China AI Development Report 2018

China Institute for Science and Technology Policy at Tsinghua University

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Contents

FOREWORD

Artificial intelligence (AI) has gradually become a reality from a sci-fi dream along with the approaching of the Fourth Industrial Revolution. Since the idea was put forward for the first time in 1956, AI has experienced ups and downs in its development. It is not until the second decade of the 21st century, with the confluence of breakthroughs in core algorithms, rapid improvement of computing capabilities and the availability of massive amounts of digital data, that AI has finally taken a leap forward and grabbed worldwide attention. After AlphaGo's victory over Go player Lee Sedol in 2016, however, the global excitement about AI has been mixed with concerns about its negative implications. Nonetheless, it is obvious that countries around the world have seen AI as a critical arena of international competition and are rolling AI initiatives to secure a favorable position in the new round of technological revolution. From the perspective of China, AI presents a historic strategic opportunity and has a crucial role to play in alleviating the pressure of a future ageing population, meeting the challenges of sustainable development and advancing economic transformation. Since 2015, China has released a series of major national strategic plans including Made in China 2015, Guiding Opinions of the State Council on Vigorously Advancing the "Internet+" Action and the Next Generation Artificial Intelligence Development Plan, which, together with AI policy initiatives of local governments, have propelled the rapid development of AI in the country.

While AI has penetrated all aspects of society, production and everyday life, opinions still vary as to the definition of AI and its current development and future direction. Governments, the public and the business community have all shown a strong interest in this emerging technology. Domestic and overseas research institutes have also paid close attention to China's AI development and published various research reports, but their views and observations and even some basic facts they cited were not entirely objective and less than comprehensive. In view of this, China Institute for Science and Technology Policy (CISTP) at Tsinghua University, Government Documents Center at Tsinghua University School of Public Policy and Management (SPPM-GDC) and Chinese Institute of Engineering Development Strategies (CIEDS), together with Clarivate Analytics, ScientistIn, China Academy of Information and Communications Technology (CAICT) and Beijing Bytedance Technology Co., Ltd., have jointly prepared this China AI Development Report 2018 to provide a comprehensive picture of AI development in China and in the world at large with a view to increasing public awareness, promoting the AI industry development, and serving policy-making. Compared to similar reports, this report has four prominent characteristics:

Forward-looking perspective: This report describes China's AI development on the four dimensions of technological development, market

applications, policy environment and social impact, drawing upon data and survey findings on talent input, paper and patent output, business development, industry financing, national and local policy, public perception and education. On the basis of the comprehensive analysis, it offers reflections on the current stage of AI development and forward-looking insights into future AI development and especially governance challenges.

Domestic and international coverage: This report offers a multi-dimensional comparison between China and developed countries in AI development and analyzes China's strengths and weaknesses and its position in the international AI competition landscape. Meanwhile, it identifies China's regional differences in AI development, market applications and policy environment with the focus on active regions in AI development.

Reliable first-hand data sources: This report uses an AI keyword list provided by Clarivate Analytics based on literature-based keyword analysis and validation by AI experts, which provides a unified standard for data search in all parts of the report. The four parts of this report are completed by leading specialized organizations including ScientistIn (Talent), Clarivate Analytics (Paper and Patent), CAICT (Industry Development and Market Applications), SPPM-GDC (Policy Environment) and Bytedance (Social Impact) based on first-hand data of specialized databases and a solid research methodology.

Systematic in-depth policy analysis: In addition to presenting comprehensive industry development data, this report, based on close examination of a total of 1,074 foreign and Chinese national and local policy AI policy documents, compares and analyzes the strategic priorities and development directions of AI policies in different regions, marking the first use of this research approach in similar reports.

EXECUTIVE SUMMARY

This report examines China's AI development from four perspectives — S&T output and talent input, industry development and market applications, development strategy and policy environment, and social perception and general impact. Below is a summary of the main findings of each part.

S&T Output and Talent

Paper output: China leads the world in AI papers and highly cited AI papers

China's AI papers as a percentage of the global total increased from 4.26% in 1997 to 27.68% in 2017, far ahead other countries. Universities have contributed the vast majority of AI papers, with 87 of the top 100 AI research institutions in the world being universities. Top Chinese universities have shown impressive performance internationally in the output of AI papers. Moreover, China's highly cited papers have also grown rapidly, overtaking the U.S. to take the first place in 2013. State Grid Corporation of China (SGCC) is the only Chinese company to rank among the world's top 20 companies in AI paper output. In terms of categories, computer science, engineering, and automatic control systems have the highest AI paper output. International collaboration has a significant effect on AI paper output, with as many as 42.64% of top papers being the product of international collaboration.

Patent application: China has more AI patents than U.S. and Japan; SGCC has an outstanding performance

China has become the largest owner of AI patents, followed closely by the U.S. and Japan, and the three countries combine to have 74% of the world's issued AI patents. Global AI patent applications have focused on categories including voice recognition, image recognition, robotics, and machine learning. Among China's top 30 institutional owners of AI patents, research institutions and universities are comparable with enterprises, with the former's patents accounting for 52% and the latter's 48%. However, performance varies greatly among main enterprise assignees of AI patents, with SGCC being a towering presence which has developed rapidly in AI research especially over the last five years and not only holds far more AI patents than other domestic assignees but ranks fourth among enterprise assignees globally. China's AI patents have been concentrated in data processing systems and digital information transmission, with image processing and analysis related AI patents accounting for 16% of the total. Electrical power engineering has also become an important area of China's AI patenting.

Talent: China has the world's second largest AI talent pool, though with a lower percentage of top talents

By the end of 2017, China's AI specialists reached 18,232, or 8.9% of the global total, next only to the U.S. (13.9%). Universities and research institutions are the main cradles of AI specialists, with Tsinghua University and the Chinese Academy of Sciences being the world's largest institutions of AI talent development. However, China has only 977 AI specialists in the world's top-tier AI talent pool based on the H-index, being only one fifth

of number in the U.S., ranking sixth in the world. Chinese companies have a comparatively low level of AI talent input. Companies with a high level of talent input are concentrated in the U.S. Huawei Technologies is the only Chinese company to make into the global top 20. China's AI specialists are concentrated in the eastern and central regions, though some cities in the western region, such as Xi'an and Chengdu, have also been prominent. International AI specialists are concentrated in categories including machine learning, data mining and pattern recognition, while Chinese AI specialists are scattered in different categories.

Industry Development and Market Applications

AI companies: China ranks second in the number of AI companies; Beijing has the highest concentration of AI companies in the world

Chinese AI companies began mushrooming from 2012 and had reached a total number of 1,011 by June 2018, ranking second in the world, though still significantly behind the U.S., which has 2028 companies. Chinese AI companies are highly concentrated in Beijing, Shanghai and Guangdong. Among the world's top 20 cities in terms of AI companies hosted, Beijing ranks first with 395, and Shanghai, Shenzhen and Hangzhou are also among the top 20. China's AI companies mainly specialize in three categories—voice, vision and natural language processing—with only a small percentage focusing on basic hardware.

Venture investment: China has the highest venture investment in AI

From 2013 to the first quarter of 2018, China received 60% of the world's total venture capital investment in AI, but in terms of the number of VC investments received, the U.S. remained the most active country in VC investment in AI. In China, Beijing led other regions by a big margin in the amount and rounds of VC investment, followed by Shanghai and Guangdong which have been fairly active in AI investment as well. From 2014, early-stage investment in AI as a percentage of the total investment in AI has gradually decreased as investment activity has become more rational, though Series A funding has remained in a dominant position.

Market scale: China's AI market grows rapidly; computer vision is the largest segment

In 2017, China's AI market reached RMB23.7 billion, up 67% Y/Y, with the top three segments being computer vision (34.9%), voice (24.8%) and natural language processing (21%), and hardware and algorithm combining to account for less than 20% of the market. The market is expected to grow 75% in 2018.

Product applications: AI gains wide applications, with voice and vision products being the most mature

AI has been widely applied in healthcare, finance, education and security. The global smart speaker market has grown rapidly, where major Chinese and international internet companies have expanded their presence, with Google and Amazon having taken up more than 60% of the global market, followed by Alibaba in third place and Xiaomi in fourth place. In 2017, the global robotics market reached US$23.2 billion, of which the Chinese market represented 27%. Other AI-related markets such as drone, smart home, smart grid, smart security, smart healthcare and smart finance have also seen rapid development.

Development Strategy and Policy Environment

International comparison: countries vary in their AI strategies and policy priorities

Since 2013, the U.S., Germany, the UK, Japan and China have rolled out their AI strategies and policies, each with their own priorities, with the U.S. focusing on the impact of AI on economic growth, technology development and national security, the EU on the ethical risks brought by AI in such aspects as security, privacy and human dignity, Japan on building "Society 5.0", and China on industrialization of AI applications in the service of its "Manufacturing Power" strategy. This leads to remarkable differences among the countries in their AI research priorities and application areas.

National policy: from IoT to big data to AI

Since 2009, China's AI policy has undergone five stages with changing keywords which reflect the different priorities in each stage, with the focus shifting from basic research in such categories as IoT, information security and database in the early period, to big data and infrastructure in the middle period, to AI itself and also intellectual property protection after 2017. Overall, China's AI policy mainly focuses on six categories: "made in China", innovation-driven development, IoT, Internet+, big data, and scientific and technological R&D.

Local policy: aligning with national policy under distinctive local themes

"Made in China 2025" is at the center of the China AI policy citation network and has served as a programmatic document for local governments' AI policymaking as they respond to the national AI development strategy. Based on policy documents, China's AI powerhouses are Beijing-Tianjin-Hebei, Yangtze River Delta and Guangdong-Hong Kong-Macao regions. At the provincial level, policy themes vary widely, with Jiangsu focusing on infrastructure, IoT and cloud computing, Guangdong on AI applications such as manufacturing and robotics, and Fujian on IoT, big data, innovation platform and intellectual property, reflecting their local development conditions.

Public Perception and General Impact

Public perception: The Chinese public has a high AI awareness, with half respondents expressing support of comprehensive AI development

From 2016 to 2017, AI drew massive public attention and became the most discussed popular science topic. According to a Toutiao survey of users, only 6.23% reported ignorance of AI; 53% expressed support of comprehensive AI development; and 27% held a conservative attitude towards AI development. Concerns included the replacement of jobs by AI and social crises that might be caused if AI is out of control. Overall, the Chinese public has distanced from the extremes of being overly optimistic or overly pessimistic and become more rational about AI. Interest in AI also varies significantly according to application area, age, gender and region.

Social impact: AI is capable of significantly increasing efficiency in different sectors but also poses risks

AI development is transforming the development patterns in different sectors including retail, agriculture, logistics, education and finance and reshaping production, allocation, exchange and consumption. AI is expected to be applied to more industries and bring substantial efficiency increases in the coming five years—specifically, efficiency improvements of 82% for education, 71% for retail, 64% for manufacturing and 58% for finance. AI will facilitate personalized education and promote the development of education. On the other hand, it will pose serious challenges in such aspects as employment, privacy, security and social equality.

Education survey: More AI programs are offered in universities and enthusiastically embraced by students

By July 2017, there were 36 universities approved by the Ministry of Education to offer the bachelor's degree program in "Intelligence Science and Technology" and 79 offering AI-related programs. Top Chinese universities have set up their AI labs. Currently, China's AI teaching and research activities are mainly concentrated in computer science, electronic information and automation faculties of universities. According to an online survey, online platforms have surpassed universities to become the No. 1 channel for young people to take AI courses. Netizens have shown a strong interest in learning AI, with 61% of respondents stating that they devote 10-20 hours a week to AI learning.

Based on existing research and the abovementioned findings of this report, we arrive at the following preliminary judgements and reflections on China's AI development.

Internationally, China ranks in the top echelon of AI development

Unlike in the past industrial revolutions where China was left behind and struggled to catch up, China has got a head start for the fourth industrial revolution. In AI, in fact, China has secured a leading position in the top echelon in both technology development and market applications and is in a race of "two giants" with the U.S.

In terms of the quality of development, China's AI development is far from admitting optimism

China's strengths are mainly shown in AI applications and it is still weak on the front of core technologies of AI, such as hardware and algorithm development, China's AI development lacks top-tier talent and has a significant gap with developed countries, especially the U.S., in this regard.

In terms of participating entities, China's AI companies leave much room for improvement in knowledge production

Research institutions and universities are the main producer of AI knowledge in China. Compared to their foreign counterparts, Chinese AI companies are technologically inventive and far behind domestic universities and research institutions in AI patenting. Even recognized domestic AI giants such as Baidu, Alibaba and Tencent (BAT) don't have an impressive performance in AI talent, papers and patents, while their U.S. competitors like IBM, Microsoft and Google lead AI companies worldwide in all indicators.

In terms of application areas, the integration of AI with energy systems is an important area that has been neglected

Electrical power engineering is an important AI patenting area of China, where SGCC has been the most prominent company in both AI paper publication and AI patenting. The fact that it has been either unmentioned or not highlighted in previous AI studies shows that the integration of AI with energy systems is likely an area that has been more or less neglected and represents a potential new direction of expansion of AI applications in China which will contribute to low-carbon transformation of the energy sector.

In terms of the pattern of development, China needs to strengthen industry-university research collaboration to promote knowledge application and transformation

International collaboration and industry-university collaboration are important means of advancing AI development. In China, a lot of AI knowledge is lying idle at universities and research institutions,

and it is imperative to increase industry-university collaboration to promote AI knowledge application and transformation. Going forward, China needs to not only vigorously promote industry-university collaborative innovation but also explicitly support companies to engage in AI basic research by leveraging their data and computing strengths.

In terms of policy environment, local governments should avoid blindly following suit in AI policymaking

The Chinese society has, overall, a positive and optimistic attitude towards AI development which has a very favorable environment in terms of policy, public opinion, finance, market and talent pool, but at the level of local government policymaking, there has been a tendency of "following the steps of the central government" and "chasing after hot areas". Currently, China's AI policy has emphasized on promoting AI technological development and industrial applications and hasn't given due attention to such issues as ethics and security regulation.

AI: Concept, Methods and Data

01 AI: Concept, Methods and Data

1.1 Concept of AI

AI is already a popular concept, but there is not yet a universally accepted definition for it. The traditional approach to AI development is to study how human intelligence occurs and create machines that imitate human thinking and behavior. John McCarthy, who developed the first modern theory of artificial intelligence, believed that AI machines do not necessarily have to obtain intelligence by thinking like a human and that it is important to make AI solve problems that can be solved by a human brain. Brain science and brain-like intelligence research and machine-learning represented by deep neural networks represent the two main development directions of core AI technologies, with the latter referring to the use of specific algorithms to direct computer systems to arrive at an appropriate model based on existing data and use the model to make judgment on new situations, thus completing a behavior mechanism. While only limited progress has been made in the first direction, tremendous strides have been taken in the second direction so much that machine learning has not only become the main paradigm of AI technology but been equated by some with AI itself. In general, the artificial intelligence we know today is based on modern algorithms, supported by historical data, and forms artificial programs or systems capable of perception, cognition, decision-making and implementation like humans.

1.2 Research Methods and Data

This report examines China's AI development from four perspectives—S&T output and talent input, industry development and market applications, development strategy and policy environment, and public perception and general impact. Bibliometrics and questionnaire survey are the two main research methods used in this study to examine the subject matter from the above perspectives. Bibliometrics refers to the use of mathematical and statistical methods to quantitatively analyze scientific and technological literature. The main objects include literature (various publications), authors (individual, collective or group), and key words (document identifications). In this report, the main objects include AI output (journal articles and technology patents), AI specialists, and policy documents. The questionnaire survey is a method of collecting standardized information from a number of respondents selected to complete the questionnaire with a set of standard questions on a certain phenomenon or subject. This report uses the questionnaire survey method to collect information about public perception and learning of AI. In addition, it draws upon specialized databases to analyze the current status of the AI industry.

The main indicators used in this report and their data sources are as follows:

- **AI Papers**

The dataset for analysis of AI research in this report is mainly based on data retrieved from Clarivate Analytics' Web of Science database using a list of AI keywords provided by experts which includes not only generic AI terms like "Artificial Intelligence" and "Machine Learning" but also specific AI technology categories such as "Natural Language Processing", "Computer Vision", "Facial Recognition", "Image Recognition", "Speech Recognition", "Semantic Search", "Semantic Web", "Text Analytics", "Virtual Assistant", "Visual Search", "Predictive Analytics"

and “Intelligent System” and additional author keywords of the highly cited papers identified by the search using the provided list of AI keywords and author keywords of the references of the highly cited papers, with the author keywords used being validated by experts.

As this part focuses on AI technology development, the search is limited to the three science-related databases of the Web of Science Core Collection: Science Citation Index Expanded (SCIE); Conference Proceedings Citation Index-Science; and Book Citation Index-Science.

As academic conferences are also an important part of AI research activity, the dataset draws on proceeding papers from representative academic conferences on AI (see Appendix 1). In addition, it includes papers in the “Computer Science, Artificial Intelligence” category of Web of Science (see Appendix 2: Category Description).

The dataset, with data from the abovementioned three sources combined, consists of a total of 1,875,809 qualifying papers (data retrieved on April 26, 2018, with no time or document type restriction) and provides the basis for data analysis in this study.

- **AI Patents**

The patent data in this report is from the Derwent World Patents IndexTM (DWPI) database, retrieved according to the scope (patent publication years 1997–2017 and patent citation time up to May 2018) determined based on the artificial intelligence (AI) keywords provided by experts, as refined by addition of keywords in related fields which fall under the thematic scope determined using Derwent Manual Codes for AI selected by experts. The Derwent Innovation patent database and Derwent Data Analyzer are used to perform multi-perspective analysis of the patent data. The results of multi-perspective analysis presented in this report are mainly based on patent-based records, which represent the current actual number of patents published, with other results being from analysis of patent records as deduplicated and rearranged according to their application numbers or patent families.

This report merged and deduplicated the application numbers of the patent-based records, where patent publication/grant numbers (i.e. multiple patent-based records) with the same underlying patent are merged as one patent record according to application number, so that each patent record retrieved after such merger represents one patent and, therefore, the number of patent applications in a given technological field can be determined.

- **AI Talent**

In this part, the paper and patent keyword list generated from Clarivate Analytics’ Web of Science database and validated by experts are used to search ScientistIn’s international and domestic expert databases. ScientistIn’s international expert database is sourced from expert pages of Research Gate and Google Scholar with data cleansing and formatting and consists of valid information relating to about 6.5 million experts. ScientistIn’s domestic expert database is sourced from heterogeneous data sources including Baidu Scholar, CNKI, NSFC Project Database and China Patent Full-text Database with formatting, deduplication and heterogeneous data matching and consists of valid information about 11 million experts. On this basis, AI experts are identified and marked according to their AI paper, patent and research area records to generate expert profiles based on label cloud and others.

International AI specialist data are obtained by matching the AI keyword list against ScientistIn’s international expert database to generate a dataset

of experts that match at least one keyword.

Chinese AI specialist data are obtained by matching the AI keyword list against ScientistIn's domestic expert database to generate a dataset of experts that match at least one keyword.

- **AI Industry Data**

AI industry data are sourced from the data monitoring platform and industry research of CAICT Data Research Center. The data monitoring platform maintained by data experts monitors and collects data from more than 100 heterogeneous data sources including ICT news sources (Telecompaper, CNET, 36kr, etc.), major venture capital databases (CB insights, Crunchbase, etc.), venture capital websites (itjuzi.com, cyzone.cn, etc.) and the industry and commerce administration databases. The platform tracks industry developments, constructs an ICT enterprise monitoring platform, generates an enterprise basic information database, and supports statistical and research analysis by industry experts.

The AI enterprises covered by this report are those enterprises that have the provision of AI products, services and related solutions as their core business. They can be divided into those that focus on AI technologies and those that focus on products/solutions. The former category includes providers and manufacturers of algorithms, basic hardware and voice and vision generic technologies and the latter category includes manufacturers and solution providers whose products/solutions include AI products and solution providers in various vertical industries (see Appendix 3).

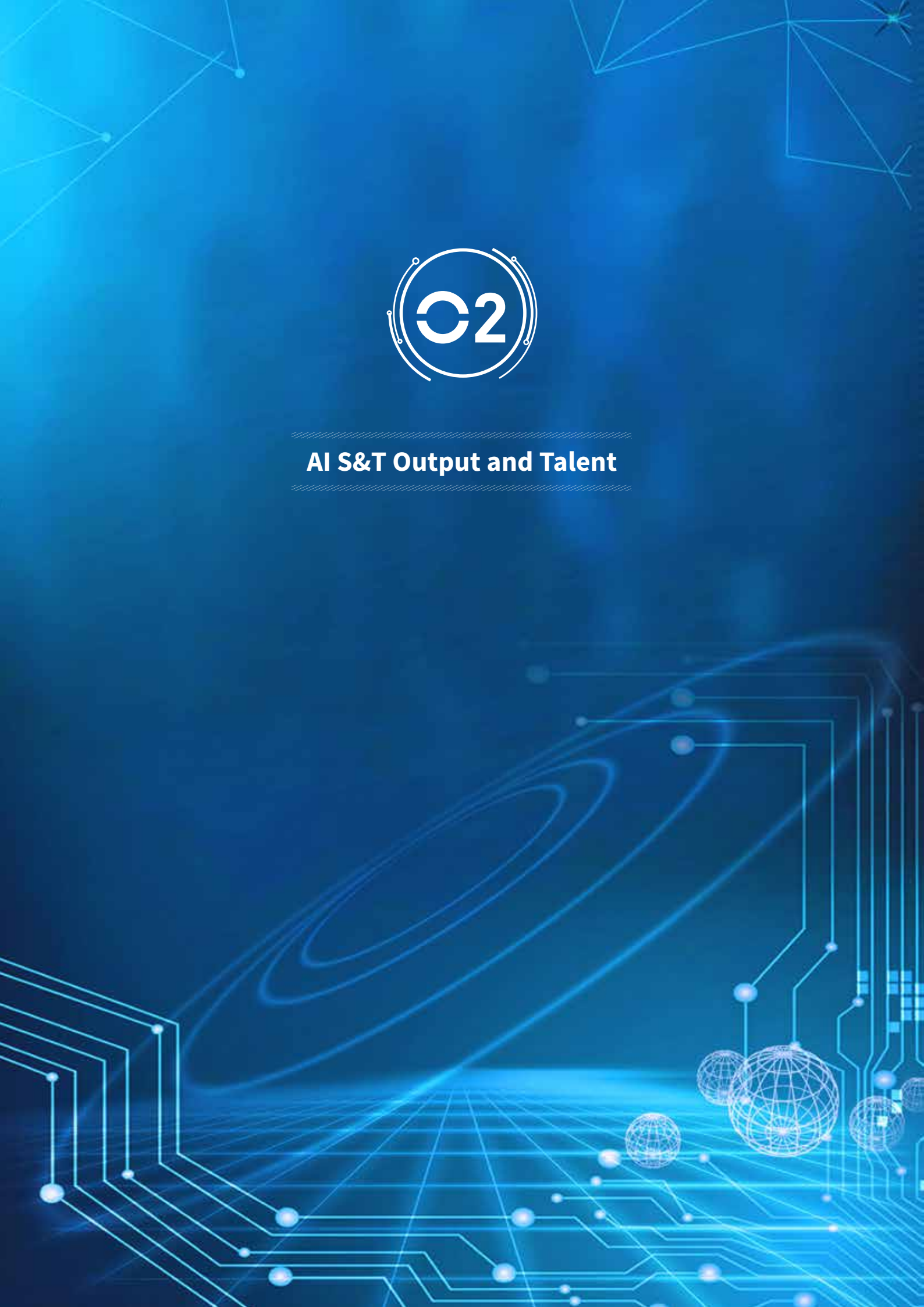
- **AI Policy Data**

The AI keyword list generated from Clarivate Analytics' database and validated by experts is further supplemented and refined with new additions, validated by experts, from policy documents containing any of the keywords in the list in the Government Documents Information System of Tsinghua University School of Public Policy and Management, to form an expanded AI keyword list. Finally, the expanded AI keyword list is used for information retrieval to create an AI policy dataset for analysis, which includes 27 international policy documents (9 for the United States, 5 for the European Union, 5 for Germany, 4 for the United Kingdom, 2 for France, 1 for Russia, 2 for Japan, and 1 intergovernmental document for Germany and France) and 1,047 Chinese AI policy documents. The data are as of May 15, 2018 (see Appendix 5).

- **AI Public Perception and Education Survey**

The research on public perception of AI is mainly based on the survey conducted by Bytedance of users on its Toutiao news aggregation platform. The survey was conducted from May 9 to 13, 2017 and collected a total of 3,088 valid samples. In addition, Toutiao Index tracked the AI interest differences by industry, user and region from January 1 to December 30, 2017.

The AI education questionnaire was designed by CISTP and implemented via the WJX platform. WJX, which has a daily visitor traffic of more than 500,000, recommended the questionnaire to its visitors for completion. As of May 15, 2018, a total of 1,154 valid responses were collecte



AI S&T Output and Talent

02 AI S&T Output and Talent

2.1 AI Paper Output

Definitions of key indicators:

Highly Cited Paper: *Highly Cited Papers are papers that perform in the top 1% based on the number of citations received when compared to other papers published in the same ESI field*[1] *in the same year.*

Hot Paper: *Hot Papers are papers published in the last two years that have been cited enough times in the most recent bimonthly period to place them in the top 0.1%.*

Top Paper: *Top Papers refer to the sum of highly cited papers and hot papers.*

2.1.1 Paper Output: World and China

The trajectory of global output of AI scientific papers began to take an upward swing from the early 1990s and remarkably more steeply in the late 1990s and then slightly went downward in 2010 before continuing the upward movement stably afterwards. In recent years, there have been over 100,000 papers published on AI every year. Papers published in this field as a percentage of all papers published globally in the same period have shown a similar pattern, pointing to the fact that as researchers have taken an increasing interest in artificial intelligence, relevant research results being publicized and published have been increasing as well.

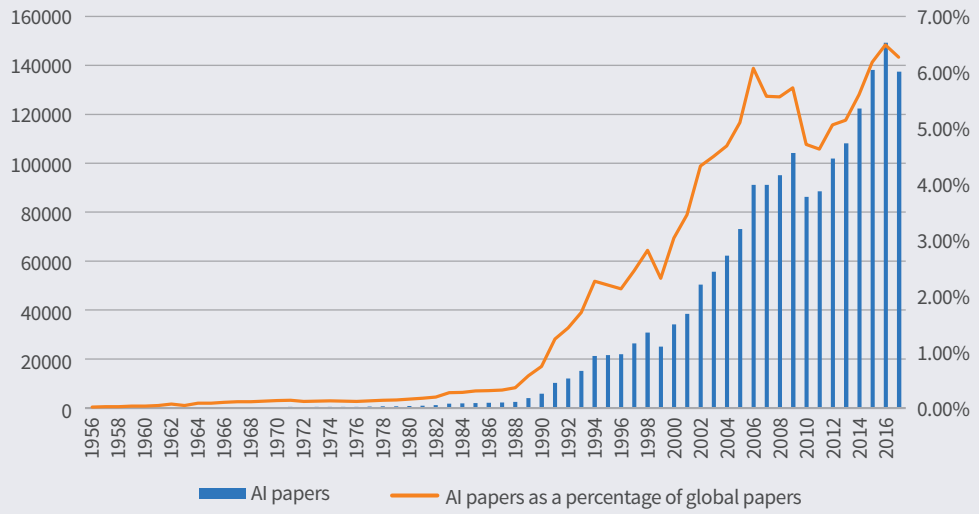


Figure 2-1 AI papers published and as a percentage of global scientific paper output from 1956 to 2017

It was found that 58.64% of AI papers were proceeding papers, showing that proceeding papers are important sources of AI research output. Articles were also significantly represented, accounting

[1] Journals included in the Web of Science Core Collection fall within 22 subject categories, i.e. ESI fields.

for 42.49% of all AI papers. Based on the above analysis, this report selected the AI-related proceeding papers, articles, reviews and book chapters published between 1997 and 2017 as the main basis for analysis [2].

In the past two decades, China (including Hong Kong and Macao) has made giant strides in AI scientific paper output, with papers published in the field increasing from more than 1,000 in 1997 to greater than 37,000 in 2017, and the percentage of the global total increasing from 4.26% in 1997 to 27.68% in 2017 (Figure 2-2).

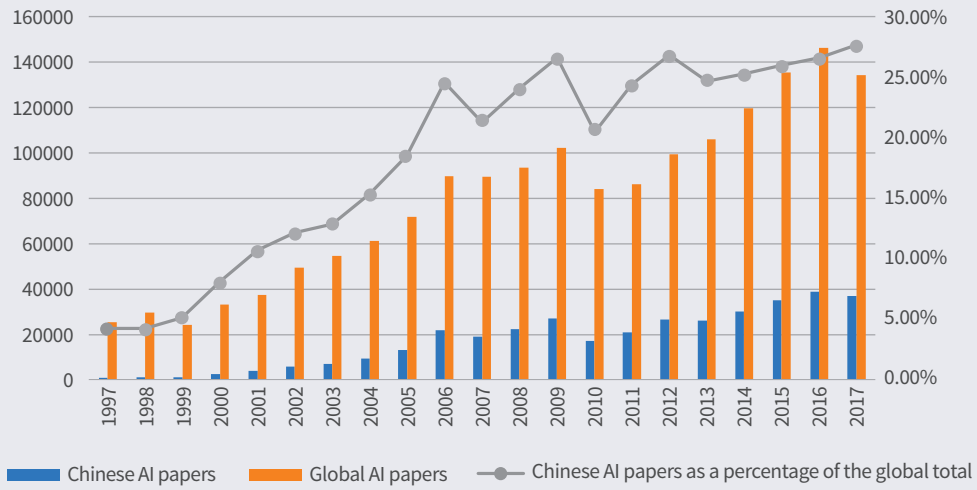


Figure 2-2 China's AI paper output and as a percentage of the global total from 1997 to 2017

As shown in the figure above, China's AI scientific papers experienced a certain decline in around 2007 and 2010 in terms of both quantity and percentage of the global total. China's output of articles and reviews has maintained an overall upward trend over the last 20 years, except a decline in 2007; in contrast, China's output of proceeding papers experienced remarkable fluctuations in a trajectory which was consistently upward before 2006 and began zigzagging afterwards, especially in 2010 when it dropped by nearly 50% from the previous year. The significant percentage of proceeding papers in all AI papers provides a partial explanation of the significant slide of paper output in 2010 in Figure 2-2. (Figure 2-3)

[2] Note: Proceeding papers and book chapters that were published in SCIE journals are also marked as articles and therefore correspond to two document types. As a result, the sum in the above figure is more than 100%.

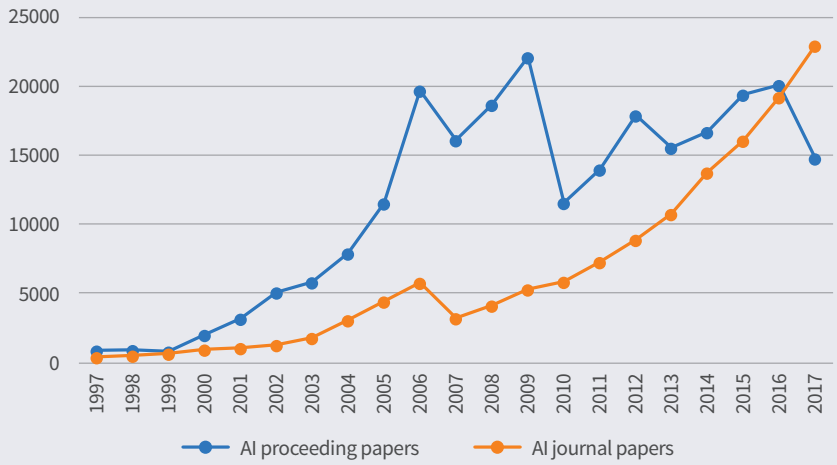


Figure 2- 3 Trend of China's AI paper output by document type

The last 20 years have seen an increasing number of countries and regions participate in basic research of AI in a race where China and the USA have ranked first and second, respectively, in terms of paper output, each with an output that is more than three times that of the United Kingdom in the third place (Figure 2-4). China and the USA are in the top echelon, followed by the United Kingdom, Japan, Germany, India, France, Canada, Italy, Spain, South Korea, Taiwan and Australia in the second echelon, and Iran, Brazil, Poland, Netherlands, Turkey, Singapore and Switzerland in the third echelon with rather strong output of AI papers.

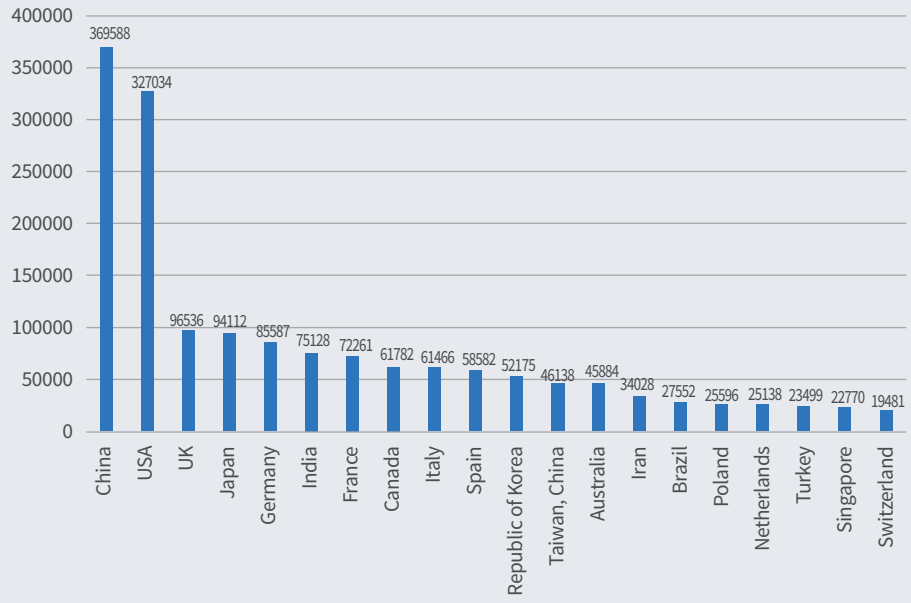


Figure 2-4 Top 20 countries/regions in AI paper output (1997-2017)

Judging from the development trajectory (Figure 2-5), the USA had been consistently in the first place in paper output before 2005, and ahead of other countries by a big margin. China's paper output

was only higher than that of India among the eight countries in 1997 but developed very fast and overtook the USA for the first time to take the first place globally in 2006. In spite of slight declines in 2007 and 2010 after that, China has remained in the lead and left the USA further behind. India, which was always at the bottom, has since 2011 picked up rapidly, and became the third largest country—after China and the USA—in terms of AI paper output in 2013, an advantage it had maintained to 2017.

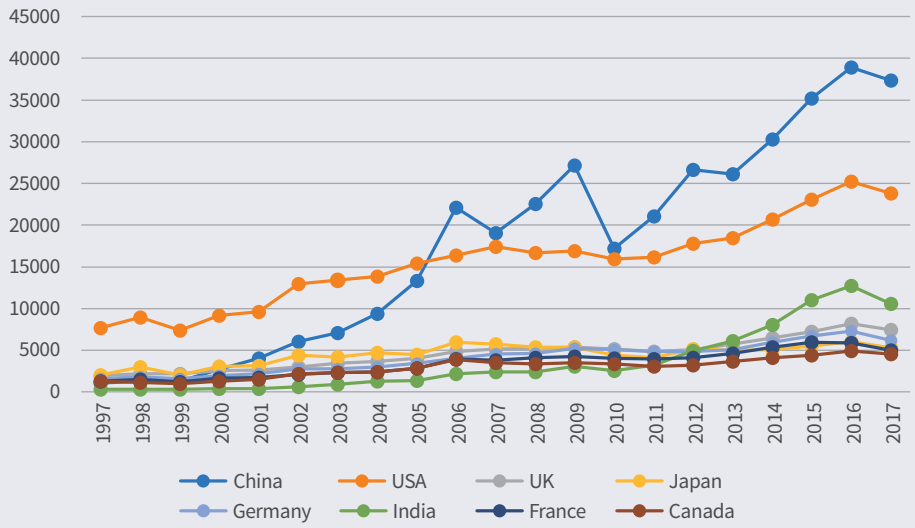


Figure 2-5 Trends of the Top 8 countries in AI paper output

In terms of institutions, Chinese Academy of Sciences (CAS), French National Center for Scientific Research (CNRS) and University of California System are the top three institutions to have published the greatest number of AI papers over the past two decades, each having more than 24,000 papers to their credit (Figure 2-6).

