	46	421	12'553	3.4%

Source: EconSight, IGE, LexisNexis PatentSight, 2019

The ranking is sorted by world-class patents in AI, also showing the total patents of the respective company in Artificial Intelligence. In addition, the entire patent portfolio of the company is shown, while the relationship between AI patents and total portfolio shows the degree of specialization of the company.

Besides the American dominance within the top 50, consolidation in patent development is also remarkable. In a fast-growing technology the patent volume has doubled in the past three years alone, the world's ten strongest companies (Microsoft, Alphabet, Intel, Qualcomm, Apple, Samsung, Sony, Tencent, Alibaba, Amazon) were able to steadily increase their share of world-class patents to about 27% in 2018. Only five years ago, the share was 19%. A view on the top 50 also shows the rising market concentration: The top 50 AI companies today hold approximately 56% (2013: 47%) of all world-class patents. Thus, in this dynamic technology market concentration is taking place at the same time. From a European point of view, this development is alarming because hardly any European company is part of this development.

Figure 6.4. Development of the top 10 companies' share of world-class patents in AI, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

The best universities and research institutions in Artificial Intelligence

With the University of California (rank 28) and MIT (rank 46), only two universities are among the top 50. Although patent development is not a primary task, Artificial Intelligence as a research-intensive technology offers great potential in basic research.

In the following, a more detailed view on universities is provided. It should be noted that also here the focus is on world-class patents. With regard to the pure AI patent quantity, Chinese universities are way ahead of the rest of the world. Measured by the number of patents, Chinese universities would dominate the top 50 with 47 positions. Moreover, 34 Chinese institutions with a total of 14,000 patents would lie in front of the University of California.

The following table shows the top 50 universities and research institutions in Artificial Intelligence in terms of world-class patents. American institutes are leading, but there are already four Chinese institutes in the top ten. In total, 30 American institutions are among the top 50. From a European perspective, there are only five institutions among the top 50: the universities of Oxford and London as well as the research institutes Fraunhofer, CNRS and CEA. China, on the other hand, is present with 11 universities and research institutions. Overall, universities and research institutions only account for about 9% of all world-class AI patents (16% of total patents in AI).

Table 6.2. The best research institutions and universities in AI, 2000-2018

Rank	Name	World-class patents in AI	Total patents in AI	Total patent portfolio	Share of AI patents
1	University of California	71	218	6'574	3.3%
2	MIT	51	144	3'291	4.4%
3	Chinese Academy of Sciences	38	1'791	81'179	2.2%
4	SRI International	37	89	536	16.6%
5	Stanford University	29	89	2'206	4.0%
6	Harvard	26	49	1'536	3.2%
7	Dana-Farber	23	38	559	6.8%
8	South China Univ. of Tech.	22	599	13'900	4.3%
9	Shenzhen University	22	156	2'627	5.9%
10	Cornell University	19	50	1'245	4.0%
11	Tsinghua University	18	805	28'748	2.8%
12	Partners Healthcare	17	52	2'175	2.4%
13	Columbia University	16	88	1'164	7.6%
14	University of Texas System	16	67	2'526	2.7%
15	Carnegie Mellon	14	122	1'006	12.1%
16	University System of Ohio	14	51	1'850	2.8%
17	Battelle	13	66	2'231	3.0%
18	Broad Institute	13	23	231	10.0%
19	University of Oxford	12	32	626	5.1%
20	Peking University	11	331	8'395	3.9%
21	Johns Hopkins University	11	69	1'918	3.6%
22	University of Southern California	10	57	886	6.4%
23	Tel Aviv University	10	26	490	5.3%
24	Xidian University	9	793	8'391	9.5%
25	CEA	9	107	6'442	1.7%
26	NICT	9	104	1'407	7.4%
27	ITRI	9	99	7'998	1.2%
28	Caltech	9	59	1'800	3.3%
29	University Health Network	9	18	216	8.3%
30	Beijing University of Technology	8	454	7'594	6.0%
31	Huazhong Univ. of Sci. & Tech.	8	340	8'770	3.9%
32	CUMT	8	150	5'792	2.6%
33	CNRS	8	71	5'342	1.3%
34	Fraunhofer	8	61	5'750	1.1%
35	University of Chicago	8	25	864	2.9%
36	Duke University	8	21	825	2.5%
37	State University System of Florida	7	116	3'211	3.6%
38	Commonwealth System (Penn.)	7	49	1'553	3.2%
39	University of Tennessee	7	26	949	2.7%
40	University of Pennsylvania	7	25	1'294	1.9%
41	Chinese University of Hong Kong	7	23	401	5.7%
42	University of London	7	23	692	3.3%
43	Rice University	7	12	421	2.9%
44	UESTC	6	618	9'445	6.5%
45	Tongji University	6	187	6'866	2.7%
46	New York University	6	76	885	8.6%
47	Northwestern University (Illinois)	6	53	1'183	4.5%
48	Russian Academy of Sciences	6	28	3'611	0.8%
49	EPF Lausanne	6	21	555	3.8%
50	CSIRO	6	19	585	3.2%

Source: EconSight, IGE, LexisNexis PatentSight, 2019

The best specialized companies in Artificial Intelligence

The top 50 ranking of the best companies does not show a single company specializing in Artificial Intelligence. In fact, the majority of companies have combined their core competencies with AI. The following table shows all companies whose AI patents make up at least 50% of their total patents and who hold at least one world-class patent. It appears that there are many companies with a product or strategy aiming to use Artificial Intelligence in order to drive a specific aspect in an industry such as pharmaceuticals or vehicle manufacturing.

Table 6.3. The best specialized AI companies, 2000-2018

Rank	Name	World-class patents in AI	Total patents in AI	Total patent portfolio	Share of AI patents
1	Brain Corp.	35	75	87	86.2%
2	HeartFlow	30	51	63	81.0%
3	Blast Motion	24	28	46	60.9%
4	Digital Doors	13	16	18	88.9%
5	Megvii	9	146	257	56.8%
6	Causam Energy	9	36	56	64.3%
7	SenseTime	7	335	415	80.7%
8	Mitek Systems	7	18	36	50.0%
9	Interaxon	7	8	9	88.9%
10	ABBYY Software	6	129	215	60.0%
11	Intelligent Technologies Int.	6	21	40	52.5%
12	Health Discovery Corporation	6	20	24	83.3%
13	Guardant Health	6	13	24	54.2%
14	uBiome	5	56	61	91.8%
15	MyScript	5	29	30	96.7%
16	Preferred Networks	5	27	30	90.0%
17	Iteris	5	23	42	54.8%
18	Sinoeast Concept	5	20	34	58.8%
19	Natera	5	19	33	57.6%
20	Veridium	5	11	14	78.6%
21	Affectomatics Ltd	5	10	10	100.0%
22	Age Of Learning Inc	5	8	12	66.7%
23	Myskin, Inc.	5	6	6	100.0%
24	Applied Recognition Inc	5	5	5	100.0%
25	Blanding Hovenweep	5	5	5	100.0%
26	Cylance	4	39	50	78.0%
27	Knowm	4	30	34	88.2%
28	Biodesix Inc	4	23	37	62.2%
29	Trust Sience	4	15	15	100.0%
30	Qeexo Company	4	12	17	70.6%
31	Great Lakes Neurotechnologies Inc	4	9	14	64.3%
32	Purepredictive Inc	4	9	9	100.0%
33	VRVis	4	6	10	60.0%
34	Arb Labs	4	5	7	71.4%
35	Blazent Inc	4	4	6	66.7%
36	Biocatch Ltd	3	39	49	79.6%
37	PCCI	3	19	19	100.0%
38	Veracyte	3	14	16	87.5%
39	Digital Reasoning Systems Inc	3	11	12	91.7%
40	Interactive Memories Inc	3	11	12	91.7%
41	Linestream Technologies Inc	3	10	16	62.5%
42	Ultrata Llc	3	10	10	100.0%
43	Pedstowe Limited	3	8	11	72.7%
44	Interos Solutions	3	8	8	100.0%
45	Memorial Health Trust Inc	3	8	8	100.0%
46	WHOOP Inc	3	5	7	71.4%
47	Solano Labs	3	5	5	100.0%
48	Advanced Elemental Technologies	3	4	5	80.0%
49	Textwise Company Llc	3	4	5	80.0%
50	Z Advanced Computing	3	4	4	100.0%

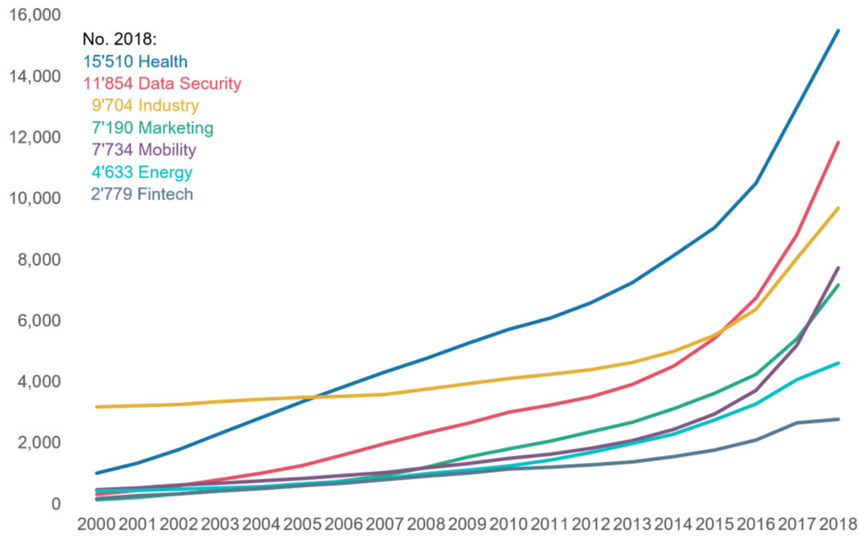
Source: EconSight, IGE, LexisNexis PatentSight, 2019

7 Application fields of Artificial Intelligence

Future Artificial Intelligence is expected to be universally applicable to any problem. However, the current state of technology allows good results only in clearly defined range of tasks. Accordingly, Artificial Intelligence can be differentiated into basic and applied research. In the following, the most significant AI application fields currently available are presented.

With 15,500 patents, healthcare is ahead of data security applications (11,800) and Industry 4.0 (9,700). While marketing applications (7,200) also show a dynamic development, the development of Artificial Intelligence in mobility (7'700) is the strongest. Here, the patent volume has doubled within the last three years. It is striking that Industry 4.0 has long been stagnating, only gaining considerable momentum from 2014 onwards.

Figure 7.1. Global patent development according to application fields, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

Focusing on world-class patents only, healthcare (2,891 patents) is the strongest application, followed by data security (1,935), Industry 4.0 (1,674), mobility (1,600), marketing (1,058), energy (738) and financial technologies (521).

In the following subchapters, the individual application fields are examined in more detail. Each chapter begins with a definition of the application field[1] , followed by a table showing the top companies in the world. The

1 As already pointed out, patents – and therefore also world-class patents – can be assigned to several application fields. Thus, the sum

companies are sorted according to their number of world-class patents and also contain the respective total patents. In addition, the share of AI world-class patents as a proportion of the total AI patents and of the entire patent portfolio of the respective company are shown.

Healthcare

Current AI applications in the healthcare sector are predominantly based on image analysis and they are used in particular in radiology for interpretation of x-ray images. Additionally, Artificial Intelligence is being used in order to reduce the development time of new medication by allowing faster search and analysis of clinical data. Artificial Intelligence is also supposed to be used in prevention, e.g. for better monitoring, linking and interpretation of different measurement values such as cardiovascular data. Besides classical medical technology, producers of wearables and fitness trackers are playing an increasing role here, too. Also, in addition to the technical challenge, the availability of extensive and high-quality sample data sets is of great importance in order to enable better recognition rates. In many countries, the focus here is on protecting the privacy of patients. The lack of availability of high-quality data sets as well as the insufficient system-related traceability of automated decisions lead to a situation in which Artificial Intelligence will not, on a large scale, replace a doctor in the foreseeable future. However, it contributes to faster and better diagnosis, more wide-ranging observation of efficacy, emergency optimization and a more individualized treatment.

The composition of the top companies shows that besides traditional medical technology companies, also pharmaceutical as well as large American IT companies and universities are present in the ranking. With Philips, Siemens and Roche, three European companies are among the top 10. The University of California ranks at 4th position as the best university. The strong presence of companies such as Alphabet, Fitbit, Apple or Nike reveals that traditional medical applications as well as preventive healthcare applications with wearables and fitness trackers are becoming increasingly important.

of patents within all application fields exceeds the total patent sum by about 10%. It can be assumed that particularly high-quality patents, which have broader requirements, are assigned to numerous application fields. From a business perspective, this has the effect that in some companies, the sum of patents within the application fields may exceed the company's total patents in Artificial Intelligence. These multiple counts are not a statistical error, but an indication of high-quality patents.