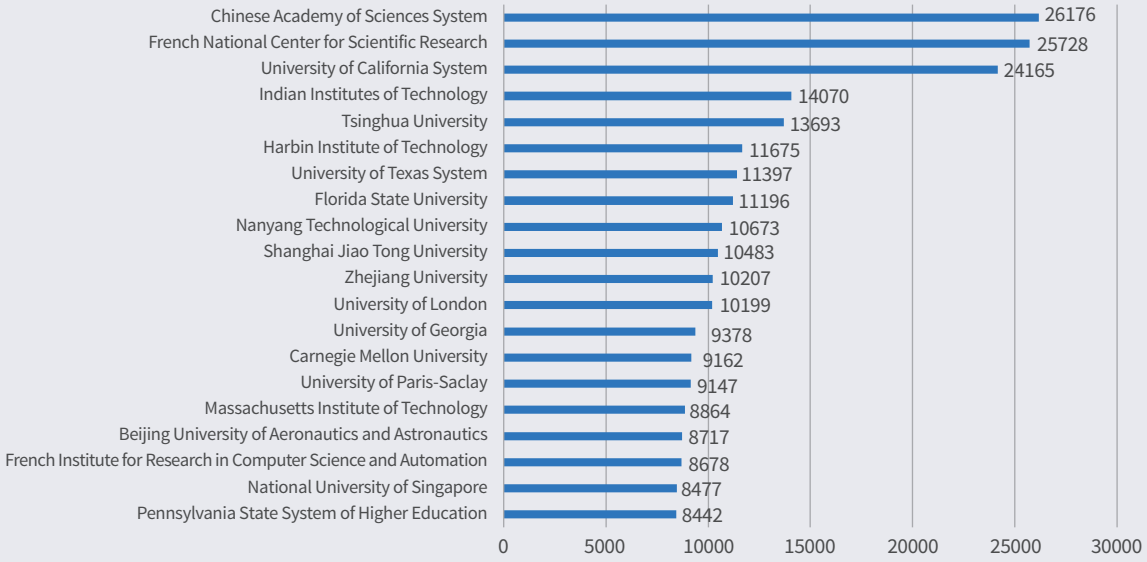


Figure 2-6 The world's top 20 institutions in AI paper output

Among the top 100 institutions in AI scientific output, there are 87 universities, 8 research institutions, 3 government agencies, and only 2 enterprises. The three government agencies are the U.S. Department of Energy, the U.S. Department of Defense and the National Aeronautics and Space Administration (NASA); and the two enterprises are IBM and Microsoft.

Figure 2-7 shows the top 20 research institutions in AI scientific output. Among them, CAS and CNRS were in the clear lead, with CAS' Institute of Software being also in the top 20. France, Germany and the USA featured prominently in this top 20 list, each with three research institutions gracing the list.

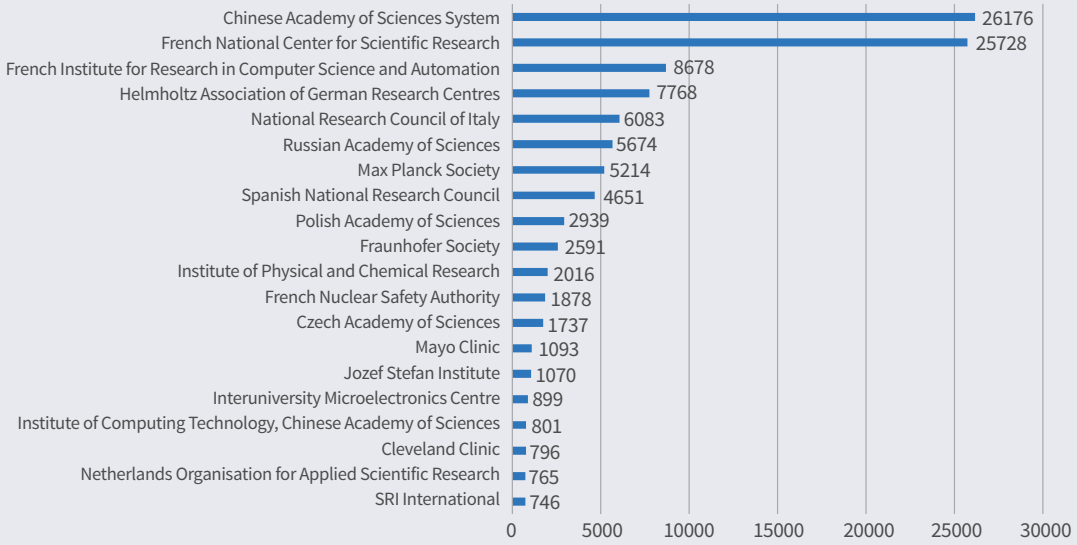


Figure 2-7 The world's top 20 research institutions in AI paper output

The top 10 government agencies in AI scientific output are all from the USA, including government departments such as Department of Defense and Department of Energy as well as funding institutions such as National Institute of Health and national laboratories, reflecting the USA's strong interest and active involvement in AI research at the government level (Figure 2-8).

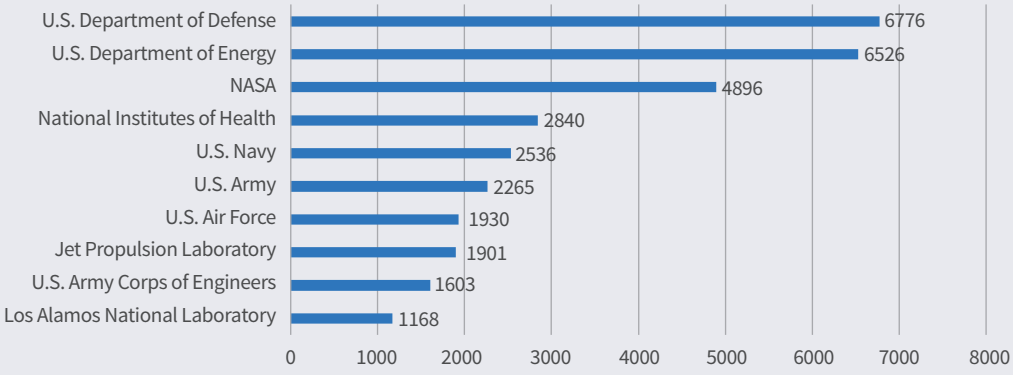


Figure 2-8 The world's top 10 government agencies in AI paper output

Many enterprises worldwide have also actively involved in basic research of AI over the last 20 years. Figure 2-9 shows the top 20 enterprises in AI paper publication, with IBM and Microsoft leaving others far behind in AI paper output. Companies such as Siemens, Samsung, Google and Intel have also yielded a significant number of AI papers.

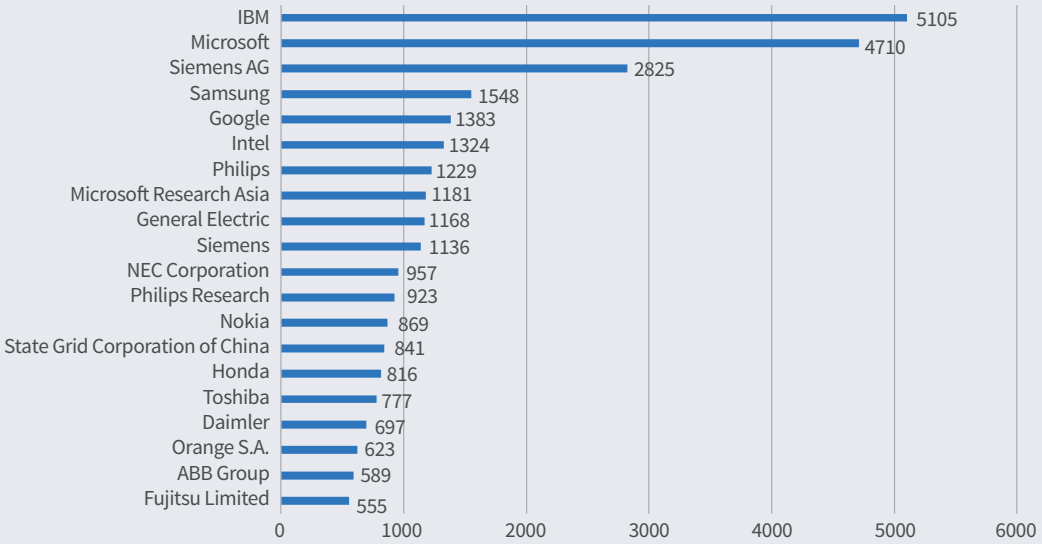


Figure 2-9 The world's top 20 enterprises in AI paper output

Many Chinese institutions have been very active in AI research over the last 20 years as well. The top twenty of them are shown in Figure 2-10. Chinese Academy of Sciences, the only research institution in the top 20 (the others are all universities), leads the list with more than 26,000 AI papers, followed by Tsinghua University, Harbin Institute of Technology, Shanghai Jiao Tong University and Zhejiang University, each having more than 10,000 papers to their credit. The top 20 list also featured three universities from Hong Kong - Hong Kong Polytechnic University, City University of Hong Kong and Chinese University of Hong Kong.

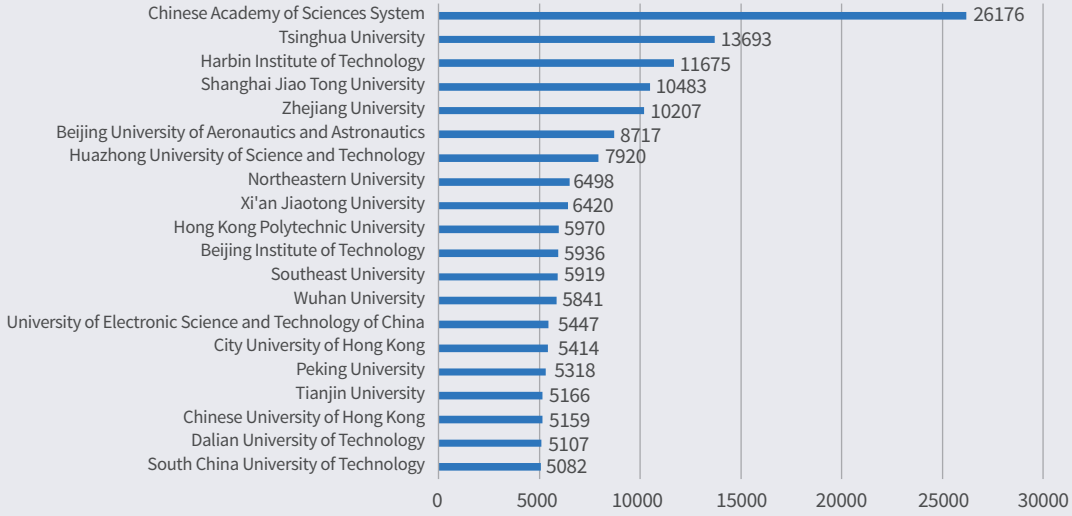


Figure 2-10 China's top 20 institutions in AI paper output

In terms of subject category[3], COMPUTER SCIENCE and ENGINEERING are the top two subject categories of AI research worldwide and in the top eight countries as well. AUTOMATION CONTROL SYSTEMS is the third-ranked subject category of AI research worldwide and in the top eight countries other than India whose third-ranked subject category of AI research is TELECOMMUNICATIONS. In addition, ROBOTICS, MATHEMATICS and IMAGING SCIENCE & PHOTOGRAPHIC TECHNOLOGY are also remarkably focused on by the top eight countries. The countries differ in their AI research strengths and priorities. Developed countries such as the USA, the United Kingdom, Japan, Germany, France and Canada have applied AI to NEUROSCIENCES & NEUROLOGY; India to ENERGY & FUELS because of energy shortage; and China to the manufacturing materials of energy management (battery system), robotics and other systems and components, leveraging its strengths in MATERIALS SCIENCE.

Table 2-1 Distribution of subject categories of AI research worldwide and in top 8 countries

Rank	Worldwide	China	United States	United Kingdom	Japan	Germany	India	France	Canada
1	Computer science	Computer science	Computer science	Computer science	Computer science	Computer science	Computer science	Computer science	Computer science
2	Engineering	Engineering	Engineering	Engineering	Engineering	Engineering	Engineering	Engineering	Engineering
3	Automation and control systems	Automation and control systems	Automation and control systems	Automation and control systems	Automation and control systems	Automation and control systems	Telecommu-nications	Automation and control systems	Automation and control systems
4	Robotics	Telecommu-nications	Robotics	Robotics	Robotics	Robotics	Automation and control systems	Robotics	Robotics
5	Telecommu-nications	Imaging science and photographic technology	Imaging science and photographic technology	Mathematics	Imaging science and photographic technology	Mathematics	Imaging science and photographic technology	Mathematics	Imaging science and photograph-ic technology
6	Imaging science and photographic technology	Robotics	Mathematics	Imaging science and photographic technology	Telecommu-nications	Imaging science and photographic technology	Energy and fuel	Imaging science and photographic technology	Telecommu-nications
7	Mathematics	Materials science	Telecommu-nications	Neurology and neuropsychol-ogy	Instruments and meters	Neurology and neuro-psychology	Mathematics	Telecommu-nications	Mathematics
8	Operations research and management science	Mathematics	Optics	Telecommuni-cations	Neurology and neuro-psychology	Telecommu-nications	Robotics	Physics	Neurology and neuro-psychology
9	Instruments and meters	Operations research and management science	Neurology and neuro-psychology	Computation-al Biology	Mathematics	Physics	Other tech-nology	Operations research and management science	Operations research and manage-ment science
10	Physics	Instruments and meters	Operations research and management science	Other technol-ogy	Physics	Biochemistry and molecu-lar biology	Materials science	Neurology and neuro-psychology	Energy and fuel

[3] Note: The Web of Science platform classifies research areas into five broad categories— Arts Humanities, Life Sciences Biomedicine, Physical Sciences, Social Sciences and Technology—which are further divided into a total of 154 subject categories (Refers to http://images.webofknowledge.com//WOKRS529AR7/help/WOS/hp_research_areas_easca.html)

2.1.2 High-impact Papers: World and China

The simple logical relations between articles (citing articles) and their references (cited references) provide the basis and background of the citation analysis. Citations underscore the value of previous research work to the current research and, therefore, papers that are more frequently cited are considered as having a higher impact[4]. Figure 2-11 shows the global distribution of top papers on AI, which highlights North America, West Europe and East Asia as the main sources of the top papers.

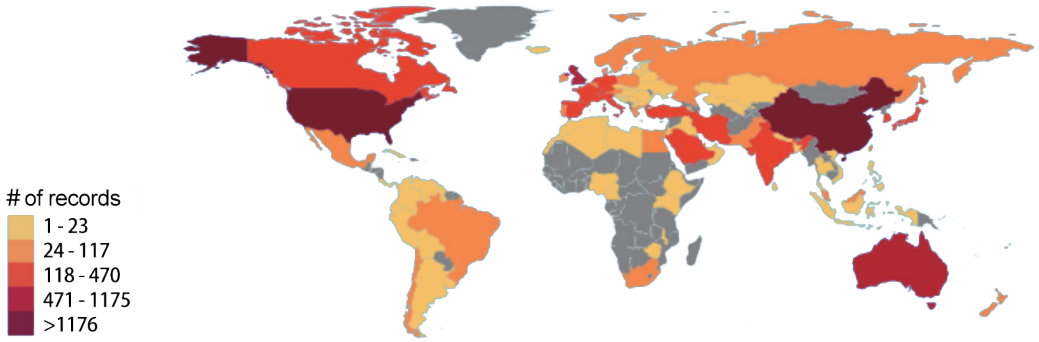


Figure 2-11 Global distribution of top papers on AI

Table 2-2 shows the quantities of highly cited papers and hot papers of the top 10 countries in AI paper output. China, the USA and the United Kingdom rank in the top 3, with Iran, the only western Asian country in the list, ranking eighth. In terms of their highly cited papers on AI as a percentage of their total papers on AI, all the top 10 countries beat the global average of 1%, with Australia ranking first in this indicator with 2.66%, followed by the United Kingdom and China whose percentages are both more than twice the global average. In terms of absolute figures, China, the USA and the United Kingdom retain their lead in hot papers as well. All the top 10 countries outperformed the global average of 0.1% in their hot papers on AI as a percentage of their total papers on AI, with Australia and China leading this indicator neck to neck with 0.7%, seven times the global average. Noteworthily, Australia, while not prominent in its total number of AI papers published in the last decade, performed prominently in the output of top papers. In addition, Japan and India, ranking 4th and 6th respectively in total AI paper output as shown in Figure 2-4, did not make into the top ten in terms of the output of top AI papers, in which indicator Japan ranks 19th and India 14th.

[4] Evidence Ltd. (2002) Maintaining Research Excellence and Volume: A report by Evidence Ltd to the Higher Education Funding Councils for England, Scotland and Wales and to Universities UK. (Adams J, et al.) 48pp.

Table 2-2 Top 10 countries in output of top papers on AI

	Highly Cited Papers	Percentage (%)	Hot Papers	Percentage (%)
China	2349	2.01	81	0.07
United States	2241	1.94	55	0.05
United Kingdom	811	2.17	23	0.06
Australia	472	2.66	13	0.07
Germany	431	1.57	12	0.04
Canada	397	1.73	10	0.04
France	354	1.46	6	0.02
Iran	271	1.28	5	0.02
Italy	253	1.12	7	0.03
Spain	247	1.03	4	0.02

Figure 2-12 shows the trends of the output of highly cited papers from the top 10 countries. It can be seen that the USA has been stable in the output of highly cited papers with a slight decline in recent years, versus the steady steep upward movement of China which overtook the USA for the first time in 2013 to rank first in the world. Australia, which has the highest percentage of highly cited papers on AI in its total papers on AI, has achieved a further modest growth in recent years. Iran, the only western Asian country in the top 10 list, has also registered a remarkable growth in the output of highly cited papers.

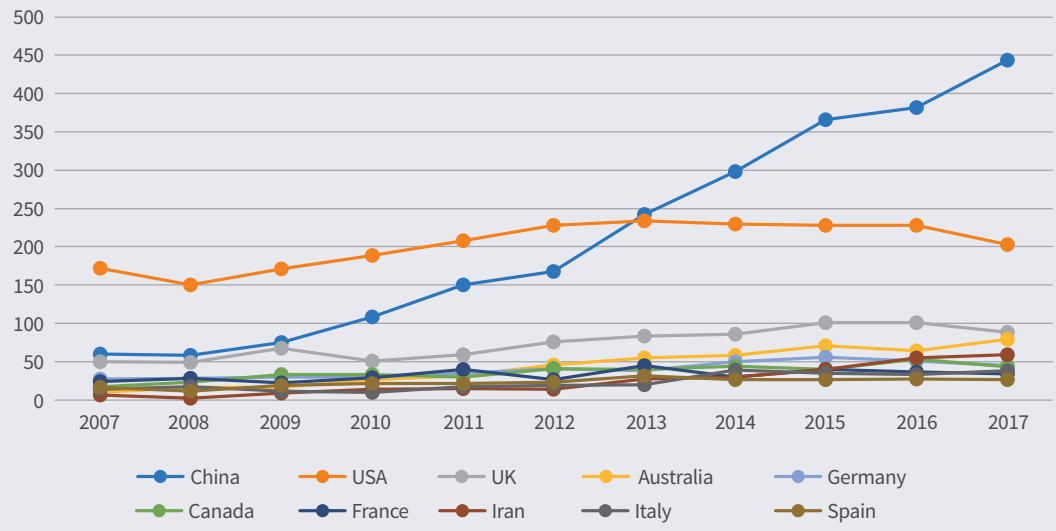


Figure 2-12 Trends of the output of highly cited AI papers of the top 10 countries

In the basic research of AI, global collaboration is indispensable. Figure 2-13 shows the collaboration graph of the top 10 countries with the greatest output of top papers on AI, where the size of a node represents the quantity of a country's output of top papers and the thickness of a line represents the

number of top papers from collaboration between the two countries connected by the line. It can be seen from the collaboration graph that China has published significant number of top papers in collaboration with such countries as the USA, the United Kingdom and Australia and that the USA has also published fairly large quantities of top papers in collaboration with the United Kingdom and Germany.

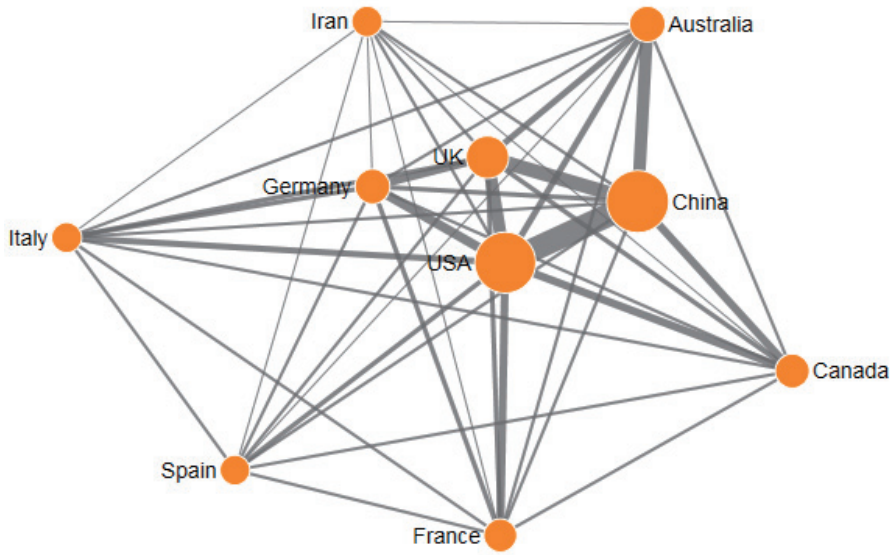


Figure 2-13 Collaboration network of the top 10 countries in the output of top papers on AI

Generally, papers yielded by international collaborative research tend to have a higher impact, as attested by Table 2-3 where international collaborative research papers on AI represent 23.42% of all AI papers but as high as 42.64% of all top papers on AI and even more than 50% of all top papers on AI of the top 10 countries with the greatest output of top papers on AI. The percentage is high at 53% for China and is even more than 80% for Australia and Germany.

As AI lends itself profitably to industrial application, a significant number of top papers was yielded by collaboration with enterprises. Compared to a global benchmark of 1.83% of industry collaborative papers as a percentage of all top papers, the percentage for the AI subject category is 3.7%, more than double the overall global benchmark. Among the top ten countries, France has the highest percentage of industry collaborative papers at 8.17%, versus more than 5% for Germany, the USA, the United Kingdom and Spain, and 2.55% for China.

Table 2-3 Representation of collaborative papers in top 10 countries' top AI papers

	Percentage of Internationally Collaborative Papers (%)	Percentage of Industry Collaborative Papers (%)
Reference Value of International Papers	23.42	1.83
Reference Value of International Top Papers	42.64	3.7
China	53	2.55
United States	53.94	6.99
United Kingdom	76.38	6.03
Australia	81.82	3.59
Germany	80.65	7.83
Canada	72.5	4.75
France	76.9	8.17
Iran	50.18	0.74
Italy	75.98	3.94
Spain	71.66	5.67

An institution's output of top papers reflects its influence in the field of research. Table 2-4 lists the top 20 institutions with the greatest output of top papers on AI, where University of California System in the USA ranks first with 337 highly cited papers and 6 hot papers, closely followed by Chinese Academy of Sciences and Harbin Institute of Technology in China. The USA occupies 7 spots in the top 20 list, followed by China with six, Singapore with two and Saudi Arabia, France, the United Kingdom, Iran and Germany with one each.

Table 2-4 The world's top 20 institutions with the greatest output of top papers on AI

Institution	Highly Cited Papers	Hot Papers	Country/Region
University of California System	337	6	United States
Chinese Academy of Sciences System	242	7	China
Harbin Institute of Technology	189	9	China
Harvard University	164	7	United States
King Abdulaziz University	136	6	Saudi Arabia
French National Center for Scientific Research	133	0	France
Southeast University	131	5	China
Nanyang Technological University	125	0	Singapore
University of London	122	2	United Kingdom
University of Texas System	115	2	United States
Massachusetts Institute of Technology	112	2	United States
Tsinghua University	110	2	China
City University of Hong Kong	106	1	Hong Kong
Stanford University	104	2	United States
U.S. Department of Energy	96	1	United States
National University of Singapore	93	0	Singapore
Islamic Azad University	91	1	Iran
Hong Kong Polytechnic University	88	1	Hong Kong
Max Planck Society	88	3	Germany
University of California, Berkeley	87	3	United States

Many enterprises have also yielded a remarkable number of high-impact papers. Microsoft, Microsoft Research Asia, and Google, have each published more than 20 top papers (Table 2-5).

Table 2-5 The world's top 13 enterprises with the greatest output of top papers on AI

Enterprise	Highly Cited Papers	Hot Papers
Microsoft	64	2
Microsoft Research Asia	27	1
Google	23	3
IBM	18	0
Siemens AG	13	0
Intel	10	0
Roche	8	1
Samsung	7	0
GlaxoSmithKline	7	0
Novo Nordisk	6	2
Toshiba	6	0
General Electric	6	0
Honda Motor	6	0

Table 2-6 lists Chinese institutions with the greatest output of top papers on AI, led by Chinese Academy of Sciences with 242 highly cited papers and 7 hot papers, followed by Harbin Institute of Technology, Southeast University of China, Tsinghua University and City University of Hong Kong in the top five. It merits noting that Liaoning University of Technology and Bohai University, though not high in total output, still made into the China top 20 list thanks to a high percentage of top papers.

Table 2-6 China's top 20 institutions with the greatest output of top papers on AI

Institution	Highly Cited Papers	Hot Papers
Chinese Academy of Sciences System	242	7
Harbin Institute of Technology	189	9
Southeast University	131	5
Tsinghua University	110	2
City University of Hong Kong	106	1
Hong Kong Polytechnic University	88	1
Huazhong University of Science and Technology	86	2
University of Electronic Science and Technology of China	77	4
Liaoning University of Technology	71	4
Northwestern Polytechnical University	67	5
Peking University	65	2
Northeastern University	65	1
Zhejiang University	64	2
Xi'an Jiaotong University	64	1
Shanghai Jiao Tong University	63	0
Central South University	60	1
Nanjing University of Science and Technology	58	1
South China University of Technology	57	5
Xidian University	55	1
Bohai University	53	0

2.1.3 Paper Citation: World and China

Authors, institutions and countries behind top papers on AI have made important contributions to AI development, which is carried forward by their citing articles that do further research on the technologies, data and theories put forward by the top papers, even though the citing articles themselves are not top papers.

Figure 2-14 shows the top 20 countries with the highest output of articles citing top papers on AI, with the USA outperforming China with more than 210,000 citing articles to take the first place, indicating the importance attached by the USA to subsequent research in the field.

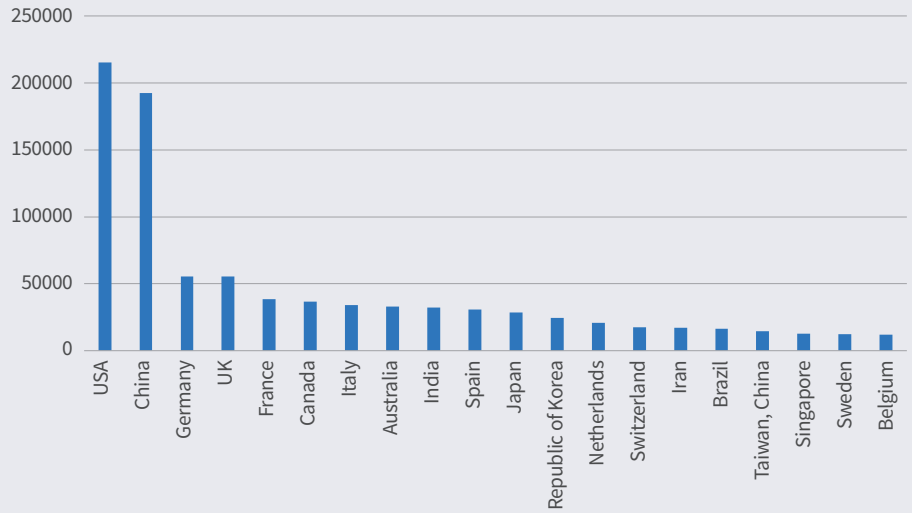


Figure 2- 14 Top 20 countries and regions with the highest output of articles citing top papers on AI

Figure 2-15 and Figure 2-16 show the top institutions with the highest output of articles citing top papers on AI worldwide and in China. Chinese Academy of Sciences, Tsinghua University, Shanghai Jiao Tong University and Zhejiang University lead the China list and are featured in the worldwide list as well.

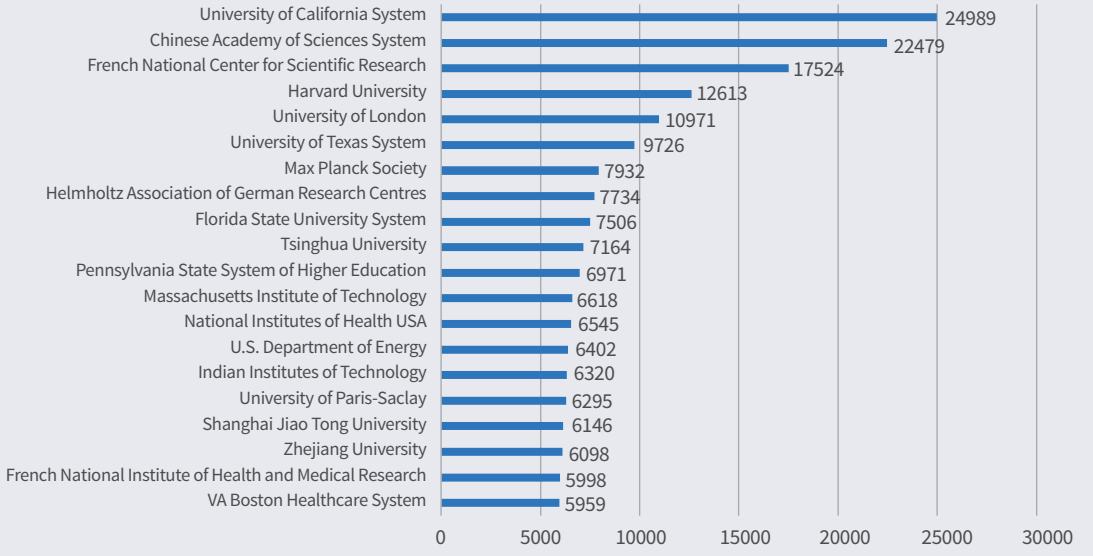


Figure 2-15 Top 20 institutions with the highest output of articles citing top papers on AI worldwide

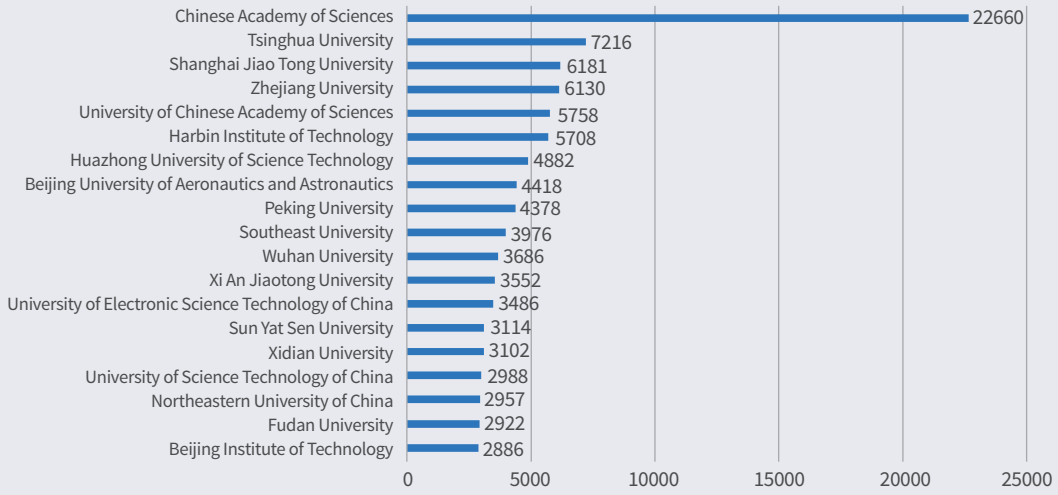


Figure 2-16 Top institutions with the highest output of articles citing top papers on AI in China

Figure 2-17 shows the top 20 subject categories with the greatest number of articles citing top papers on AI, with the top-ranked categories including ENGINEERING, COMPUTER SCIENCE, BIOCHEMISTRY MOLECULAR BIOLOGY, AUTOMATION CONTROL SYSTEMS, and NEUROSCIENCES NEUROLOGY, reflecting the interdisciplinary nature of AI research.

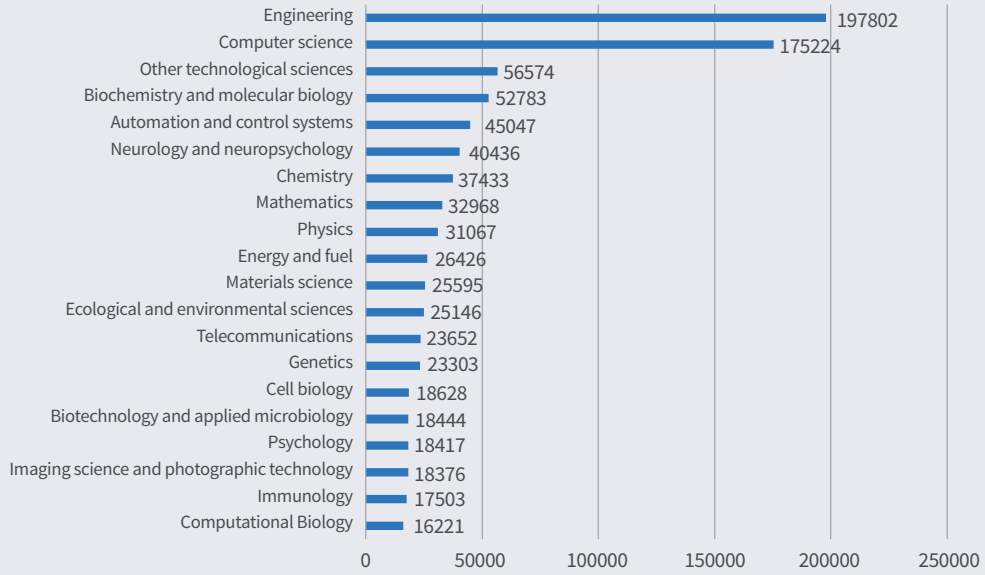


Figure 2-17 Top 20 subject categories with the greatest number of articles citing top papers on AI

Figure 2-18 and Figure 2-19 are overlay maps visually representing the trends of high-frequency keywords of top papers on AI worldwide and in China. The text analysis of high-frequency words is based on word co-occurrence, where the closer two words are to each other, the higher the frequency

of their co-occurrence is. The overlay maps feature words with a high frequency of co-occurrence, where words that are closer to red appeared more recently, and those that are closer to blue appeared earlier. The co-occurring keywords can provide valuable inputs for analysis of the evolving of hot areas of AI research. The figures indicate different focuses of global top AI papers and China's top AI papers in recent years, with the former focusing on a wide range of fields such as deep learning, neural network, adaptive control, optimization, smart grid and big data, while the latter on a fewer areas such as adaptive control, neural network, and big data.

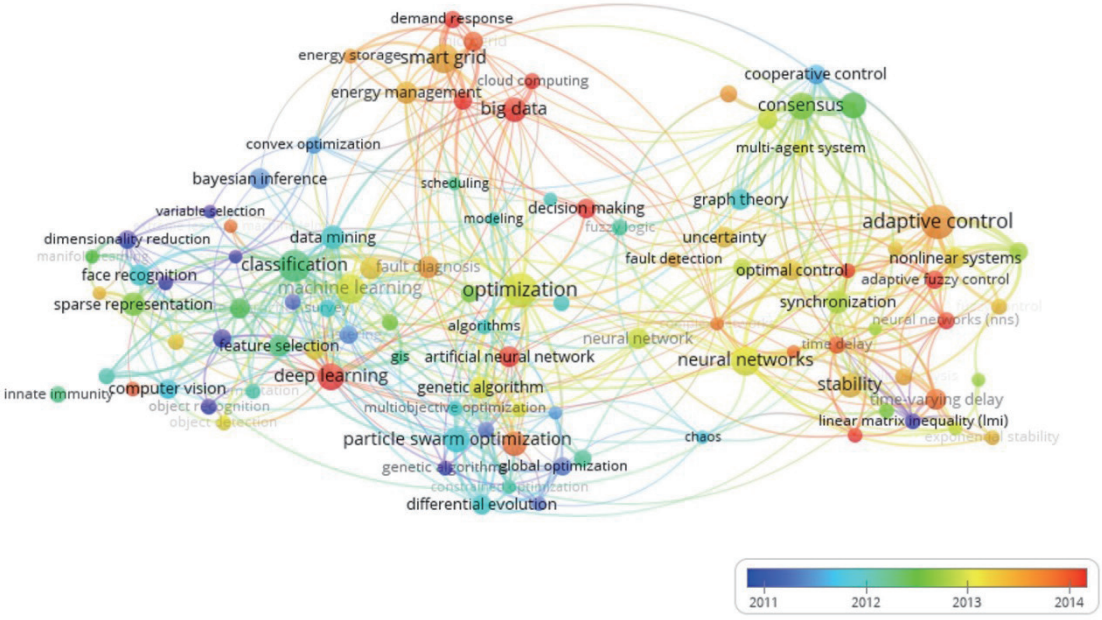


Figure 2-18 Keyword co-occurrence analysis of global highly cited AI papers from 2007 to 2017

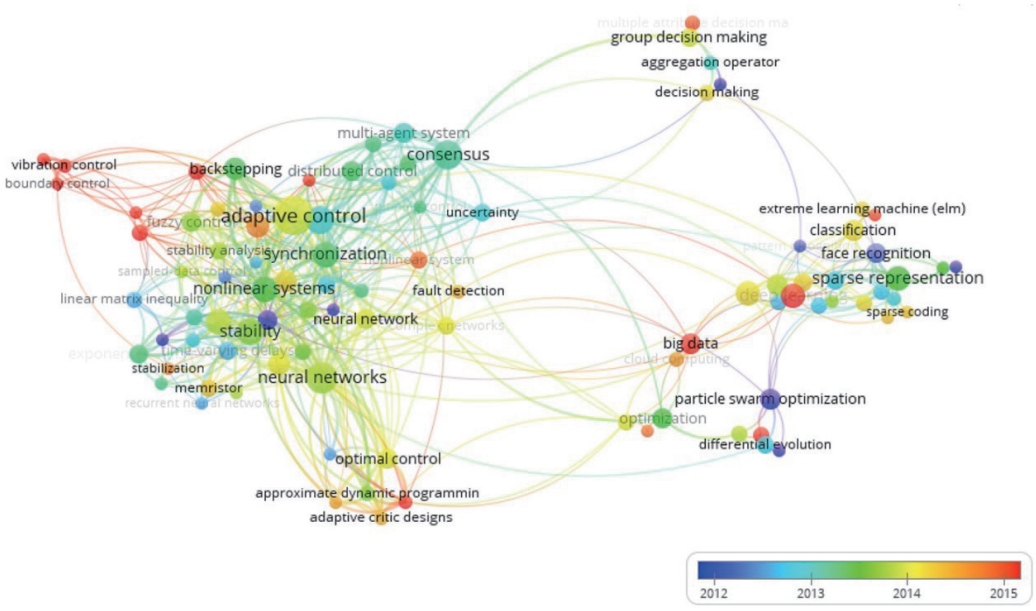


Figure 2-19 Keyword co-occurrence analysis of China's highly cited AI papers from 2007 to 2017

2.2 AI Patent Output

2.2.1 Global AI Patent Output

- **Trend of patent applications:**

Figure 2-20 shows the trend of patent applications in AI, indicating an overall upward trend on an application number consolidation basis over the last nearly 20 years, which peaked in 2016 with a total of more than 52,000 patent applications.

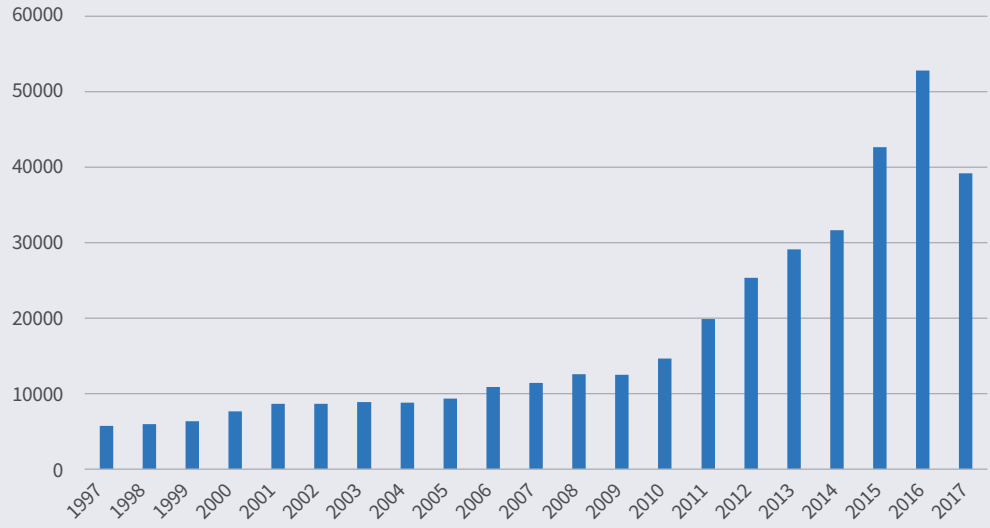


Figure 2-20 Trend of AI patent applications

- **Main assignees**

In DWPI database, the assignee of each patent document is designated with a four-letter code. The assignee code is generally based on the assignee's name. An analysis of the number of patents published by assignees revealed through Derwent assignee codes identified the companies that have the greatest number of AI patents, i.e. leaders in AI, including Chinese and foreign companies such as IBM, Microsoft, State Grid Corporation of China (SGCC) and Samsung (Figure 2-21).

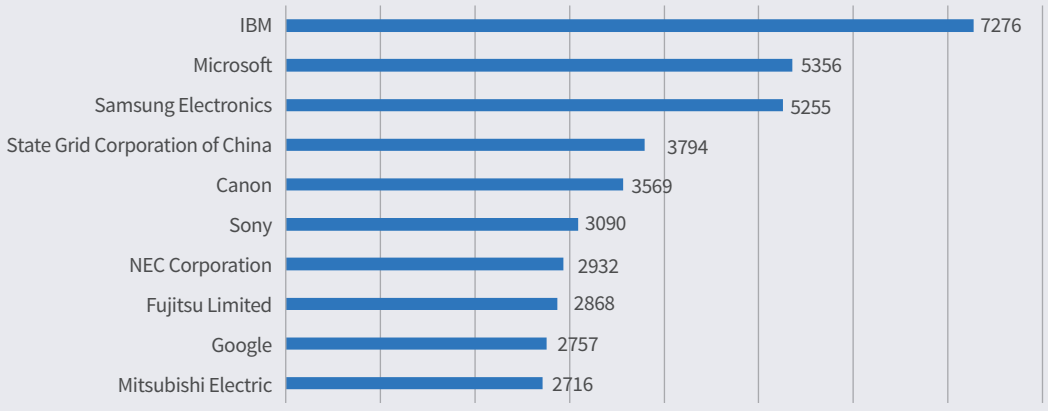


Figure 2-21 Top 10 assignees in AI

As shown by the competitive landscape of main assignees, IBM outperformed its closest competitor Microsoft by 36% in the number of patents, with its published patents accounting for 18% of the total published patents of the top ten assignees.

In terms of patent maintenance, SGCC has the highest percentage (87%) of valid patents in its total published patents among the top ten assignees. In contrast, as many as 40% of Sony's patents in AI has expired (Figure 2-22).

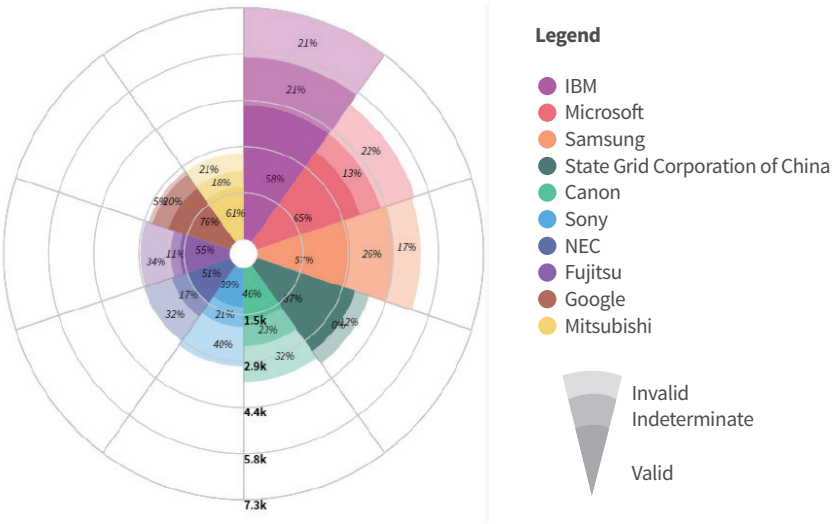


Figure 2-22 Competitive landscape of major assignees in AI

According to the analysis of main assignees, SGCC is the only Chinese company to secure a place in international competition in AI patents. As shown in Figure 2-23, SGCC's AI-related technological inventions focus on fields such as grid control, power distribution and utilization networks, smart substation transformer, wind farm and new energy, also with a remarkable interest in AI-related smart algorithms and robotics. According to interviews with experts, the quick increase of AI patents of SGCC in recent years is attributable to the following three main reasons: First, grid operations and management involve the collection and analysis of different types of data, which provide excellent use scenarios for AI technologies such as image processing, voice recognition and big data analysis. Secondly, SGCC not only has full life-cycle data of its massive assets and rich user data but also has massive operations data across wide regions and time frames. On top of those, it has completed its transformation of digitalization and information, and its operation has achieved automation to a large extent, which provides great conditions for making grid operations even more intelligent. Thirdly, SGCC has a clearly defined project management system, and its AI projects are managed with strict quantitative evaluation indicators.

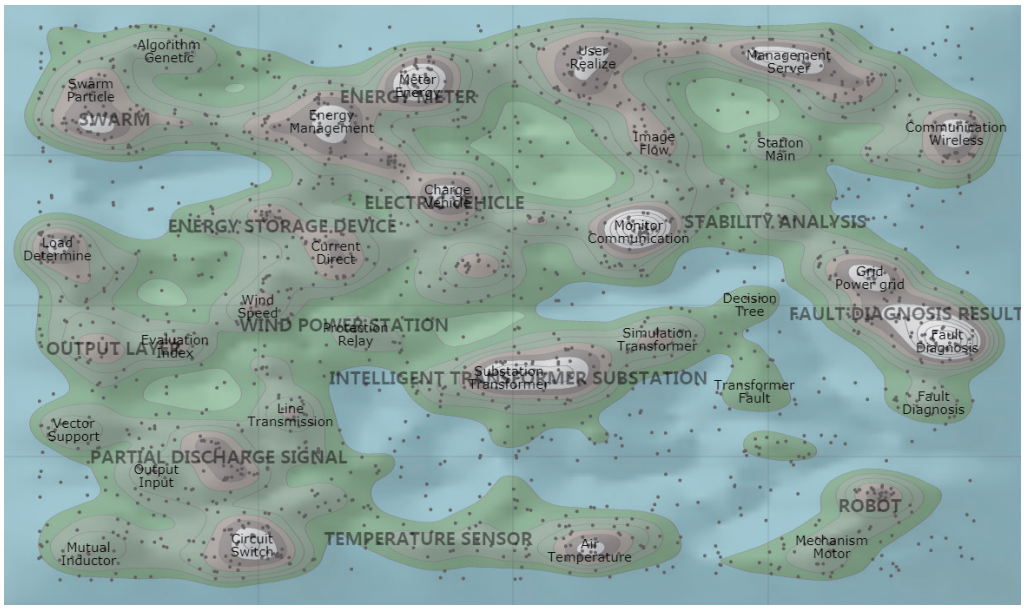


Figure 2-23 SGCC's main areas of AI research

● Global distribution of AI patents

A further analysis of priority countries/regions identified originating countries/regions of AI technologies. As shown in Figure 2-24, China, the United States and Japan are the top three countries/regions of origin of AI technologies, whose AI patents account for 74% of the total published AI patents.

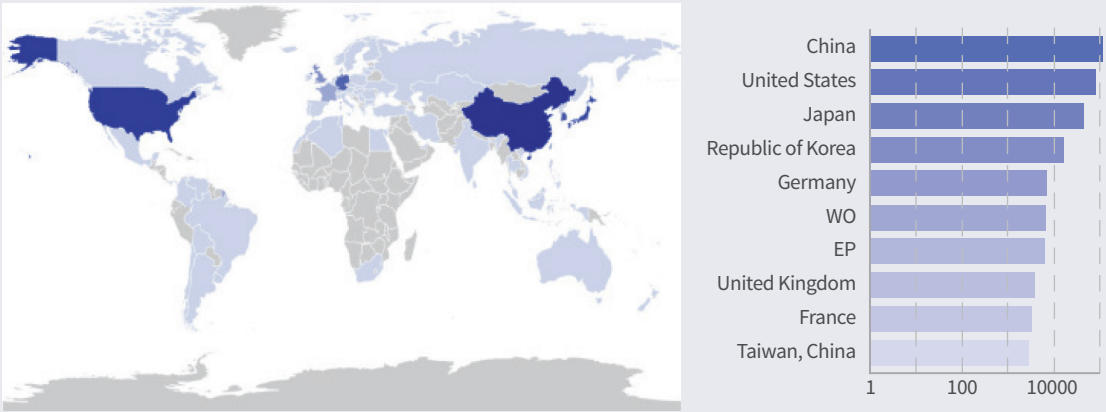


Figure 2-24 Distribution of countries/regions of origin of AI technologies

Analysis of countries/regions with published AI patents identified countries/regions where AI technologies have gained further development. As shown in Figure 2-25, China ranks first in the comprehensiveness of patented AI technologies, while the United States has the highest patent grant rate.

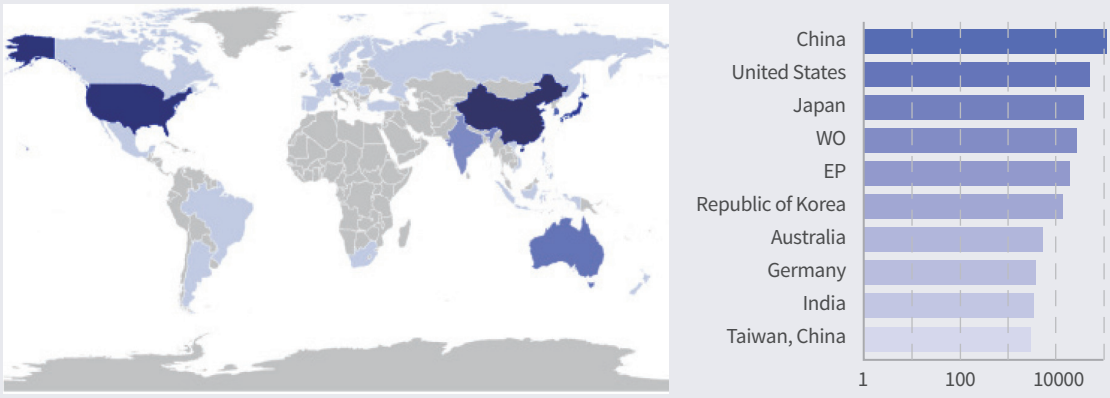


Figure 2-25 Global distribution of AI patents

- **Fields of patented AI technologies**

ThemeScape within Derwent Innovation, which performs statistical and textual analysis of the semantic similarity of patent texts and presents its findings visually in a map, can provide a vivid thematic panorama of an industry or technological field.

Figure 2-26 is a ThemeScape map of patented AI technologies. As shown in the figure, patent applications focus on fields including voice recognition, image recognition, robotics, and currently most popular deep learning (such as neural network, human-machine interaction, decision tree, and fuzzy logic). Figure 2-26 also shows the main application fields of AI technologies, such as energy, communication and vehicles.

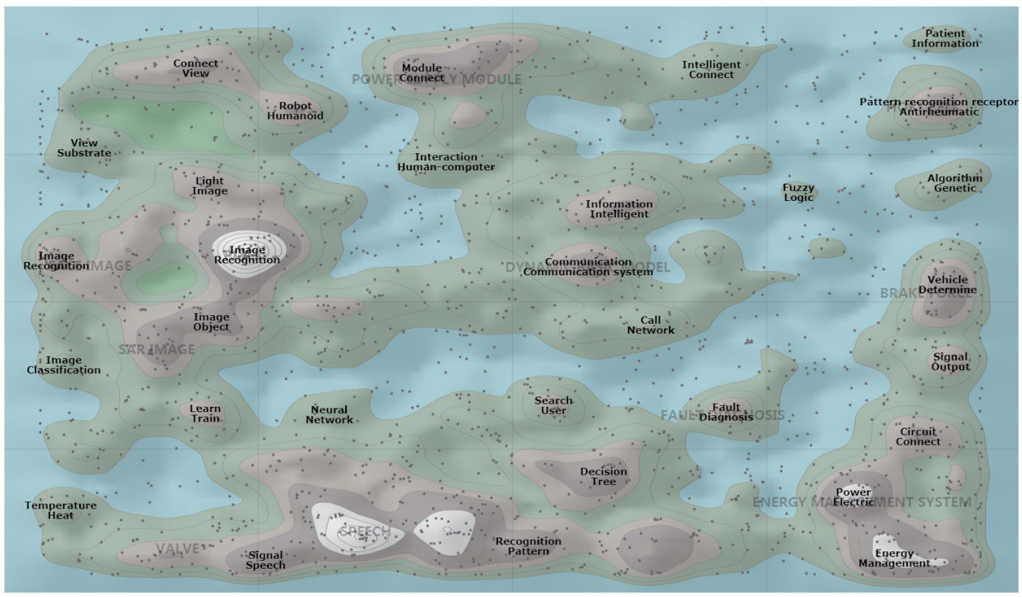


Figure 2-26 The ThemeScape of AI patents

2.2.2 China's AI Patent Output

- **Distribution of major assignees**

This report analyzed China as the earliest priority country with records being deduplicated using the Derwent patent family mechanism. As a patent right is valid only in the regions where it is granted, one patented invention may have multiple published patent documents. In view of this fact, this report merged multiple patent documents of the same invention in a single patent family so that calculation reflects the number of actual inventions rather than the number of patents which may have duplicates. On this basis, the statistics of the number of inventions belonging to each assignee will provide a comprehensive picture of AI R&D in China (the earliest priority country/region: CN; years of publication 2013-2017). Shown in Figure 2-27 are the top 15 assignees from academia and the top 15 from the business world in terms of the AI patents held over the last five years, with the first list featuring universities such as Chinese Academy of Sciences, Zhejiang University, Xidian University, South China University of Technology, Tsinghua University, Hohai University, Southeast University, University of Electronic Science and Technology of China, Beihang University and Tianjin University, and all being more or less comparable, and the second list featuring companies such as SGCC, Baidu, Changhong, OPPO, Xiaomi and Midea (but differing drastically in terms of patents held, with SGCC holding far more than others). Overall, slightly more patents are from academia (52%) than from the business world.

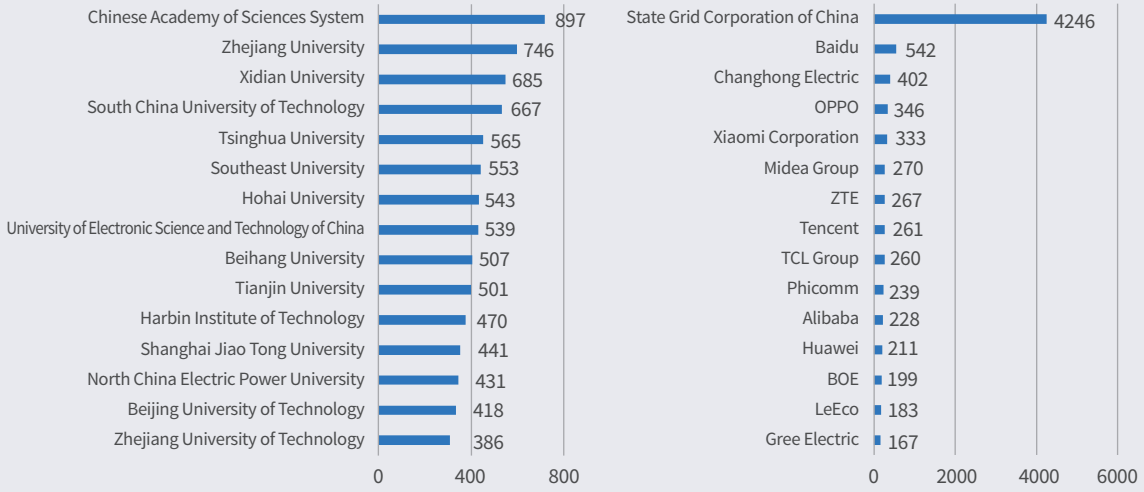


Figure 2-27 Top assignees from the academia and from the business world

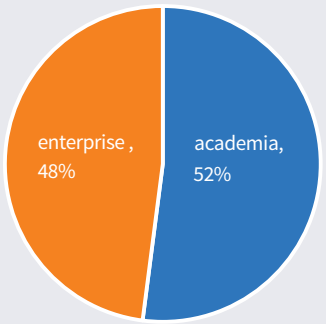


Figure 2-28 AI patents held by top 30 assignees by category

- **Distribution of key technological fields**

This report analyzed Derwent Manual Codes for AI and provides a picture of the fields and sub-fields of China's AI technologies patented in the last five years. As shown in Figure 2-29, AI technologies developed by China have focused on such fields as data processing systems and digital information transmission. Image processing and analysis (T01-J10B), in particular, has had more inventions patented (representing 16% of the total inventions) than in other sub-fields.

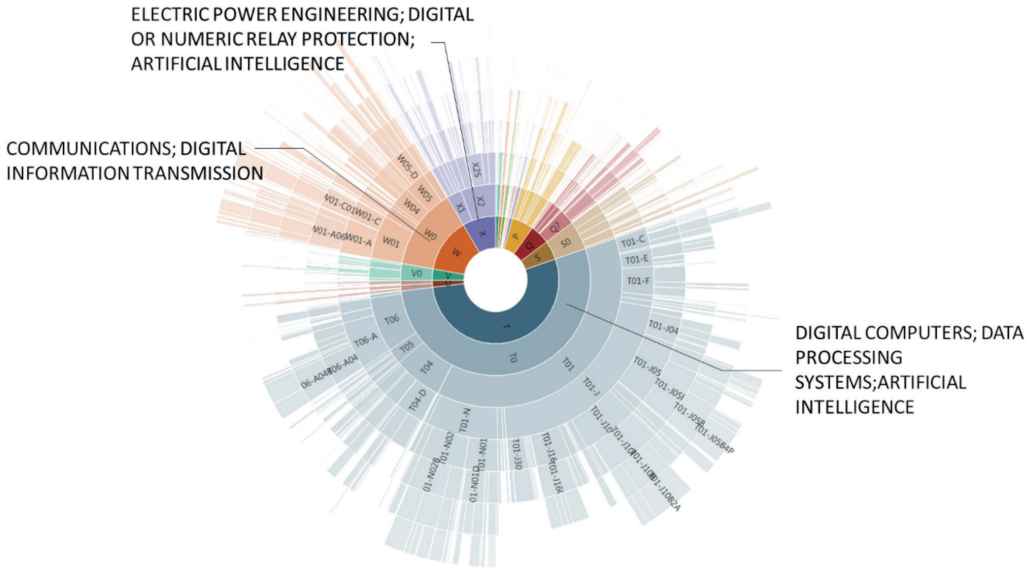


Figure 2-29 Distribution of patented inventions in AI (Derwent Manual Codes)

2.3 AI Talent

Definitions of Main Indicators:

International AI talent: *Researchers possessed of creative research ability and technical expertise in their research area and active in AI research with innovative outcomes. Innovative outcomes refer to issued patents and/or published English papers. "Active" refers to the creation of innovative outcomes in the last ten years.*

Top international AI talent: *International AI talent with leading research ability. To ensure access to and measurement of assessment indicator data, this report adopts the h-index widely recognized in the academic community as the indicator of research ability and qualify researchers whose H-index score ranks among the top 10% of international AI researchers as top international AI talent.*

Chinese AI talent: *Researchers possessed of creative research ability and technical expertise in their research area and active in AI research with innovative outcomes. Innovative outcomes refer to issued Chinese patents and/or published papers in Chinese or English. "Active" refers to the creation of innovative outcomes in the last ten years.*

2.3.1 Global AI Talent Distribution

- **Distribution by regions**

International AI talent is highly concentrated in several countries including the United States, China, India, Germany and the United Kingdom. By the end of 2017, the international AI talent pool

had 204,575 people, densely distributed in North America, Western Europe, Northern Europe, East Asia, South Asia and West Asia. At the country level, AI talent is concentrated in a few countries, with the top ten countries representing 61.8% of the global total.

China ranks second with an AI talent number that is 65% of the United States'. The United States takes the lead with as many as 28,536 AI talents, representing 13.9% of the global total; followed by China in the second place with 18,232, representing 8.9%; India in third place with 17384; Germany in fourth place with 9,441; and the United Kingdom in fifth place with 7,998. In terms of city distribution, the top five cities of AI talent as a percentage of the national total is 10.5% for the United States, 20.0% for China, 14.9% for India, 17.3% for the United Kingdom, and 23.3% for Germany.

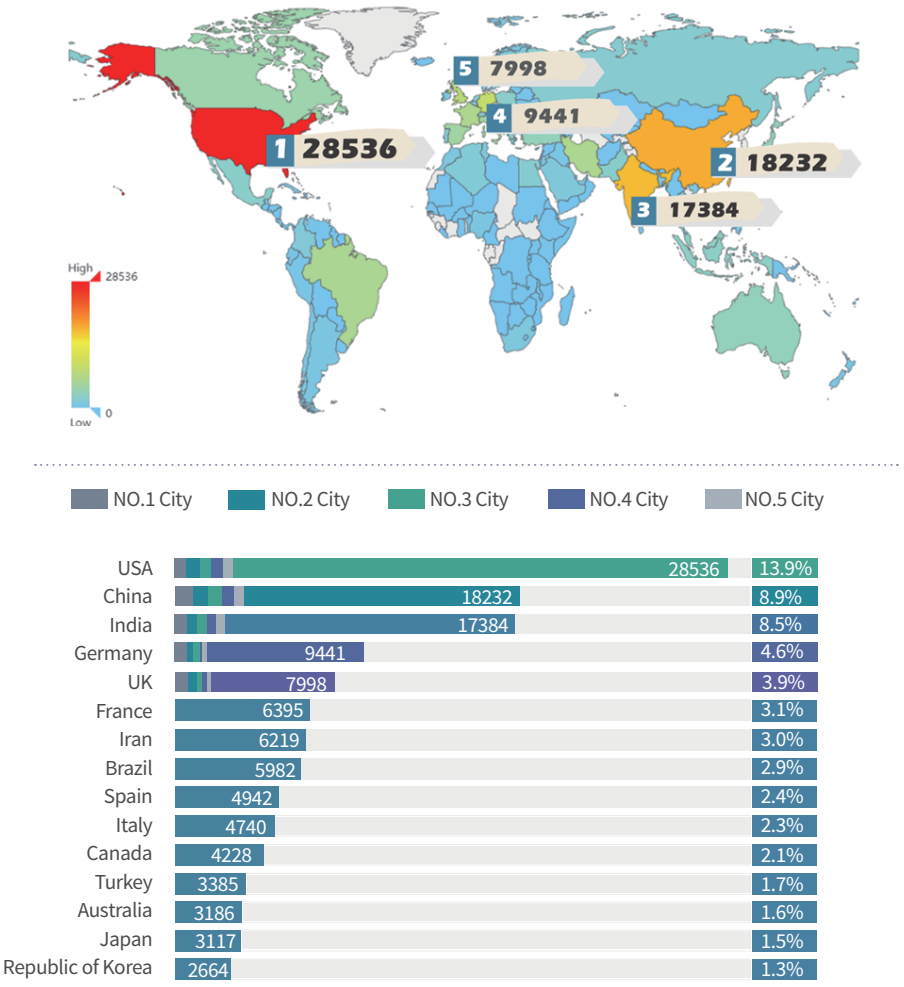
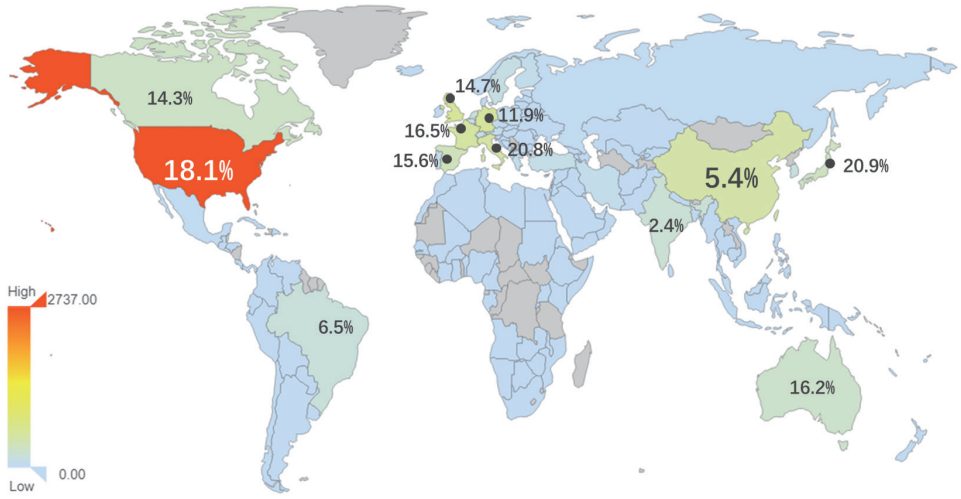


Figure 2-30 Global distribution of AI talent

Top international AI talent is concentrated in a handful of developed countries including the United States, United Kingdom, Germany, France and Italy. By the end of 2017, the top international AI talent pool had 204,575 people, densely distributed in North America, Western Europe, East

Asia and South Asia. At the country level, top AI talent is concentrated in a few countries, with the top ten countries representing 63.6% of the global total, with a slightly higher concentration than that of all AI talent (61.8%).

Developing countries such as China are underrepresented by top AI talent. The United States maintains its safe lead with 5,158 top AI talents, representing 25.2% of the global total, 4.4 times of the number of the United Kingdom in second place. The United Kingdom, and Germany in third place, France in fourth place, and Italy in fifth place, are at comparable levels. China ranks 6th with 977 top AI talents at a rather low level, especially in comparison with its all AI talent in second place globally. Developing countries like India (ranking third in all AI talent) and Brazil (8th) are also in the same situation, whose rank in terms of top AI talent falls to 11th and 13th, respectively.



Country	Number of top AI talent ÷	Number of total AI talent =	top AI talent as a percentage of all AI talent in each country
USA	5158	28536	18.1%
UK	1177	7998	14.7%
Germany	1119	9441	11.9%
France	1056	6395	16.5%
Italy	987	4740	20.8%
China	977	18232	5.4%
Spain	772	4942	15.6%
Japan	651	3117	20.9%
Canada	606	4228	14.3%
Australia	515	3186	16.2%

Figure 2-31 Global distribution of top AI talent (top AI talent as a percentage of all AI talent in each country)

- **Distribution by universities**

International AI talent is concentrated in universities. Universities host a total of 147,914 international AI talents, accounting for 72.3% of the total, versus 31,123 in research institutions such as national academies of sciences and research centers and 6,488 in for-profit business entities.

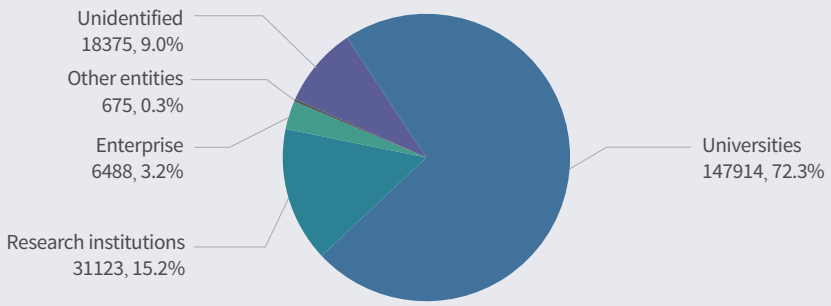


Figure 2-32 Global AI talent by type of affiliated entities

Universities that have a high intensity of International AI talents are concentrated in China, with Tsinghua University having the greatest number of international AI talents. Thanks to its large research force and master's and doctoral degree programs, Tsinghua University leads universities around the world with 822 international AI talents, followed by Shanghai Jiao Tong University in second place with 590; Vellore Institute of Technology in third place with 526; Beihang University in 4th place with 525; and Carnegie Mellon University in 5th place with 523. Massachusetts Institute of Technology, Stanford University and Georgia Institute of Technology rank 14th, 17th and 18th, respectively.

Tsinghua University	822	China	Nanyang Technological University	418	Singapore
Shanghai Jiao Tong University	590	China	Xi'an Jiaotong University	400	China
Vellore Institute of Technology	526	India	University of Science and Technology of China	382	China
Beihang University	525	China	Massachusetts Institute of Technology	368	USA
Carnegie Mellon University	523	USA	National University of Singapore	367	Singapore
Zhejiang University	506	China	University College London	365	UK
Huazhong University of Science and Technology	465	China	Stanford University	364	USA
Peking University	463	China	Georgia Institute of Technology	358	USA
Wuhan University	446	China	Harbin Institute of Technology	353	China
Beijing University of Posts and Telecommunications	443	China	Imperial College London	334	UK

Figure 2-33 International AI talent by affiliated university

However, there is no Chinese university in the top ten universities by the number of top international AI talent. In this indicator, Stanford University takes the lead with 79, followed closely by Massachusetts Institute of Technology, University College London, University of Washington and University of São Paulo. Tsinghua University ranks 15th and Shanghai Jiao Tong University 33rd, falling steeply from their positions in terms of all AI talents.

Stanford University	79	USA	University of Oxford	49	UK
Massachusetts Institute of Technology	72	USA	Sapienza University of Rome	47	Italy
University College London	67	UK	University of Cambridge	45	UK
University of Washington	60	USA	ETH Zurich	43	Switzerland
University of São Paulo	60	Brazil	Tsinghua University	42	China
University of Michigan	55	USA	University of California, San Francisco	42	USA
University of Toronto	53	Canada	University of Southern California	42	USA
University of California, San Diego	51	USA	Catholic University of Leuven	41	Belgium
University of California, Berkeley	51	USA	Karolinska Institute	40	Sweden
University of California, Los Angeles	49	USA	Yale University	40	USA

Figure 2-34 Top international AI talent by affiliated university

- **Distribution by research institutions**

The Chinese Academy of Sciences is the world's largest institution in terms of AI talent. The Chinese Academy of Sciences, with its vast system and affiliated research institutes, has as many as 1,244 AI talents, taking the clear lead globally. NASA ranks second globally with 103. Centre for Research and Technology Hellas ranks third with 67, followed by Toulouse Institute of Computer Science Research in 4th place with 64 and Bulgarian Academy of Sciences in 5th place with 63.

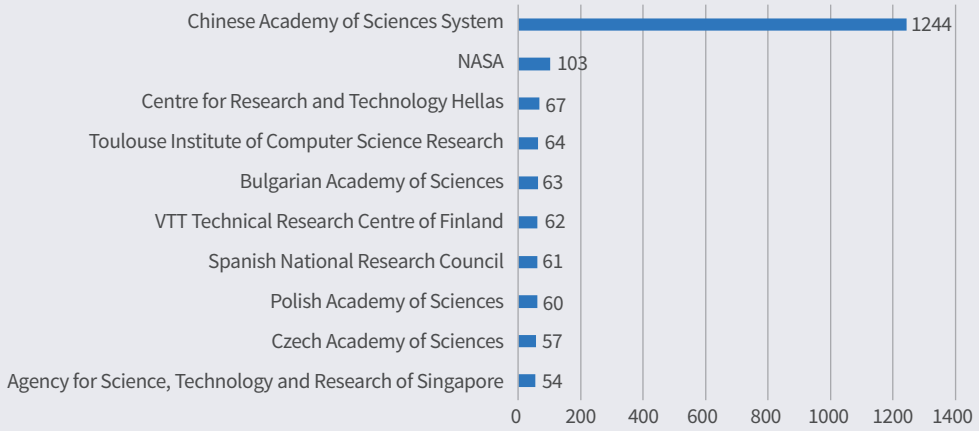


Figure 2-35 World's top 10 research institutions by AI talent

In terms of the number of top AI talents, Chinese Academy of Sciences still has a shining performance. It ranks first globally with 88, followed closely followed by National Research Council of Italy and French National Center for Scientific Research.