Table 7.1. Total patents and world-class patents within Healthcare applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Philips	81	379	21.4%	12'877
2	Microsoft	53	130	40.8%	31'804
3	Boston Scientific	53	91	58.2%	7'196
4	University of California	50	134	37.3%	6'574
5	Siemens	46	459	10.0%	31'453
6	Johnson & Johnson	42	63	66.7%	11'789
7	Roche	41	94	43.6%	6'282
8	Alphabet	38	67	56.7%	22'161
9	Medtronic	34	162	21.0%	12'997
10	MIT	33	75	44.0%	3'291
11	Samsung	32	197	16.2%	99'143
12	GE	31	162	19.1%	38'785
13	HeartFlow	27	47	57.4%	63
14	LabCorp	27	45	60.0%	252
15	Fitbit	25	54	46.3%	168
16	Dana-Farber	22	37	59.5%	559
17	Dexcom	22	27	81.5%	183
18	Sony	21	78	26.9%	31'399
19	Intel	21	54	38.9%	34'189
20	Illumina	20	39	51.3%	558
21	Harvard	20	31	64.5%	1'536
22	Canon	19	118	16.1%	80'437
23	Stanford University	18	56	32.1%	2'206
24	Magic Leap	18	19	94.7%	229
25	Qualcomm	16	28	57.1%	26'762
26	NantWorks	16	26	61.5%	410
27	Partners Healthcare	15	48	31.3%	2'175
28	Asahi Kasei	13	29	44.8%	11'166
29	Nestle	13	29	44.8%	2'852
30	Broad Institute	13	22	59.1%	231
31	Cornell University	12	30	40.0%	1'245
32	Stryker	12	22	54.5%	2'862
33	Medibotics	12	13	92.3%	44
34	IBM	11	274	4.0%	45'824
35	Fujitsu	11	92	12.0%	44'739
36	Johns Hopkins University	11	53	20.8%	1'918
37	Abbott Laboratories	11	42	26.2%	6'578
38	Apple	11	22	50.0%	14'979
39	Intuitive Surgical	11	20	55.0%	863
40	Masimo Corp	11	20	55.0%	210
41	Align Technology	11	19	57.9%	316
42	Nike	11	17	64.7%	2'295
43	Intellectual Ventures	10	65	15.4%	9'028
44	University of Texas System	10	28	35.7%	2'526
45	Pfizer	10	21	47.6%	1'288
46	Fujifilm	9	93	9.7%	45'668
47	Honeywell	9	24	37.5%	15'115
48	Bayer	9	18	50.0%	9'470
49	University Health Network	9	16	56.3%	216
50	Panasonic	8	43	18.6%	78'673

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Data Security

AI-based behavioral monitoring is used to protect computer networks more effectively. Specifically, behavioral trends of users in the network or at the computer are analyzed, so that in case of deviations an alarm can be triggered immediately. Besides that, biometric information such as speech recognition is checked for identification. Also, faster response times due to the use of Artificial Intelligence lead to enhanced prevention and faster detection, which is particularly important to e.g. reduce the potential for damage from cyber-attacks.

Conversely, hackers increasingly use Artificial Intelligence to get access to networks or evade security systems. This leads to the assumption that an AI application-based upgrading between security specialists and hackers will take place in the future.

Another field is “Threat Hunting”, which refers to the review of data using Artificial Intelligence. Examples of this are image analysis in social networks, scans of smartphone applications and security analysis of cloud systems. Extensions and links with personal data and log files allow predictions on the risk assessment of certain persons and their actions.

A further point concerns the security of Artificial Intelligence itself. Hacking attacks on the AI algorithm can influence decision-making mechanisms and are difficult to detect due to the difficult traceability of AI results.

Microsoft, Intel and Alphabet are once again in the lead in terms of AI-supported data security, but also software and network specialists such as Qualcomm and Cisco are present in the ranking. Furthermore, specialized security companies such as FireEye, McAfee, Symantec, Kaspersky Lab, Bitdefender or Trend Micro are active in the field of Artificial Intelligence.

In addition, major online retailers such as Alibaba and Amazon are active due to their extensive customer database. But there are also payment service providers such as VISA that want to recognize payment abuse easier with the help of AI.

Table 7.2. Total patents and world-class patents within Data Security applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Microsoft	175	443	39.5%	31'804
2	Qualcomm	94	155	60.6%	26'762
3	Alphabet	72	180	40.0%	22'161
4	Intel	67	182	36.8%	34'189
5	McAfee	38	80	47.5%	1'032
6	Alibaba Group	31	94	33.0%	11'338
7	FireEye	30	33	90.9%	126
8	Cisco	27	167	16.2%	12'238
9	Tencent	26	82	31.7%	16'075
10	Sony	23	70	32.9%	31'399
11	Samsung	22	171	12.9%	99'143
12	Symantec	22	151	14.6%	2'130
13	Amazon	20	98	20.4%	7'878
14	Visa	20	37	54.1%	1'251
15	Apple	19	42	45.2%	14'979
16	IBM	18	341	5.3%	45'824
17	Facebook	16	77	20.8%	4'124
18	Accenture	14	49	28.6%	1'722
19	Kaspersky Lab	14	48	29.2%	402
20	Juniper Networks	14	35	40.0%	1'885
21	Digimarc	13	22	59.1%	389
22	Palantir Technologies	13	16	81.3%	286
23	Lookout Inc	13	14	92.9%	56
24	Xiaomi	12	40	30.0%	13'673
25	Rockwell Automation	12	27	44.4%	1'837
26	Digital Doors	12	15	80.0%	18
27	AT&T	10	63	15.9%	8'765
28	Nokia	10	53	18.9%	21'802
29	Boeing	9	48	18.8%	12'553
30	Trend Micro	9	40	22.5%	623
31	Panasonic	9	31	29.0%	78'673
32	Honeywell	9	21	42.9%	15'115
33	Bitdefender	9	11	81.8%	59
34	Verizon	8	45	17.8%	8'155
35	Ricoh	8	39	20.5%	41'592
36	LG Electronics	8	19	42.1%	47'446
37	360 Security Technology	7	76	9.2%	9'023
38	NTT	7	62	11.3%	30'478
39	Huawei	7	50	14.0%	53'102
40	Hitachi	7	32	21.9%	74'484
41	InterDigital	7	22	31.8%	7'622
42	SHAPE SECURITY INC	7	22	31.8%	54
43	Columbia University	7	21	33.3%	1'164
44	Broadcom	6	51	11.8%	15'331
45	Baidu	6	43	14.0%	4'570
46	Mitsubishi Electric	6	34	17.6%	56'940
47	Toshiba	6	30	20.0%	52'971
48	Extreme Networks	6	11	54.5%	548
49	Servicenow	6	11	54.5%	873
50	Magic Leap	6	9	66.7%	229

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Industry 4.0

Industry 4.0 connects production processes and ensures that machines, interfaces and components can communicate with each other. The resulting data is used to further optimize the production process. With special regard to process optimization, image analysis and image recognition are used to identify and sort objects on conveyor belts. Artificial Intelligence also plays an essential role in quality control, as e.g. faulty products can be better identified. In terms of maintenance control (Predictive Maintenance), machines themselves are analyzed in order to detect possible failures at an early stage and to prevent production downtimes. Additionally, AI is able to better link industrial production with product sales. This facilitates planning of manufacturing processes, capacities, utilization and material purchasing with partners, suppliers and customers. Lastly, the importance of robotics is increasing in industrial production, which also reveals an intensified use of Artificial Intelligence.

Besides Emerson Electric as the leading company, also GE, Rockwell Automation, Hitachi and FANUC have a clear focus on Industry 4.0 and connect it with Artificial Intelligence.

While Alphabet is involved in Artificial Intelligence in process automation and sensor technology, Microsoft rather owns patents in basic networking areas. Sony, on the other hand, is active in the Internet of Things with its subsidiary Convida Wireless, particularly in networking technologies.

With Siemens (rank 9), ABB, Bosch and Philips, European companies are also among the top 50. The patents of the Midea Group in this field stem from the acquisition of Kuka (robotics). Due to the medium-sized structure of the European mechanical engineering and electronical industry, no other Europeans can be found in the top 50.

Table 7.3. Total patents and world-class patents within Industry 4.0 applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Emerson Electric	72	128	56.3%	4'508
2	Alphabet	60	104	57.7%	22'161
3	Microsoft	56	130	43.1%	31'804
4	GE	46	167	27.5%	38'785
5	Rockwell Automation	45	147	30.6%	1'837
6	Qualcomm	40	76	52.6%	26'762
7	Intel	38	64	59.4%	34'189
8	Sony	27	76	35.5%	31'399
9	Siemens	25	165	15.2%	31'453
10	Fanuc	22	223	9.9%	3'665
11	Hitachi	21	98	21.4%	74'484
12	Brain Corp.	20	46	43.5%	87
13	Samsung	17	120	14.2%	99'143
14	Honeywell	16	64	25.0%	15'115
15	Blast Motion	15	17	88.2%	46
16	ABB	13	67	19.4%	7'587
17	LG Electronics	13	31	41.9%	47'446
18	Apple	12	24	50.0%	14'979
19	Honda Motor	11	114	9.6%	31'573
20	Johnson Controls	11	31	35.5%	3'250
21	iRobot	11	17	64.7%	217
22	InterDigital	10	15	66.7%	7'622
23	Boeing	9	58	15.5%	12'553
24	Panasonic	9	32	28.1%	78'673
25	Softbank	9	23	39.1%	7'671
26	Mitsubishi Electric	8	50	16.0%	56'940
27	Baidu	8	34	23.5%	4'570
28	AT&T	8	26	30.8%	8'765
29	Amazon	8	24	33.3%	7'878
30	Exxon Mobil	8	17	47.1%	5'273
31	Humatics	8	13	61.5%	75
32	Digital Doors	8	10	80.0%	18
33	Canon	7	23	30.4%	80'437
34	Midea Group	7	22	31.8%	26'827
35	Digimarc	7	11	63.6%	389
36	Bosch	6	78	7.7%	52'629
37	GM	6	69	8.7%	19'565
38	Verizon	6	25	24.0%	8'155
39	Tokyo Electron	6	24	25.0%	8'698
40	Schlumberger	6	20	30.0%	9'842
41	Illumina	6	14	42.9%	558
42	Philips	6	14	42.9%	12'877
43	MIT	6	13	46.2%	3'291
44	Intuitive Surgical	6	10	60.0%	863
45	United Technologies	5	38	13.2%	19'936
46	Denso	5	30	16.7%	43'369
47	Deere & Co	5	19	26.3%	4'516
48	Applied Materials	5	17	29.4%	6'826
49	Schneider Electric	5	17	29.4%	5'024
50	Mitutoyo	5	12	41.7%	1'864

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Marketing

Another major AI application field is marketing, for example the use of speech and text recognition to optimize and personalize customer contact, especially in advertising. Besides communication, the segmentation and identification of target groups based on an intelligent linking and analysis of multiple data sources is required. Here, interests, contributions to discussions and consumer behavior are of particular importance. Such an optimized customer contact reduces costs and leads to competitive advantages. In an expanded form, Artificial Intelligence can bring the findings from marketing back into the entire value chain including purchasing, sales and logistics.

Furthermore, Artificial Intelligence is used for the automated creation of texts. Besides stock market and sport reports or weather forecasts, discussion contributions in social media and optimization in customer service (chatbots) are major areas of growth.

While online retailers such as Alibaba, Amazon and Ebay as well as social media companies like Facebook are ranking high in AI-based marketing, specialists such as Digimarc or Genesys, a provider of call center technologies, can also be found. Activities of payment systems operators such as Visa and PayPal are also noticeable due to a wide application range.

With a few exceptions like Philips, Artificial Intelligence in marketing is an exclusive competence of American and Asian companies.

Table 7.4. Total patents and world-class patents within Marketing applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Microsoft	108	339	31.9%	31'804
2	Alphabet	66	236	28.0%	22'161
3	Alibaba Group	48	141	34.0%	11'338
4	Facebook	37	233	15.9%	4'124
5	Verizon	32	204	15.7%	8'155
6	Visa	19	38	50.0%	1'251
7	Qualcomm	17	20	85.0%	26'762
8	Beijing Didi Infinity Technology	16	17	94.1%	314
9	Amazon	15	102	14.7%	7'878
10	Valcon	14	57	24.6%	860
11	Accenture	14	50	28.0%	1'722
12	Genesys	14	21	66.7%	419
13	Digimarc	12	17	70.6%	389
14	Altaba	11	108	10.2%	1'957
15	Samsung	11	69	15.9%	99'143
16	Sony	11	61	18.0%	31'399
17	Tencent	11	48	22.9%	16'075
18	(24)7.AI INC	11	28	39.3%	92
19	Ebay	8	90	8.9%	1'428
20	IBM	7	240	2.9%	45'824
21	Xerox	7	40	17.5%	10'422
22	Huawei	6	24	25.0%	53'102
23	Ricoh	6	16	37.5%	41'592
24	NEC	5	54	9.3%	33'257
25	Toshiba	5	32	15.6%	52'971
26	Apple	5	19	26.3%	14'979
27	InterDigital	5	13	38.5%	7'622
28	Twitter	5	11	45.5%	1'011
29	Invidi Technologies Corporation	5	8	62.5%	23
30	Snap	5	5	100.0%	289
31	PayPal	4	25	16.0%	1'337
32	TiVo Corp	4	12	33.3%	1'135
33	Philips	4	10	40.0%	12'877
34	Affectomatics Ltd	4	8	50.0%	10
35	Gula Consulting	4	6	66.7%	543
36	Palantir Technologies	4	5	80.0%	286
37	Applied Recognition Inc	4	4	100.0%	5
38	Magic Leap	4	4	100.0%	229
39	Baidu	3	45	6.7%	4'570
40	Oracle	3	27	11.1%	14'228
41	AT&T	3	26	11.5%	8'765
42	Intel	3	19	15.8%	34'189
43	Denso	3	6	50.0%	43'369
44	NantWorks	3	6	50.0%	410
45	Uber	3	6	50.0%	435
46	Interactive Memories Inc	3	4	75.0%	12
47	S&P Global Inc	3	4	75.0%	24
48	Afiniti International Holdings, Ltd.	3	3	100.0%	47
49	Dressbot Inc.	3	3	100.0%	4
50	Emerson Electric	3	3	100.0%	4'508

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Mobility

Within mobility, the advantage of Artificial Intelligence lies in data linking. In vehicles, for example, accident reduction and predictive maintenance systems are at the center stage. In public and rail transport, demands and capacities can be better coordinated. More generally speaking, AI is beneficial across different transport modes as for example traffic flows can be better coordinated. In this respect, Artificial Intelligence is an essential factor for developments in the entire Smart City environment. Autonomous mobility is also an important branch of research: Besides the intelligent interaction of the vehicle with its passengers, the main focus is on interacting with the environment. The safe detection of obstacles and the embedding and networking with other road users are central topics of research. Here, vehicles can benefit from each other through the constant exchange and analysis of information about traffic situations. While partially autonomous mobility with distance alert and lane assistants will be possible in the next few years, full autonomous mobility outside of demarcated areas (such as industrial areas) will have to overcome ethical, legal, as well as technical issues first. Different legal framework conditions may have a significant impact on the research and development of AI in the mobility sector in individual countries.

In terms of Artificial Intelligence in mobility, Intel is leading with its subsidiary Mobileye, followed by other large IT companies such as Alphabet, which are expected to have breakthrough activities in the field of autonomous vehicles. Even classic automotive companies such as General Motors, Ford, Honda and Toyota are among the top 10 companies.

In addition to vehicle manufacturers, service companies are also in the top 50: Didi Technology and Uber as mobility agents, Here Navigation and TomTom in the navigation sector as well as trading platforms such as Amazon and Alibaba. The latter are, among others, experimenting with drones to optimize the supply chain.

Only six companies from Europe are among the top 50. The car manufacturers VW and BMW are behind the domestic suppliers such as Continental and Bosch. Daimler, for example, are not present, while its American and Japanese competitors can be found frequently among the top 10. However, the picture would change when looking at the total patents. Volkswagen and Bosch would advance to rank 12 and 13, while Daimler would continue to be in the rearmost position with only one world-class patent and a total of 19 mobility patents related to Artificial Intelligence. Compared to direct competitors, German car manufacturers only hold a few world-class patents in this field.

Table 7.5. Total patents and world-class patents within Mobility applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Intel	68	112	60.7%	34'189
2	Alphabet	65	120	54.2%	22'161
3	Microsoft	63	100	63.0%	31'804
4	GM	41	194	21.1%	19'565
5	Ford	40	188	21.3%	17'544
6	LG Electronics	38	120	31.7%	47'446
7	Toyota Motor	36	198	18.2%	66'805
8	Beijing Didi Infinity Technology	30	31	96.8%	314
9	Qualcomm	28	43	65.1%	26'762
10	Honda Motor	27	110	24.5%	31'573
11	Baidu	27	70	38.6%	4'570
12	Brain Corp.	25	46	54.3%	87
13	Samsung	22	142	15.5%	99'143
14	Denso	22	96	22.9%	43'369
15	Sony	19	59	32.2%	31'399
16	Amazon	17	50	34.0%	7'878
17	Apple	17	27	63.0%	14'979
18	Uber	16	49	32.7%	435
19	Hitachi	15	80	18.8%	74'484
20	Aisin Seiki	15	33	45.5%	15'908
21	DJI Innovations	15	16	93.8%	1'639
22	Continental	14	50	28.0%	17'484
23	Verizon	14	28	50.0%	8'155
24	Panasonic	13	78	16.7%	78'673
25	Cisco	13	42	31.0%	12'238
26	Boeing	12	65	18.5%	12'553
27	HERE Navigation	12	53	22.6%	949
28	Digimarc	12	19	63.2%	389
29	Signify	12	13	92.3%	3'351
30	Tata Motors	10	17	58.8%	1'514
31	iRobot	10	15	66.7%	217
32	INRIX	10	12	83.3%	51
33	Emerging Automotive	9	9	100.0%	28
34	GE	8	29	27.6%	38'785
35	SRI International	8	10	80.0%	536
36	TomTom	8	10	80.0%	376
37	Bosch	7	81	8.6%	52'629
38	Hyundai Motor	7	74	9.5%	29'223
39	Nissan Motor	7	29	24.1%	18'506
40	Fujitsu	7	27	25.9%	44'739
41	Alibaba Group	7	16	43.8%	11'338
42	Accenture	7	15	46.7%	1'722
43	Honeywell	7	15	46.7%	15'115
44	Humatics	7	10	70.0%	75
45	VW Group	6	91	6.6%	29'392
46	BMW	6	41	14.6%	11'754
47	Intelligent Technologies Int.	6	18	33.3%	40
48	United Technologies	6	14	42.9%	19'936
49	Allstate Corp	6	9	66.7%	206
50	InterDigital	6	9	66.7%	7'622

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Energy

High expectations of Artificial Intelligence within the energy sector are linked to the optimization of the interaction between generation, grid, consumption and storage (Smart Grid). In particular, the increasing importance of renewable energies and corresponding weather and time-related fluctuations in production are aimed to be optimized with the help of AI, for example through the integration of weather forecasts. Peak loads arising from charging processes of electric cars are also aimed to be better forecasted and balanced. In private environments, Artificial Intelligence can help to reduce energy demand through self-learning heating systems.

Moreover, in the field of international energy trading, AI-based trading algorithms can act more quickly, accurately and cheaper through the combination and analysis of environmental, system and market data as well as stock market prices and grid and border capacities.

In practice, this area is dominated by electrical engineering and automotive companies. GE and Siemens, for example, show activities in the field of Smart Grid. While the automobile manufacturers are active in the area of battery management, AI approaches can also be found in fuel cell technology. Battery management also includes Asian electrical engineering companies such as Samsung and LG. However, the activities are not limited to battery management in the vehicle sector only, but also include smaller batteries e.g. for wearables. The field of decentralized energy management up to Smart House is covered in particular by IT companies. In addition, there are also some suppliers of renewable energy.

The application of AI to energy trading is not reflected in the data. Presumably, the basic methodology is the research focus rather than the concrete application of energy. Accordingly, the majority of patents are supposed to be found in AI basics.

On the whole, the lower patent quantities show that the use of Artificial Intelligence within the energy sector is even less profound than in other application fields.

Table 7.6. Total patents and world-class patents within Energy applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	GE	35	121	28.9%	38'785
2	Toyota Motor	28	99	28.3%	66'805
3	Siemens	16	83	19.3%	31'453
4	GM	13	78	16.7%	19'565
5	Panasonic	13	29	44.8%	78'673
6	Samsung	12	38	31.6%	99'143
7	Alphabet	12	21	57.1%	22'161
8	Ford	11	30	36.7%	17'544
9	Microsoft	11	22	50.0%	31'804
10	Bosch	10	34	29.4%	52'629
11	LG Chem	10	19	52.6%	17'701
12	Semiconductor Energy Lab	10	18	55.6%	8'365
13	Emerging Automotive	10	10	100.0%	28
14	Toshiba	9	36	25.0%	52'971
15	Nissan Motor	9	34	26.5%	18'506
16	Hitachi	9	29	31.0%	74'484
17	Sony	9	19	47.4%	31'399
18	Emerson Electric	8	13	61.5%	4'508
19	Qualcomm	8	11	72.7%	26'762
20	Vestas Wind Systems	7	11	63.6%	1'297
21	Apple	7	8	87.5%	14'979
22	Hyundai Motor	6	68	8.8%	29'223
23	ABB	6	23	26.1%	7'587
24	Johnson Controls	6	16	37.5%	3'250
25	Denso	6	13	46.2%	43'369
26	Accenture	6	6	100.0%	1'722
27	IBM	5	36	13.9%	45'824
28	Honda Motor	5	27	18.5%	31'573
29	Causam Energy	5	18	27.8%	56
30	Intel	5	13	38.5%	34'189
31	Mitsubishi Heavy	5	12	41.7%	21'126
32	Rockwell Automation	5	8	62.5%	1'837
33	Boston Scientific	5	5	100.0%	7'196
34	Kia Motors	4	18	22.2%	7'184
35	Schneider Electric	4	16	25.0%	5'024
36	Furukawa Electric	4	10	40.0%	7'693
37	Exxon Mobil	4	6	66.7%	5'273
38	Gridpoint	4	6	66.7%	27
39	KLA-Tencor	4	6	66.7%	1'838
40	VITO	4	5	80.0%	131
41	State Grid Corp	3	630	0.5%	75'125
42	United Technologies	3	29	10.3%	19'936
43	Fitbit	3	23	13.0%	168
44	NEC	3	22	13.6%	33'257
45	Intelligent Energy	3	7	42.9%	433
46	Medtronic	3	6	50.0%	12'997
47	Nike	3	4	75.0%	2'295
48	Benhov Gmbh	3	3	100.0%	163
49	China Southern Power	2	130	1.5%	12'709
50	North China Electric Power University	2	93	2.2%	4'592

Source: EconSight, IGE, LexisNexis PatentSight, 2019

Fintech

In financial technologies (Fintech), pressure to innovate is generated by new market entrants who invade the traditional banking business by offering new, better and less expensive services with highly IT-based and AI-based processes. The aim is to better understand customers in order to provide them with more tailor-made services, for example in wealth management or granting of credits. Besides the improvement of risk management in the investment process, growth opportunities are seen in new payment systems. In particular, the big software companies are entering the market here.

The complexity of the financial industry has led to increasing demands on risk management and compliance regulations in recent years, and in turn to rapidly rising costs. The expectation towards Artificial Intelligence in regulatory technologies (Regtech) is that extensive financial data flows can be properly evaluated. Furthermore, it calls for faster response rates, e.g. in the case of security risks or violations of applicable law such as money laundering.

In the insurance industry (Insuretech), digital added value concentrated on insurance comparison and the generation of new customers. New activities in Insuretech digitize the entire insurance business and offer insurance products, which are more custom-fit, faster and cheaper due to, among others, the increasing use of Artificial Intelligence in risk assessment.

At the moment, there are strong dynamics particularly in the field of payment systems, which make up almost half of the world-class patents in Fintech. Also here, the big IT companies are leading, particularly due to their activities in mobile payment systems. Even classic credit card companies like VISA are active, and wealth and credit management (Equifax) are focus areas, too.

Insurance and regulatory technologies are still poorly represented, at least in the larger companies, with patents accounting for less than 15% each. With Coinplug and Spondoolies Tech, two companies from the Bitcoin environment (Mining) are among the top 50.

Table 7.7. Total patents and world-class patents within Fintech applications, 2018

Rank	Name	World-class patents in AI	Total patents in AI	Share of AI patents	Total patent portfolio
1	Microsoft	19	63	30.2%	31'804
2	Alphabet	19	50	38.0%	22'161
3	Visa	15	35	42.9%	1'251
4	Alibaba Group	11	34	32.4%	11'338
5	Qualcomm	9	10	90.0%	26'762
6	Digimarc	8	10	80.0%	389
7	Tencent	7	18	38.9%	16'075
8	Verizon	7	15	46.7%	8'155
9	Palantir Technologies	7	8	87.5%	286
10	Accenture	6	27	22.2%	1'722
11	Lexmark	6	8	75.0%	1'525
12	IBM	5	54	9.3%	45'824
13	State Farm	5	13	38.5%	231
14	Allstate Corp	5	8	62.5%	206
15	Mitek Systems	5	6	83.3%	36
16	FICO	4	31	12.9%	178
17	PayPal	4	23	17.4%	1'337
18	Toshiba	4	18	22.2%	52'971
19	NCR	4	14	28.6%	1'511
20	Thomson Reuters	4	11	36.4%	333
21	Intel	4	10	40.0%	34'189
22	Apple	4	5	80.0%	14'979
23	NantWorks	4	4	100.0%	410
24	MasterCard	3	49	6.1%	2'195
25	Hartford Financial	3	22	13.6%	241
26	Facebook	3	10	30.0%	4'124
27	Huawei	3	10	30.0%	53'102
28	AT&T	3	8	37.5%	8'765
29	NEC	3	8	37.5%	33'257
30	Equifax	3	6	50.0%	54
31	McAfee	3	4	75.0%	1'032
32	S&P Global Inc	3	4	75.0%	24
33	Veridium	3	4	75.0%	14
34	Oracle	2	13	15.4%	14'228
35	Amazon	2	12	16.7%	7'878
36	Sony	2	11	18.2%	31'399
37	Hitachi	2	9	22.2%	74'484
38	Ricoh	2	6	33.3%	41'592
39	CoreLogic	2	5	40.0%	72
40	Philips	2	5	40.0%	12'877
41	Xiaomi	2	5	40.0%	13'673
42	Coinplug	2	4	50.0%	96
43	Advent International	2	3	66.7%	2'316
44	Cantor Fitzgerald	2	3	66.7%	387
45	New Bis Safe Luxco Srl	2	3	66.7%	23
46	Outerwall	2	3	66.7%	88
47	Spondoolies Tech	2	3	66.7%	3
48	Valcon	2	3	66.7%	860
49	Berkshire Partners Llc	2	2	100.0%	71
50	Cloudparc	2	2	100.0%	4

Source: EconSight, IGE, LexisNexis PatentSight, 2019

8 Comparison: Corporate HQ & research sites

Hitherto, technological performance has been analyzed from two perspectives:

1. Where were the patents developed? – the analysis of international research sites. It shows in which country the inventors named on the patent reside, i.e. where the research has been performed.

2. By whom were the patents developed? – the analysis of companies and research institutions. It shows the patent owners and provides information about which companies and institutions are leaders in Artificial Intelligence.

The result of both analyses showed, firstly, that the US is a leading research location and that half of all world-class patents have been developed in the US in 2018. Second, it revealed that American companies are leaders in general, and in almost all application areas. However, the present analysis does not show how strongly companies use domestic and foreign research locations and how domestic and foreign companies develop at specific research locations. Thus, both approaches will be combined in the following. Due to this, the structure of research locations according to domestic and foreign companies can be presented on the one hand. On the other hand, the significance of individual countries as research locations for domestic companies can be shown.

Research site and corporate headquarters - two different concepts

In this study, all comparative country analyses based on the home address of the inventors named in the patents have been carried out. If, for example, an inventor with a residential address in Switzerland has been mentioned in the patents, the patent is attributed to Switzerland. It is therefore assumed that the corresponding technological competence lies in the inventor's country. If, in addition, an inventor with a residential address in the USA is mentioned, the patent is also assigned to the United States. In this case, the patent would be an international research cooperation with participating researchers from Switzerland and the USA. Furthermore, it is possible that a company owns a patent that was invented exclusively by researchers living abroad.

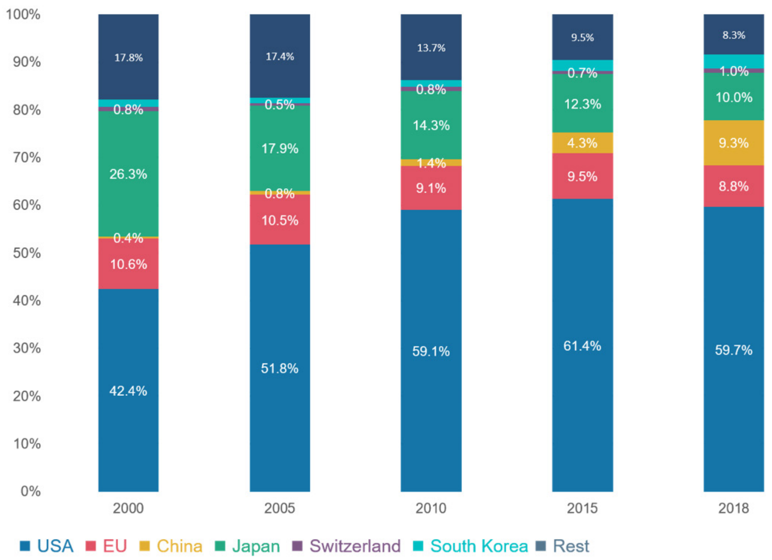
At company level, a patent is usually assigned to the address provided at the time of registration. This may be the corporate headquarters or a presence/subsidiary in another country. In this study, all patents were assigned to the corporate headquarters in order to clearly differentiate between domestic and foreign companies, depending on the analyzed country. Moreover, all patents were attributed to the parent companies (based on the principle of "Ultimate Owner") that have final control or decision-making power over the patent.