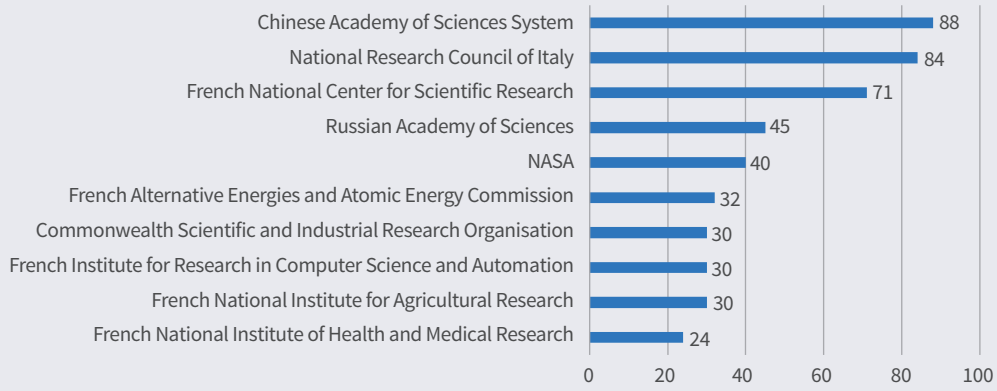
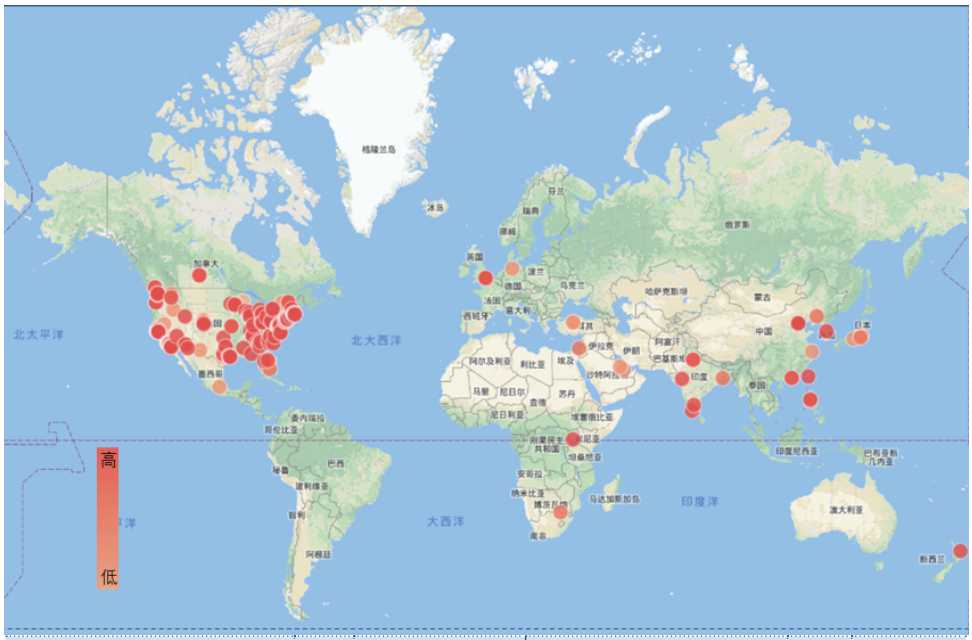


Figure 2-36 World's top 10 research institutions by top AI talent

- **Distribution by enterprises**

Enterprises with a high intensity of International AI talents are concentrated in the United States. Huawei Technologies is the only Chinese company to make into the top 20. In the business world, international AI talents are mainly employed by computer hardware and software development companies. The related industries in the United States started in the mid 20th century and their leading companies such as IBM, Microsoft and Google wield a wide global influence and represent the top three companies in the world in AI talent. Well-known American companies such as Intel, General Electric, Hewlett-Packard, Honeywell, Cisco, Qualcomm, and Apple are also on the list.

Three German companies—Siemens, SAP and Bosch, being all large manufacturers—break into the top 20 list. India has two companies on the list—Tata Consultancy Service and Cognizant, being mainly IT service providers. The Republic of Korea, the Netherlands, China, Ireland and Italy each have one company on the list.

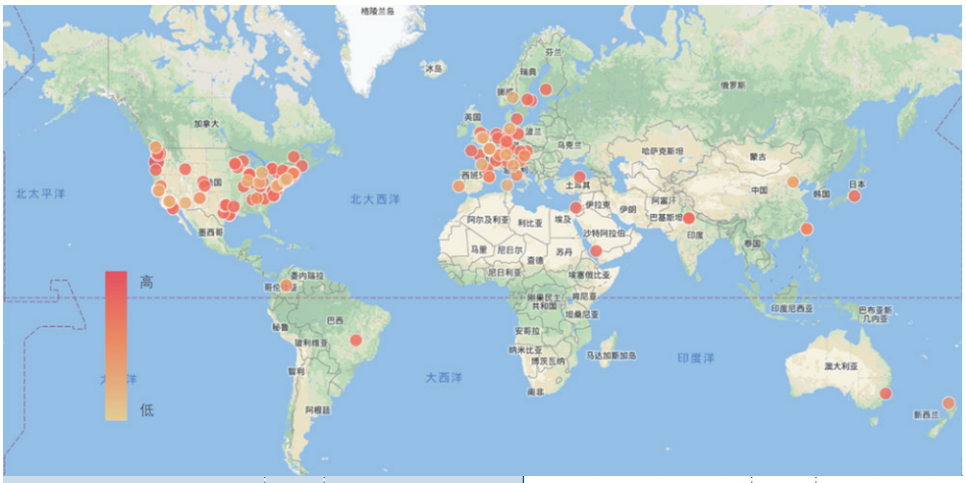


IBM	538	USA	Hewlett-Packard	62	USA
Microsoft	341	USA	Accenture	59	Ireland
Google	256	USA	SAP Research	58	Germany
Tata Consultancy Service	189	India	Robert Bosch	56	Germany
Siemens	176	Germany	Cognizant	55	India
Samsung	142	Republic of Korea	MITRE	55	Italy
Intel	142	USA	Honeywell International	53	USA
Philips	118	Netherlands	Cisco	51	USA
General Electric	87	USA	Qualcomm	47	USA
Huawei	73	China	Apple	46	USA

Figure 2-37 International AI talent by affiliated enterprise

IBM has the largest top-tier AI talent force among enterprises globally. IBM leads the corporate world by a big margin with 83 top AI talents, followed by Intel with 39, Google with 32 and Microsoft with 31.

Overall, American internet companies have a clear edge. There is no Chinese company in the top ten, with only Huawei making into the top 20.



IBM	83	USA	Ericsson	11	Sweden
Intel	39	USA	ABB	10	Switzerland
Google	32	USA	Roche	10	Switzerland
Microsoft	31	USA	Sanofi	9	France
Siemens	22	Germany	AstraZeneca	9	Sweden
Philips	18	Netherlands	Novartis	9	Switzerland
Samsung	16	Republic of Korea	Pfizer	9	USA
General Electric	15	USA	Merck	8	Germany
Eli Lilly	12	USA	Nokia	8	Finland
Qualcomm	11	USA	Huawei	7	China

Figure 2-38 Top international AI talent by affiliated enterprise

- **Distribution by research areas**

International AI talent is mostly devoted to AI algorithm development, especially such hot areas as machine learning, data mining and pattern recognition. Specifically, there are 70,031 people devoted to machine learning, 68,736 to data mining, 53,241 to pattern recognition, 32,619 to computer vision, 21,794 to feature extraction and 13,404 to artificial neural networks.

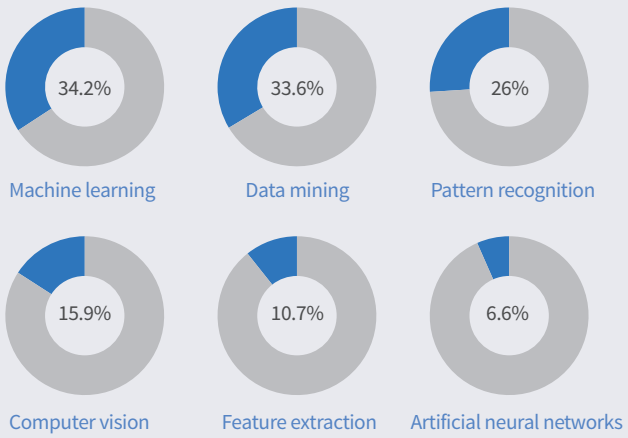


Figure 2-39 International AI talent by research area

2.3.2 China's AI Talent Distribution

In this report, Chinese AI talent refers to researchers having published Chinese patents or papers in Chinese or English over the last ten years, and their distribution, therefore, is more or less different from the distribution of international AI talent with English papers or patents only.

- **Distribution by regions**

Chinese AI talent is tilted towards the eastern region. By the end of 2017, China had 201,281 AI talents with a dense concentration in the eastern region. Eastern provinces had 126,120 AI talents, or 62.7% of the national total, versus 37,514, or 18.6%, for the central region, and 37,362, or 18.6%, for the western region. Beijing has a clear edge and ranks first nationwide with 27,355 AI talents. Jiangsu Province ranks second with 19,293, followed by Shaanxi with 12,878 in third place, being the only province in the western region to rank among the top ten. Hubei was closely behind with 11,773, followed by Shanghai with 10,592. Overall, Beijing and Jiang-Zhe-Hu (Jiangsu, Zhejiang and Shanghai) represent the two AI talent centers in the eastern region, with Hubei being the AI center of the central region and Shaanxi being the AI center of the western region.

Compared to the number of AI talents, there is not much regional difference in academic performance. Beijing ranks first with an average H-index of 9, followed by Shanghai in second place with 8, and Zhejiang, Hunan and Tianjin, each with 7.

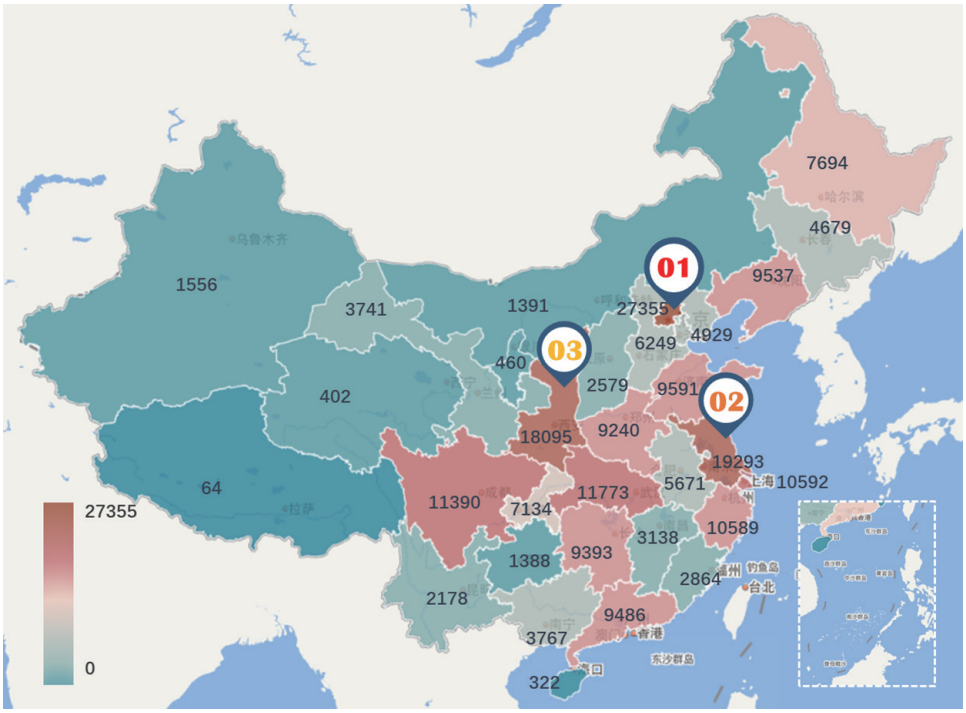


Figure 2-40 Distribution of Chinese AI talent

Among the cities, Beijing leads other cities by a big margin and is followed by Xi'an, Shanghai, Wuhan and Nanjing. As China's cultural center, Beijing has a high AI research intensity, with its AI talent force accounting for 13.5% of the national total. In the second echelon are Xi'an, Shanghai, Wuhan, and Nanjing, each with an AI talent force of over 10,000. In the third echelon are Changsha, Guangzhou, Chengdu, Harbin and Hangzhou, each with over 5,000.

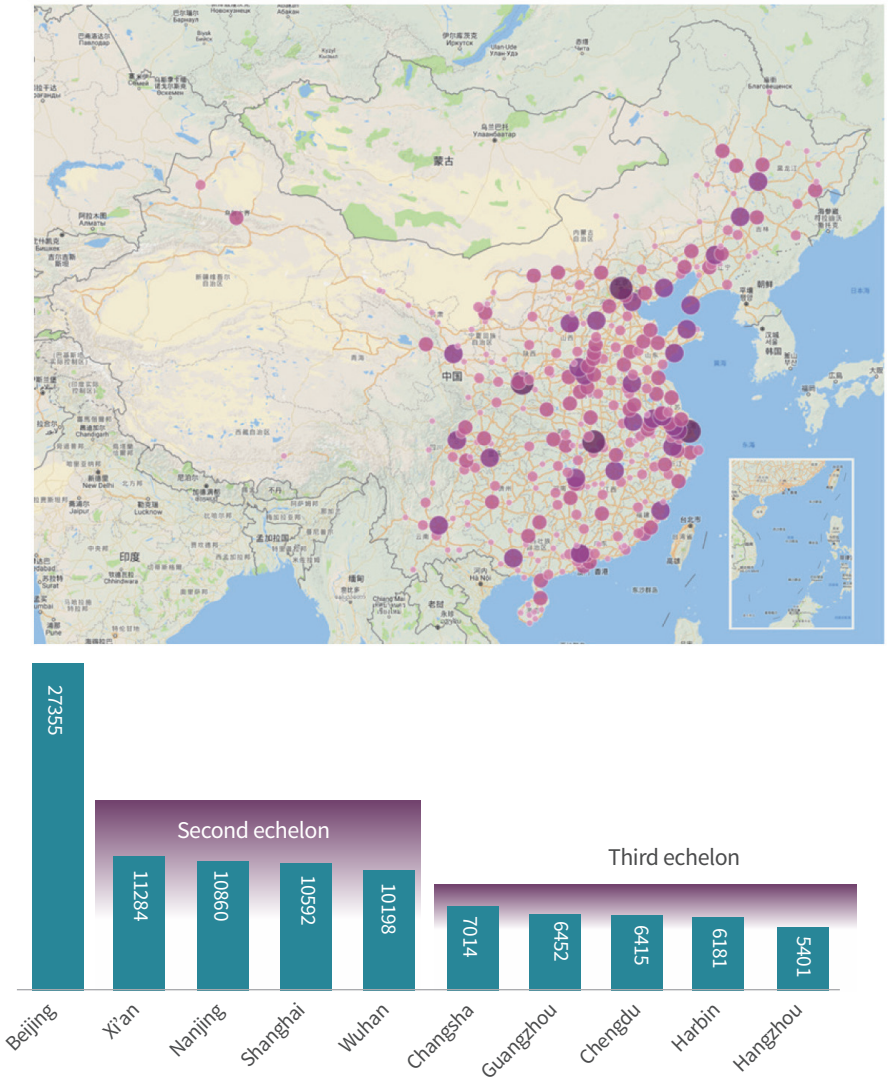


Figure 2-41 Chinese AI talent by city

- **Distribution by universities**

China's AI talents are mainly concentrated in universities. There are 179,349 AI talents in universities nationwide, representing 81.3% of the national total, versus 19,422 in research institutions, or 8.8%, and 13,065 in enterprises, or 5.9%, slightly higher than the global average of 3%.

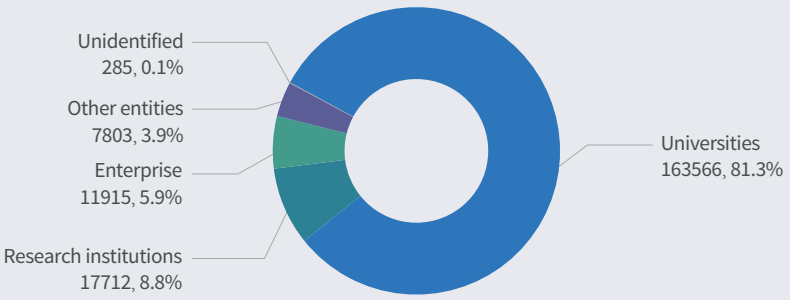


Figure 2-42 Chinese AI talent by affiliated entity type

Among the universities, Zhejiang University ranks first with 2,273 AI talents. Harbin Institute of Technology is in second place with 2,252. Shanghai Jiao Tong University is closely behind in third place with 2,211, followed by Northwestern Polytechnical University with 2,102 and Tsinghua University with 1,996. Compared to the commitment of international AI talent, there are significant changes in the overall ranking places, which show that Tsinghua University and Shanghai Jiao Tong University are in the lead nationwide in both international AI talent and top international AI talent, while Zhejiang University and Harbin Institute of Technology outperform in the number of AI talents active in China's domestic academic community.

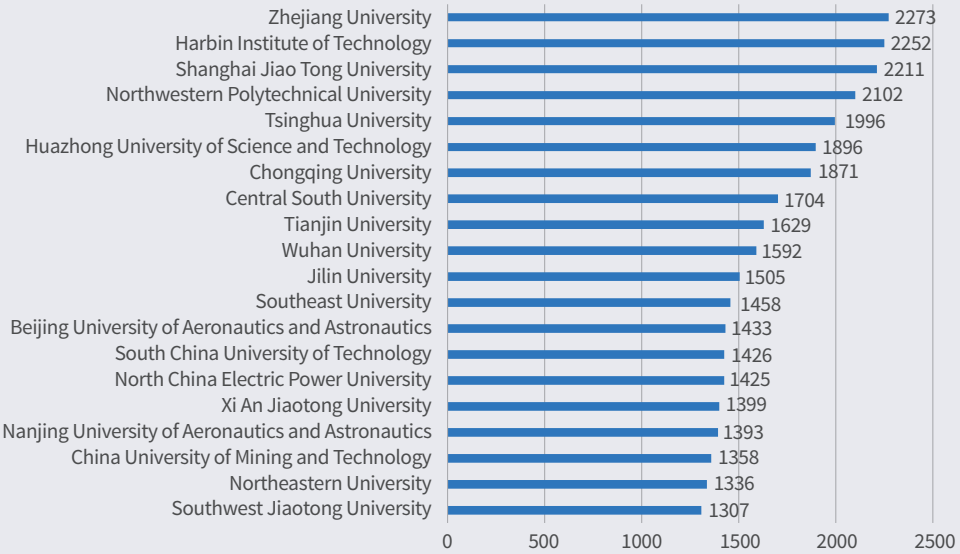


Figure 2-43 Top 20 Chinese universities by AI talent force

- **Distribution by research institutions**

The Chinese Academy of Sciences (CAS) System has the largest AI talent force in China. CAS has a total of 4,832 AI talents, with top-ranked members including Changchun Institute of Optics, Fine Mechanics and Physics (191), Institute of Computing Technology (188) and Shenyang Institute of Automation (135).

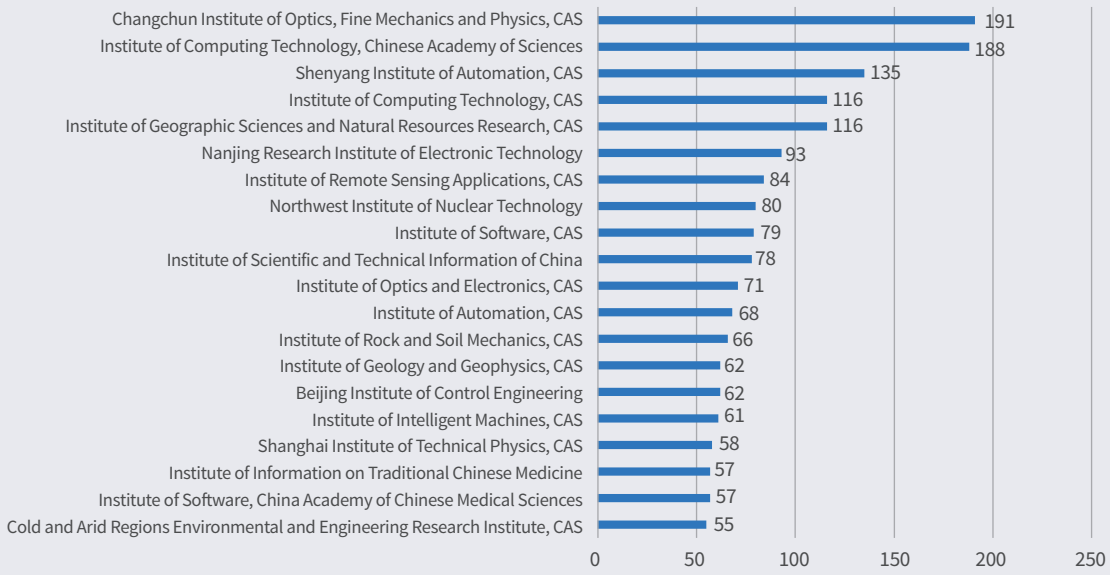


Figure 2-44 Top 20 Chinese research institutes by AI talent force

- **Distribution by research areas**

China's AI research areas are more dispersed. The top two research areas are genetic algorithm (42,706 AI talents) and neural networks (41,226), each representing more than 15% of the national total of AI talents. Other major research areas include fault diagnosis (25,161), data mining (23,976), BP neural networks (18,945) and support vector machine (18,783).

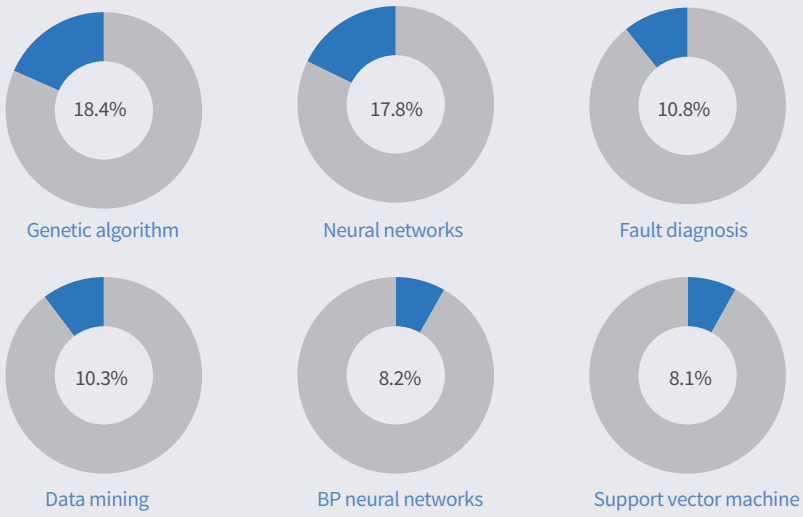


Figure 2-45 Chinese AI talent by research area

03

AI Industry Development and Market Applications

03 AI Industry Development and Market Applications

This chapter examines China's AI industry development from the perspectives of AI enterprises, venture capital investment, standard formulation, market size, and products and applications. In view of the wide applications of AI, AI enterprises in this report only include enterprises that have AI technologies or products as their core operations, as defined by the ICT industry monitoring platform of CAICT Data Research Center.

3.1 AI Enterprise Distribution

3.1.1 Regional Distribution of Chinese AI Enterprises

As of June 2018, there were 4,925 AI enterprises worldwide, with the United States having the greatest number at 2,028. China (excluding Hong Kong, Macao and Taiwan regions) came second with 1,011, followed by the United Kingdom, Canada and India.

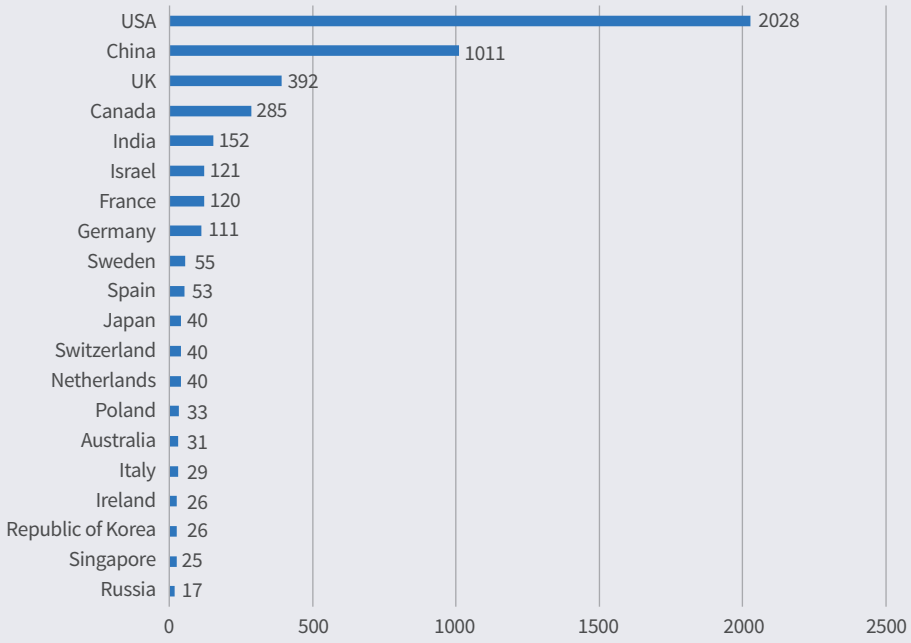


Figure 3-1 AI enterprises by country

The world's top 20 cities by the number of hosted AI enterprises include nine for the United States, four for China, three for Canada, and one for each of the United Kingdom, Germany, France and Israel. Among them, Beijing has the greatest number of AI enterprises in the world, followed by San Francisco and London. The other three Chinese cities on the list are Shanghai, Shenzhen and Hangzhou, respectively.

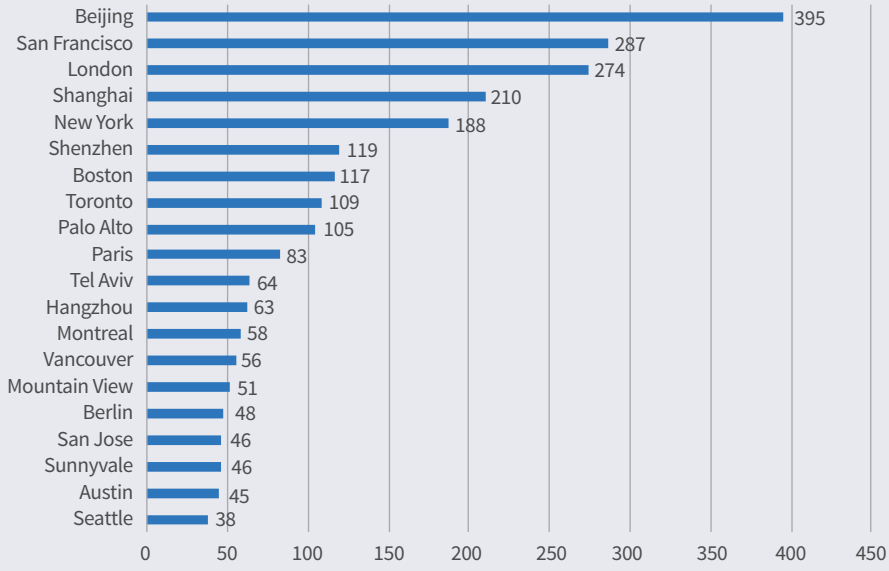


Figure 3-2 The world's top 20 cities by the number of hosted AI enterprises

In China, AI enterprises are mainly concentrated in Beijing, Shanghai and Guangdong. Beijing takes the lead with 395, far ahead of other regions. Zhejiang and Jiangsu provinces also have a fairly large number of AI enterprises.

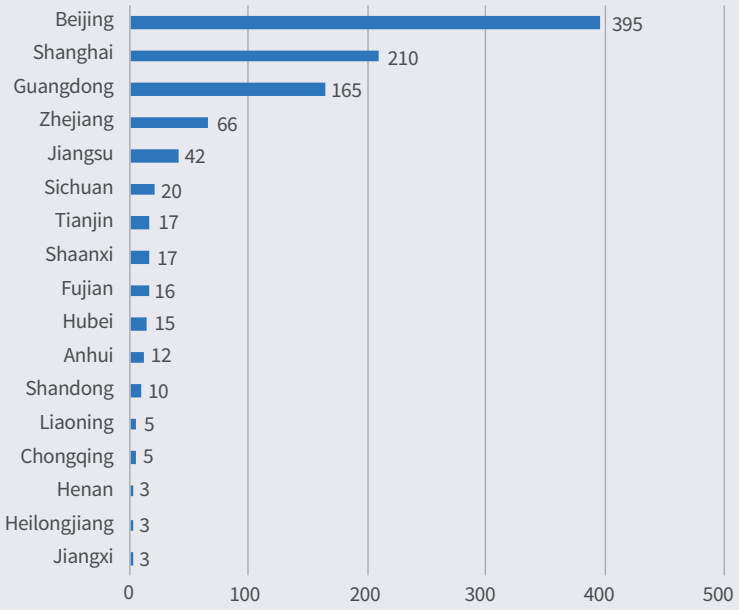


Figure 3-3 China's top provinces/municipalities by the number of hosted AI enterprises

3.1.2 Establishment Time of Chinese AI Enterprises

In terms of the time of establishment, most of Chinese AI enterprises were established between 2012 and 2016 and the growth peaked in 2015 with an addition of 228. After 2016, the growth of AI startups began slowing down.

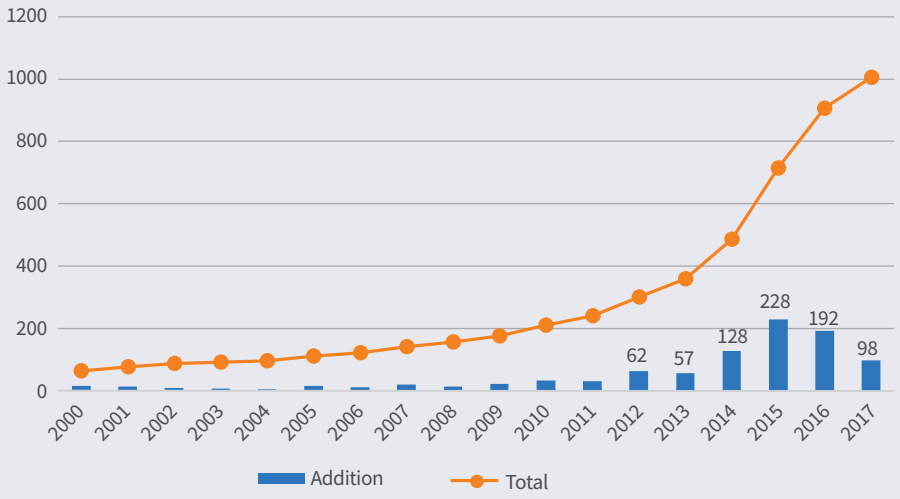


Figure 3-4 Growth of Chinese AI enterprises

Chinese AI enterprises have an average age of 5.5 years. Those in Beijing, Shanghai and Tianjin are younger than the national average. Those in Shandong and Liaoning, with many of them developed from well-established industrial robot and automation enterprises, are comparatively older.

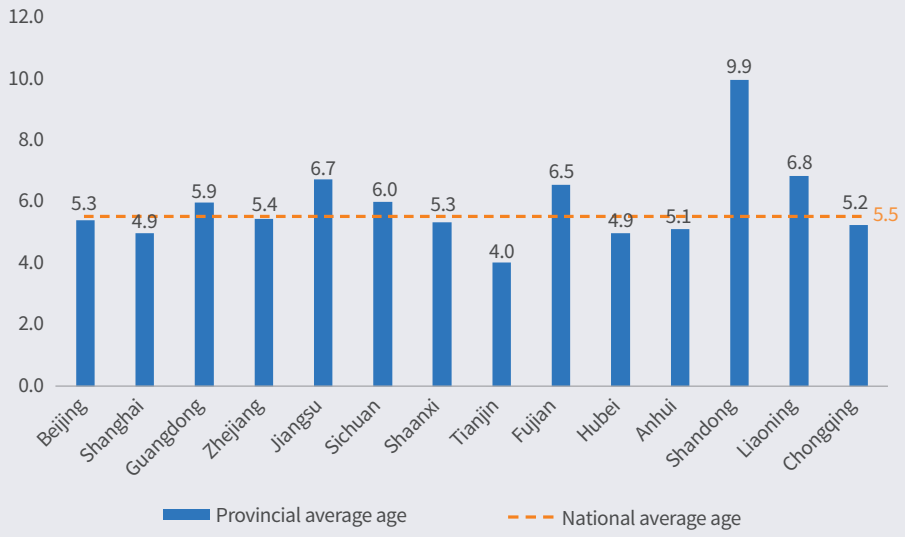


Figure 3-5 Average age of AI enterprises by province (unit: year)

3.1.3 Specialized Areas of Chinese AI Enterprises

Applied AI technologies mainly include voice technologies (speech recognition, speech synthesis, etc.), vision technologies (biometric recognition, image recognition, video recognition, etc.) and natural language processing technologies (machine translation, text mining, emotional analysis, etc.). With basic hardware included, the distribution of applied AI technologies of domestic and overseas AI enterprises is shown in Figure 3.6. Compared to their overseas counterparts, Chinese AI enterprises have a greater focus on vision and voice and are less focused on basic hardware.

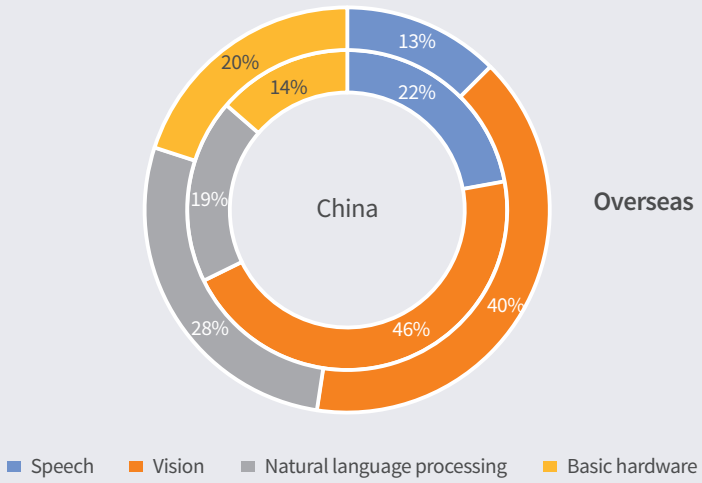


Figure 3-6 Distribution of applied AI technologies of AI enterprises in China and worldwide

The industry applications of AI include industrial robot, intelligent driving, drone, AR/VR, big data and data services, and various vertical applications (defined as "AI+" in this report). The distribution of industry applications of domestic and overseas AI enterprises is shown in Figure 3-7.

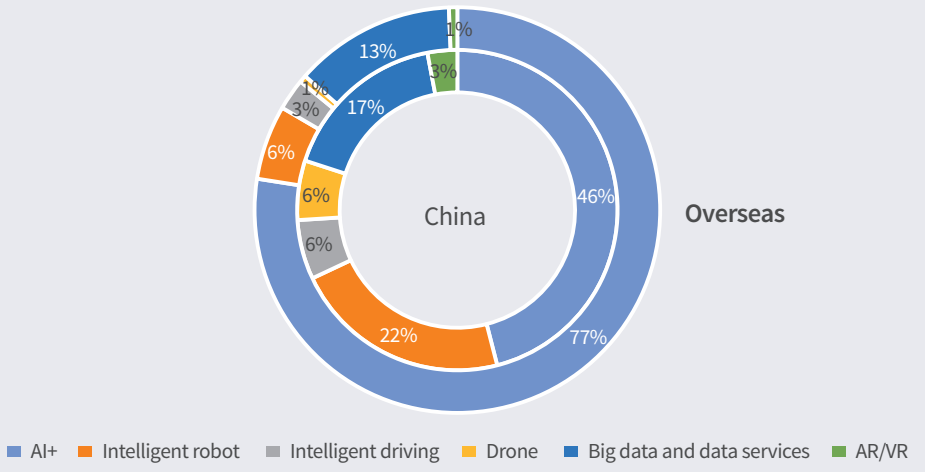


Figure 3-7 Industry distribution of domestic and overseas AI enterprises

It can be seen that domestic enterprises are more focused on terminal products such as intelligent robots, drones and smart cars, while foreign companies are more focused on the applications of AI in various vertical industries.

3.2 AI Industry Investment

3.2.1 Investment and Financing Scale of China's AI Industry

Since 2013, the global AI industry and the Chinese AI industry both have received steadily increasing investment. In 2017, global AI investment reached US$39.5 billion, including 1,208 investment transactions, with China alone posting US$27.71 billion of investment and 369 investment transactions. China's AI enterprises represented 70% of the global AI investment and 31% of global AI investment transactions.

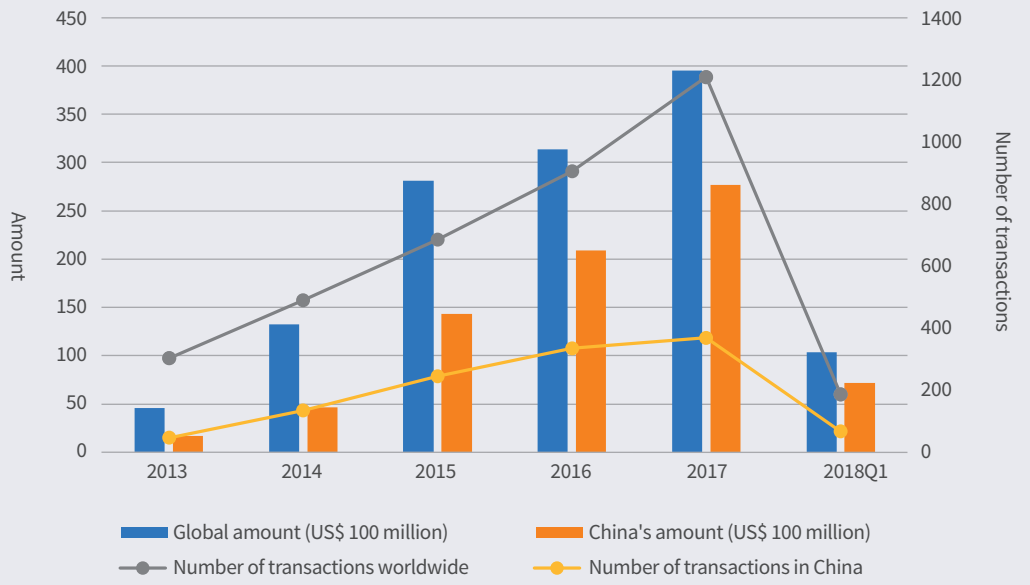


Figure 3-8 Trend of AI investment - worldwide and China

According to global investment and financing data for the period from 2013 to the first quarter of 2018, China surpassed the United States in financing scale to become the world's No. 1 destination of AI investment, though the United States kept its lead in terms of the number of investment transactions.