The consequences can be explained using the following example: The German company Kuka was bought by the Chinese Midea Group. The patents of Kuka became property of Midea and were counted for Midea, i.e. these are patents owned by a Chinese company. The research effort is still assigned according to the inventor's addresses, i.e. it counts as an effort performed in Germany. The same applies e.g. to the purchase of the Swiss Syngenta by ChemChina.

Development of world-class patents by corporate headquarters

While the overall analysis (chapter 6) focused on the importance of individual research locations (based on the addresses of the named inventors), in the following the patent activities of the companies are summarized according to their headquarters.

Figure 8.1. Shares of world-class patents in AI according to the company's country of origin, 2000-2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

It becomes obvious that US companies are dominating Artificial Intelligence since 60% of all world-class patents are held by American companies. Companies from China, Japan and the European Union are well behind the USA with shares between 9% and 10%. However, Chinese companies have doubled their global share of AI world-class patents to 9.3% within the last three years, while the shares of US and EU companies have remained constant. Since patents are published with a delay of up to 18 months, the years 2017 and 2018 are very likely to be still incomplete. It can therefore be assumed that the share of Chinese companies will continue to rise and that it will be significantly above that of the European and Japanese companies already this year.

Broken down by individual countries and in absolute patent numbers, the following table results from the above figure. On the left-hand side, the ranking of countries with the most patents is shown as measured by the corporate headquarters. The right-hand side shows the ranking of the strongest countries as measured by the research efforts of the inventors (as listed on the patents) in that country.

Table 8.1. Country ranking, comparison of corporate headquarters and research site, patents, 2018

Ranking according to corporate headquarters				Ranking according to research site		
Rank	Country	Patents		Rank	Country	Patents
1	USA	9'069		1	USA	9'928
2	Japan	1'515		2	China	1'912
3	China	1'417		3	Japan	1'288
4	South Korea	446		4	Great Britain	757
5	Germany	441		5	Germany	689
6	Netherlands	254		6	Canada	642
7	Great Britain	181		7	Israel	509
8	Canada	171		8	India	499
9	Switzerland	150		9	South Korea	415
10	France	150		10	France	369
11	Israel	125		11	Netherlands	273
12	Sweden	89		12	Switzerland	228
13	Finland	76		13	Australia	162
14	Saudi Arabia	54		14	Sweden	128
15	Australia	38		15	Ireland	112
16	India	35		16	Belgium	102
17	Denmark	29		17	Italy	91
18	Singapore	26		18	Russia	89
19	Russia	26		19	Spain	88
20	Belgium	21		20	Finland	68

Source: EconSight, IGE, LexisNexis PatentSight, 2019

The ranking shows the USA as the country with the most world-class patents by companies that are headquartered in the USA. At the same time, the USA is also the leading research location. Both cannot be equated, since US companies also conduct research abroad and, respectively, international companies also use the American research location.

The US is followed by countries that also have both innovative companies and an innovative research location. Usually, countries with innovative companies also have an innovative research site in Artificial Intelligence. However, this is not always the case. Differences are particularly evident in Canada, Great Britain, Israel and Australia. AI research sites are relatively large, while own companies play only a minor role. The research sites are particularly attractive for foreign companies.

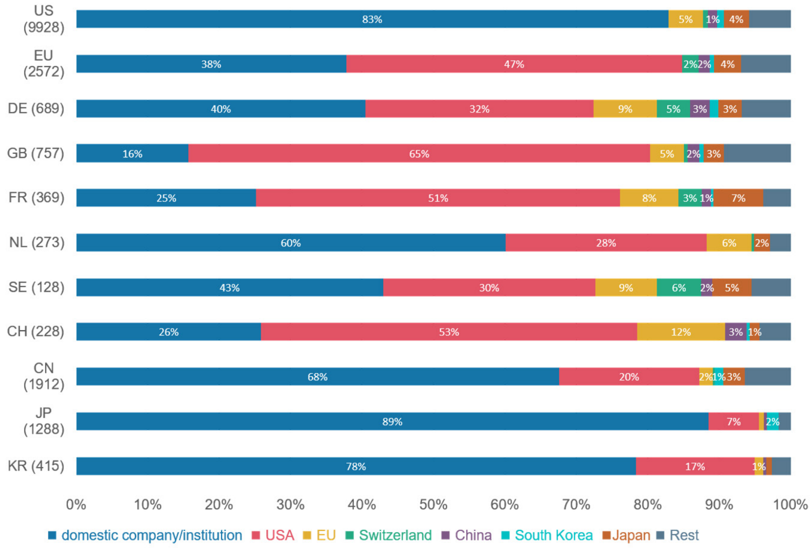
The UK will be further examined below and it is shown that of the 181 AI patents, only 119 were developed at the domestic research location. This example is intended to illustrate the complex relationships behind the apparently unique rankings.

Research locations by country of origin of the companies

The following figure shows the origin of the researching companies for selected research locations and their significance for the particular site[1]. This combines the previous analyses (inventor's address and headquarters). It becomes obvious that American companies provide at least the largest research effort of all foreign companies in each country. In many cases, they even constitute the most important group of companies.

1 The numbers used for the calculations are based on the sum of world-class patents combining the corporate headquarters and the inventor's addresses as mentioned in the patents. Due to international research cooperations (inventors from several countries in one patent) and corporate collaborations (several domestic and/or foreign companies are sharing a patent), double counts occur. A top-down calculation for all patents developed in one country results in a smaller sum than a bottom-up calculation of the patent activities of all companies in one country. Random tests have shown that the double counts lead to a deviation in a single-digit percentage range. This deviation is accepted because this analysis is primarily about shares and structures. Furthermore, for 96% of all companies active in Artificial Intelligence, the country of the corporate headquarters was identified. Incomplete data sets mainly concern companies with only one AI patent.

Figure 8.2. Patent structure of selected research locations according to companies' country of origin, shares 2018



Source: EconSight, IGE, LexisNexis PatentSight, 2019

For example, US companies in the UK currently hold almost two-thirds of all patents invented in the country. In France and Switzerland, they are responsible for 51% and 53% of the patents, respectively. In Germany, the share of US companies is slightly lower at 32%. For the entire EU, the share of US companies is 47%.

Table 8.2. Patent structure of selected research locations according to companies' country of origin

Research locations	Companies with headquarters in								
	Domestic	USA	EU	Switzerland	China	South Korea	Japan	Rest	Total
USA	8'228	-	485	64	133	87	352	579	9'928
European Union	972	1'209	-	60	40	16	97	178	2'572
Germany	279	220	61	32	19	8	23	47	689
Great Britain	119	489	36	4	12	5	21	71	757
France	93	188	30	12	5	1	26	14	369
Netherlands	164	77	17	1	0	0	6	8	273
Sweden	55	38	11	8	2	0	7	7	128
Switzerland	59	120	28	-	7	1	3	10	228
China	1'292	375	36	5	-	23	58	123	1'912
Japan	1'140	91	9	0	5	21	-	22	1'288
South Korea	325	69	5	0	2	-	3	11	415

Source: EconSight, IGE, LexisNexis PatentSight, 2019

While European companies have developed 485 patents in the US, American companies are involved in the development of 1,209 patents in the EU. Thus, US companies hold more world-class AI patents in the EU (1,209) than the EU countries themselves (972).

With 757 patents, the UK is the strongest AI research location in Europe, followed by Germany with 689 patents. However, in none of the shown industrialized countries the share of domestic companies is lower than in Great Britain. In the UK, only 119 patents (16%) are developed by domestic companies. Two-thirds of British patent development is pushed forward by American companies. The patent activities of domestic companies are also low in France (25%), and here American companies are by far the leaders.

A similar picture is evident in Switzerland. American companies in Switzerland develop twice as many patents (120) as the Swiss companies themselves (59).

In Germany, the share of domestic companies in patents developed in Germany is significantly higher with 40%. But also here, the American companies are strongly represented with 32%. The share of Asian companies is at a low level.[1]

Furthermore, low activities of other European companies in Germany, Great Britain and France are noticeable. It is likely that European companies are less interested in further European research locations in terms of AI, but rather do research in the United States. It is noteworthy that Swiss companies have a higher share of EU activities (12%) than the majority of EU companies themselves.

Outside of Europe, fewer interconnections between research locations can be observed. In Japan, South Korea and China, the shares of domestic companies are 68% (China), 78% (South Korea) and 89% (Japan). While European companies are only involved in a few world-class patents in these countries, American companies in China are responsible for 375 patents, which represents 20%. A special case is India (not part of the figure): Here, the share of domestic companies in world-class AI patents is 5%. American companies are responsible for 75% of total world-class AI activity in India. However, the intellectual property rights, which are often described as poor, are an obstacle here.

Importance of individual countries as research sites for domestic companies

In the following section, the perspective is changed. While the previous section focused on the structure of selected research locations according to the companies' origin, here the research structures are presented by target countries for selected companies (exchange of columns and rows).

Table 8.3. World-class patents of domestic companies according to research location, 2018

Corporate headquarters in	Research location in							
	Domestic	USA	EU	Switzerland	China	South Korea	Japan	Total
USA	8'228	-	1'209	120	375	69	91	9'069
European Union	972	485	-	28	36	5	9	1'335
Germany	279	178	23	10	9	3	8	441
Great Britain	119	51	11	2	6	0	0	181
France	93	51	16	0	3	0	0	150
Netherlands	164	124	17	3	7	0	0	254
Sweden	55	33	11	2	2	2	1	89
Switzerland	59	64	60	-	5	0	0	150
China	1'292	133	40	7	-	2	5	1'417
Japan	1'140	352	97	3	58	3	-	1'515
South Korea	325	87	16	1	23	-	21	446

Multiple counts possible due to research cooperations EU=Patent sum of the resp. remaining 27 countries without the home country

Source: EconSight, IGE, LexisNexis PatentSight, 2019

1 The small share of Asian companies speaks against the statement of the «sellout of key German technologies», at least in this technology. Since the study makes use of the principle of «Ultimate Owner», the identified 28 Kuka AI patents (25 of which are researched in Germany and 9 of which are world-class patents), for example, are already assigned to the new owner, the Chinese Midea Group. Nevertheless, Chinese companies only account for 3% of all patents researched in Germany.

The figure shows the world-class Artificial Intelligence patents of all companies headquartered in one of the selected countries. The columns show the patents developed by these companies at the other research locations.[1] The UK serves as an example: UK-based companies hold a total of 181 world-class AI patents. Of these, 119 were developed by British companies domestically. This means that 62 patents have been developed outside the UK. The following columns show that 11 of these have been developed in the EU, 2 in Switzerland, 51 in the US and 6 in China.

European companies each do about two-thirds of their world-class AI research in their home country. The low importance of other European research locations for European companies is particularly noteworthy. All in all, European companies involved in Artificial Intelligence are mainly using their research sites in the USA.

From a European perspective, AI research in Asian locations is still at a very early stage. American companies are active with ten times the amount of patent developments in China (375 vs. 36 from the EU). The attractiveness of the American research landscape is also evident for companies from Asian countries. However, on average the shares are significantly lower than those of European companies.

A special case is the research structure of Swiss companies in terms of Artificial Intelligence. Overall, the research share of domestic companies in Switzerland is particularly lower, i.e. companies with headquarters in Switzerland develop more than 60% of their world-class patents abroad. However, research done by the Swiss companies is relatively evenly distributed to one third each on domestic research, research locations in the EU and research locations in the USA. Thus, Switzerland is more closely linked to the EU research landscape than the EU member states themselves. However, the sum of patents at the research locations considerably exceeds the total number of patents of Swiss companies. This means that in many cases there are international co-operations involving a number of research locations.

Table 8.4. Global shares of companies from selected countries in AI application fields, 2018

Global share of all companies from the particular country of origin	Application fields of Artificial Intelligence						
	Healthcare	Data security	Industry 4.0	Marketing	Mobility	Energy	Fintech
USA	57.3%	67.3%	60.5%	69.7%	55.4%	44.3%	65.6%
European Union	14.8%	6.2%	10.3%	4.4%	10.1%	15.0%	5.2%
Germany	4.5%	1.3%	4.6%	0.9%	4.5%	6.9%	1.7%
Great Britain	2.1%	1.1%	1.0%	0.6%	0.6%	1.6%	0.8%
France	1.3%	0.7%	0.9%	0.8%	0.6%	2.2%	0.8%
Netherlands	3.7%	0.7%	1.2%	0.9%	2.5%	0.4%	0.8%
Sweden	0.7%	0.7%	1.0%	0.3%	0.8%	1.2%	0.2%
Switzerland	2.4%	0.1%	1.7%	0.1%	0.5%	1.4%	0.4%
China	3.8%	6.9%	5.4%	10.4%	8.3%	4.6%	8.1%
Japan	6.3%	6.2%	11.6%	4.2%	11.4%	17.8%	5.2%
South Korea	1.9%	2.6%	2.8%	1.4%	5.9%	6.1%	0.8%

Source: EconSight, IGE, LexisNexis PatentSight, 2019

1 The numbers also include international research cooperations across different locations, with researchers from more than one country. Thus, the sum of foreign patents can exceed the difference between total patents and domestic patents (the same applies to the calculation of shares). The domestic patents may also include national (several companies) or international (several companies and/or research sites) cooperations. Each number indicates that the corresponding patents contain a research contribution from that country.

Application fields in Artificial Intelligence by companies' country of origin

The dominance of US companies is also evident in the identified application fields of Artificial Intelligence.

Divided into the individual application fields, it becomes clear that US companies achieve particularly high shares in data security (67%), marketing (70%) and Fintech (66%). In these areas, in turn, the shares of European companies are particularly low. This was already evident in the previous chapter when looking at the top 50 rankings of the individual application fields. Hardly any European company reached the top 50 here. This can be explained, at least in the areas of marketing and Fintech, by the fact that business methods are only patentable in the USA. However, it should not be neglected that many of such patents can be successfully expanded to other countries if they have a technical share.