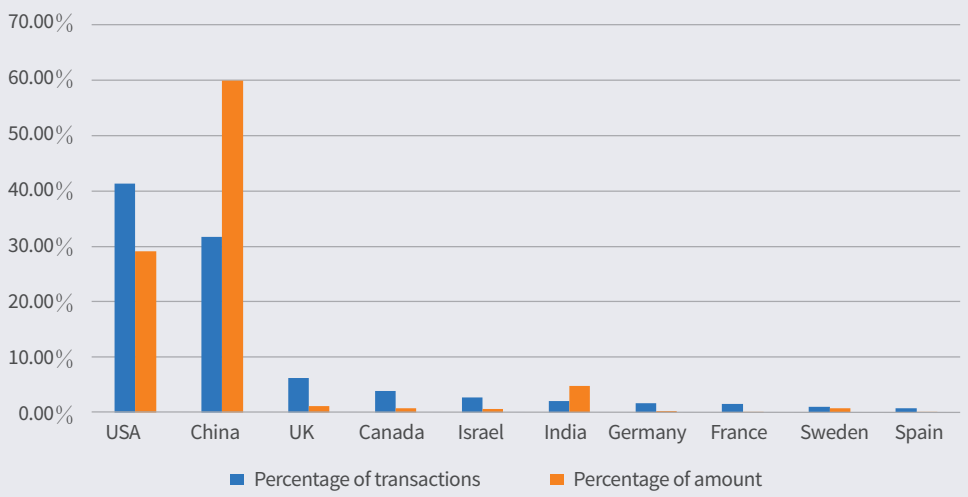


Figure 3-9 Distribution of global AI investment by country (2013 – Q1 2018)

3.2.2 Regional Differences of AI Industry Investment and Financing in China

Beijing led other provinces and municipalities in terms of financing amount and number of financing transactions. Provinces and municipalities including Shanghai, Zhejiang, Jiangsu and Guangdong also performed strongly. It merits noting that Guangdong, while receiving a comparatively less total amount of AI financing, had a high level of AI financing activity with its number of AI transactions being next only to that of Beijing and Shanghai. The AI financing amounts and numbers of AI financing transactions of the provinces are shown in Figure 3-10.

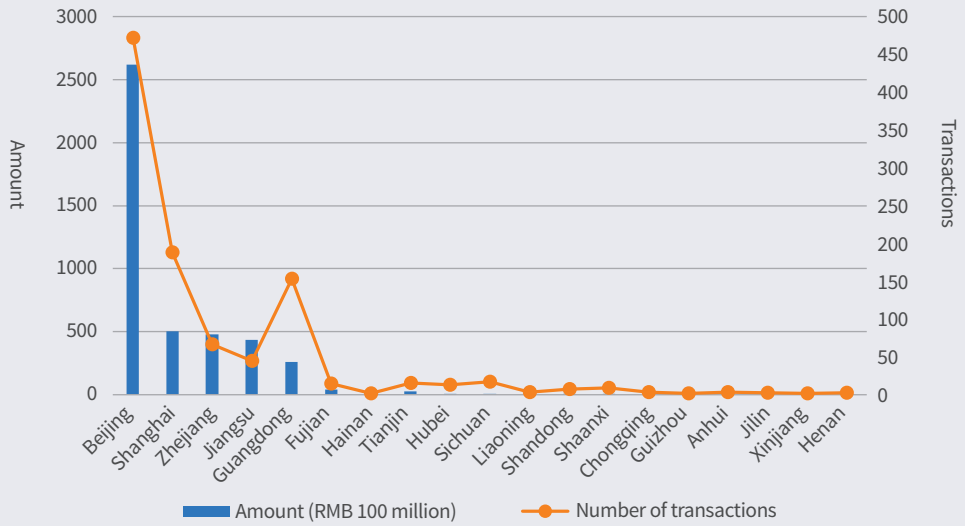


Figure 3-10 AI financing in China by region (2015 – Q1 2018)

3.2.3 Investment and Financing Round Changes in China's AI Industry

In terms of financing series, early-phase (Seed, Angel and Series A) financing as a percentage of the total AI financing began decreasing from 2015, indicating the increasing rationality of financing activity and the gradual maturing of the industry. The breakdown of domestic AI financing is shown in Figure 3-11.

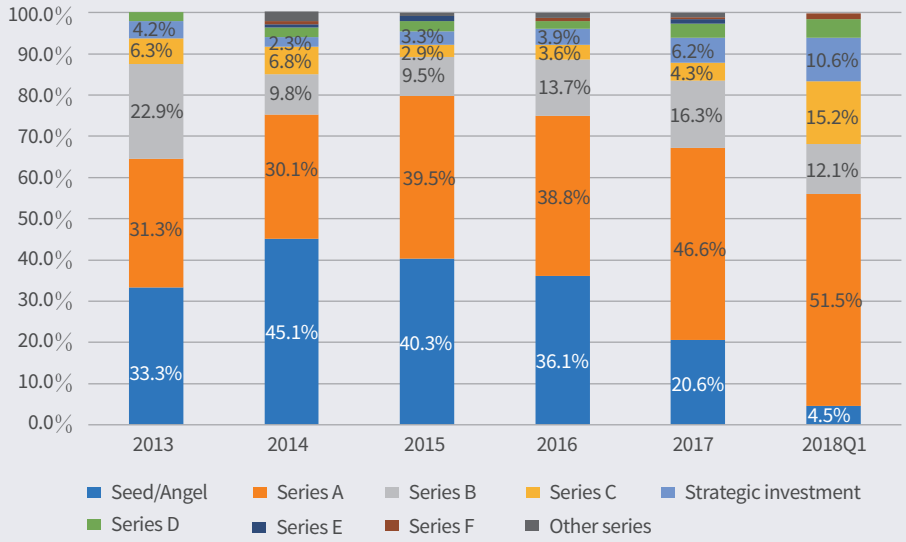


Figure 3-11 AI financing in China by series

3.3 Structure and Scale of The AI Market

3.3.1 Structure of China's AI Market

In 2017, China's AI market reached RMB23.74 billion, up 67% from 2016. The computer vision segment with technologies such as biometrics, image recognition and video recognition at its core was the largest segment, representing 34.9% of the market with RMB 8.28 billion.

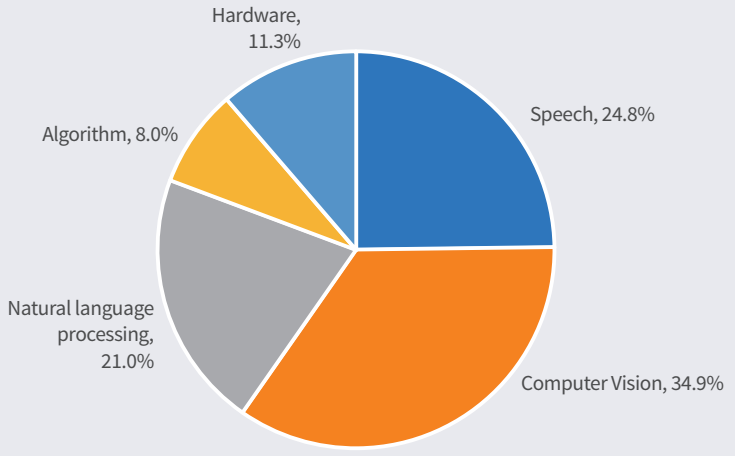


Figure 3-12 Structure of the Chinese AI market

3.3.2 Scale of China's AI Market

China's AI venture capital investment and financing fever began cooling off in 2017, but with the maturing of various AI technologies and their real-life applications, the AI market is expected to grow 75% to RMB 41.55 billion in 2018.

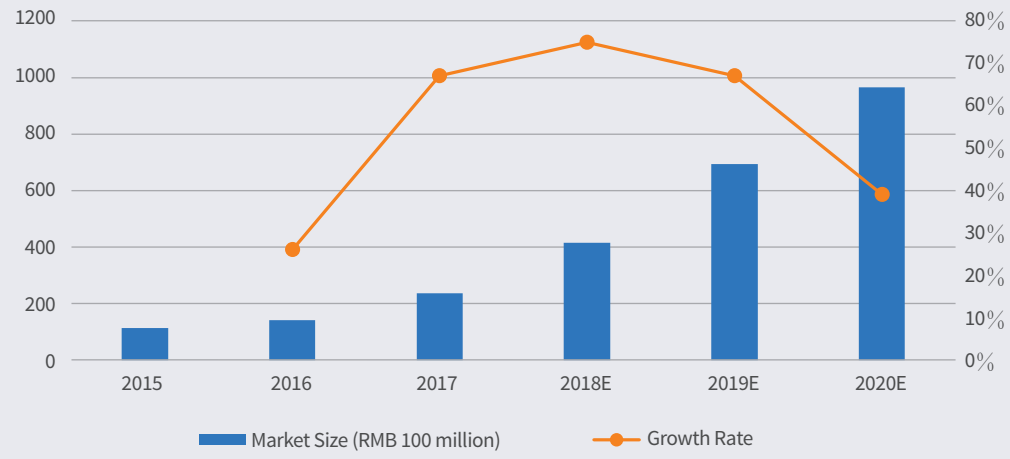


Figure 3-13 Size of the Chinese AI market 2015-2020

In 2018, the enhancement of machine learning and deep-learning algorithms will drive breakthroughs in computer vision, speech and related technologies. Core computing chips are also an important area where industry giants have made deployments, such as Google's upgraded TPU 3.0, NVIDIA's most powerful ever GPU, Chinese AI startup Cambricon's first cloud AI chip MLU100, and AI products rolled out by Chinese technology firms such as Alibaba, Huawei and Xiaomi which are expected to hit the market on a large scale soon. Against this backdrop, the AI industry will continue growing with accelerated integration with vertical industries.

3.4 AI Industry Standards

3.4.1 International AI Standards

With the development of the AI industry, international and domestic standardization organizations have started to work on AI standards Internationally, the joint technical committee of the International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC JTC 1) has been engaged in AI standardization for more than 20 years. In the early stage, ISO/IEC JTC 1 has carried out relevant standardization in key areas such as AI terminology, human-computer interaction, biometrics, computer image processing, as well as in AI enabling technologies such as cloud computing, big data and sensor networks. ISO's work has been focused on AI standardization in areas including industrial robotics, intelligent finance and intelligent driving. IEC's work has been focused on AI standardization for wearable devices.

In addition, the Institute of Electrical and Electronics Engineers (IEEE) has focused on the research of AI ethics and approved seven IEEE standards. The U.S. National Institute of Standards and Technology (NIST) has conducted research in various AI areas including AI acquisition and analysis tools, future expert systems, AI-based collective production quality control, high-throughput material discovery

and optimization, and optimized applications of machine learning, but has not yet worked on or released any related standards.

3.4.2 Chinese AI Standards

In China, the Standardization Administration of China (SAC) has done standardization work in areas such as terminology, human-computer interaction, biometrics, big data and cloud computing and released a series of standards and norms (see Appendix 4 for details).

3.5 AI Products and Applications

With the continuous evolution and improvement of algorithms and computes, there have been more and more applications and products based on speech recognition, natural language processing and vision technologies. Typical ones include interactive products (such as smart speakers, smart voice assistants and intelligent in-vehicle systems), intelligent robots, drones and autonomous cars. In industry solutions, AI is even more widely applied and has been used in multiple vertical areas including healthcare, finance, education, security, business, and smart home.

3.5.1 AI-Powered Devices

As AI remains in the development stage and next-generation AI technologies such as machine learning and deep learning have been mainly confined to algorithms, mature AI devices are not very many. The following sections focus on three AI products that have been fairly mature and reached a certain market scale—smart speaker, smart robot and drone.

- **Smart speaker**

The AI interactive speaker market has seen a compound annual growth rate of 30% in recent years and is expected to grow from US$1.15 billion in 2017 to US$3.52 billion in 2021.

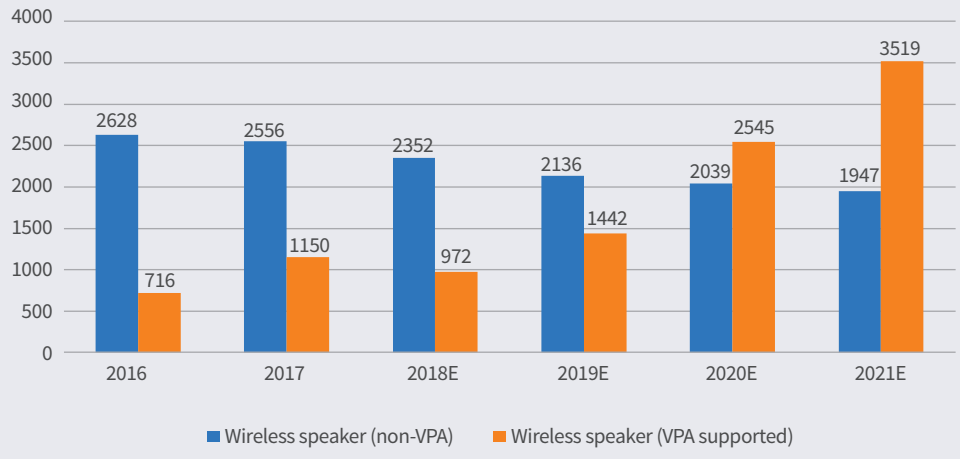


Figure 3-14 Global smart speaker market size (US$ 1 million)

Major products in the global smart speaker market are shown in Table 3-1.

Table 3- 1 Major smart speaker products in the market

	Vendor	Product Name
China	Baidu	Xiao Du
	Tencent	Tencent Tingting
	Xiaomi	Xiao AI
	Alibaba	Tmall Genie
	JD	Dingdong
Overseas	Amazon	Echo Series
	Google	Google Home Series
	Apple	HomePod
	Microsoft	Invoke

According to data released by research firm Canalys in May, Google had surpassed Amazon to lead the global smart speaker market. In the first quarter of 2018, Google sold 3.2 million smart speakers, representing 36.2% of the market. Amazon came in second place with 2.5 million Echo smart speakers sold, representing 27.7% of the market. China's Alibaba and Xiaomi came third and fourth, taking up a market share of 11.8% and 7.0%, respectively.

Table 3-2 Global smart speaker market share by vendor

Rank	Vendor	Q1 2017	Q1 2018	Y/Y growth
#1	Google (Home Series)	19.3%	36.2%	483%
#2	Amazon (Echo Series)	79.6%	27.7%	8%
#3	Alibaba (Tmall Genie)	-	11.8%	-
#4	Xiaomi (Xiao AI)	-	7.0%	-
Other Vendors		1.1%	17.3%	161%
Overall market (US$)		2.9 million	9 million	210%

Data source: Canalys

- **Intelligent robot**

Key technologies for intelligent robots include vision, sensing, human-computer interaction and mechatronics. From the application point of view, intelligent robots can be divided into industrial robots and service robots. Industrial robots generally include handling robots, palletizing robots, painting robots, and collaborative robots. Service robots can be divided into professional service robots and personal/home robots. Professional service robots include intelligent customer service, medical robots, logistics robots and receptionist robots; personal/home robots include personal virtual assistants, homework robots (such as home cleaning robots), children's educational robots, elderly care robots, and emotional support robots.

The structure of global intelligent robot enterprises is shown in Figure 3-15.

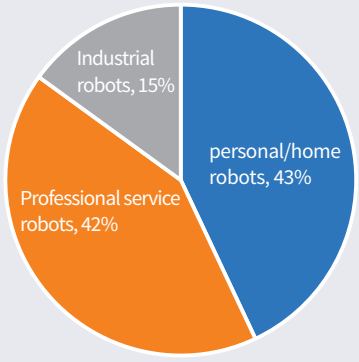


Figure 3-15 Global intelligent robot enterprises by type

According to data released by IFR in June 2018, the global robot market reached US$50 billion in 2017. The market posted 380,000 industrial robots sold in 2017, up 29% y/y. China has been the world's largest industrial robot market since 2013. In 2017, China posted 138,000 industrial robots in sales, followed by Korea with approximately 40,000 and Japan with approximately 38,000. In the Americas, the United States is the largest single market, selling approximately 33,000 industrial robots in 2017. In Europe, Germany is the largest seller with approximately 22,000 industrial robots sold. The top five countries - China, Korea, Japan, United States and Germany - combined to take up 71% of the global industrial robot market in 2017.

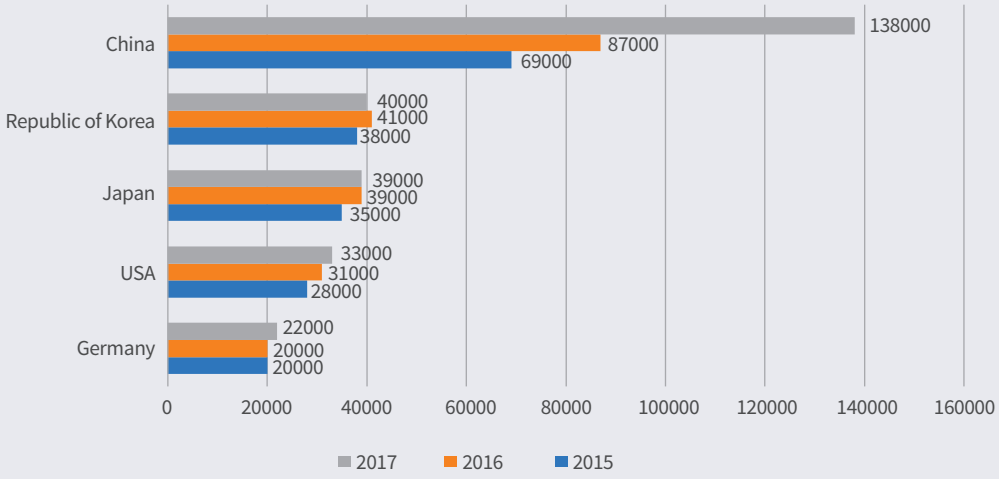


Figure 3-16 Industrial robot shipments in major markets

- **Drone**

At present, the drone market is mainly composed of consumer drones and commercial drones. Consumer drones are mainly used for entertainment scenarios such as aerial photography and tracking shots. Commercial drones have very wide applications

in many areas such as agriculture, forestry, logistics, security and patrol.

Consumer drones are generally priced below US$5,000 with a battery range of not more than one hour. Compared to consumer drones, commercial drones have a higher payload and longer flying time and are the most successfully applied in industrial fields. Commercial drones, small in shipments but high in prices, take up two-thirds of the revenue of the drone market.

Gartner predicts that the global drone market will reach US$7.3 billion with 3.13 million drones sold in 2018, up 28% from 2017.

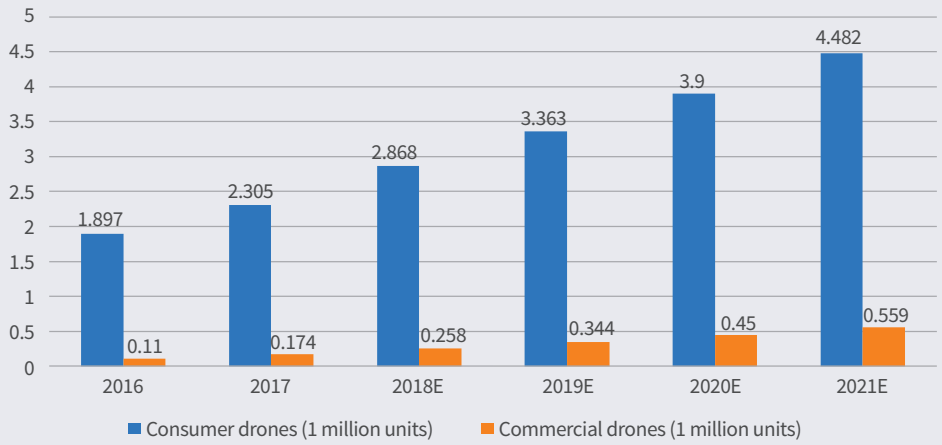


Figure 3-17 Global drone shipments from 2016 to 2021

DJI is the most influential drone manufacturer in China. It is focused on consumer drones but is also expanding in the commercial drone market. DJI is the clear leader in the global consumer drone market.

According to its financial data, DJI achieved RMB 17.57 billion in 2017, up 79.6% y/y. Data from drone market research firm Skylogic Research shows that DJI has taken up 50% of the North American market. For drones that cost between US$500 and US$1,000, DJI represented 36% of the market by units sold in North America in 2017. DJI also fetched 66% of the North American market for drones priced between US$1,000 and US$2,000, and 67% of the market in the US$2,000-US$4,000 range.

Besides DJI, other Chinese drone manufacturers such as EHANG, Zero Zero Robotics, Zerotech and XAG have also achieved rapid development and are fairly influential.

3.5.2 Industry Applications of AI

Compared to terminal products, AI has found more diversified applications in industrial fields. The following sections examine AI applications in smart healthcare, smart finance, smart security, smart home, and smart grid.

- **Smart healthcare**

As AI finds increasing real-world use, there have been quite a few success stories of AI rendering superior healthcare services. AI has been applied in many aspects of healthcare such as intelligent diagnosis and treatment, medical image analysis,

medical data management, health management, precision medicine, and new drug research and development.

Traditionally, doctors rely on their own medical knowledge and clinical experience to make a diagnosis according to symptoms and testing results. Today, they have got a super assistant in the form of a smart diagnosis and treatment system capable of "learning" specialized medical knowledge, "remembering" massive medical records and "reading" diagnostic imaging reports. IBM's Watson Health has furnished a compelling example with its ability to read 3,469 medical books, 248,000 papers, 69 therapeutic plans, results of 61,540 experiments and 106,000 clinical reports in only 17 seconds. Watson Health passed the U.S. Medical Licensing Exam in 2012 and has been deployed in multiple hospitals in the United States to provide assistant medical services. Currently, Watson Health can diagnose multiple cancers including breast cancer, lung cancer, colon cancer, prostate cancer, bladder cancer, ovarian cancer and uterine cancer.

- **Smart finance**

Smart finance is the integration of AI technologies and the financial system. AI applications in the financial sector mainly include AI financial advisor and intelligent financial fraud detection, among others.

AI financial advisor is now a common Fintech application scenario. An AI financial advisor, powered by machine learning algorithms, can automatically build investment portfolios according to a customer's investment goal, age, income, existing assets and risk tolerance to achieve their return target. In addition, the algorithms can automatically update investment strategies according to goal and market changes to maintain the optimal investment portfolio for their investment goals. Some major investment firms in the United States such as Betterment and Wealthfront have launched their AI-powered, low-priced financial advisor services which have been embraced and recognized by younger investors.

Traditional financial fraud detection systems rely heavily on rules that are complex and rigid and have become powerless in the face of continuously evolving and increasingly sophisticated fraud practices and techniques. Frauds based on forgery and impersonation have become common occurrences and caused massive losses to financial institutions and consumers. Chinese fintech companies represented by anti-fraud solution provider Maxent have developed AI-powered automatic intelligent anti-fraud technologies and systems that help enterprises build user behavior tracking and analysis and automatic anomaly detection capabilities to achieve controlled real-time identification of new fraud patterns.

- **Smart security**

Security is another area where AI has been successfully applied. AI-powered security involves algorithms and model training based on massive image and video data to provide comprehensive protection including early warning, effective response and post-incident handling.

At present, AI-powered security is mainly for police and civilian use. In the field of police use, applications in public security management are the most representative, where AI technologies are used to analyze in real time image and video content, collect human and vehicle information and identify criminal suspects, bringing substantial efficiency improvement and time savings. In the civilian use direction, AI enables intelligent building management and intelligent monitoring of industrial areas. Intelligent building management includes many AI-enabled applications such as face

recognition-based entry/exit management, theft identification and unauthorized access detection. In industrial areas, fixed cameras and patrol robots can be combined to implement real-time monitoring of all places and give alerts on potential hazards. Another important scenario of civilian use of AI is home security. A home security camera system, for example, is automatically activated when it detects no family member in the home and gives alarms and at the same time remotely notifies family members when it detects an intrusion. The system is automatically deactivated when any family member comes home for privacy protection.

Many Chinese security companies have developed their AI solutions and products. Traditional video surveillance companies such as Dahua, Hikvision and NetPosa have stepped up development of intelligent products. Companies that specialize in algorithms like SenseTime, Face++, CloudWalk and YITU Tech are focused on image processing areas such as face recognition and behavior analysis.

- **Smart home**

Smart home is an IoT-based home management system comprising hardware, software and a cloud platform. Integrating extensive functions such as home appliance control, human-machine interaction, interconnectivity of devices, user behavior analysis and user profiling, it brings the modern family with personalized services for greater convenience, comfort and security.

For examples, speech recognition and natural language processing technologies enable users to control smart home devices, such as curtains (windows), lights and TV sets by talking to them and telling them what to do; smart devices such as smart TV and smart speaker that are empowered by machine learning and deep learning technologies can learn about the user through their subscriptions or use history and recommend content according to their interests and preferences. In home security, biometric technologies such as face recognition and fingerprint recognition can be used to enable biometric door access, in addition to real-time camera monitoring and unauthorized intrusion detection.

In China, technology firm and device maker Xiaomi has established a complete system of R&D, manufacturing and selling of smart home devices, and its smart home ecosystem has had as many as more than 60 million connected devices. In addition, traditional home appliance makers Midea, Haier and Gree, leveraging their massive product lines and high market shares, have also actively pursued a smart home transition and pushed ahead with their smart device strategy.

- **Smart grid**

As power grids become increasingly extended, AI will become integral to their efficiency and adaptability. On the demand side, AI technologies will enable continuous monitoring of electricity usage of households and businesses through smart meters and sensors and electricity scheduling in a safer and more reliable, economical and efficient way.

On the supply side, AI technologies will help power grid operators or governments to optimize the energy mix, adjust the use of fossil energy sources, increase the production of renewable energy, and reduce the impact of renewable energy intermittency to the minimum. Energy producers will be able to manage energy output from different sources to continuously match supply with demand changes according to social, spatial and time changes.

In terms of line inspection, intelligent patrol robots and drones equipped with sophisticated sensors and detectors makes the inspection work more accurate, more efficient and safer. As for data diagnostics, intelligent patrol robots not only offer

more precise diagnosis than human eyes and all types of hand-held devices, but also support automatic operation round the clock, thus greatly expediting fault identification. Meanwhile, history inspection data can be analyzed to reveal hidden patterns and degradation trends of equipment and inform scientific formulation of maintenance and repair strategies. Drones fitted with high-resolution cameras capable of high-accuracy positioning and automatic detection can hover over power towers dozens of meters high, take photographs of them, and identify even the slightest disjunction. According to its official data, Guangdong Power Grid performs aerial power line inspection of over 180,000 km annually, equivalent to 4.5 times the earth's circumference, 85% of which is conducted by drones, representing the largest drone inspection workload in the world. Drone inspection has increased its overall inspection efficiency by 2.6 times.

AI Development Strategy and Policy Environment

04 AI Development Strategy and Policy Environment

This chapter compares and analyzes AI development from the perspective of international policy (United States, European Union, Germany, United Kingdom, France, Japan and Republic of Korea), China's national policy, and China's provincial-level government policy.

4.1 International AI Strategy and Policy

4.1.1 Key AI Policy Initiatives in Major Countries and Regions

In recent five years, countries have paid increasing attention and stepped up efforts to promote AI research and rolled out their national AI strategies and policies. The United States' AI policy documents include The National Artificial Intelligence Research and Development Strategic Plan; Artificial Intelligence, Automation, and the Economy; Preparing for the Future of Artificial Intelligence; and Artificial Intelligence White Paper.

The European Union has released policies and plans including Strategic Research Agenda For Robotics in Europe 2014-2020, Robotics 2020 Multi-Annual Roadmap, Gauging the Future of EU Research & Innovation, Draft Report with Recommendations to the Commission on Civil Law Rules on Robotics, and Civil Law Rules on Robotics.

Germany has released Die neue Hightech-Strategie Innovationen für Deutschland (New High-Tech Strategy Innovations for Germany), Technik zum Menschen bringen-Forschungsprogramm zur Mensch-Technik-Interaktion ("Bringing Technology to the People" Research Program on Human-Machine Interaction), BMBF gründet Plattform "Lernende Systeme" (BMBF launches Platform for Learning Systems), Innovation Policy, and Präsentation zur Künstlichen Intelligenz (Presentation on Artificial Intelligence) co-prepared with France.

The United Kingdom has released RAS 2020 Robotics and Autonomous Systems, Industrial Strategy: Building a Britain Fit for the Future, Growing the Artificial Intelligence Industry in the UK, and Robotics and Artificial Intelligence: Government Response to the Committee's Fifth Report of Session 2016–17.

France's AI policy documents include For a Meaningful Artificial Intelligence—Towards a French and European Strategy and Präsentation zur Künstlichen Intelligenz (Presentation on Artificial Intelligence) co-prepared with Germany.

Japan has released two major AI policy documents—Japan Revitalization Strategy 2016 and Artificial Intelligence Technology Strategy: Report of Strategic Council of AI Technology.

Since 2013, China has released a series of AI and related policy documents, including State Council Guidelines on Promoting the Healthy and Orderly Development of the Internet of Things, State Council Notice on Issuing "Made in China 2025", State Council Guidelines on Promoting the "Internet+" Action, State Council Notice on Issuing the Action Outline for Promoting the Development of Big Data, Thirteenth Five-year Plan on National Economic and Social Development, and State Council Notice on Issuing the "Next Generation

Artificial Intelligence Development Plan" released in 2017, referred to in the media as "Year 1 of AI development in China", which identifies the development directions and priority areas of China's AI development.

Figure 4-1 provides a survey of AI strategies and policies released by the United States, European Union, Germany, United Kingdom, France, Japan and China since 2013. The United States' AI policies are geared to dealing with the general trend of AI development and the impact and changes it may bring to the national security and social stability in the long term, and maintaining the leading position of the United States as a technology superpower in AI development and its key areas (internet; computer software and hardware such as chips and operating systems; and finance, military and energy areas). The United States strives to take a full measure of the effects of AI-driven automation on the economy, examine the opportunities and challenges that AI will bring to employment, and come up with strategies to deal with them. The European Union and European countries represented by Germany, United Kingdom and France stress the ethical and moral risks of AI development and in policymaking focus on how to respond to the potential security, privacy, integrity and other ethical threats posed by AI to humankind. Japan's AI policies, launched rather recently, have been geared to establishing a fairly comprehensive AI research advancement mechanism with a view to leveraging AI to promote its "Society 5.0" building.

China's AI policies in the early phase were tilted towards the Internet and therefore applications-oriented and focused on such areas as computer vision, natural language processing, intelligent robots and speech recognition. Despite having built some advantages in these areas, China's AI development was less than balanced when compared to the AI deployments of the United States. Therefore, China's current AI strategy emphasizes systematic deployments at the national level with a view to, as stated in the report to the 19th CPC National Congress, "promoting further integration of the internet, big data, and artificial intelligence with the real economy", by emphasizing the establishment of an open and collaborative AI technology and innovation system, grasping AI's characteristic of high integration of technological attributes and social attributes, adhering to the "three in one" synergy of AI R&D, product application and industry fostering, and strengthening AI's comprehensive support for technological, economic and social development and national security.

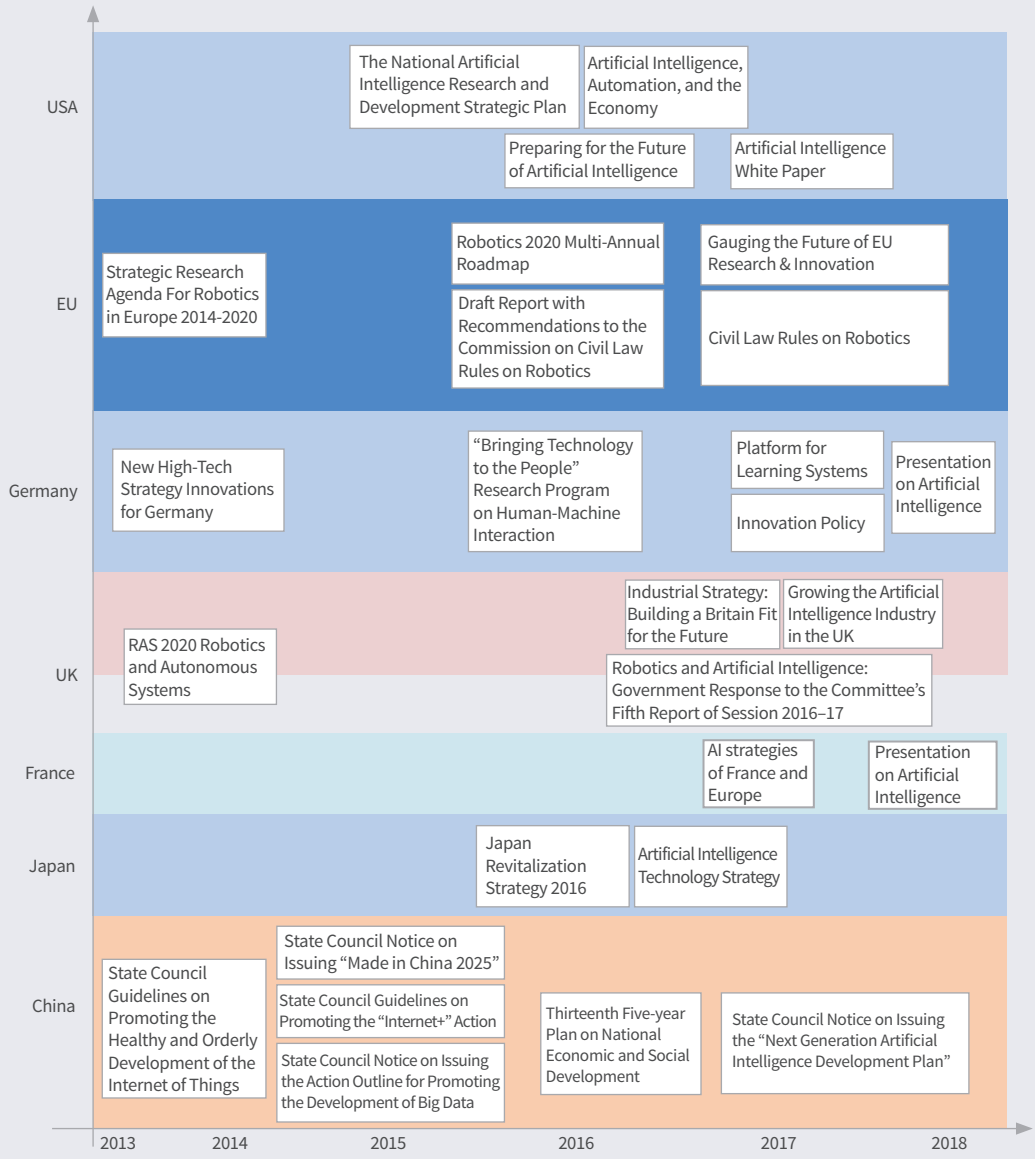


Figure 4-1 AI strategy and policy documents worldwide

4.1.2 Key AI Research and Application Areas in Major Countries and Regions

Because of significant differences among countries in their level of technological development and national conditions, their AI policies vary greatly in terms of priority areas of research and application.

Table 4-1 AI policies and priority areas worldwide

	Key research areas	Key application areas
USA	President Trump's FY2019 budget request was the first in American history to designate artificial intelligence and autonomous and unmanned systems as Administration R&D priorities. The Trump Administration's "Budget Blueprint to Make America Great Again" gives prioritized support to homeland security, military defense and medical care.	Homeland security: Face recognition, Flood Apex Program, wearable alarm system, etc. (The Department of Homeland Security has issued the Artificial Intelligence White Paper and Report on the Executive Summary of Emerging Technologies Strategy to the President (Draft)); Medical imaging (The Roadmap for Medical Imaging Research and Development has been released, which mentions the coordination between AI and medical imaging); National defense and military (Special Program Announcement for 2018 Office of Naval Research Basic Research Opportunity: "Advancing Artificial Intelligence for the Naval Domain")
EU	Data protection; network security; AI ethics; digital technology training; e-government	Supercomputer; data processing; financial economy; digital society; education
Germany	Human-computer interaction; cyber-physical system; cloud computing; computer identification; intelligent service; digital network; microelectronics; big data; network security; high-performance computing	Intelligent transportation (land, sea and air); healthcare; agriculture; ecological economy; energy; digital society
UK	Hardware CPU; identification	Underwater robotics; offshore engineering; agriculture; aerospace; mineral collection
France	Supercomputer	Ecological economy; gender equality (AI education for women); e-government; medical care
Japan	Robotics, brain-to-brain communication, sound recognition, language translation, social knowledge analysis, innovative network construction, big data analysis, etc.	Production automation, Internet of Things, medical health and care, space movement (automatic driving, unmanned delivery, etc.)
China	Key Generic Technologies System "1+N" Plan: "1" refers to the next-generation AI major S&T project which focuses on basic theories and key generic technologies; "N" refers to AI theoretical research, technological breakthroughs and product development and applications. Efforts are also outlined to strengthen interdisciplinary research and free exploration in the frontiers of artificial intelligence.	Smart manufacturing; smart agriculture; smart logistics; smart finance; smart commerce; smart home; smart education; smart pension; administrative management; judicial management; urban management; environmental protection Strengthening demonstration and application of AI technologies in key projects such as deep underwater space station, health security, smart city and smart agricultural machinery.