The EU companies reach relatively high shares in the fields of healthcare, Industry 4.0, mobility as well as energy. Especially energy (15%) and healthcare (15%) stand out here. With regard to healthcare, Dutch and German companies make a major contribution, particularly Philips (81 patents) and Siemens (46 patents). Swiss companies are also focusing on Artificial Intelligence in healthcare. Roche is particularly noteworthy with 41 healthcare AI patents on a global scale.

However, it must be emphasized that in most application fields significantly more than half of the world-class patents are being developed by American companies and research institutions.

This shows a fivefold dominance of the United States in Artificial Intelligence:

- High importance of the US research location for global AI research: more than 50% of all world-class patents are being researched in the US
- High shares of US companies and research institutions on patents researched in the home market: 83%
- Technology leadership of companies and institutions: the top five companies and four of the top five universities and research institutions are located in the United States
- Special importance of American companies for global research sites: 60% of all world-class patents in Artificial Intelligence are being developed by American companies and research institutions
- Dominance in all application fields of Artificial Intelligence: more than half of the world-class patents in most application fields are developed by American companies and institutions

9 Country profiles

In the following, the most important data, time series and rankings are shown for selected countries on one page each. This includes the most important researching companies in Artificial Intelligence per country, the technology structure within Artificial Intelligence by sub-technologies and application fields as well as the structures of the research location and target regions of the research activities of particular companies.

The strength of American companies also becomes evident from the country profiles. The world's leading American IT companies can generally be found at top positions in the rankings of the leading researching companies in Artificial Intelligence within the respective countries.

Germany

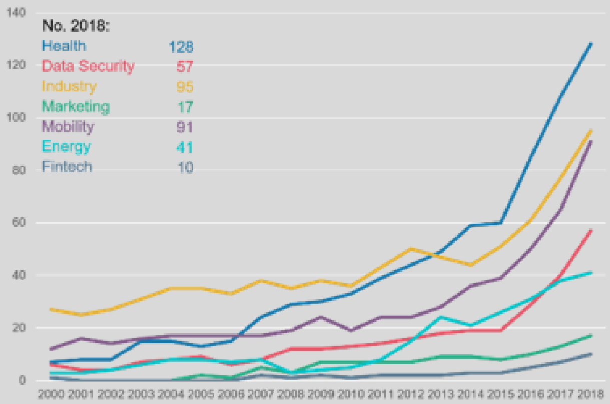
689 world-class patents at the research location

4'712 total patents at the research location

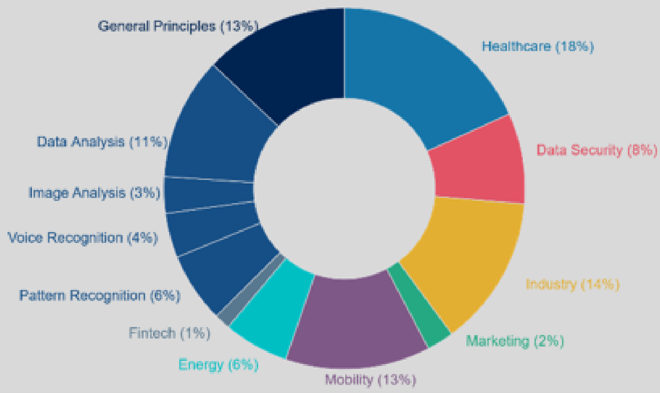
441 world-class patents by domestic companies

3'940 total patents by domestic companies

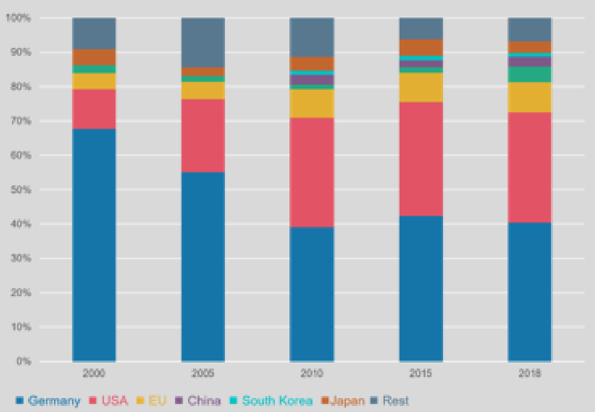
Development of AI application fields 2000-2018



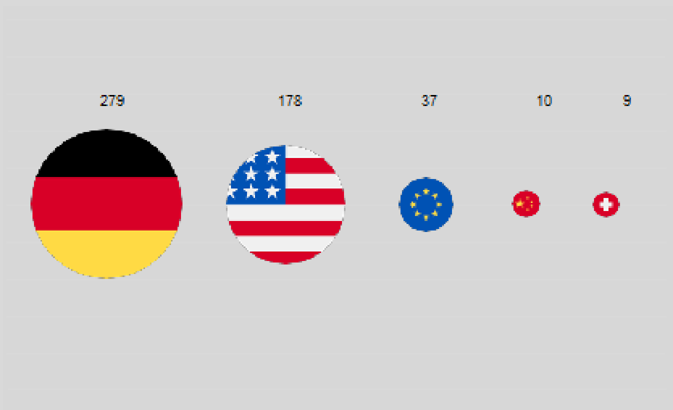
AI structure, sub-technologies and application fields 2018



Structure of the German research location according to companies' country of origin, share of world-class patents, 2000-2018



Most important research locations of German companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in Germany according to research locations, 2018
(Comparison of research activities in Germany with other research sites)

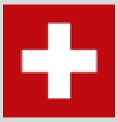
	World-class patents in Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	DE	World	DE	DE	EU	USA	China	Japan	DE	EU	USA	China	Japan	DE	World	DE
Siemens	50	99	50%	23	27	43	0	0	27	7	33	3	0	518	984	53%
Bosch	25	41	61%	19	20	9	0	2	6	7	7	1	2	276	354	78%
Intel	24	409	6%	8	38	163	35	0	16	42	101	19	3	46	1237	4%
Microsoft	21	1339	2%	0	11	906	23	0	21	144	409	82	6	52	4187	1%
Alphabet	17	901	2%	1	67	616	0	0	16	98	204	20	3	31	2311	1%
Continental	17	20	85%	12	13	2	0	0	5	5	4	1	0	85	110	77%
Philips	15	108	14%	0	34	22	0	0	15	54	41	2	0	57	545	10%
GE	12	126	9%	4	10	86	1	1	8	14	27	1	0	34	732	5%
Roche	11	50	22%	5	6	23	0	0	6	10	13	1	0	25	106	24%
McAfee	11	45	24%	4	9	19	0	0	7	11	12	1	0	15	96	16%
Apple	10	201	5%	6	10	143	0	0	4	34	44	3	0	16	444	4%
Honda Motor	10	52	19%	9	9	16	0	22	1	1	4	0	2	59	390	15%
VW Group	10	13	77%	9	11	2	0	0	1	0	0	0	0	160	190	84%
Midea Group	9	16	56%	9	9	0	4	0	0	0	2	2	0	25	97	26%
Nokia	8	62	13%	5	30	12	4	0	3	12	5	5	0	22	398	6%
Deere & Co	8	24	33%	4	4	16	0	0	4	4	4	0	0	24	69	35%
Fraunhofer	8	8	100%	7	7	0	0	0	1	1	1	0	0	57	61	93%
Bayer	7	17	41%	6	6	7	0	0	1	2	4	1	0	12	55	22%
BMW	7	8	88%	5	5	1	0	0	2	2	1	0	0	93	96	97%
Qualcomm	6	353	2%	0	5	172	0	0	6	65	179	28	4	10	671	1%
Nuance	6	72	8%	1	11	43	1	0	5	9	17	1	0	48	434	11%
BASF	6	13	46%	5	6	2	0	0	1	3	4	0	0	14	35	40%
GM	5	81	6%	0	0	72	0	0	5	6	12	0	0	31	595	5%
SAP	5	14	36%	3	3	6	2	0	2	2	2	0	0	186	349	53%
Agt International Gmbh	5	5	100%	4	4	0	0	0	1	1	0	0	0	18	21	86%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location

** All inventors of the patent live in one country, i.e. research has taken place only in the specified country

*** The patent is an international research cooperation of at least two countries, including the specified country

Switzerland



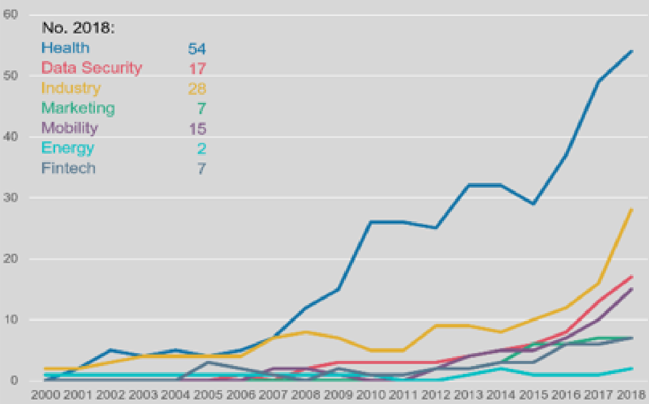
228 world-class patents at the research location

150 world-class patents by domestic companies

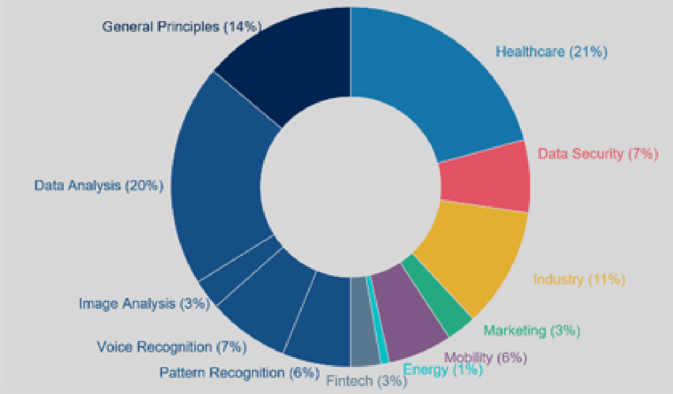
1'016 total patents at the research location

628 total patents by domestic companies

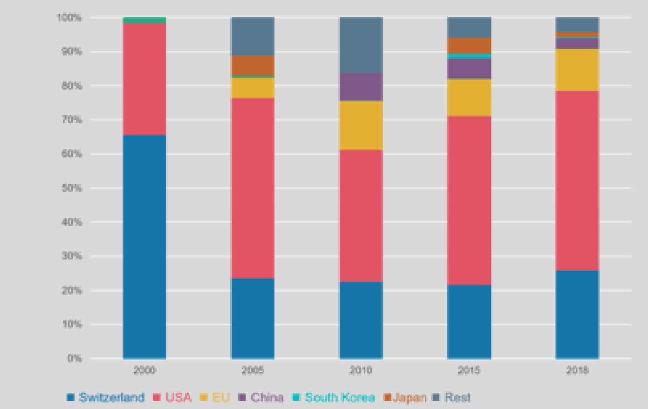
Development of AI application fields 2000-2018



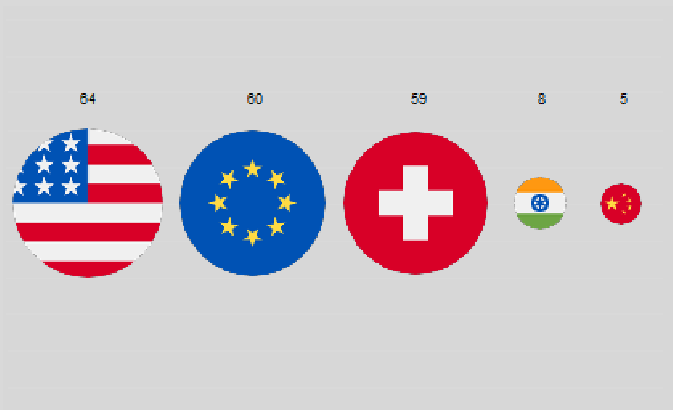
AI structure, sub-technologies and application fields 2018



Structure of the Swiss research location according to companies' country of origin, share of world-class patents, 2000-2018



Most important research locations of Swiss companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in Switzerland according to research locations, 2018
(Comparison of research activities in Switzerland with other research sites)

	World-class patents in Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	CH	World	CH	CH	EU	USA	China	Japan	CH	EU	USA	China	Japan	CH	World	CH
Alphabet	68	901	7%	14	67	616	0	0	54	98	204	20	3	177	2311	8%
Roche	11	50	22%	6	6	23	0	0	5	10	13	1	0	22	106	21%
Apple	7	201	3%	0	10	143	0	0	7	34	44	3	0	10	444	2%
Cisco	7	68	10%	0	3	34	0	0	7	15	20	0	0	88	418	21%
ABB	6	22	27%	1	4	3	2	0	5	5	4	1	0	30	127	24%
Thomson Reuters	6	11	55%	0	0	4	0	0	6	1	6	0	0	22	50	44%
EPF Lausanne	6	6	100%	2	0	0	0	0	4	4	0	0	0	21	21	100%
Qualcomm	4	353	1%	0	5	172	0	0	4	65	179	28	4	6	671	1%
IBM	4	153	3%	1	4	84	9	5	3	24	44	5	4	74	4028	2%
Nestle	4	16	25%	2	1	10	0	0	2	2	2	1	0	5	33	15%
Logitech	4	4	100%	1	0	0	0	0	3	2	2	0	0	12	16	75%
Philip Morris	4	4	100%	4	0	0	0	0	0	0	0	0	0	12	12	100%
Schindler Holding	4	4	100%	4	0	0	0	0	0	0	0	0	0	5	5	100%
GE	3	126	2%	0	10	86	1	1	3	14	27	1	0	6	732	1%
Novartis	3	8	38%	0	1	4	0	0	3	3	1	0	0	5	14	36%
Codexis	3	6	50%	0	0	2	0	0	3	1	4	0	0	3	18	17%
Endress+Hauser	3	4	75%	1	1	0	0	0	2	2	0	0	0	3	7	43%
Microsoft	2	1339	0%	0	11	906	23	0	2	144	409	82	6	20	4187	0%
Intel	2	409	0%	0	38	163	35	0	2	42	101	19	3	4	1237	0%
Amazon	2	159	1%	0	2	143	0	0	2	7	17	0	0	2	842	0%
Philips	2	108	2%	0	34	22	0	0	2	54	41	2	0	2	545	0%
Hexagon	2	5	40%	0	1	2	0	0	2	2	0	0	0	5	14	36%
Swiss Re	2	2	100%	1	0	0	0	0	1	0	1	0	0	13	16	81%
University of Bern	2	2	100%	2	0	0	0	0	0	0	0	0	0	5	5	100%
Myotest SA	2	2	100%	1	0	0	0	0	1	1	0	0	0	4	4	100%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location