The Trump administration initially reacted slowly and indifferently to the rise of artificial intelligence, but this situation is undergoing changes. At the recently concluded "Artificial Intelligence for American Industry" summit, the White House announced the establishment of the Select Committee on Artificial Intelligence to examine U.S. priorities and investments on AI development. The R&D budget will focus on autonomous and unmanned systems, especially in such areas as homeland security and national defense. In application innovation, AI has been widely applied in different sectors in the United States such as homeland security, medical imaging, and national defense and military, with applications including face recognition and wearable alarm systems in homeland security and AI-powered medical imaging in medical care.

The European Union has attached great importance to AI and actively united its member states to conduct related legislative discussions. Most EU countries have joined the Horizon 2020 program and the SPARC robotics program in an effort to improve Europe's overall competitiveness through innovation in this field. Some EU countries, such as Italy and Finland, have not yet formed a unified government-level strategic policy, but their major universities and research institutions have undertaken their national research tasks in the field of AI. In general, the EU pays more attention to AI's impact on human society. Its research usually involves social sciences such as data protection, network security and AI ethics. At present, it has also invested considerably in digital technology training and e-government related research. In applications, the EU stresses AI-related basic research and has spent heavily on supercomputers and data processing applications in particular. The EU has also shown interest in in-depth AI applications in such fields as financial economy, digital society and education.

Germany, which launched its "Industry 4.0" program in 2013 leveraging its strong industrial infrastructure, has prioritized human-computer interaction, cyber-physical systems, cloud computing, computer identification, intelligent services, digital networks, microelectronics and big data, network security and high-performance computing. In AI applications, it has focused on intelligent transportation, healthcare, agriculture, ecological economy, energy digital society and other fields, involving all aspects of German society.

The United Kingdom is committed to the R&D of AI technologies in the fields of hardware CPU and identification. In applications, it has widely applied AI technologies in areas including underwater robotics, offshore engineering, agriculture, aerospace and mineral collection. Compared to the United States and Germany, the United Kingdom is more confined in both research and applications of AI but has greater specificity and depth with an emphasis on practicality. Meanwhile, the UK government has also emphasized AI talent development and invested heavily in technical colleges which have attracted many high-level specialists from universities.

France has allocated a lot of resources for R&D of AI-related supercomputers. In AI applications, it has focused on ecological economy, gender equality, e-government and medical care. When it comes to practicality, France has paid close attention to industries that are closely related to AI such as healthcare and autonomous cars and adopted a more cautious attitude towards investment in new AI research areas, with its R&D priorities concentrated in traditional fields.

Japanese society has always had a strong interest in robotics-related R&D and manufacturing. Japan has invested greatly in the fields of robotics, brain-to-brain communication, sound recognition, language translation, social knowledge analysis,

innovative network construction and big data analysis. In AI applications, Japan has focused on two lines: 1) traditional robot manufacturing and applications to achieve production automation, automatic delivery and large-scale IoT deployment in replacing workers; and 2) AI-powered medical care and autonomous vehicles to solve the country's increasing population ageing. It can be seen that Japan's AI R&D and applications are geared to solving specific real-world issues while reflecting its traditional cultural setting.

China's AI development is guided by the "1+N" planning system and has its focus on basic theories and key technologies while also supporting free exploration in interdisciplinary research. In applications, China has highlighted the important role played by AI in extensive fields including smart manufacturing, smart agriculture, smart logistics, smart finance, smart commerce, smart home, smart education, smart healthcare, smart pension, administrative management, judicial management, urban management, environmental protection and underwater space exploration. It can be seen that China's AI research and applications have been driven by the pursuit of sustainable economic and social development and cover wide research and application areas with a view to achieving comprehensive development of the AI industry.

4.1.3 AI Policy Advancement Agencies in Major Countries and Regions

The United States' AI policy steering agencies are the National Science and Technology Council (NSTC), the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB). Through the joint efforts of the U.S. government and the private sector, the NSTC Subcommittee on Machine Learning and Artificial intelligence and the Select Committee on Artificial Intelligence were established to facilitate AI industry financing. In 2016, NSTC and NSTC Subcommittee on Networking and Information Technology Research and Development (NITRD) jointly released the National Artificial Intelligence Research and Development Strategic Plan which states that NSTC is the principal means by which executive branches coordinate science and technology policy across diverse entities. NSTC oversees the working groups focused on different aspects of AI, and establishes clear national goals for Federal science and technology investments. This makes NSTC an important agency for AI investments.

The EU AI policy's two principal driving forces are the European Commission (EC) and the European Parliament Committee on Legal Affairs (JURI), which not only design AI development plans but also address issues that AI development may encounter. In 2013, the EC and euRobotics jointly launched the SPARC robotics program aimed at driving Europe's robotics development, promoting industry and supply chain development, and encouraging the development of robotic technologies. The JURI committee has proposed bills that emphasize research on legal issues relating to robotics and AI development and related issues such as ethics, safety and intellectual property protection. Subsequent agencies that have come to the AI scene include euRobotics, SPARC, European Robotics Technology Platform (EUROP) and European Robotics Network (EURON). Among them, euRobotics launched the SPARC robotics program and Horizon 2020 initiative and set forth a robotics development roadmap. Other agencies such as EUROP and EURON play an important organizing and coordinating role and promote AI research and industry development by integrating AI research institutes and researchers.

Germany's main AI policy steering agencies are the federal government, Federal Ministry of Education and Research (BMBF), Federal Ministry for Economic

Affairs and Energy (BMWi) and German Academy of Science and Engineering (acatech), which lead Germany's AI policy making and implementation. Among them, BMBF is directly involved in AI technology development, such as in the service robot project. BMWi supports six robotics projects and conducts research on robotic autonomous learning and behavioral decision-making models. Other mechanisms later introduced such as Industry 4.0 Platform in 2013, Platform for Learning Systems in 2017 and German-French Artificial Intelligence Joint R&D Center and German Research Center for Artificial Intelligence (DFKI) in 2018 are also important R&D instruments of Germany's AI policy.

The United Kingdom has put in place a well-functioning AI development ecosystem comprising researchers, developers and enterprises, where the main driving forces of AI policy are the Engineering and Physical Sciences Research Council (EPSRC), Royal Academy of Engineering, and subsequently established or introduced entities such as the RAS Leadership Council, the National Artificial Intelligence Research Center and the UK AI Council. The British government has hoped to make the UK an innovation center for artificial intelligence and to establish a partnership with the industry to promote artificial intelligence in various fields. In this context, the AI Council came into being. The council is a body of publicizing and promoting AI that comprises AI researchers and provides scientific data and reference for the government's AI reports. It conducted discussions on AI applications in the medical sector and has become an important factor in the UK government's AI policymaking.

France has made active efforts to advance AI innovation and R&D, leveraging the opportunities from the EU's robotics development. The main driving forces of France's AI policy making include the French Parliament, French Institute for Research in Computer Science and Automation, French Digital Council and Directorate General of Armaments (DGA). At the same time, France's AI research has also focused on the ethical issues relating to AI industry development, and this concern led to the establishment of an AI ethics committee to advance the country's AI strategy with a series of measures to establish a fair and sound assessment system to ensure that data is appropriately used and avoid any misleading use of AI.

In Japan, Prime Minister Shinzo Abe proposed the establishment of AI R&D targets and industrialization roadmap at the 5th Public-Private Dialogue towards Investment for the Future held in April 2016. After that, the Japanese government officially set up the Artificial Intelligence Technology Strategy Council that serves as a national-level general management agency that coordinates the Ministry of Internal Affairs and Communications, Ministry of Education, Culture, Sports, Science and Technology and Ministry of Economy, Trade and Industry to jointly promote AI technology R&D and applications. Among them, the Ministry of Internal Affairs and Communications is mainly responsible for AI development in areas including brain-to-brain communication, sound recognition, language translation, social knowledge analysis and innovation network, with efforts led by the National Institute of Information and Communications Technology under it; the Ministry of Education, Culture, Sports, Science and Technology is mainly responsible for AI development in areas including basic research, innovation based on relevant S&T achievements, development of emerging next-generation basic technologies, provision of high-performance computing resources and talent development, with efforts led by Institute of Physical and Chemical Research under it; and the Ministry of Economy, Trade and Industry is mainly responsible for AI development relating to applied research, practical use and social applications of AI, standard assessment methods and techniques, and research on large-scale use of AI, with efforts

led by the National Institute of Advanced Industrial Science and Technology (AIST) under it.

In China, AI development has been in line with a three-step strategy introduced in 2017 in an effort led by the State Council, the Central Leading Group for National Science and Technology System Reform and Innovation System Construction and the Ministry of Science and Technology which are responsible for formulation and implementation of AI plans and projects and supported by the Office for Advancing AI Plans and the Advisory Committee on AI Strategy with research on relevant issues such as AI theories and technologies and related legal and ethical issues and regular publication of government white papers on AI. The Advisory Committee on AI Strategy was established in November 2017 with the release of the Next-Generation AI Development Plan in a significant move which marked China's commitment to promoting innovative applications of AI on a large scale, optimizing its systematic deployments of AI development, and turning AI into a major driver of China's industry upgrade and economic transformation and which, so to speak, ushered China's AI development into the stage of comprehensive implementation.

Table 4-2 Steering Forces of AI Policy Worldwide

Country	Driving Forces (Policymaking and Funding)	Agencies Subsequently Created or Added
USA	National Science and Technology Council (NSTC); White House Office of Science and Technology Policy (OSTP); Office of Management and Budget (OMB)	NSTC Subcommittee on Machine Learning and Artificial intelligence (formed to help coordinate Federal activity in AI); Networking and Information Technology Research and Development (NITRD) (formed to define the Federal strategic priorities for AI R&D, with particular attention on areas that industry is unlikely to address); Select Committee on Artificial Intelligence (formed to assist the NSTC to improve the overall effectiveness and productivity of Federal R&D efforts related to artificial intelligence (AI))
EU	European Parliament Committee on Legal Affairs (JURI); European Commission (EC)	euRobotics; SPARC; European Robotics Technology Platform (EUROP); European Robotics Network (EURON)
Germany	Bundesregierung (Federal Government); Federal Ministry of Education and Research (BMBF); Federal Ministry for Economic Affairs and Energy (BMWi); German Academy of Science and Engineering (acatech);	German Research Center for Artificial Intelligence (DFKI); 2018 German-French Artificial Intelligence Joint R&D Center; 2017 Platform for Learning Systems 2013 Industry 4.0 Platform;
UK	Engineering and Physical Sciences Research Council (EPSRC); Royal Academy of Engineering	RAS Leadership Council; National Artificial Intelligence Research Center; AI Council; Open Data Institute (ODI); Royal Statistical Society (RSS) Data Science Section; techUK; All-Party Parliamentary Group on Artificial Intelligence

Country	Driving Forces (Policymaking and Funding)	Agencies Subsequently Created or Added
France	French Parliament; French Institute for Research in Computer Science and Automation; French Digital Council; Directorate General of Armaments (DGA);	AI Ethics Committee; Planning to set up an environmental impact assessment platform to build a green value chain of AI
Japan	Public-Private Dialogue towards Investment for the Future	Artificial Intelligence Technology Strategy Council, serving as a national-level general management agency that coordinates the Ministry of Internal Affairs and Communications, Ministry of Education, Culture, Sports, Science and Technology and Ministry of Economy, Trade and Industry to jointly promote AI technology R&D and applications
China	State Council; Central Leading Group for National Science and Technology System Reform and Innovation System Construction; Ministry of Science and Technology;	Office for Advancing AI Plans; Advisory Committee on AI Strategy (advancing project implementation through coordination of the Ministry of Science and Technology and other government authorities)

4.2 China's National AI Policy

4.2.1 China's National AI Policy Trend

Since the rise of AI research in China, the country has released a series of AI policies which have effectively promoted the stable development of AI technology and related industries. Searching the government documents database using keywords in the AI keyword list returned 202 central-level AI policy documents of China.

On August 8, 2016, the State Council issued the National Plan for Scientific and Technological Innovation During the Period of the Thirteenth Five-year Plan, which explicitly specified AI as the main direction of developing next-generation information technology, emphasized that the effort to build a modern industrial technology system should focus on "developing natural human-computer interaction, especially intelligent perception and cognition, virtual-physical integration and natural interaction, and semantic understanding and smart decision-making" and required "vigorously developing big data-driven human-like intelligence technologies and methods; making breakthroughs in human-centric human-machine fusion theories, methods and key technologies and developing related equipment, tools and platforms; and making breakthroughs in human-like intelligence based on big data analysis and achieving human-like vision, hearing, speech and thinking to support AI-driven industrial development and demonstrative applications in key sectors such as education, office and healthcare." At present, AI has become a core part of China's "Deep Blue" program geared to safeguard national security and strategic interests with strategic high tech. The report to the 19th CPC National Congress highlighted the commitment to "building China into a manufacturer of quality and develop advanced manufacturing and promoting further integration of the internet, big data, and artificial intelligence with the real economy", showing that AI has become a key national strategy and an important direction of China's industrial transformation. In the field of AI, China has rolled out a series of policy

documents including State Council Guidelines on Promoting the Healthy and Orderly Development of the Internet of Things, Made in China 2025, Robotics Industry Development Plan (2016-2020), State Council Guidelines on Promoting the "Internet+" Action, State Council Notice on Issuing the Action Outline for Promoting the Development of Big Data, Thirteenth Five-year Plan on National Economic and Social Development and State Council Notice on Issuing the "Next Generation Artificial Intelligence Development Plan". Among them, the Next Generation Artificial Intelligence Development Plan stated that the comprehensive AI advancement in terms of disciplinary development, theoretical modelling, technological innovation and software and hardware upgrade is triggering a chain reaction that will accelerate the change of economic and social development from digitalization and connectivity to artificial intelligence. Facing a complicated national security and international competition situation, China must adopt a global perspective and develop AI as a national strategy by making proactive systematic deployments and always maintaining the strategic initiative in international competition in the AI era to build new competitive edge, increase the development potential of the country, and effectively protect national security. Specific measures that have been outlined include thoroughly implementing the innovation-driven development strategy, accelerating the integration of AI with economy, society and national defense, improving innovation capabilities powered by next-generation AI technology, developing the intelligent economy, building an intelligent society, safeguarding national security, establishing an ecosystem where knowledge clusters, technology clusters and industry clusters are integrated based on positive interaction and talent, systems and culture support each other, anticipating and addressing potential risks and challenges, advancing AI-driven sustainable development, comprehensively increasing China's productivity, overall national strength and international competitiveness, and providing a powerful support for China's efforts to become an innovative nation and technology superpower and achieve the two centennial goals and the great rejuvenation of the Chinese nation.

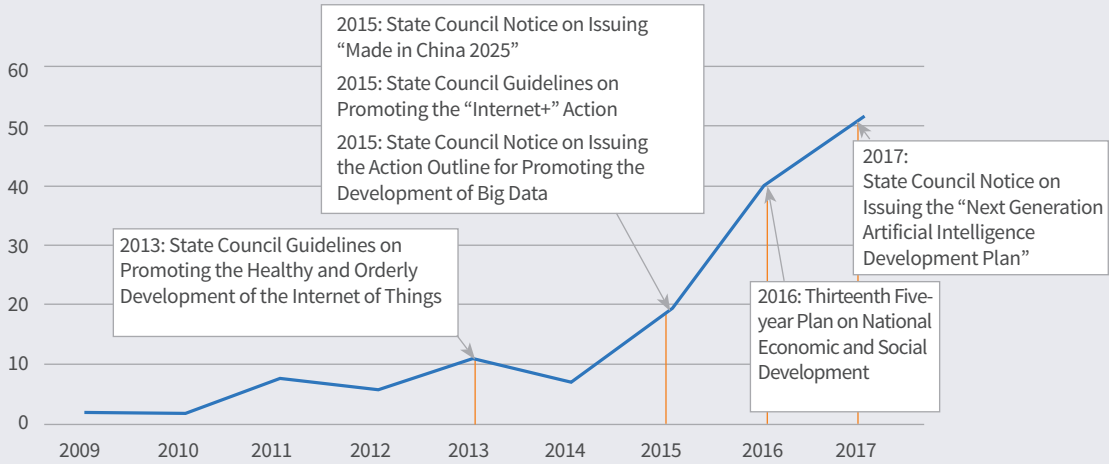


Figure 4-2 AI policy citation frequency and stages

China's AI policies can be divided into five stages according to the time of release of key AI policy documents: Stage 1 (before 2013), of potential development, where few policy documents were released and AI was not specified as a national priority; Stage 2 (2013-2015), of preliminary development, where the importance of AI began gaining recognition across all circles of society; Stage 3 (2015-2016), of rapid development, where a lot of policies documents were released and AI was elevated as a national strategy; Stage 4 (2016-2017), of stable development, where understanding of AI R&D and industry development was increasingly mature and policy documents came out stably; and Stage 5 (2017 to the present), of steady iteration, where all sectors have a more pragmatic understanding of AI and related policies are more specifically targeted.

4.2.2 Evolution of China's National AI Policy Themes

Corresponding with the release of key policy documents, each stage had remarkably different themes.

In Stage 1 (2009–2013), AI policy themes focused on IoT, information security, database, AI and infrastructure. In this stage, AI R&D and applications did not attract public attention and were mainly discussed in the academic fields, especially in computer science research.

In Stage 2 (February 2013–May 2015), the main AI policy keywords, in the descending order of frequency, included IoT, technical standards, infrastructure, big data and AI. In this preliminary stage of AI development, all circles of society gradually realized the importance of AI and policy adjustments were made that reflected increasing importance attached to technologies such as big data and infrastructure and emphasized the creation of standards in the early stage of AI development;

In Stage 3 (May 2015–March 2016), the main AI policy keywords included big data, infrastructure, IoT, cloud computing and data sharing. This stage saw rapid AI development in China, marked by the release of a large number of AI policy documents, the enshrining of AI development as a national strategy and the focus of AI policy keywords on infrastructure, especially on big data, cloud computing, data sharing and AI infrastructure. It can be seen that this stage saw the entry of AI into the big data era and related policies began attaching importance to mining and analysis of massive data;

In Stage 4 (March 2016–July 2017), the main AI policy keywords, in the descending order of frequency, included big data, AI, infrastructure, IoT and cloud computing. This stage represented a period of stable AI development in China, which saw an increasingly mature understanding of AI R&D and industry development and an increase of AI policy documents issued. The frequent mentioning of AI indicated a sharp increase of attention paid by all circles of life to AI, and relevant segments of the AI industry began experiencing rapid development.

In Stage 5 (July 2017–the present), the main AI policy keywords included AI, big data, information security, cloud computing and infrastructure. This stage experienced an AI fever and since then has seen a more pragmatic understanding of AI from all sectors of life and a greater specificity within produced AI policy documents. In this stage, AI, supported by technologies such as big data, cloud computing and information security as well as rapid development of relevant infrastructure, has become a national strategic industry.

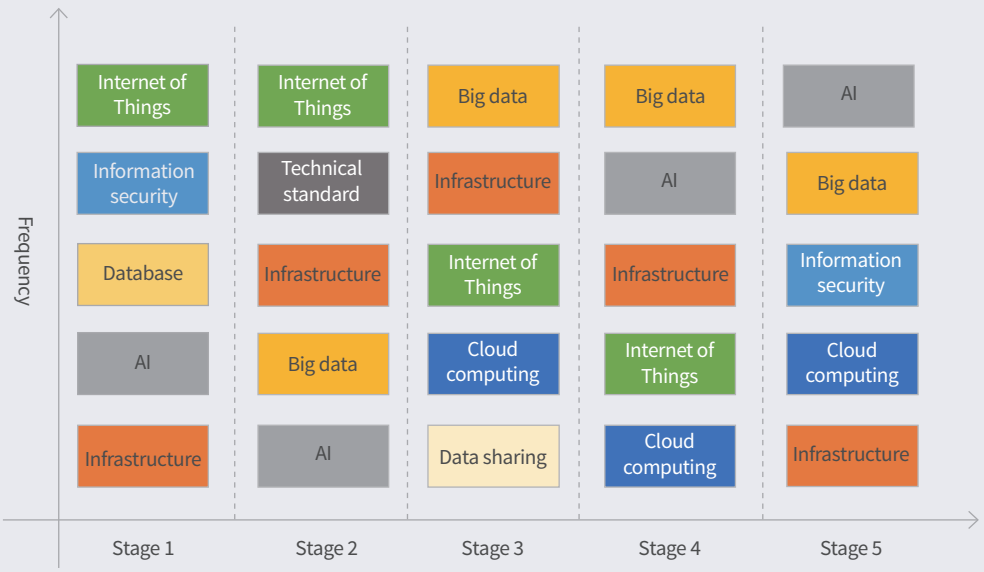


Figure 4-3 AI policy theme evolution

Keyword co-occurrence analysis is a common bibliometric method that uses the number of co-occurrence of two keywords in the same policy document as an indication of the degree of their relevance. Keywords can be clustered according to their co-occurrence relationships to identify core themes. On this basis, a keyword co-occurrence network can be created to identify the core themes in each stage.

- **Stage 1: before February 2013This stage**

marked the period of potential development of AI with policy keywords including IoT, technical standards, information security and infrastructure. This keyword distribution was closely related to the stage of social development at that time. In this stage, there had been a certain amount of infrastructure required by AI development, where remarkable progress had been made in such aspects as data collection, data mining, data sharing, database/data warehouse development. At the same time, this stage saw the rise of IoT in China, driven by significant breakthroughs in relevant fields including wireless intelligent sensor network communication technology, micro-sensors, sensor terminals and mobile base stations, and a complete industry chain had been formed in fields such as smart healthcare, smart logistics, smart transportation and smart agriculture. This stage, however, left many important things unattended such as intellectual property, intellectual rights protection, technical standards, information security and public security due to the absence of AI and IoT policies offering guidance on such matters.

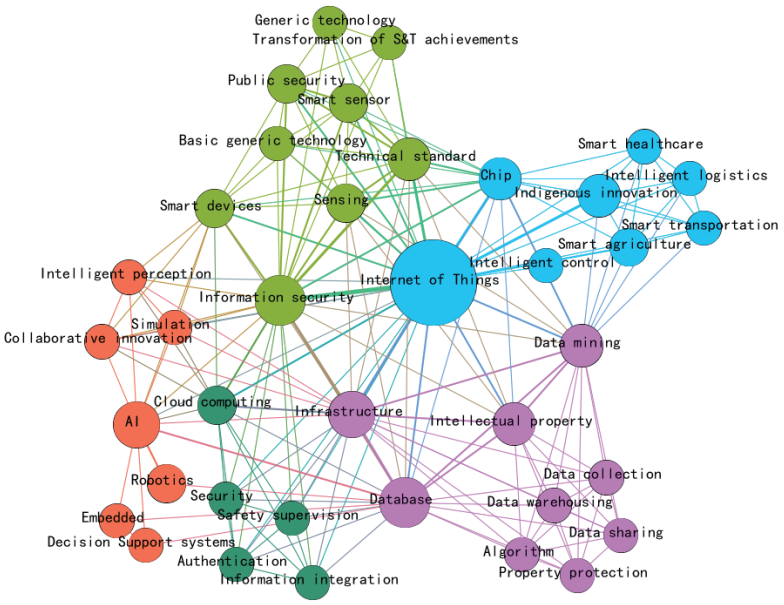


Figure 4-4 AI policy keyword co-occurrence diagram before February 2013

- **Stage 2: February 2013 – May 2015**

In this stage, which began with the release the State Council Guidelines on Promoting the Healthy and Orderly Development of the Internet of Things on February 17, 2013, IoT and technical standards remained core themes, but keywords such as AI, security regulation, big data and indigenous innovation began occurring more frequently. This stage saw China lay some groundwork in IoT technology development, standard formulation, industry fostering and industry application and saw big data technology gain application in IoT development, but AI policy keywords still focused on issues that remained unsolved such as difficulty in key technology R&D, yet-to-be-improved infrastructure, and information security threats. Meanwhile, it saw steady development in such fields as smart grid, smart city and smart device, with relevant AI research projects expecting to gain actual applications in public security and other fields and provide more advanced information processing and analysis capabilities.

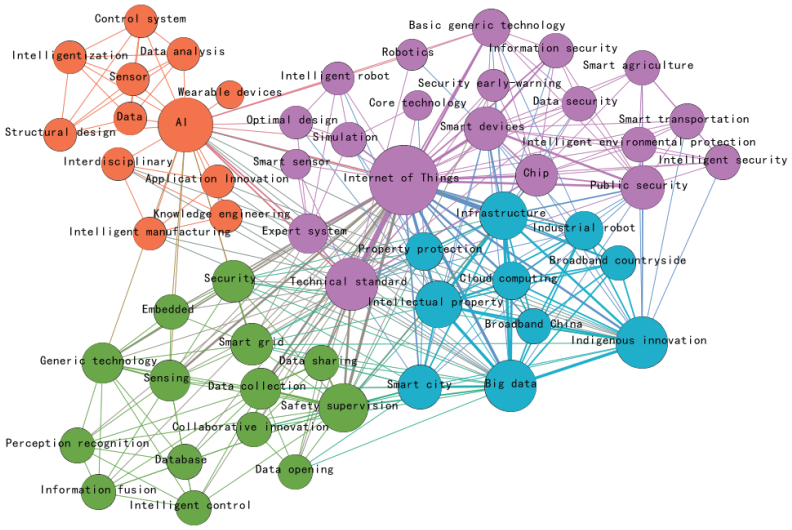


Figure 4-5 AI policy keyword co-occurrence diagram from February 2013 to May 2015

- **Stage 3: May 2015 – March 2016**

This stage saw the release of a series of important policy documents such as Made in China 2025, Robotics Industry Development Plan (2016-2020), State Council Guidelines on Promoting the "Internet+" Action, and State Council Notice on Issuing the Action Outline for Promoting the Development of Big Data, with basic technologies of AI such as big data, infrastructure, information security and IoT becoming core themes and AI disappearing altogether. This, however, did not mean that AI was fading away but that as increasing importance was attached to the foundation of AI development and as understanding of AI became more mature, the focus had been shifted to basic technologies and relevant real-world applications of AI (such as smart agriculture). This stage saw the rapid development of AI. In May 2015, the State Council issued Made in China 2025, in which it outlined comprehensive deployments to turn China into a manufacturing power. Smart manufacturing was designated as a key direction of Chinese manufacturing, and efforts were highlighted to accelerate integrated development of next-generation information technology and manufacturing technology, develop intelligent equipment and smart devices, advance production automation, and promote AI application in wide fields including smart home, smart devices, smart cars and robots. In July 2015, the State Council issued the Guidelines on Promoting the "Internet+" Action which explicitly identified AI as one of the 11 prioritized areas of development to form new industrial models and thus elevated AI to the level of a national strategy, ushering AI into the new era of "Internet+" and big data.

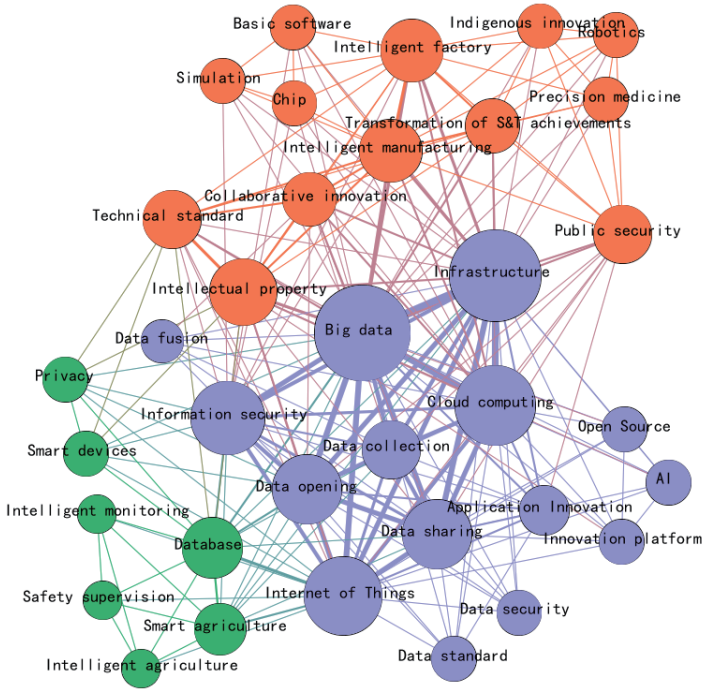


Figure 4-6 AI policy keyword co-occurrence diagram from May 2015 to March 2016

- **Stage 4: March 2016 – July 2017**

In March 2016, the Thirteenth Five-year Plan on National Economic and Social Development (Draft) was released which highlighted a commitment to making breakthroughs in AI. The keyword co-occurrence network for this stage became more complicated, though big data, AI, infrastructure, IoT and technical standards remained to be core themes, themes such as robotics, smart manufacturing and deep learning gained prominence. The background was that with the development of AI technology, all circles of life had an increasingly mature understanding of AI R&D and industry development and as a result paid more attention to AI's future applications (robotics, smart manufacturing, etc.) and enabling technologies (deep learning, etc.). The fact that high-frequency AI policy keywords continued to be big data and AI showed China's determination and attitude towards AI development in this stage. In this stage, development in key fields such as virtual technology, smart commerce and industrial robotics marked the gradual establishment and improvement of the AI industrial system, and at the same time, emerging technologies like IoT, cloud computing and big data gradually became strategic enablers of AI innovation and development.

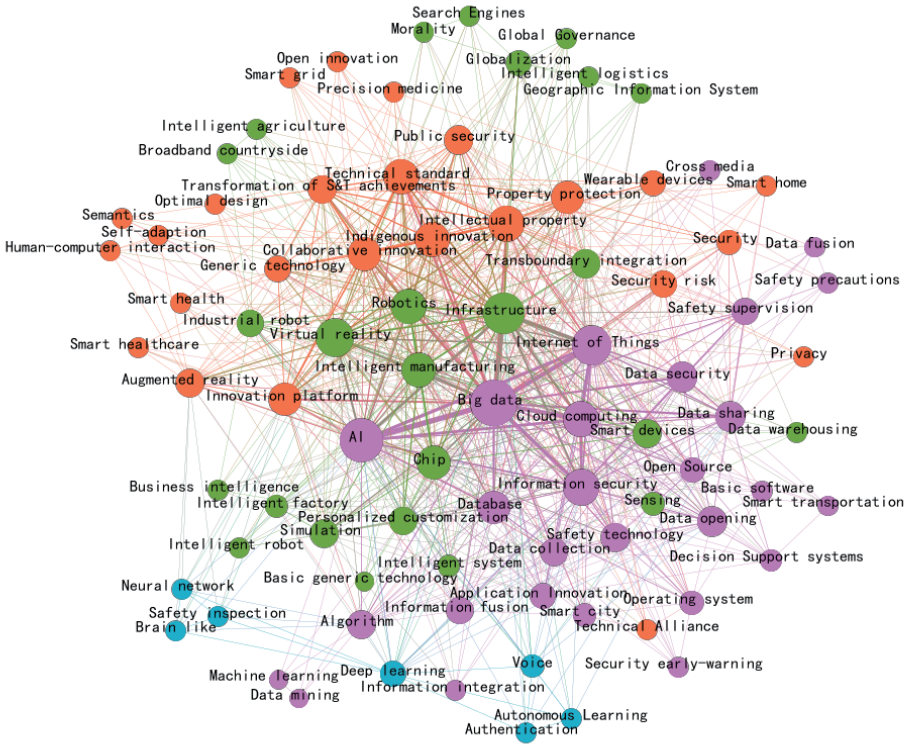


Figure 4-7 AI policy keyword co-occurrence diagram from March 2016 to July 2017

- **Stage 5: July 2017 – May 2018**

In July 2017, China released the State Council Notice on Issuing the "Next Generation Artificial Intelligence Development Plan", signifying the start of the advancement of next-generation AI. This stage saw AI become the No. 1 core AI policy keyword, followed by other prominent keywords such as intellectual property and intellectual rights protection. This stage experienced a fever of AI development and saw a more pragmatic and more internationally-contextualized understanding of AI

across society, leading to increasing attention paid to the intellectual property and intellectual rights protection relating to AI technologies. Policies in this stage were more targeted as well. In this stage, China placed a greater emphasis on building a safe intelligent society, with initiatives including developing efficient intelligent services, leveraging AI to improve public security, and promoting sharing and mutual trust in social interaction. Next-generation AI showed the characteristic of military-civilian two-way transformation which became a practical policy benefiting people by promoting integration-based innovation in six prioritized industries including manufacturing, agriculture, logistics, finance, commerce and home, marking the beginning of comprehensive AI development and applications in various sectors of the real economy.

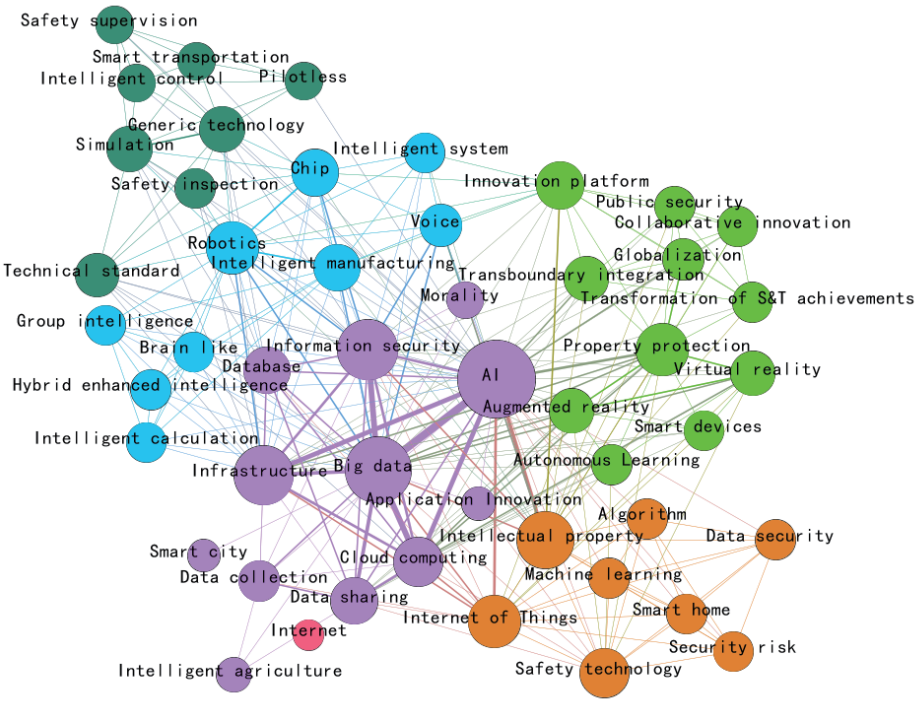


Figure 4-8 AI policy keyword co-occurrence diagram from July 2017 to May 2018

4.2.3 Citation Network Analysis of China's National AI Policy

In recent years, China's central government has issued a number of AI policies that are intertwined and cite each other. Figure 4-9 shows the citation network of China's central-level AI policy documents, where the individual policy documents vary in their relationship with other documents and their position in the citation network. Each code corresponds to a policy document. The table of contents of each document can be found on the website of the electronic version of this report.

According to the network graph, it can be seen that the AI policy at the center include the following: Thirteenth Five-year Plan on National Economic and Social Development, Made in China 2025, Outline of the National Medium- and Long-Term Program for Science and Technology Development (2006-2020), National Science, Technology and Innovation Plan for the 13th Five-year Plan Period, Outline of the National Strategy of Innovation-Driven Development, Interim Measures for the Management of Special Funds for the Development of the Internet of Things, Report to the 18th CPC National Congress, State Council issued the

Guidelines on Promoting the “Internet+” Action, State Council Notice on Issuing the Action Outline for Promoting the Development of Big Data, and State Council Guidelines on Promoting the Healthy and Orderly Development of the Internet of Things. These documents serve as core policy and programmatic documents in China’s AI policy system and direct and influence the formulation of other AI policy documents. The AI policy citation network identifies several groups of documents that are closely related with each other and form relatively independent sub-networks in the overall network, which are marked in different colors and represent six core thematic areas of China's AI policies, namely, Made in China, IoT, Internet+, big data, innovation strategy, and technical research and development.

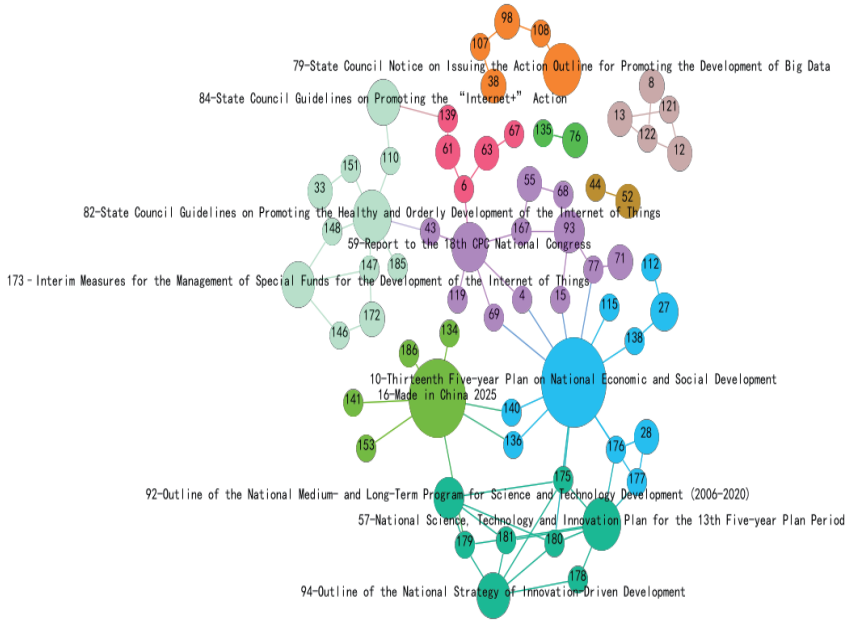


Figure 4-9 China's national AI policy citation network

4.3 China's Provincial-level AI Policy

A total of 845 provincial-level government AI policy documents were identified by searching the keywords in the AI policy keyword list. These policies were guideline documents formulated in a top-down approach in line with national AI industry plans and in the light of local conditions to steer local AI industry deployments. They led to a series of support policies and funds geared to strengthening AI technology R&D and product applications and promoting the integration of multiple fields such as healthcare, education, pension and culture to provide broad prospects for the AI industry development.

4.3.1 Number of Provincial-level AI Policy Documents

The first provincial-level AI policy came out in 2009 and since then, especially after the release of the State Council Guidelines on Promoting the Healthy and Orderly Development of the Internet of Things, a steadily increasing number of local government AI policies have been released every year.

Figure 4-10 Number of Provincial AI policy documents

After 2014, with the release of central AI policy documents including State Council Notice on Issuing "Made in China 2025", State Council Guidelines on Promoting the "Internet+" Action, State Council Notice on Issuing the Action Outline for Promoting the Development of Big Data and Thirteenth Five-year Plan on National Economic and Social Development, AI policy documents issued by local governments have grown exponentially. The number of such documents issued annually peaked in 2016 with 276. The recent release of the State Council Notice on Issuing the "Next Generation Artificial Intelligence Development Plan" has triggered a new round of release of local government AI policies.

Jiangsu, Guangdong and Fujian are the top three provinces by the number of AI policies issued in response to the national AI policies.

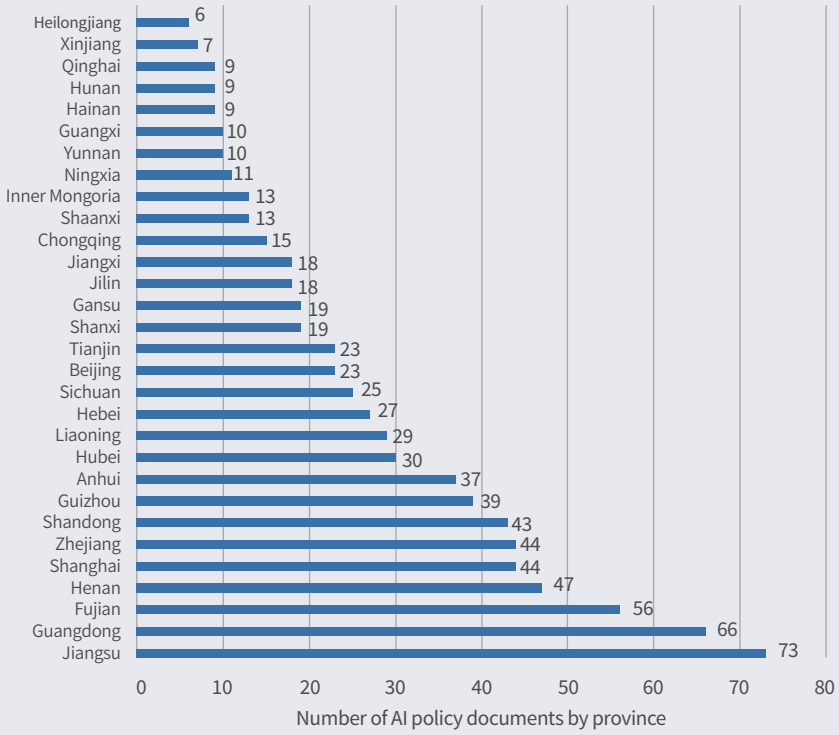


Figure 4-11 Number of provincial government AI policy documents

From the graph of the number of AI policy documents by province, it can be seen that three core regions of AI development have emerged—Beijing-Tianjin-Hebei, Yangtze River Delta, and Guangzhou-Hong Kong-Macao.

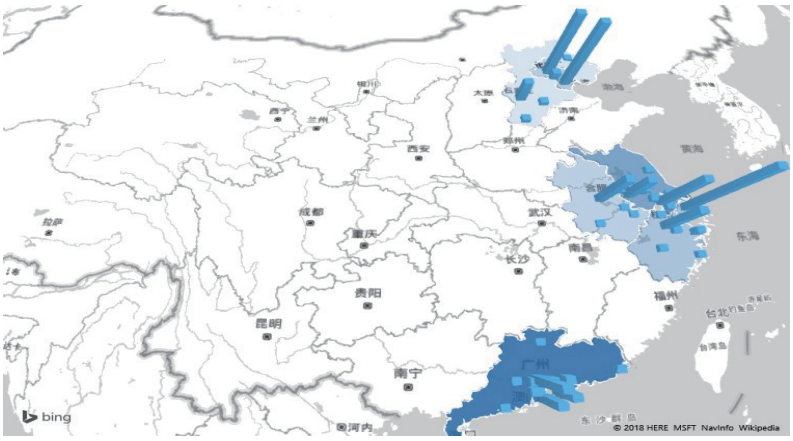


Figure 4-12 Top regions by the number of AI policy documents issued

Beijing-Tianjin-Hebei has many state-level scientific research institutions, numerous research institutes and many innovative industrial parks, and has gathered a large number of high-tech talents. Leveraging its unique advantages in knowledge resources, Beijing-Tianjin-Hebei has become the Asia Pacific's knowledge innovation center. By introducing industry development plans, creating R&D platforms and building industrial bases, Beijing-Tianjin-Hebei has not only driven the development of AI-related industries but also preliminarily formed several internationally competitive industrial clusters including autonomous driving, smart manufacturing, smart healthcare and public services.

The Yangtze River Delta region is represented by Zhejiang, Jiangsu and Shanghai. Jiangsu launched the "Jiangsu Brain Plan" to establish a national AI industry innovation base; Shanghai, located in the center of the Yangtze River Delta and relying on strong technical innovation resources, has built an "AI development cluster" in Xuhui district and established the "National Engineering Laboratory for Brain-like Intelligence Technology and Application"; and Zhejiang launched an AI town development plan to build the China (Hangzhou) AI Town in Future Sci-Tech City in Hangzhou, which is home to the Zhijiang Lab supported by leading research forces from Zhejiang University and Alibaba Group.

The Guangdong-Hong Kong-Macao region, represented by Guangzhou, Shenzhen, Hong Kong and Macau, has also seen local governments issue multiple AI policy documents, including Guangzhou Consensus on Artificial Intelligence and Support Plan of Foshan Municipality on Promoting Robotics Applications and Industry Development. Shenzhen, though not possessed of the knowledge resource advantages of Beijing and Shanghai, has built a high-tech industrialization platform and

become a frontier of China's efforts to respond to AI and other high-tech challenges by leveraging international trade liberalization and enabling quick marketization, productization and wide application of emerging technologies. Hong Kong, as an international financial, information and trade center, has become China's AI technology and product market-based transformation center by leveraging its professional financial talent forces and mature legal system. The government of Macao SAR signed a Strategic Cooperation Framework Agreement on Smart City Development with Alibaba Group to apply Alibaba's leading AI technologies to Macao's city development and build the world's largest city AI system.

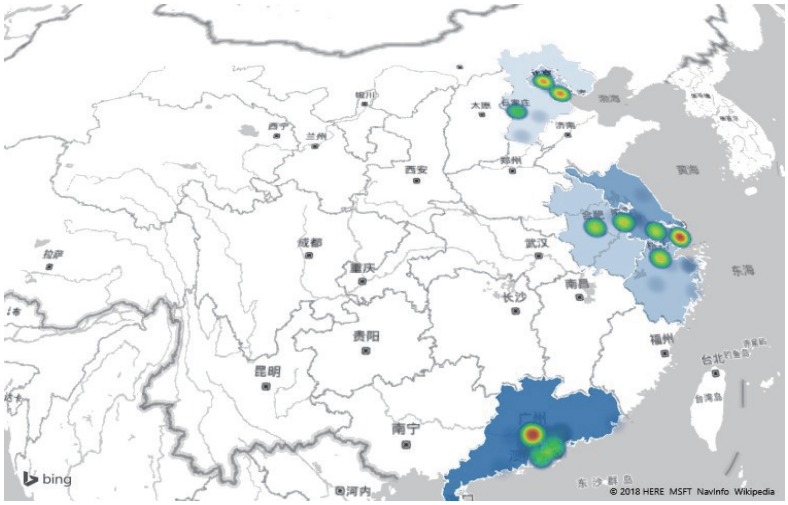


Figure 4-13 AI development trends in Beijing-Tianjin-Hebei, Yangtze River Delta and Guangdong-Hong Kong-Macao

4.3.2 Citation Relationship of Provincial-level AI Policies

AI policy documents issued by China's provincial governments in recent years have been intertwined with mutual citation of each other. Figure 4-14 shows the citation network of China's provincial-level AI policy documents, where the individual policy documents vary in their relationship with other documents and their position in the citation network. The table of contents of each document can be found on the website of the electronic version of this report.

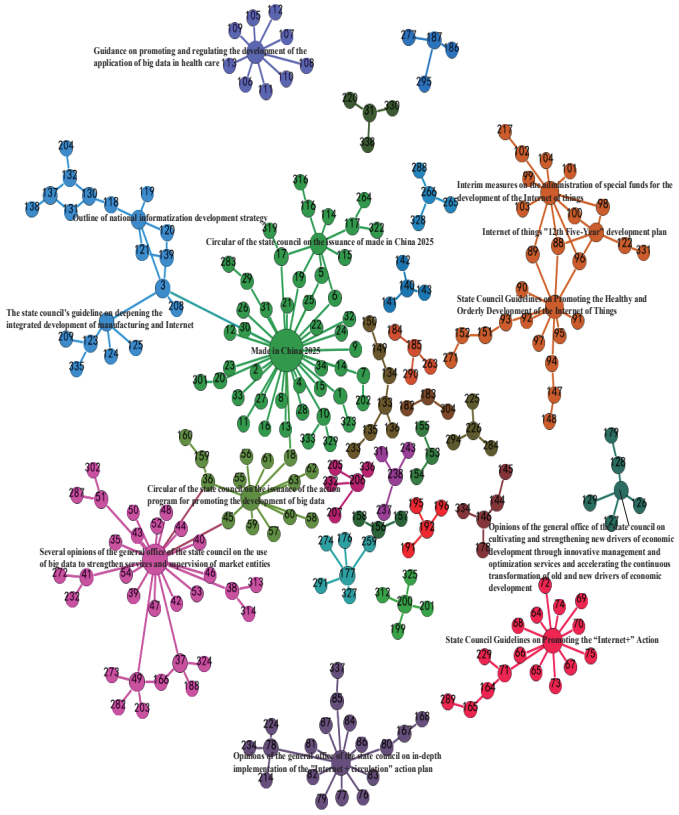


Figure 4-14 Graph of provincial policy documents citing central policy documents

It can be seen from Figure 4-14 that policy documents represented by the Opinions on In-depth Implementation of the "Internet + Circulation" Action Plan and the Guidelines on Promoting the “Internet+” Action and their corresponding provincial-level citing policies form simple first-level citation networks with no further policy derivatives, so that each network assumes a single-core single-level star-like structure. The snowflake-shaped networks are core citation networks represented by Made in China 2025 which is a single-core multi-center multi-level network with a single document serving as its main center. A citing policy of the core policy that is cited with a higher frequency in a subordinate network becomes a sub-center of the entire network which consists of a number of clusters. It can be seen from the graph that Made in China 2025 is a programmatic document in China’s AI development and connects to other policy clusters through citing policies and thereby directly or indirectly connects most provincial-level AI policies and plays an irreplaceable guiding role in the entire AI industry development process.

4.3.3 Theme Analysis of National and Provincial-level AI Policies

• Keyword co-occurrence analysis of national and provincial AI policy documents

Figure 4-15 shows the keyword co-occurrence of national and provincial AI policy documents, which provides an intuitive picture of the relevance of national and provincial AI policy documents in goals and contents. Keyword co-concurrence analysis finds that provincial AI policy documents are consistent with central AI policy documents in terms of both direction and content. Specifically, the State Council Notice on Issuing the “Next Generation

Artificial Intelligence Development Plan" released in July 2017 explicitly specified a three-step policy of AI development. In line with this policy, local governments such as Shanghai, Beijing, Zhejiang, Anhui, Guizhou and Jiangxi formulated their own AI policies. Overall, these local government AI policies were basically consistent with the national policies in goals and contents. The policy contents focused on three aspects, i.e. industry, technology and application. To be specific, they focused on machine learning, smart chips and cloud storage in industry; IoT, big data, AI and smart manufacturing in technology; and geographic information system, smart grid, smart agriculture, information security and precision medicine in application.

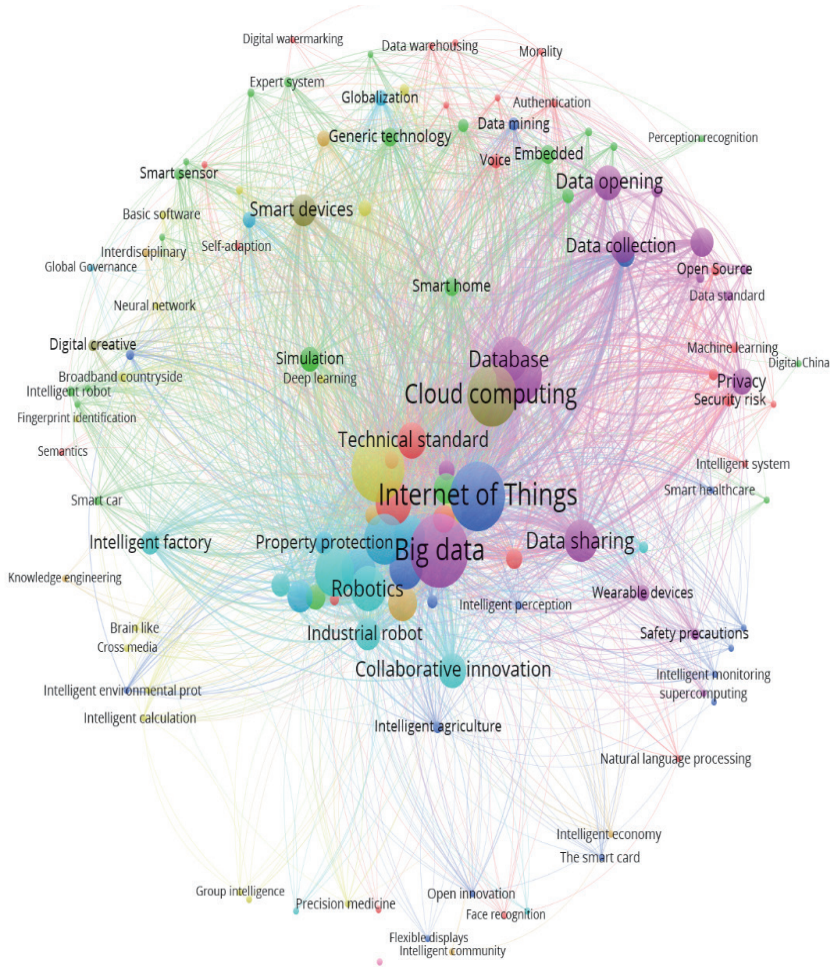


Figure 4-15 Keyword co-occurrence of national and provincial AI policy documents

• Keyword co-occurrence analysis of provincial AI policy documents

Figure 4-16 shows the keyword co-occurrence of provincial AI policy documents, which examines the AI policy priority areas of those provinces whose AI industries are closer to implementation. As shown by the graph, AI has had a solid foundation of development in such areas as unmanned systems, security, smart home, wearable engineering and smart robotics with smart analysis, decision, sensing and control capabilities and enabling technologies in fields including environmental monitoring, home security, medicine and health,

and energy management. All the provincial AI policy documents have been geared to making advancements in AI enabling technologies and mechanisms such as big data, IoT, indigenous innovation, intellectual property, research result transformation and data sharing and promoting the integration of AI with different industries with the emphasis on indigenous innovation and data sharing and the application of AI in wide fields including transportation, geography, economy and security regulation to accelerate AI development and uptake for the benefit of all citizens.

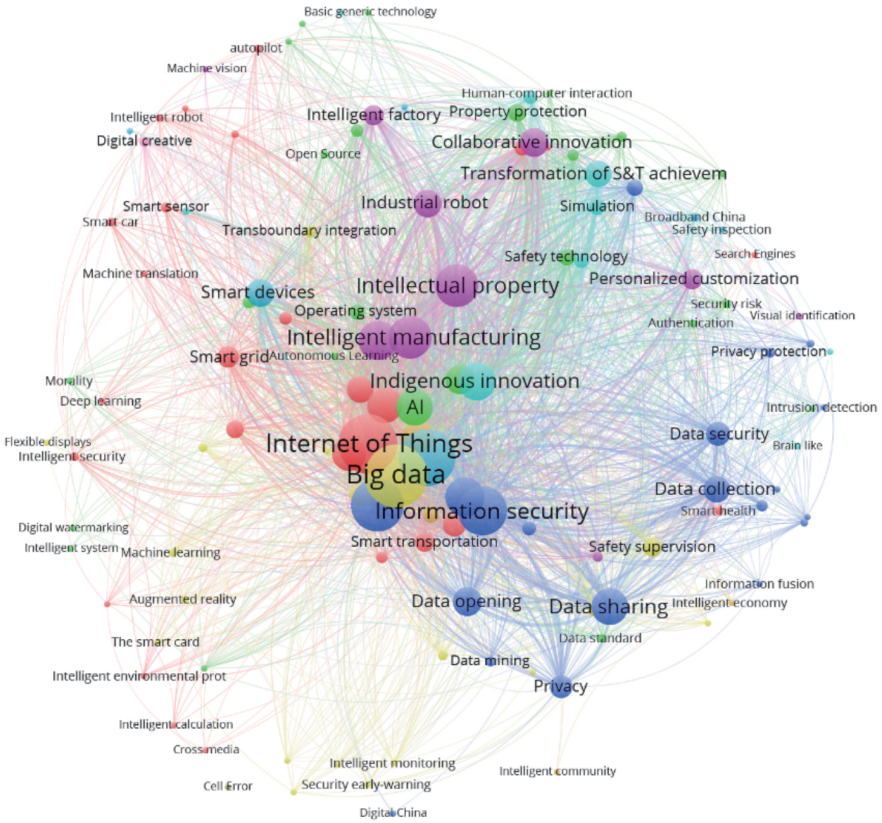


Figure 4-16 Keyword co-occurrence of provincial AI policy documents

While aligning with national AI strategic plans, local government AI policies had their own characteristics and priorities due to their local conditions, as illustrated by the top three provinces in terms of AI policy documents issued, with Jiangsu focusing on infrastructure, IoT and cloud computing; Guangdong on infrastructure, smart manufacturing and robotics, showing a great interest in AI applications; and Fujian on IoT, big data, innovation platform and intellectual property rights. A closer look at these differences explains that Jiangsu is more concerned with basic R&D of AI, especially basic AI technologies such as cloud computing and big data; Guangdong, a strong manufacturing province with the ability to quickly productize technologies, is more concerned with the applications of AI in fields such as manufacturing and robotics while working on basic AI technologies like big data and cloud computing; and Fujian, whose priority area of AI development is IoT, has leveraged its IoT industry alliance platform and Mawei IoT industry base to build a nationally leading IoT sensing and identification industry cluster.

05

Public Perception and General Impact of AI

05 Public Perception and General Impact of AI

5.1 Public Perception of AI

The flourishing of AI is profoundly changing people's lives. Half a century ago when AI was sprouting, most people would not expect that humans and machines would be so close. In fact, the discussions about human-machine relations have quickly gone beyond the academic world. From top-down design at the national level to the penetration into various sectors, AI is becoming a powerful engine driving disruptive changes.

From 2016 to 2017, AI received 286.3% more attention and became the most trending science topic of the year. [1]High technologies that can improve the life of ordinary people tend to have a higher reputation and influence. According to Toutiao Index monitoring for the first quarter of 2018 (Figure 5-1), analysis of article views, comments and sharing identified March 14 as the peak date in the quarter in terms of the amount of attention received by AI. The passing away of the famous UK physicist Stephen Hawking attracted massive attention from users and triggered many commemorative activities online.

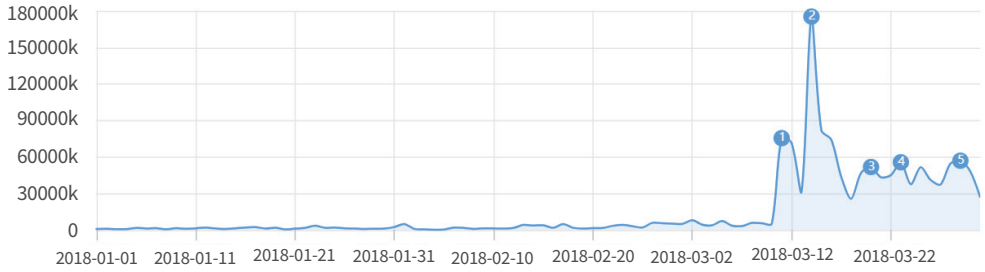


Figure 5-1 Public attention on AI related topics in Q1 2018

5.1.1 Survey of Public Perception of AI

Toutiao conducted a survey of its users from May 9 to May 13, 2017, which collected a total of 3,088 valid responses. According to the survey, only 6.23% of the respondents were ignorant of AI, and the rest knew about it from news (80.27%) and movies (37.25%).

[1] AI Impact Report, Toutiao.

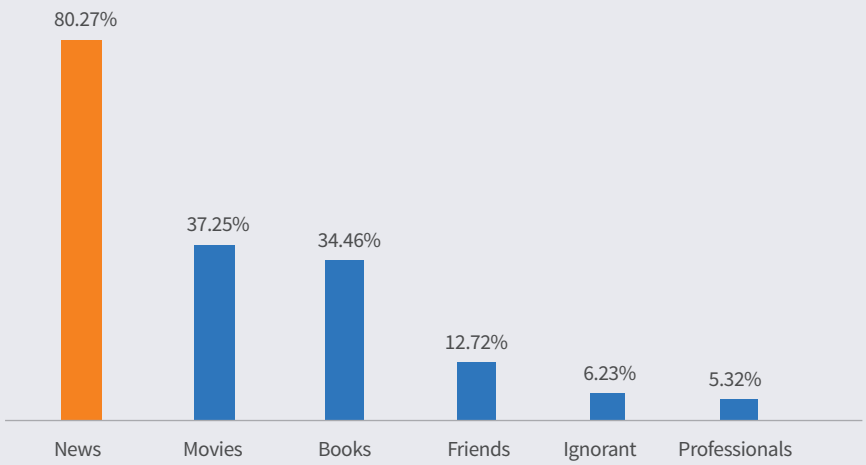


Figure 5-2 AI awareness by channel

AI has penetrated everyday life, but not all are aware of it or its effects. Although there was a high level of AI awareness, only 41.58% reported that they had used AI products, with 40.74% stating that they had never used any AI products, and 17.68% saying that they were not sure what makes a product an AI product.

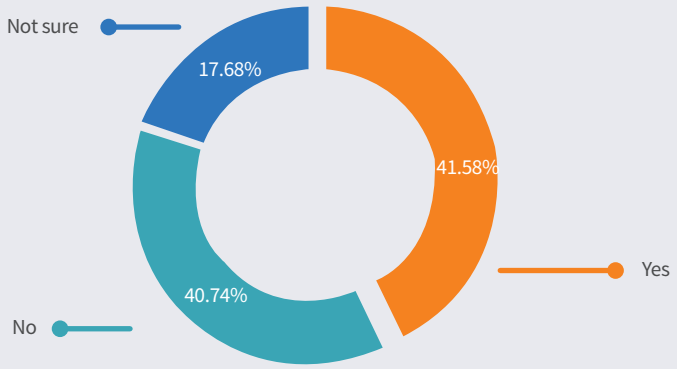


Figure 5-3 Awareness of AI product use

According to the survey, respondents were most interested in how AI development will affect themselves, with the top three questions being: What jobs will be replaced by AI? (46.14%) What harms will AI cause? (43.61%) Will AI become a subject capable of legal and moral awareness and civil conduct? (40.36%) All the three questions have negative implications, indicating that despite a supportive attitude towards AI development, people want to know more about the direct risks that AI might bring. For the question, "what worries you the most about AI", the top three concerns were

"AI losing control and causing social crises" (selected by 54.9% of respondents), "AI making wrong decisions or judgments" (46.01%), and "AI losing control and causing personal injuries" (45.81%), respectively.

With respect to the expectation of AI development, 53.15% of respondents expressed support of the in-depth and comprehensive development of AI, with more than 60% of respondents in provinces including Xinjiang, Shanxi, Guizhou, Anhui and Shandong expressing support. Respondents who held a conservative attitude accounted for 28.68%, who believed that AI development should be confined to those relatively low-risk projects. The rest included 15.77% who did not oppose AI but believed that the pace of development should slow down and 2.4% who opposed AI development.

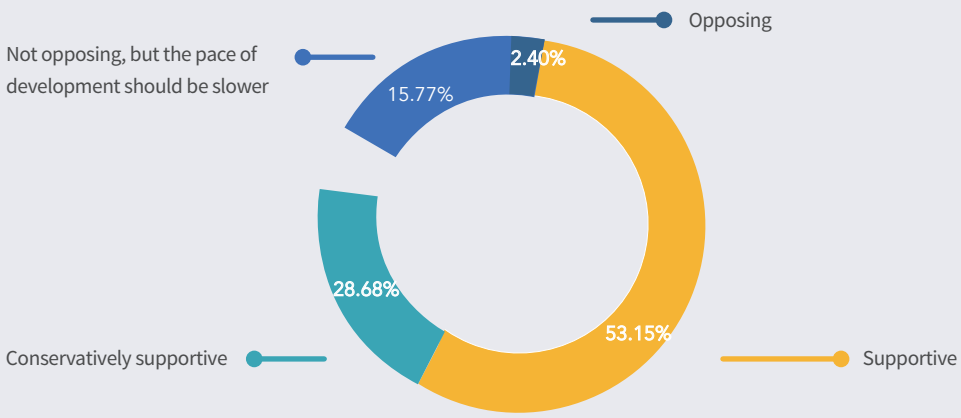


Figure 5-4 Expectation of AI development

5.1.2 Differences in Public Interest in AI

- **Industry differences**

The key to AI deployment is the rich variety of its application scenarios. In the current stage, AI has been applied in fairly wide areas, with the most common and familiar forms including autonomous cars, intelligent assistants, recommendation engines and multi-language translation. AI will find more and greater-depth applications at work and in everyday life in the future.

According to Toutiao Index data, the top four sectors of AI application in 2017 were finance, transport, education and healthcare, respectively.

In terms of the attention received for AI application, the financial sector came first, followed by transportation, education and healthcare.

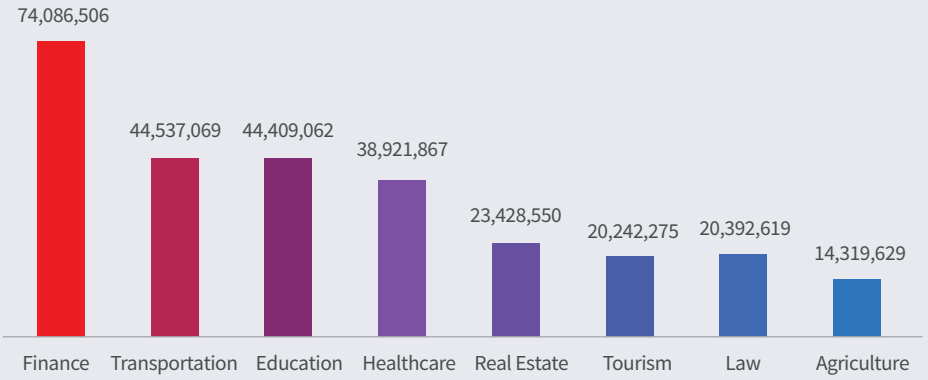


Figure 5-5 Top eight sectors of AI application by attention received

* Data explanation: The popularity index indicates the amount of attention received by a keyword. It is a weighted value based on a number of indicators such as views, comments, sharing and favoriting.
* Data monitoring time: January 1 – December 30, 2017

• Age and gender differences

The data collected from January 1 to December 30, 2017 were analyzed against the two indicators of age penetration and gender penetration, where age penetration is the number of views of articles containing AI keywords by users in an age group divided by the number of views of all articles by users in the age group, and gender penetration is the number of views of articles containing AI keywords by users of a gender divided by the number of views of all articles by users of the gender. According to data, users over 30 are more interested in AI, with the top group being the 31-40 age group, followed by the 41-50 age group. In terms of gender difference, male users are significantly more interested in AI than female users.

Users over 30 are more interested in AI, with male users showing a significantly greater interest in AI than female users

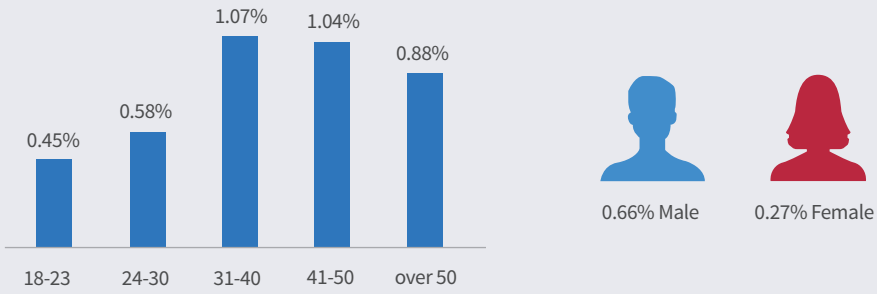
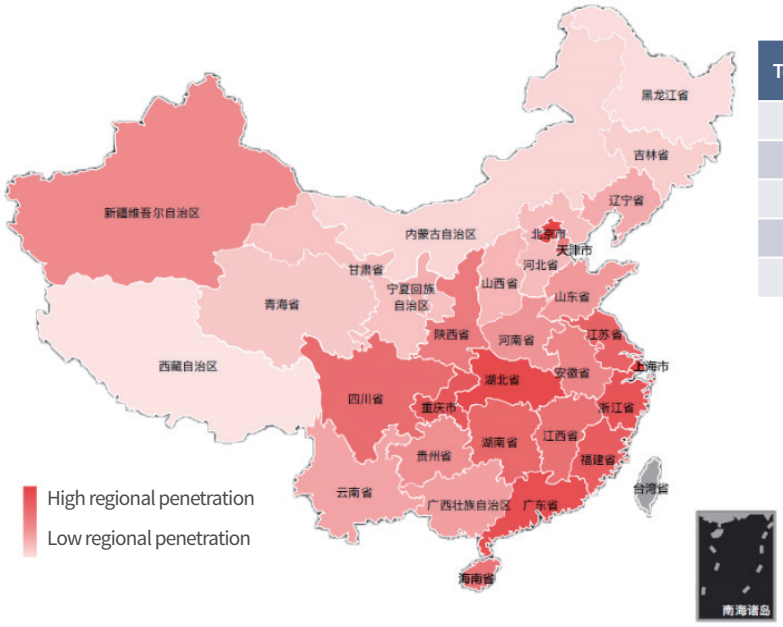


Figure 5-6 Interest in AI by age group and gender

- **Regional differences**

Regionally, the data was analyzed against the regional penetration indicator, where regional penetration is measured by dividing the number of views of articles containing AI keywords with the number of views of all articles in the region. The analysis identified Shanghai, Beijing, Hubei, Guangdong and Zhejiang as the top five regions in terms of the interest shown by local users in AI (Figure 5-7). In terms of cities, users interested in AI are mainly distributed in super first-tier and first-tier cities including Beijing, Shanghai, Shenzhen, Guangzhou, Hangzhou, Chengdu and Wuhan (Figure 5-8).



Top 5	Region	Regional Penetration
1	Shanghai	0.77%
2	Beijing	0.75%
3	Hubei	0.62%
4	Guangdong	0.61%
5	Zhejiang	0.61%

Figure 5-7 AI regional penetration

Figure 5-8 Interest in AI by cities

5.1.3 Public Attitudes towards AI

User comments on hot AI-related articles collected by Toutiao Index from 2016 to 2017 were analyzed to show the changes in user attitude to AI. The analysis identified a shift of user attitude from enthusiastic endorsement to reflection on potential negative implications of AI, reflecting a gradually rational attitude towards AI (as shown in Figure 5-9).

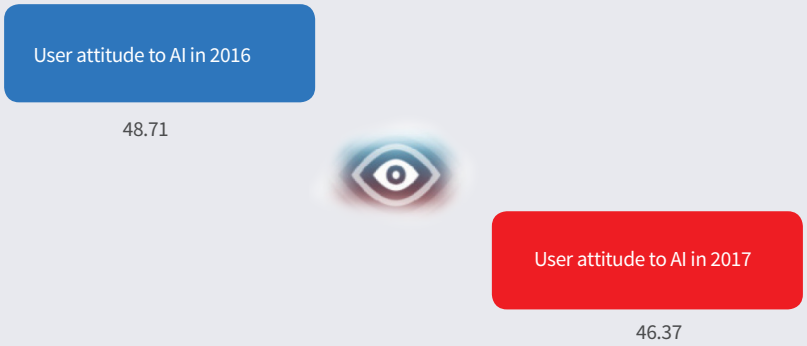


Figure 5-9 Attitude towards AI

* Data description: The user attitude analysis was conducted with technical support from partner Kismet Technology.
* User attitude description: User attitude is analyzed based on over 10,000 hot comments on AI-related articles, where a higher score indicates a more positive attitude towards AI.
* Data monitoring time: January 1 – December 30, 2017

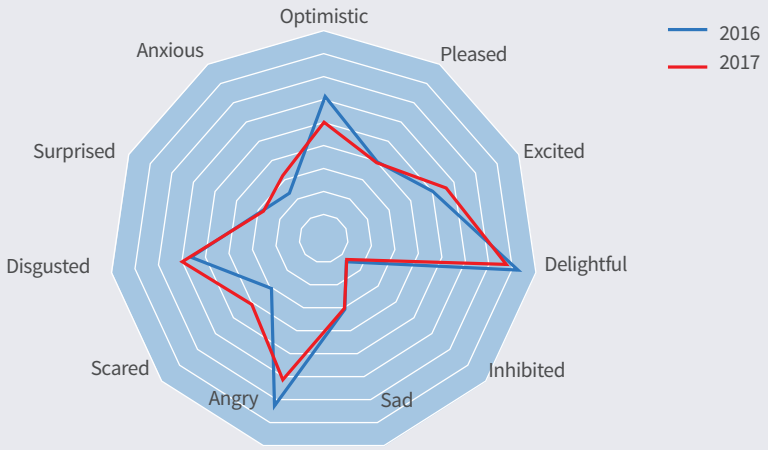


Figure 5-10 Changes in user attitude towards AI revealed by user comments from 2016 to 2017

* Data description: The user attitude analysis was conducted with technical support from partner Kismet Technology.
* Data monitoring time: January 1 – December 30, 2017

Data collected from 2016 to 2017 revealed attitude shifts marked by decreasing optimism and anger and increasing anxiety, excitement and fear.

5.2 General Impact of AI on Society

With the full development of AI and the greatly increased labor productivity it brings, people will be able to live a richer and more colorful life and, as they are liberated from manual labor and even conventional intellectual labor, devote more energy to creative activities for fuller development of humankind and human society. Currently, the rapid development of AI technology has transformed many sectors including retail, agriculture, logistics, education, healthcare, finance and commerce and reshaped how production, distribution, exchange and consumption take place. According to data from IDC[2], the coming five years will see AI be applied in more industries and bring substantial efficiency improvements—82% for education, 71% for retail, 64% for manufacturing and 58% for finance.