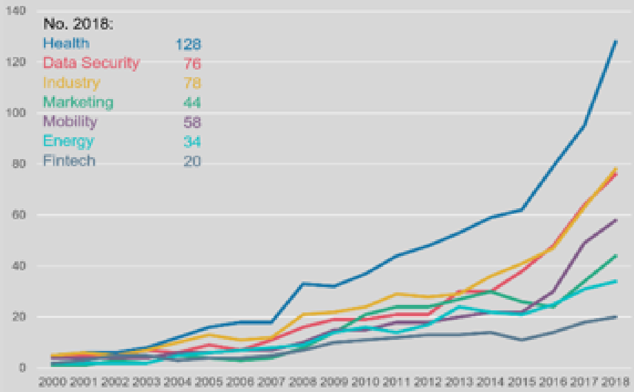
** All inventors of the patent live in one country, i.e. research has taken place only in the specified country

*** The patent is an international research cooperation of at least two countries, including the specified country

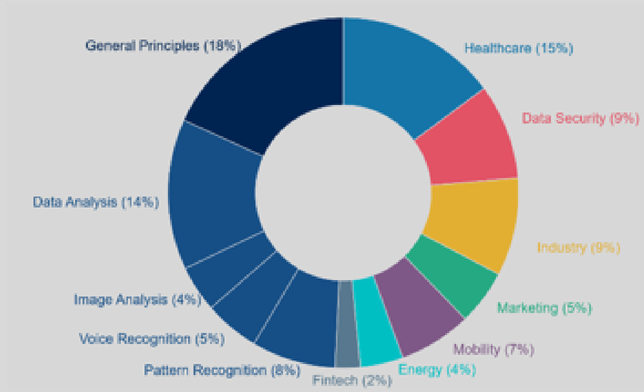
Great Britain

757 world-class patents at the research location	**3'359** total patents at the research location
181 world-class patents by domestic companies	**1'355** total patents by domestic companies

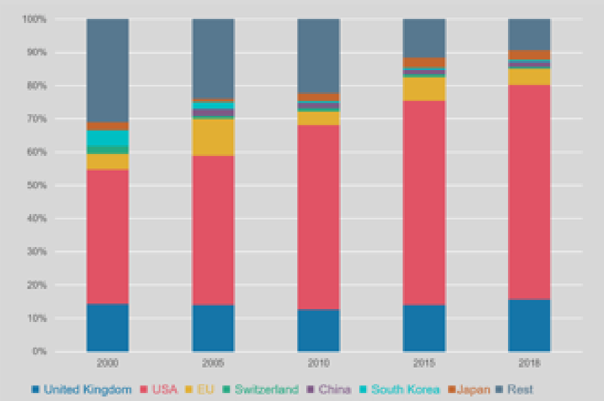
Development of AI application fields 2000-2018



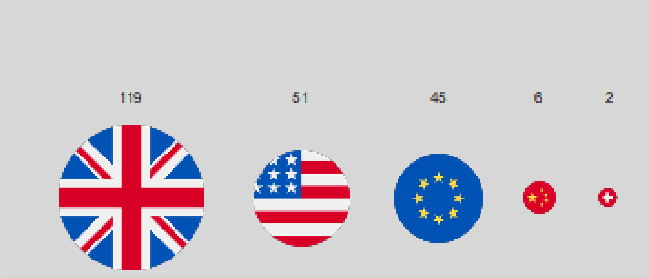
AI structure, sub-technologies and application fields 2018



Structure of the UK research location according to companies' country of origin, share of world-class patents, 2000-2018



Most important research locations of UK companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in UK according to research locations, 2018
(Comparison of research activities in UK with other research sites)

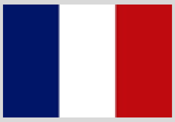
	World-class patents in Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	GB	World	GB	GB	EU	USA	China	Japan	GB	EU	USA	China	Japan	GB	World	GB
Alphabet	115	901	13%	64	67	616	0	0	51	98	204	20	3	206	2311	9%
Microsoft	95	1339	7%	11	11	906	23	0	84	17	409	82	6	261	4187	6%
IBM	19	153	12%	0	4	84	9	5	19	24	44	5	4	153	4028	4%
Twitter	17	30	57%	13	13	12	0	0	4	4	4	0	0	19	65	29%
Qualcomm	16	353	4%	2	5	172	0	0	14	65	179	28	4	26	671	4%
Palantir Technologies	16	39	41%	1	1	20	0	0	15	16	18	0	0	18	49	37%
Emerson Electric	15	83	18%	1	1	63	0	0	14	15	18	1	0	22	152	14%
Intel	14	409	3%	3	38	163	35	0	11	42	101	19	3	47	1237	4%
Apple	14	201	7%	0	10	143	0	0	14	34	44	3	0	26	444	6%
Tata Motors	14	14	100%	13	13	0	0	0	1	1	1	0	0	25	25	100%
University of Oxford	12	12	100%	9	9	0	0	0	3	3	0	2	0	32	32	100%
Facebook	10	130	8%	1	1	97	0	1	9	19	34	11	0	47	887	5%
Schlumberger	10	23	43%	2	2	5	0	1	8	11	13	1	0	31	132	23%
McAfee	9	45	20%	3	9	19	0	0	6	11	12	1	0	20	96	21%
Verizon	7	75	9%	1	1	56	0	0	6	10	17	2	0	25	759	3%
BT Group	7	7	100%	7	7	0	0	0	0	0	0	0	0	107	110	97%
University of London	7	7	100%	6	6	0	0	0	1	1	1	0	0	23	23	100%
Chinese University Hong Kong	7	7	100%	0	0	0	0	0	7	7	1	7	0	11	23	48%
Oxford Nanopore Technologies	7	7	100%	7	7	0	0	0	0	0	0	0	0	7	7	100%
Philips	6	108	5%	0	34	22	0	0	6	54	41	2	0	11	545	2%
Nokia	6	60	10%	2	30	12	4	0	4	12	5	5	0	28	398	7%
Waters	6	11	55%	3	7	3	0	0	3	1	0	0	0	25	37	68%
Samsung	5	198	2%	3	7	45	5	0	2	4	13	15	5	19	1683	1%
GE	5	126	4%	3	10	86	1	1	2	14	27	1	0	38	732	5%
Sony	4	186	2%	3	12	33	0	116	1	6	20	5	16	22	919	2%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location

** All inventors of the patent live in one country, i.e. research has taken place only in the specified country

*** The patent is an international research cooperation of at least two countries, including the specified country

France



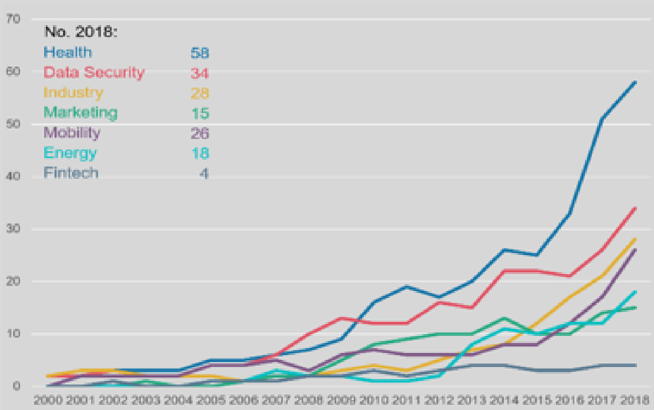
369 world-class patents at the research location

150 world-class patents by domestic companies

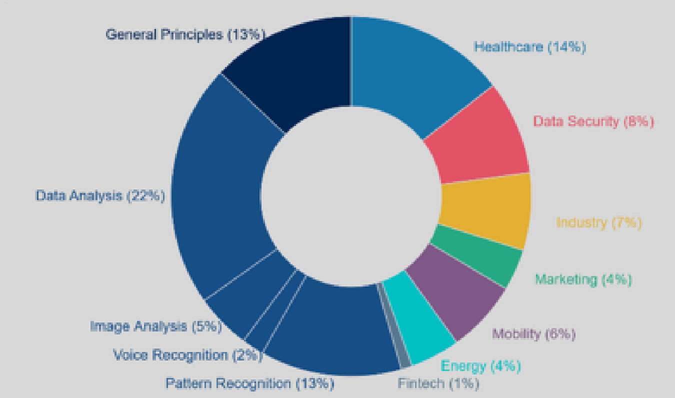
2'629 total patents at the research location

1'431 total patents by domestic companies

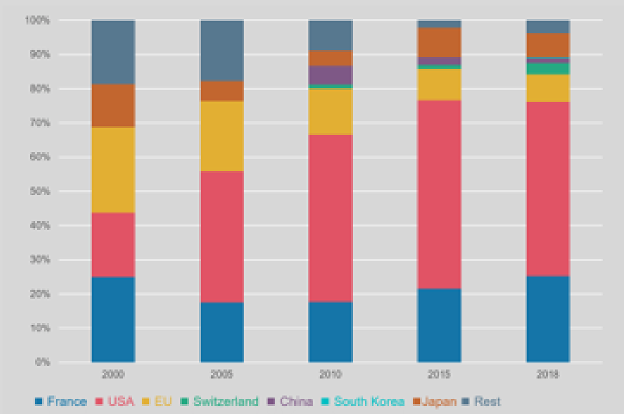
Development of AI application fields 2000-2018



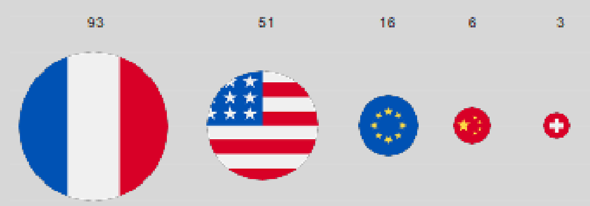
AI structure, sub-technologies and application fields 2018



Structure of the French research location according to companies' country of origin, share of world-class patents, 2000-2018



Most important research locations of French companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in France according to research locations, 2018
(Comparison of research activities in France with other research sites)

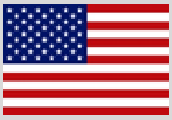
	World-class patents in Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	FR	World	FR	FR	EU	USA	China	Japan	FR	EU	USA	China	Japan	FR	World	FR
Xerox	32	64	49%	21	27	28	0	0	11	7	7	2	1	217	587	37%
Alphabet	20	901	2%	0	67	616	0	0	20	98	204	20	3	36	2311	2%
Cisco	14	68	21%	1	3	34	0	0	13	15	20	0	0	121	418	29%
InterDigital	14	52	26%	6	13	17	2	0	8	12	19	4	0	66	154	43%
Apple	11	201	5%	0	10	143	0	0	11	34	44	3	0	23	444	5%
CEA	10	10	100%	10	10	0	0	0	0	0	0	0	0	107	107	100%
Qualcomm	8	353	2%	2	5	172	0	0	6	65	179	28	4	13	671	2%
Nokia	8	60	13%	3	30	12	4	0	5	12	5	5	0	37	398	9%
Accenture	8	58	14%	4	10	25	4	0	4	4	10	1	0	32	333	10%
Softbank	8	11	73%	8	10	0	0	0	0	0	1	0	1	16	104	15%
CNRS	8	8	100%	6	6	0	0	0	2	2	1	0	0	71	71	100%
Microsoft	5	1339	0%	0	11	906	23	0	5	144	409	82	6	13	4187	0%
MyScript	5	5	100%	5	5	0	0	0	0	0	0	0	0	29	29	100%
Intel	4	409	1%	1	38	163	35	0	3	42	101	19	3	6	1237	0%
GE	4	126	3%	0	10	86	1	1	4	14	27	1	0	20	732	3%
Conduent	4	11	36%	2	3	5	0	0	2	1	3	0	0	56	205	27%
Dassault Systemes	4	5	80%	4	4	0	0	0	0	1	1	0	0	34	43	79%
Nuance	3	72	4%	3	11	43	1	0	0	9	17	1	0	12	434	3%
Schlumberger	3	23	13%	0	2	5	0	1	3	11	13	1	0	9	132	7%
L´Oreal	3	8	38%	3	3	3	0	0	0	0	0	0	0	7	15	47%
Elo Touch Solutions Inc	3	5	60%	3	4	0	0	0	0	0	1	1	1	5	9	56%
Valeo	3	4	75%	2	3	1	0	0	1	0	0	0	0	36	68	53%
Safran	3	3	100%	3	3	0	0	0	0	0	0	0	0	38	39	97%
Amadeus IT Group	3	3	100%	1	2	0	0	0	2	1	1	0	0	17	19	89%
Sorbonne University	3	3	100%	3	3	0	0	0	0	0	0	0	0	15	15	100%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location

** All inventors of the patent live in one country, i.e. research has taken place only in the specified country

*** The patent is an international research cooperation of at least two countries, including the specified country

USA



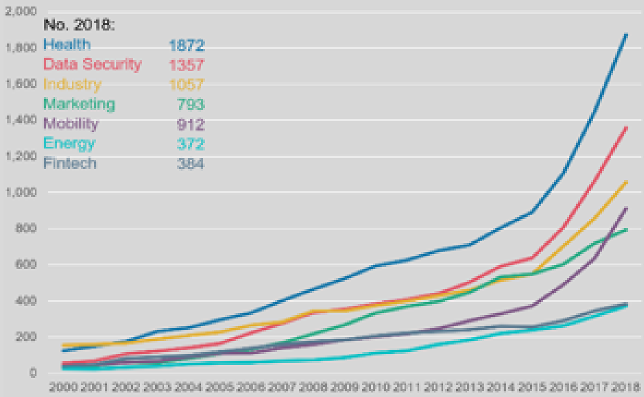
9’928 world-class patents at the research location

48’735 total patents at the research location

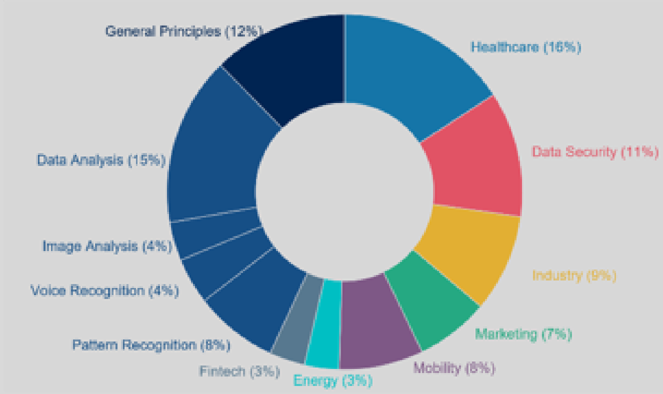
9’069 world-class patents by domestic companies

44’937 total patents by domestic companies

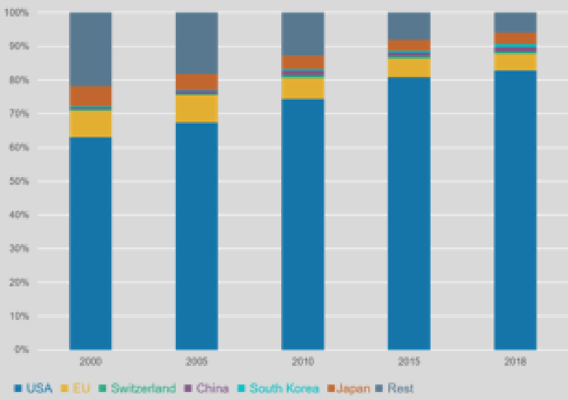
Development of AI application fields 2000-2018



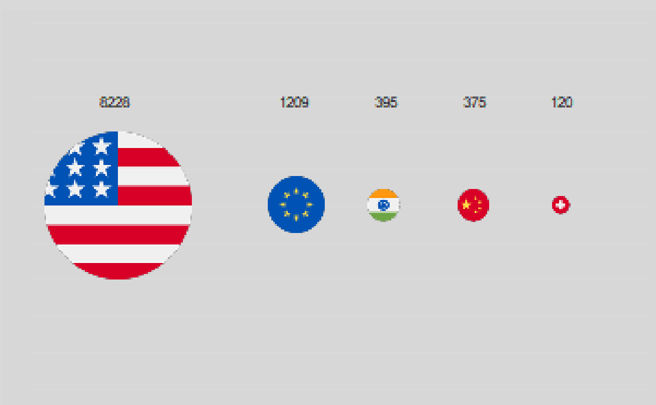
AI structure, sub-technologies and application fields 2018

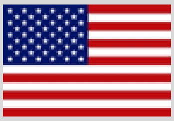


Structure of the US research location according to companies’ country of origin, share of world-class patents, 2000-2018



Most important research locations of US companies, number of world-class patents, 2018





The most important companies in Artificial Intelligence in the USA according to research locations, 2018
(Comparison of research activities in the USA with other research sites)

	World-class patents in Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	USA	World	USA	USA	EU	China	Japan	Korea	USA	EU	China	Japan	Korea	USA	World	USA
Microsoft	1315	1339	97%	906	11	23	0	0	409	144	82	6	4	3820	4187	91%
Alphabet	820	901	90%	616	67	0	0	0	204	98	20	3	4	2095	2311	91%
Qualcomm	351	353	97%	172	5	0	0	0	179	65	28	4	19	634	671	94%
Intel	264	409	63%	163	38	35	0	3	101	42	19	3	11	873	1237	71%
Apple	187	201	93%	143	10	0	0	0	44	34	3	0	0	409	444	92%
Amazon	158	159	98%	143	2	0	0	1	15	7	0	0	0	799	842	95%
Facebook	131	133	98%	97	1	0	1	0	34	19	11	0	0	872	887	98%
IBM	128	153	80%	84	4	9	5	0	44	24	5	4	1	2907	4028	72%
GE	113	128	89%	86	10	1	1	0	27	14	1	0	0	612	732	84%
GM	81	81	99%	72	0	0	0	0	9	6	0	0	1	551	595	93%
Emerson Electric	81	82	98%	63	1	0	0	0	18	15	1	0	0	147	152	97%
Siemens	76	99	72%	43	27	0	0	0	33	31	3	0	0	581	984	59%
Honeywell	75	81	94%	48	2	0	0	0	27	5	4	0	0	238	270	88%
Verizon	72	73	97%	55	1	0	0	0	17	10	2	0	0	627	759	83%
University of California	71	71	100%	60	0	0	0	0	11	2	4	1	2	214	218	98%
Philips	63	108	57%	22	34	0	0	0	41	54	2	0	0	245	545	45%
Nuance	60	72	81%	43	11	1	0	0	17	9	1	0	0	327	434	76%
Samsung	58	198	28%	45	7	5	0	109	13	4	15	5	27	395	1683	23%
Ford	55	55	96%	54	1	0	0	0	1	0	1	0	0	276	295	94%
Cisco	54	68	79%	34	3	0	0	1	20	15	0	0	0	319	418	76%
Sony	53	186	28%	33	12	0	116	0	20	6	5	16	0	147	919	16%
Rockwell Automation	53	55	96%	37	1	0	0	0	16	5	1	1	0	170	183	93%
Boston Scientific	52	55	95%	51	3	0	0	0	1	0	0	0	0	90	93	97%
KLA-Tencor	51	53	96%	16	0	0	0	0	35	2	19	0	2	100	108	93%
MIT	51	51	100%	45	0	0	0	0	6	4	1	1	0	143	144	99%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location
** All inventors of the patent live in one country, i.e. research has taken place only in the specified country
*** The patent is an international research cooperation of at least two countries, including the specified country

China

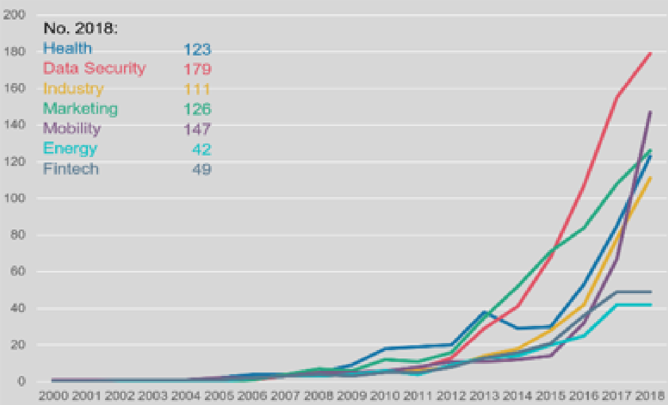
1’912 world-class patents at the research location

57’439 total patents at the research location

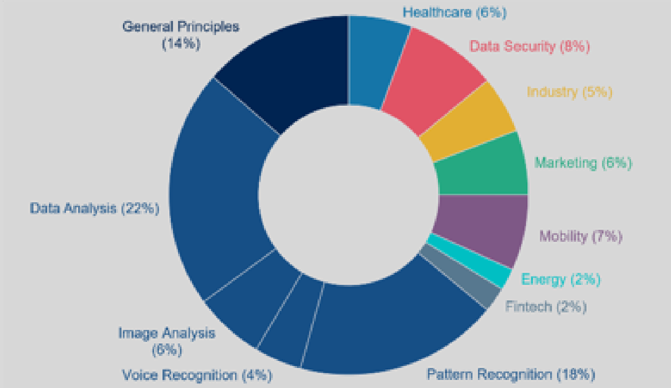
1’417 world-class patents by domestic companies

49’018 total patents by domestic companies

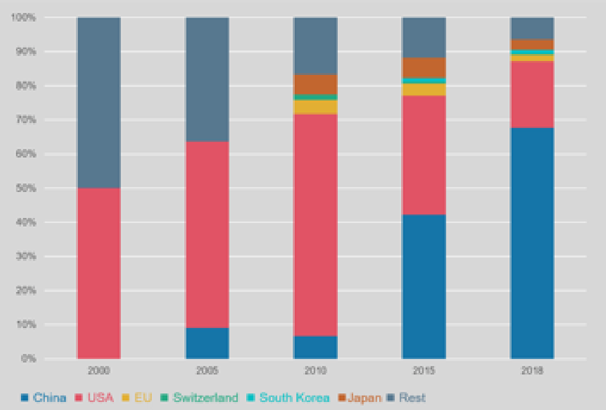
Development of AI application fields 2000-2018



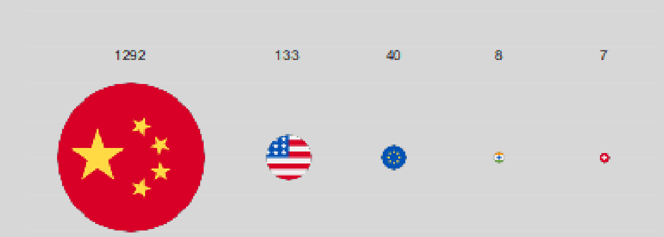
AI structure, sub-technologies and application fields 2018



Structure of the Chinese research location according to companies’ country of origin, share of world-class patents, 2000-2018



Most important research locations of Chinese companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in China according to research locations, 2018
(Comparison of research activities in China with other research sites)

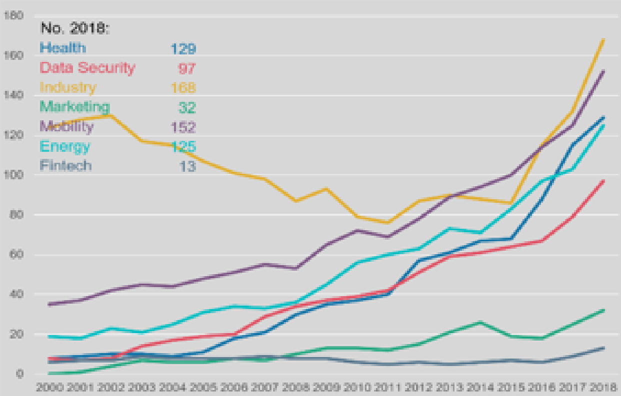
	World-class patents in Artificial Intelligence														Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***						Domestic share of total patents in AI		
	China	World	China	China	EU	USA	Japan	Korea	China	EU	USA	Japan	Korea		China	World	China
Tencent	177	177	100%	177	0	0	0	0	0	0	0	0	0		864	912	100%
Alibaba Group	166	167	99%	153	0	2	0	0	13	0	11	0	0		687	744	95%
Microsoft	105	1356	8%	23	11	906	0	0	82	144	409	6	4		392	4187	9%
Baidu	75	82	89%	62	0	9	0	0	13	0	13	0	0		1424	1492	95%
Xiaomi	59	61	97%	57	0	2	0	0	2	2	6	0	0		506	553	92%
Intel	54	409	13%	35	38	163	0	3	19	42	101	3	11		170	1237	14%
Huawei	53	63	82%	46	3	7	0	0	7	0	4	0	0		522	656	80%
Chinese Academy of Sciences	38	38	100%	38	0	0	0	0	0	0	0	0	0		1791	1791	100%
South China Univ. of Tech.	22	22	100%	22	0	0	0	0	0	0	0	0	0		599	599	100%
Shenzhen University	22	22	100%	22	0	0	0	0	0	0	0	0	0		156	156	100%
Samsung	20	198	10%	5	7	45	0	109	15	4	13	5	27		151	1683	9%
Tsinghua University (China)	18	18	100%	17	0	0	0	0	1	0	0	1	0		803	805	100%
OPPO Electronics	17	18	94%	17	0	1	0	0	0	0	0	0	0		452	453	100%
State Grid Corp	16	16	100%	16	0	0	0	0	0	0	0	0	0		1397	1397	100%
IBM	14	153	9%	9	4	84	5	0	5	24	44	4	1		218	4028	5%
Sogou	13	13	100%	13	0	0	0	0	0	0	0	0	0		116	116	100%
Qihoo 360	12	12	100%	12	0	0	0	0	0	0	0	0	0		368	368	100%
Peking University	11	11	100%	11	0	0	0	0	0	0	0	0	0		331	331	100%
Xidian University	9	9	100%	9	0	0	0	0	0	0	0	0	0		793	793	100%
Megvii	9	9	100%	9	0	0	0	0	0	0	0	0	0		142	142	100%
Huazhong Univ. of Sci. & Tech.	8	8	100%	8	0	0	0	0	0	0	0	0	0		340	340	100%
CUMT	8	8	100%	8	0	0	0	0	0	0	0	0	0		144	144	100%
Beijing University of Technology	8	8	100%	8	0	0	0	0	0	0	0	0	0		454	454	100%
Tongji University	6	6	100%	6	0	0	0	0	0	0	0	0	0		187	187	100%
SenseTime	6	6	100%	6	0	0	0	0	0	0	0	0	0		320	320	100%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location
** All inventors of the patent live in one country, i.e. research has taken place only in the specified country
*** The patent is an international research cooperation of at least two countries, including the specified country

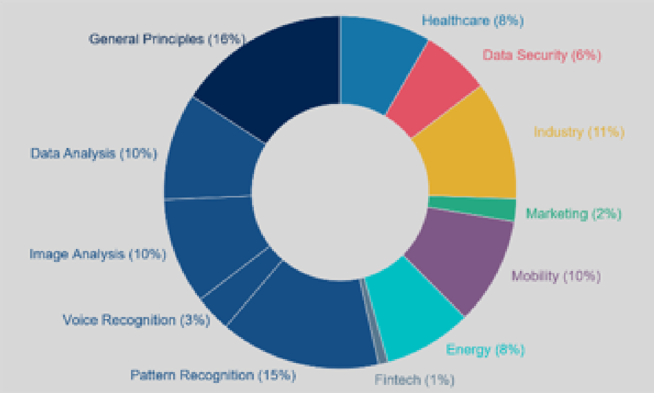
Japan

1’288	world-class patents at the research location	13’685	total patents at the research location
1’515	world-class patents by domestic companies	16’113	total patents by domestic companies

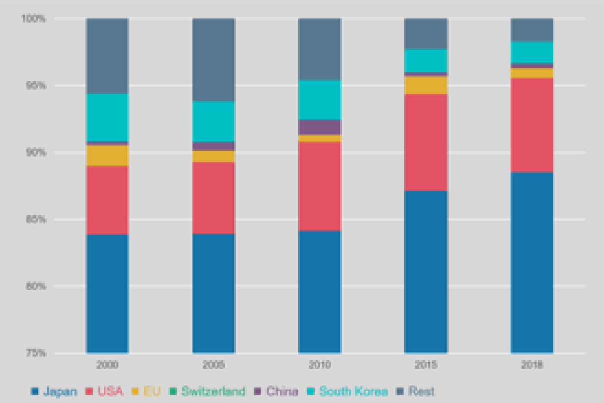
Development of AI application fields 2000-2018



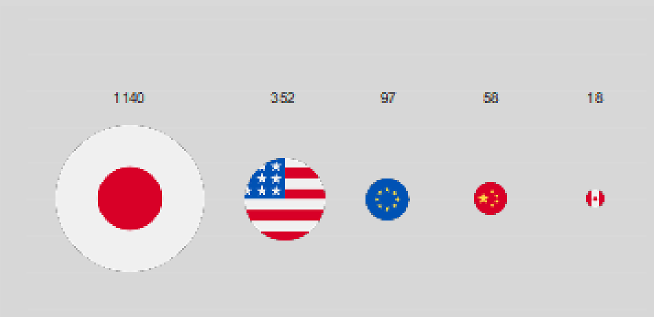
AI structure, sub-technologies and application fields 2018

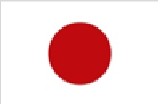


Structure of the Japanese research location according to companies’ country of origin, share of world-class patents, 2000-2018



Most important research locations of Japanese companies, number of world-class patents, 2018





The most important companies in Artificial Intelligence in Japan according to research locations, 2018
(Comparison of research activities in Japan with other research sites)

	World-class patents in Artificial Intelligence														Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***						Domestic share of total patents in AI		
	Japan	World	Japan	Japan	EU	USA	China	Korea	Japan	EU	USA	China	Korea		Japan	World	Japan
Sony	132	186	71%	116	12	33	0	0	16	6	20	5	0		691	919	75%
Canon	87	102	84%	83	5	2	0	0	4	3	4	2	0		767	942	81%
Hitachi	80	81	99%	79	0	0	1	0	4	2	2	0	0		626	669	94%
Panasonic	74	78	96%	70	0	3	0	0	4	0	2	1	0		491	521	94%
Semiconductor Energy Lab	73	73	100%	73	0	0	0	0	0	0	0	0	0		111	111	100%
Toyota Motor	72	85	84%	63	0	13	0	0	9	3	7	0	0		344	495	69%
Denso	41	41	100%	41	0	0	0	0	0	0	0	0	0		249	254	98%
Mitsubishi Electric	40	61	63%	32	1	19	0	0	8	2	11	0	0		250	402	62%
Fujifilm	34	42	81%	33	0	8	0	0	1	0	0	1	0		523	604	87%
Fujitsu	32	42	76%	28	0	5	3	0	4	1	3	2	0		630	927	68%
Toshiba	31	34	91%	31	1	2	0	0	0	0	0	0	0		576	627	92%
NEC	27	58	47%	27	0	24	2	0	0	1	3	0	0		700	997	70%
Omron	27	28	96%	22	0	1	0	0	5	0	2	3	0		173	174	99%
Honda Motor	24	52	46%	22	9	16	0	0	2	1	4	0	0		259	390	66%
Ricoh	21	46	46%	17	0	20	5	0	4	0	3	1	0		236	408	58%
Fanuc	21	23	91%	20	0	2	0	0	1	0	1	0	0		268	275	97%
Nissan Motor	19	19	100%	18	0	0	0	0	1	0	1	0	0		99	110	90%
Aisin Seiki	19	19	100%	18	0	0	0	0	1	1	1	0	0		72	77	94%
NTT	17	17	100%	14	0	0	0	0	3	1	2	0	0		864	881	98%
Olympus	10	11	91%	10	0	1	0	0	0	0	0	0	0		96	98	98%
IBM	9	153	6%	5	4	84	9	0	4	24	44	5	1		237	4028	6%
Foxconn	9	16	56%	9	0	2	1	0	0	0	1	1	0		104	220	47%
Tokyo Electron	9	15	60%	2	0	2	0	0	7	4	11	7	1		30	68	44%
NICT	9	9	100%	6	0	0	0	0	3	3	0	1	2		104	104	100%
Mitsubishi Heavy	7	12	58%	7	4	1	0	0	0	0	0	0	0		45	64	70%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location
** All inventors of the patent live in one country, i.e. research has taken place only in the specified country
*** The patent is an international research cooperation of at least two countries, including the specified country

South Korea

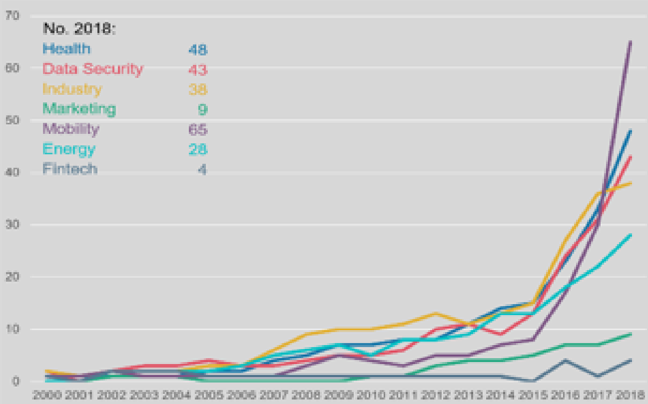
415 world-class patents at the research location

7'428 total patents at the research location

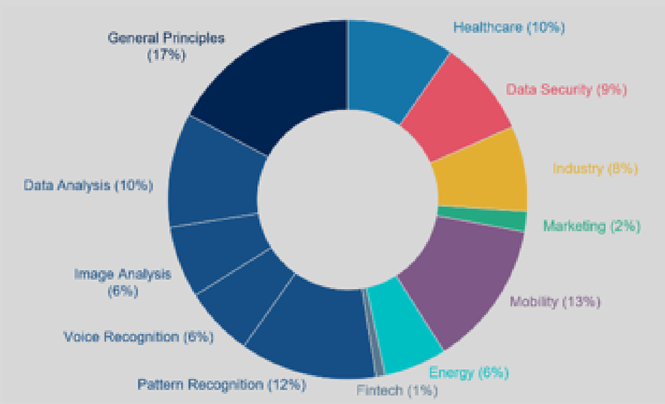
446 world-class patents by domestic companies

7'422 total patents by domestic companies

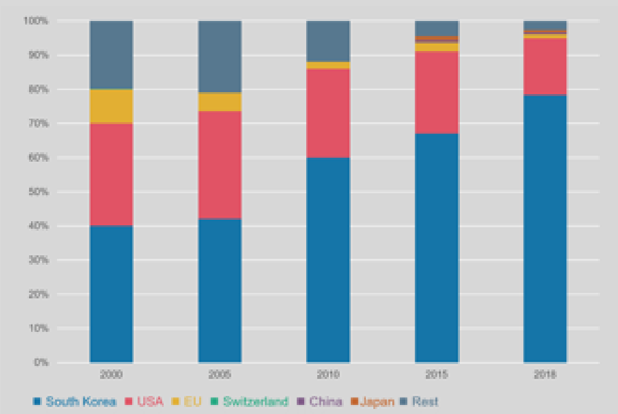
Development of AI application fields 2000-2018



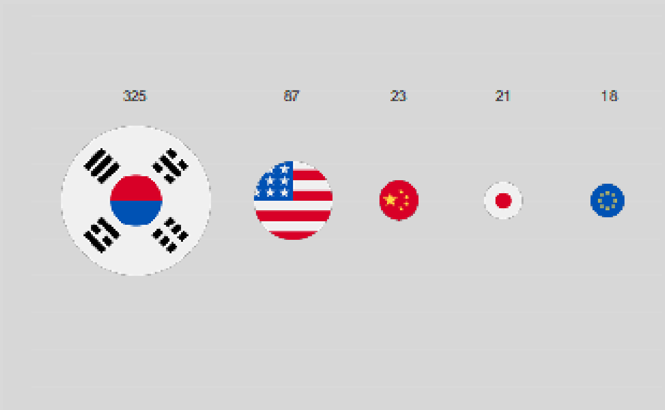
AI structure, sub-technologies and application fields 2018



Structure of the South Korean research location according to companies' country of origin, share of world-class patents, 2000-2018



Most important research locations of South Korean companies, number of world-class patents, 2018



The most important companies in Artificial Intelligence in South Korea according to research locations, 2018
(Comparison of research activities in South Korea with other research sites)

	World-class patents ins Artificial Intelligence													Total patents		
	Domestic share of world-class patents*			Exclusively developed in one country**					International research cooperation among others with***					Domestic share of total patents in AI		
	DE	World	KR	KR	EU	USA	China	Japan	KR	EU	USA	China	Japan	KR	World	KR
Samsung	136	198	68%	109	7	45	5	0	27	4	13	15	5	1183	1683	70%
LG Electronics	86	88	99%	84	0	2	0	0	2	1	0	1	0	295	300	98%
Qualcomm	19	353	5%	0	5	172	0	0	19	65	179	28	4	30	671	4%
Hyundai Motor	17	17	100%	16	0	0	0	0	1	1	0	0	0	214	217	99%
Intel	14	409	3%	3	38	163	35	0	11	42	101	19	3	34	1237	3%
Kia Motors	8	8	100%	8	0	0	0	0	0	0	0	0	0	80	82	98%
LG Chem	5	11	45%	4	0	6	0	0	1	0	1	0	0	18	26	69%
LS Industrial Systems	5	5	100%	5	0	0	0	0	0	0	0	0	0	19	19	100%
ETRI Korea	4	4	100%	3	0	0	0	0	1	0	0	1	0	454	455	100%
KAIST	4	4	100%	4	0	0	0	0	0	0	0	0	0	202	205	99%
Samsung SDS	4	4	100%	4	0	0	0	0	0	0	0	0	0	58	61	95%
Hyundai Mobis	4	4	100%	4	0	0	0	0	0	0	0	0	0	22	22	100%
SK Telecom	3	4	75%	3	0	1	0	0	0	0	0	0	0	92	93	99%
POSTECH	3	3	100%	3	0	0	0	0	0	0	0	0	0	81	81	100%
Naver	3	3	100%	3	0	0	0	0	0	0	0	0	0	74	75	99%
Hanwha Aerospace	3	3	100%	3	0	0	0	0	0	0	0	0	0	54	58	93%
Halla Holdings	3	3	100%	3	0	0	0	0	0	0	0	0	0	37	39	95%
HP Inc.	2	15	13%	2	0	11	0	0	0	2	2	0	0	22	253	9%
Seoul National University	1	1	100%	1	0	0	0	0	0	0	0	0	0	131	131	100%
12CM, INC	1	1	100%	1	0	0	0	0	0	0	0	0	0	119	119	100%
Hanyang University	1	1	100%	1	0	0	0	0	0	0	0	0	0	81	81	100%
KT Corp	1	1	100%	1	0	0	0	0	0	0	0	0	0	64	64	100%
Inha University	1	1	100%	1	0	0	0	0	0	0	0	0	0	63	63	100%
Kyungpook National University	1	1	100%	1	0	0	0	0	0	0	0	0	0	52	52	100%
KIST Korea	1	1	100%	0	0	0	0	0	1	0	1	0	0	47	47	100%

* The sum of world-class AI patents of the company, thereof the share and number of which were invented at the domestic location

** All inventors of the patent live in one country, i.e. research has taken place only in the specified country

*** The patent is an international research cooperation of at least two countries, including the specified country

10 Profound results through intelligent partnerships

EconSight – Re-thinking economics

With a tailor-made communication, EconSight offers intelligent analyses with new arguments and perspectives as a sustainable basis for decision-making. The future cannot be tackled with old methods of analysis and collections of data. It is about using more sophisticated approaches, analyzing comprehensively, designing scenarios and thinking in terms of opportunities and risks to ultimately reduce complexity and convince with new arguments. EconSight's aim is to re-think.

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Federal Institute of Intellectual Property (IGE)

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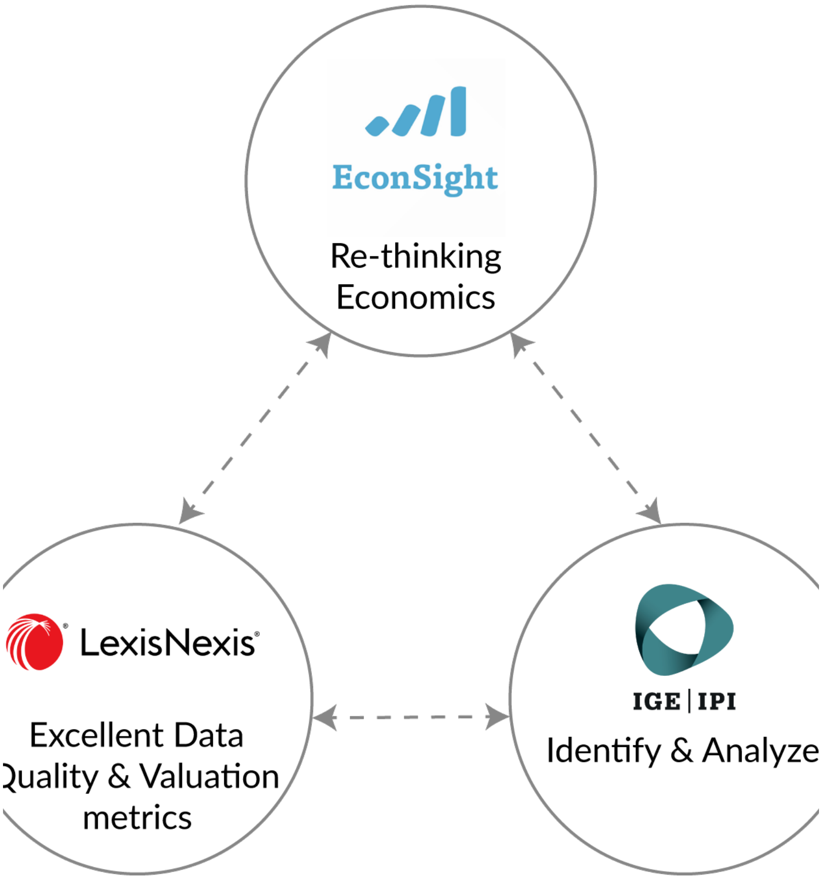

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