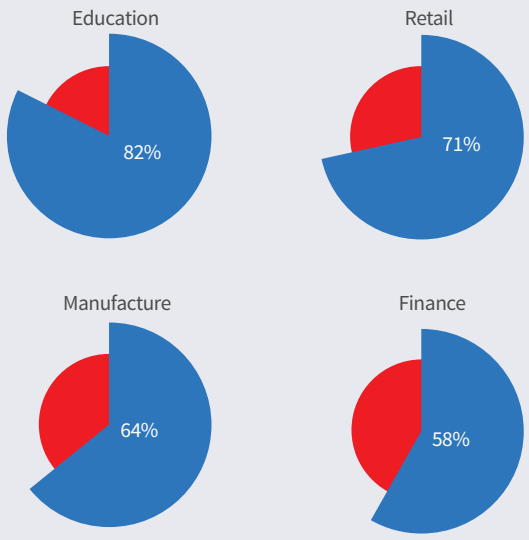


Figure 5-11 Efficiency improvement brought by AI to major industries

AI has been recognized by a broad spectrum of people ranging from technologists to sci-fi authors and from intellectual elites to the general public as the most disruptive and transformative ever innovation in human history and a technology capable of profoundly changing the world with far-reaching implications that cannot be exactly estimated. A large number of visionary people, including Norbert Wiener, the father of automation, recently deceased world-renowned scientist Stephen Hawking, Yuval Noah Harari, author of Sapiens: A Brief History of Humankind, and Tesla founder Elon Musk have warned that the quick development of AI, while bringing great conveniences to people, will pose huge potential risks and even challenge the existing social values and the value of the human race itself. They urge people to rethink the relationship between humans and machines and the future of humankind, and to ensure such AI systems are made as safe as possible before being deployed widely.

[2] IDC China: Artificial Intelligence White Paper: Towards the AI Era Led by Information Flow, 2017

5.2.1 AI's Impact On Education and Employment

The ultimate purpose of developing AI is not to replace humans but make humans smarter, where education will play a key role. By increasing productivity, AI liberates humans from mechanical, repetitive or dangerous labor and allows them to have more time at their disposal and focus more on developing and improving their potential of innovation, thinking, aesthetic appreciation and imagination. From the perspective of knowledge acquisition, with reduced mandatory labor and increased discretionary time, people will be able to acquire more soft knowledge that is closely related to human emotions and cannot be easily converted to data that can be processed by AI and therefore is more difficult to be learned or grasped by machines.

The intrinsic nature of education determines that personalization will be a basic direction of education. The talents needed in different periods vary greatly. In the AI era, personalized learning and communication and collaboration on different dimensions will become the main methods of learning, and students can get more personalized learning content support. At present, AI applications in education are mainly focused on the following areas: adaptive (personalized) learning, virtual teaching, educational robot, science and technology education based on programming and robotics, and situational education based on VR/AR. Learning in ways that are working to individual students will not only increase learning efficiency but also help keep a high level of interest in learning. In-depth applications of AI in education are not for the purpose of replacing teachers but to make teaching more efficient and fulfilling for teachers. Furthermore, in the AI-enabled educational system, there will be much higher requirements on students' ability to import and export information and learn independently, and the development of innovation skills will also become an important direction.

With the replacement of humans by machines for an increasing amount of onerous work or manual labor as technological development steadily advances, humans will face unprecedented challenges while enjoying the benefits of this replacement. In fact, more and more people are already worrying about their jobs being taken by AI or the prospect of their eking out a living in the shadow of AI. According to an estimate of the likelihood of jobs being replaced by AI in China, the coming 20 years will see approximately 76% of the working force being impacted by AI, or 65% if only the non-agricultural working force is considered[3]. At the same time, however, AI will also create new jobs. According to a survey, Chinese technology firms will expand their AI team by an average of 20% annually, and this demand for AI specialists will grow further. An expert from the Education and Examination Center of MIIT said that the demand for AI specialists in China will likely increase to five million in the coming several years.[4]

It can be safely averred that as AI transforms industries and consumption, some jobs will become things of the past and at the same time AI will incubate a series of new jobs. On the other hand, the human-machine relations will be restructured with the emergence of a new job market where non-routine cognitive jobs will be difficult to replace and have higher requirements on innovation skills, deep thinking and imagination.

As mechanization and intelligent automation give rise to a new employment landscape, vigilance needs to be exercised with respect to ensuing issues such

[3] Chen Yongwei, "How AI Will Impact Employment", Journal of Northeast University of Finance and Economics, No. 3, 2013
[4] AI: Job Destroyer or Job Creator
http://www.xinhuanet.com/tech/2018-02/26/c_1122452172.htm

as rising unemployment, widening wealth gap and social instability. The impact of AI will be continuous and so will its multifaceted impact on education and employment. Therefore, it is necessary to explore the educational and employment mechanisms that match and adapt to the technological revolution.

5.2.2 AI's Impact on Privacy and Security

Today, personalized experience has been emphasized in many consumption scenarios as personally and situationally relevant services gradually become one of the main directions of AI-driven innovation. With information access increasingly based on social media and user attention being more and more fragmented, service providers will strive to create more flexible and convenient consumption scenarios and provide better user experiences. Meanwhile, the development and maturing of speech recognition, face recognition and other capabilities derived from machine learning algorithms will allow businesses to get an unprecedented understanding of customers based on customer profile analysis and provide more satisfying experiences through precisely targeted and differentiated services. On the other hand, this ability, while promising an enormous business value, will pose some challenges to the existing regulatory framework and public security.

The virtual online space makes it easy for the collection and sharing of personal data and greatly facilitates the storage, analysis and exchange of information including identity IDs, health information, credit records, and location and movement information. However, at the same time, this makes it more difficult to determine how personal information was leaked and the degree of leakage. Examples include how to define the ownership of patients' electronic medical records and personal information in AI-supported smart healthcare, how to regulate hospitals' acquisition and use of patients' private data, and the copyright of AI-generated works. The open industry ecosystem will also make it difficult for regulatory authorities to determine the objects of regulation and blur the boundaries of laws.

The wide use of AI will bring about a radical change in human-machine relations in the form of a new mutually embedded relationship as human-machine interaction becomes increasingly complex. The unpredictability and irreversibility of the blurring of time and space and of virtual reality and reality will likely trigger a series of potential risks. Unlike information leakage that is often neglected by people, AI may be used by people with a secret agenda for fraud and other criminal activities, such as impersonation fraud on social media based on data profiling of personal information illegally obtained and security breach with information including image, video, audio and biometric information based on AI-enabled learning and simulation, as demonstrated by the hacking last year of iPhone's face ID system. In terms of potential risk, many things such as drones, autonomous cars and intelligent robots are vulnerable to intrusion and unauthorized control for fraudulent or other criminal purposes.

5.2.3 AI's Impact on Social Equality

As AI R&D and applications make giant strides, a series of value issues have gradually surfaced. At present, there are still a lot of internet illiterates and old-timers who are defined as “outsiders” in the AI era which has even higher requirements on people’s educational level and technology literacy[5]. As AI technology advances, the digital divide will widen even further and translate into a divide in access to services and benefits. In the AI era, it will become

[5] Sun Weiping. “Reflection on the Value of AI”, Philosophical Researches, No. 10, 2017

even more difficult for the “outsiders” to access convenient intelligent information services and scarce service resources.

For human society, AI technology should be for the benefit of all in accordance with the principle of equality and has the benefits and conveniences it brings accessible to as many people as possible. At the Beneficial AI conference held in Asilomar in the United States in early 2017, the “Asilomar AI Principles” were emphasized, i.e. developing AI in a way that is safe, transparent, responsible, accountable, contributable to society and for the benefit of the majority of people. [6]The best way to promote harmonious and positive human-machine relations is to make public services benefit all regions, all industries and all groups equally. Therefore, amid rapid AI development, it is necessary to think and come up with methods of using AI to improve basic public service platforms to steadily narrow the digital divide, build an efficient, developed and livable intelligent society, advance social inclusiveness and sustainable development, and create a beautiful future where the benefits of technology are enjoyed by all citizens.

5.3 Survey of China's AI Education

5.3.1 Current Situation of China's AI Education Development

As an interdisciplinary emerging technology field, AI involves various disciplines such as computer science, mathematics, neuroscience, statistics, electronic information engineering and automation. The basic courses in the field of AI mainly include basic computer courses such as programming language, algorithm design and data structure, as well as basic mathematics courses such as probability and mathematical statistics, numerical analysis and mathematical planning, and also courses related to engineering and natural sciences and humanities.

Since the Ministry of Education approval of the "Intelligent Science and Technology" undergraduate program at Peking University in 2004, higher education in AI has attracted more and more attention from universities. By July 2017, there had been as many as 36 universities approved by the Ministry of Education to offer the "Intelligent Science and Technology" undergraduate program, in addition to 79 programs related to AI[7]. Universities including University of Chinese Academy of Sciences, Xidian University, Nanjing University, Chongqing University of Posts and Telecommunications, Hunan University of Technology, Changchun University of Science and Technology, Tianjin University and Nankai University have established their AI colleges.[8]

In terms of undergraduate education, the Next Generation Artificial Intelligence Development Plan issued by the State Council in 2017 clearly pointed out that it is necessary to “improve the AI discipline structure, establish the AI specialty, and promote AI as a first-level discipline”, and requires AI pilot universities to establish their AI colleges as soon as possible. The Argumentation Report on Intelligence Science and Technology as a First-level Discipline issued by Chinese Association for Artificial Intelligence (CAAI) made the suggestion that the first-level discipline Intelligence Science and Technology” be divided into five second-level disciplines including “brain cognition”, “machine perception and pattern recognition”, “natural language

[6] Duan Weiwen. “Value Examination and Ethical Regulation in the AI Era”, Journal of Renmin University of China, No. 6, 2017
[7] Data source: “Call for AI as a first-level discipline”, Guangming Daily http://epaper.gmw.cn/gmrb/html/2017-07/28/nw.D110000gmrb_20170728_1-06.htm
[8] Data source: Nankai University and Tianjin University inaugurate AI colleges on the same day, focusing on robotics and brain cognitionhttps://www.thepaper.cn/newsDetail_forward_2133192

processing and understanding", "knowledge engineering" and "robotics and intelligent systems", with courses including basic specialized courses (such as "cognitive mechanism of brain, neural network, computational cognition, interactive cognition, memory cognition, introduction to artificial intelligence, robotics and machine ethics) and other specialized courses (such as cognitive physics, memory and reasoning, natural language processing and understanding, uncertainty in artificial intelligence, machine translation, emotional robots, intelligent robots, image cognition, machine learning, data mining and knowledge mapping).

In postgraduate education, the Next Generation Artificial Intelligence Development Plan required "increasing the quotas of doctoral and master's candidates in AI and related disciplines". It encouraged universities, on their existing basis, to expand the content of AI specialized education to form the new "AI+X" hybrid specialized training model with a greater focus on the integration of AI with other disciplines such as mathematics, computer science, physics, biology, psychology, sociology and jurisprudence. At present, China's AI teaching and research activities are concentrated in computer science, electronic information and automation faculties/departments of universities. In addition, leading Chinese universities have established their AI labs (Table 5-1).

Table 5-1 AI Labs at leading Chinese universities

No.	University	Lab
1	Tsinghua University	State Key Laboratory of Intelligent Technology and Systems
2	Peking University	State Key Laboratory of Visual and Auditory Information Processing Laboratory, MOE Key Laboratory of Machine Perception
3	Chinese Academy of Sciences	State Key Laboratory of Pattern Recognition, Key Laboratory of Intelligent Information Processing
4	Zhejiang University	Institute of Artificial Intelligence, i-MD Research Center for Artificial Intelligence
5	Shanghai Jiao Tong University	Intelligent Computing and Intelligent Systems Laboratory (co-developed with Microsoft Research Asia)
6	Nanjing University	State Key Laboratory for Novel Software Technology
7	Fudan University	Institute of Science and Technology for Brain-Inspired Intelligence
8	Harbin Institute of Technology	MOE-MS Key Laboratory of Natural Language Processing and Speech
9	University of Science and Technology of China	National Engineering Laboratory for Brain-inspired Intelligence Technology and Application
10	Beijing University of Posts and Telecommunications	Lab of Mobile Robot and Intelligent Technology

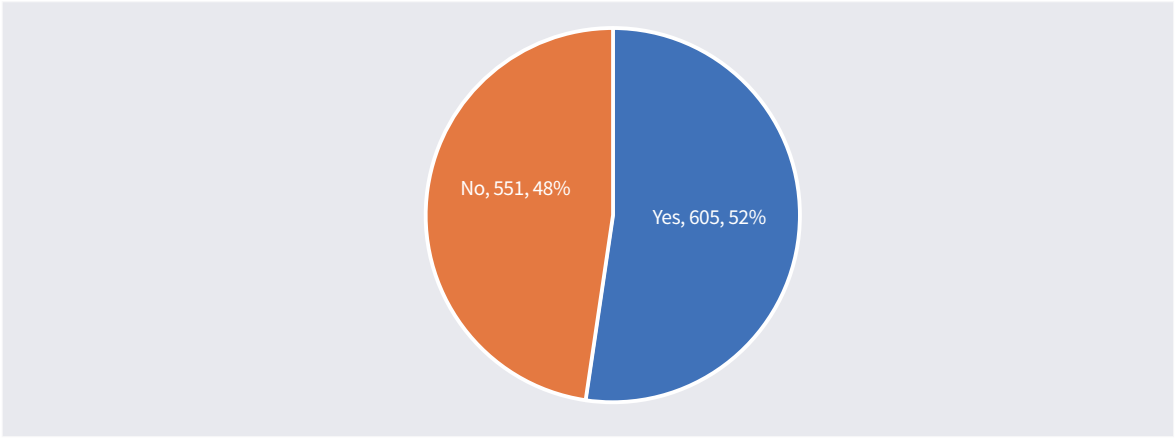
Source: *2017 Global Artificial Intelligence Talent White Paper*, Tencent Research Institute

In addition to degree programs at universities, there are various online learning platforms in China that offer AI courses and serve as a necessary supplement to the AI academic education. Currently, major active online education platforms include study.163.com, www.xuetangx.com, www.mooc.cn and www.icourse163.org.

5.3.2 Questionnaire on AI Education

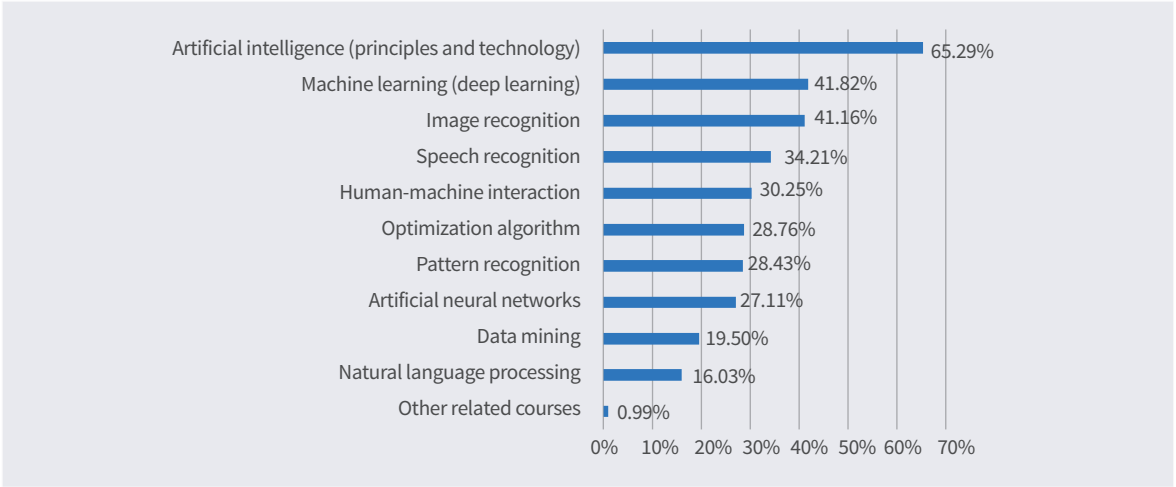
To get a further understanding of China's AI education development, this report collected first-hand data through an online questionnaire survey. The survey, conducted via the WJX platform, collected a total of 1,154 valid responses (as of May 15, 2018). The platform automatically recommends questionnaires to more than 500,000 visitors for completion every day. The valid responses had a fairly balanced age structure and university distribution, with most of the respondents (57.19%) falling within the 20-30 age group, which met the survey's expectation.

Question 1: Have you ever taken an AI course? [Single-select multiple choice question]



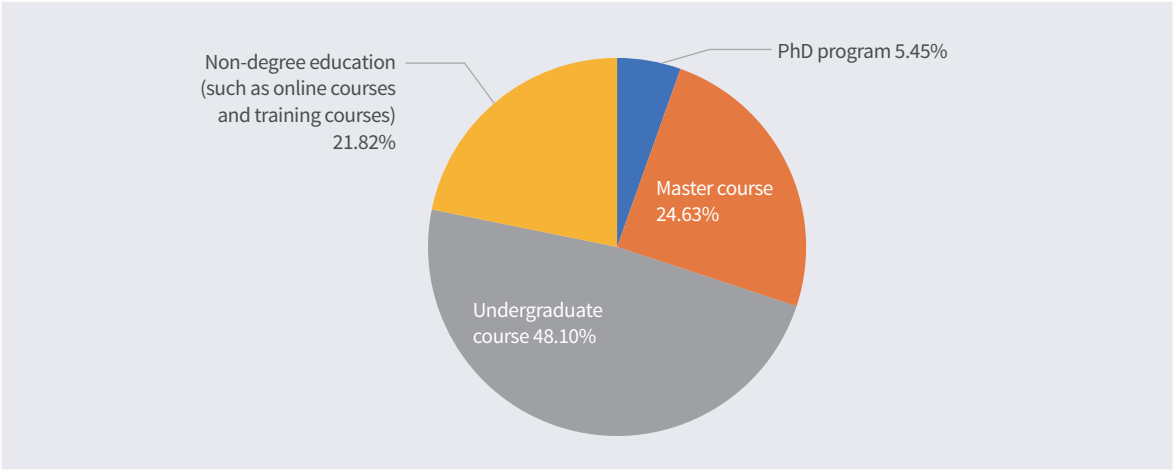
More than half of the 1,154 respondents have taken some sort of AI course (52.34%).

Question 2: Which of the following technologies did your courses cover? [Multi- select multiple choice question]



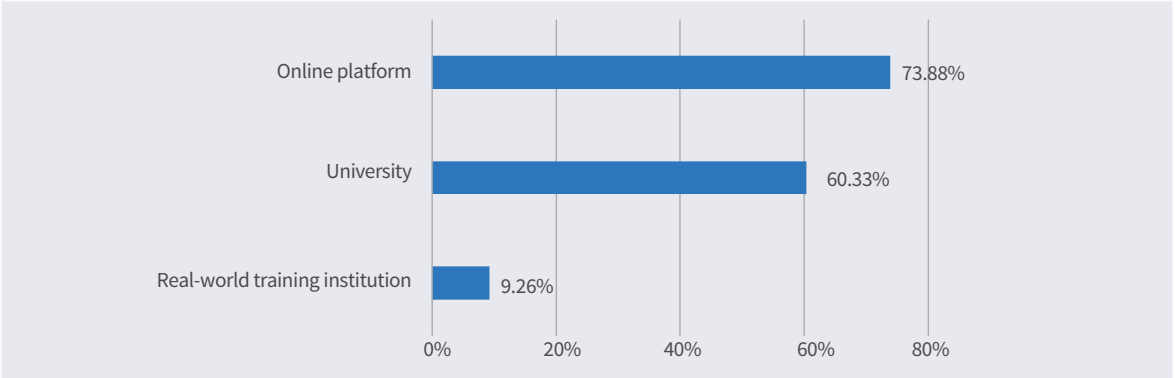
Among the AI courses, "artificial intelligence (principles and technology)", "machine learning (deep learning)" and "image recognition" are the top three most popular courses.

Question 3: At what stage of education did you take your AI course? [Single- select multiple choice question]



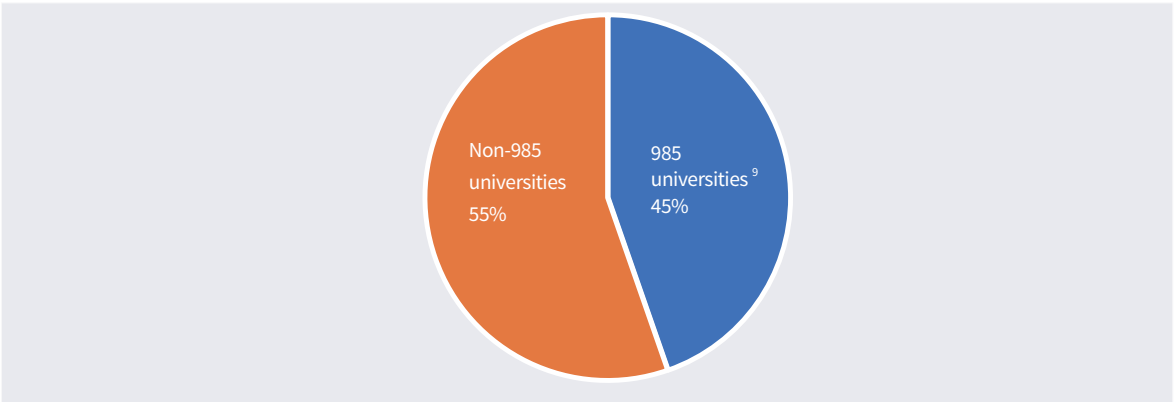
Most respondents took their AI course during their undergraduate studies.

Question 4: At what type of institutions did you take your AI course? [Multi- select multiple choice question]



University and online education are the top two platforms of AI course.

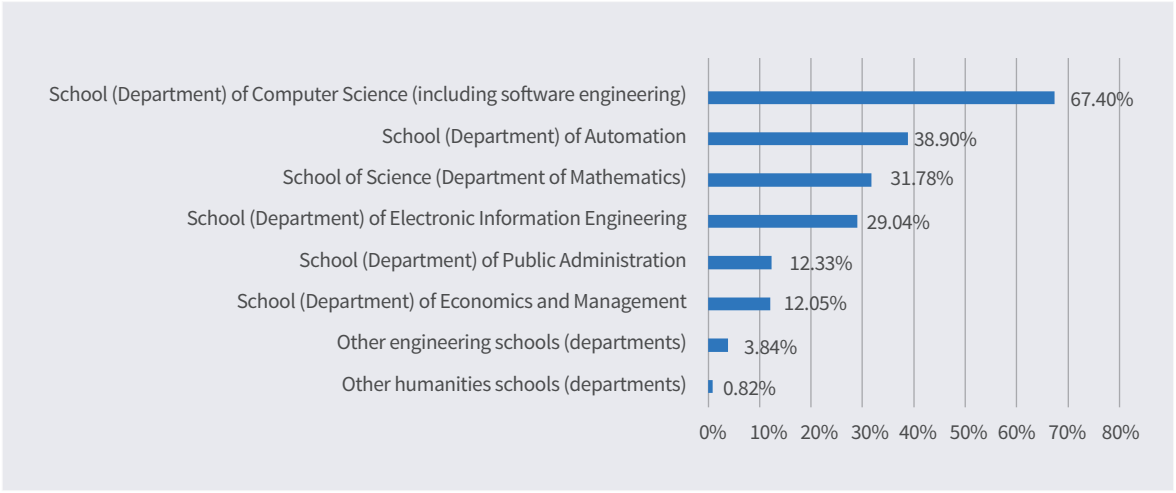
Question 5: At what university did you take your AI course? [Fill-in-the-blank question]



Note: Based on the number of respondents, the pie chart reflects the proportion of respondents who have studied artificial intelligence courses at a certain type of institution (985/non-985).

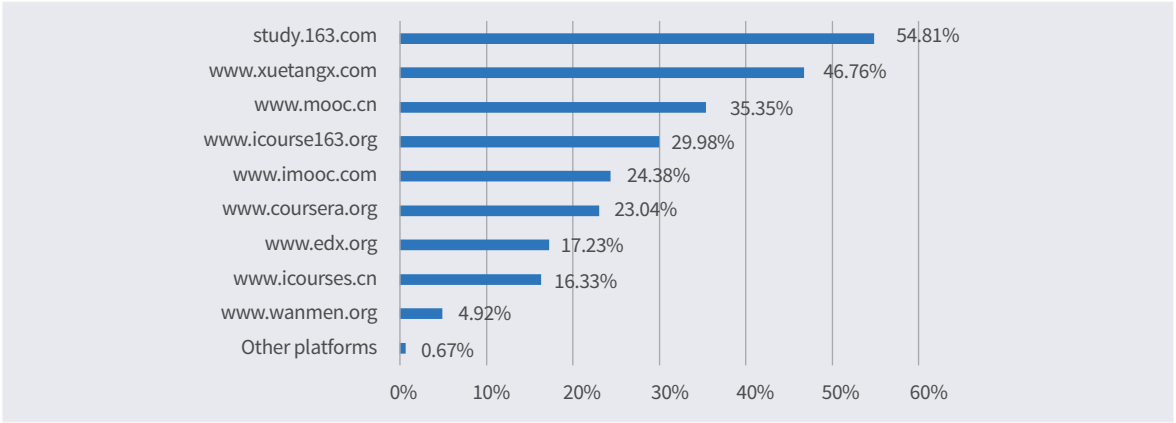
[9] a group of elite universities in China, as identified by the "985 Program"

Question 6: At what school/department did you take your AI course? [Multi- select multiple choice question]



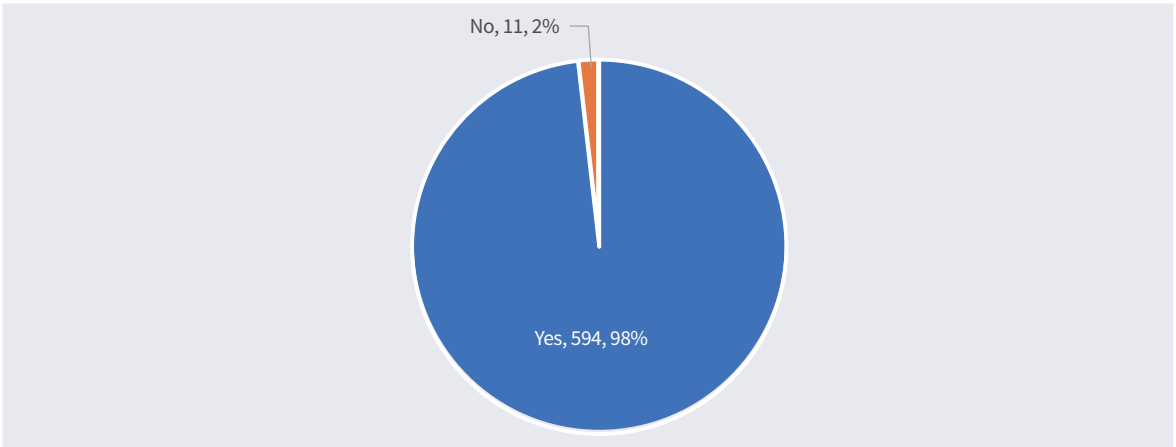
AI courses are mostly offered by computer and automation schools

Question 7: On what online platform did you take your AI course? [Multi-select multiple choice question]



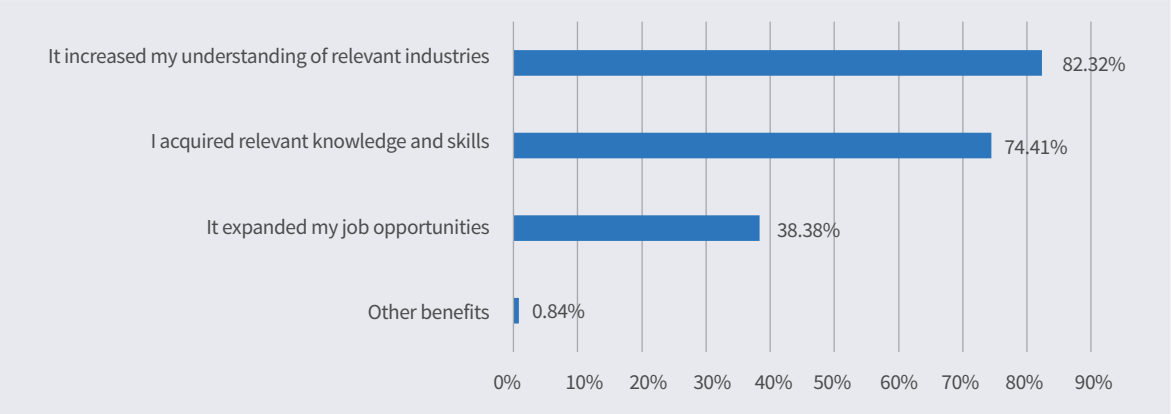
The main online platforms reported include study.163.com, www.xuetangx.com and www.mooc.cn.

Question 8: Do you think your AI course was helpful? [Single-select multiple choice question]



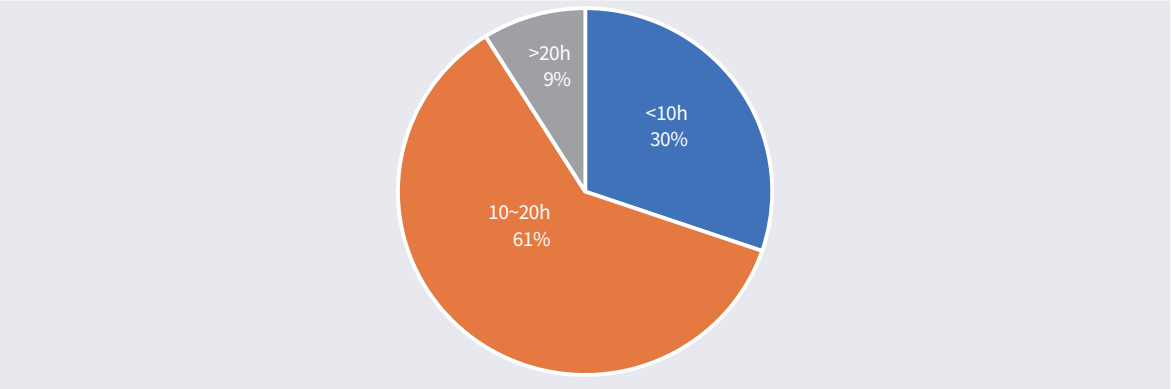
More than 98% of the respondents considered the courses to be helpful.

Question 9: In what ways do you think your AI course helped you? [Multi select multiple choice question]



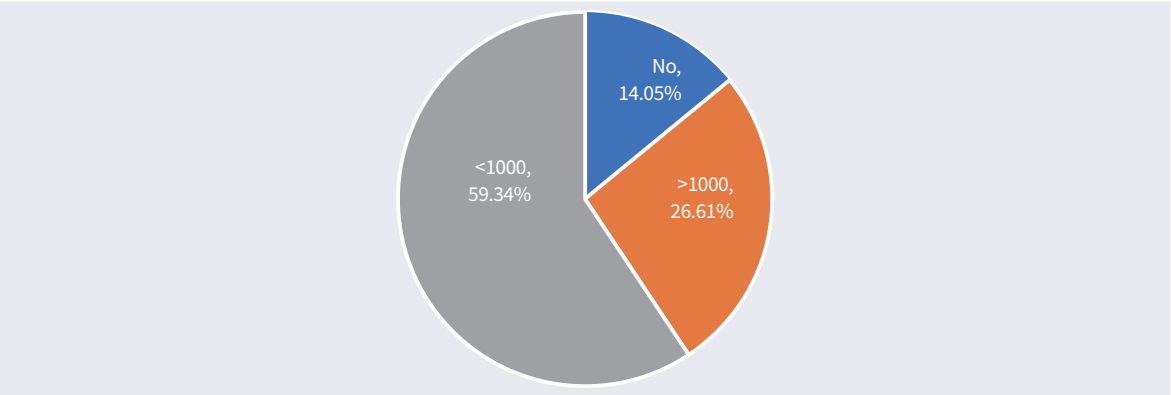
Only approximately 38% of the respondents stated that their AI courses expanded their job opportunities. The AI courses benefited the respondents mainly by way of acquisition of relevant knowledge and skills and strengthening their understanding of relevant industries.

Question 10: How much time did you devote to your AI course? (Weekly average) [Single-select multiple choice question]



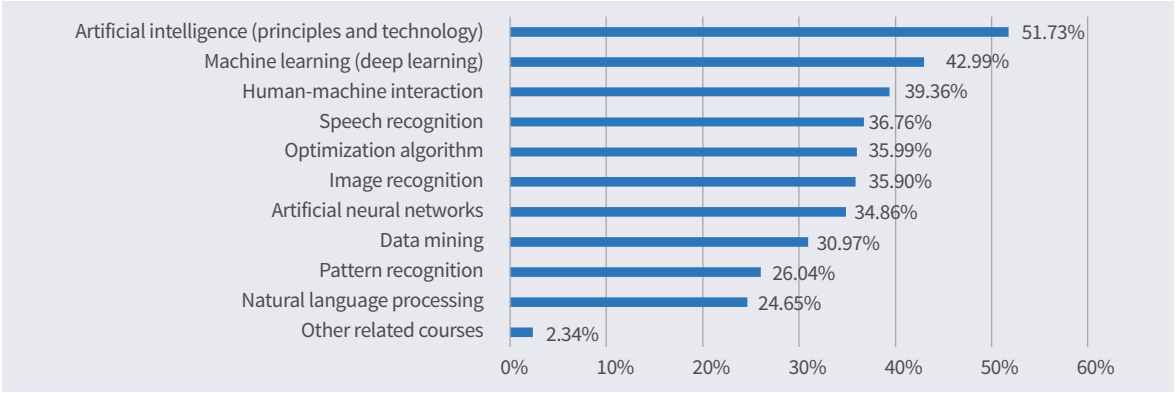
Approximately 61% of the respondents spent 10-20 hours on their AI courses per week.

Question 11: How much money did you spend on your AI course? [Single-select multiple choice question]

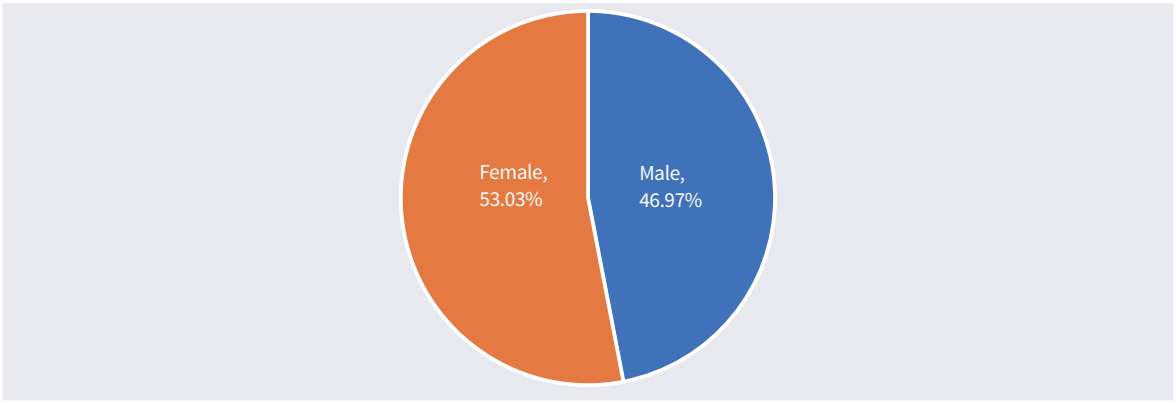


The majority of the respondents spent less than RMB 1,000 on their AI courses.

Question 12: What AI-related courses do you want to learn in the future? [Multi- select multiple choice question]

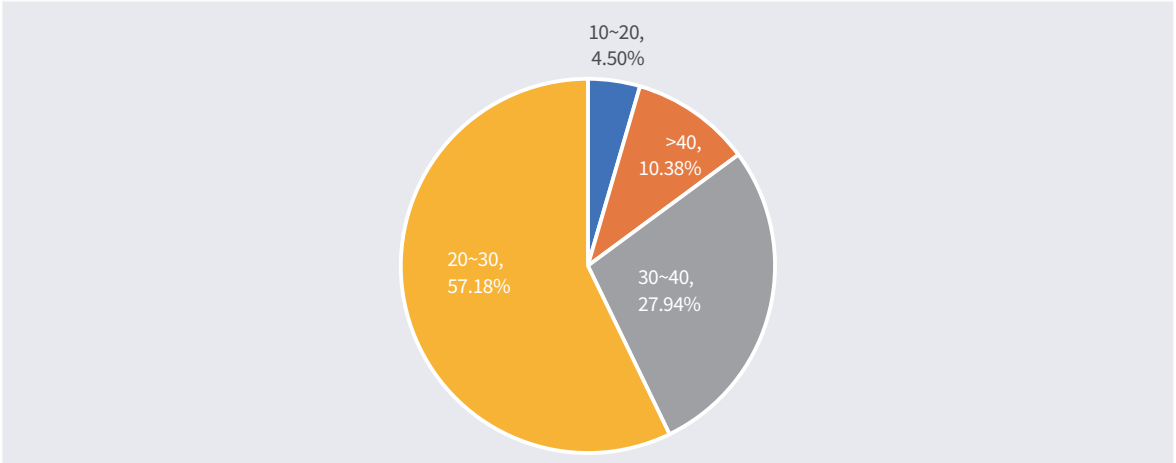


Question 13: Your gender? [Single select multiple choice question]



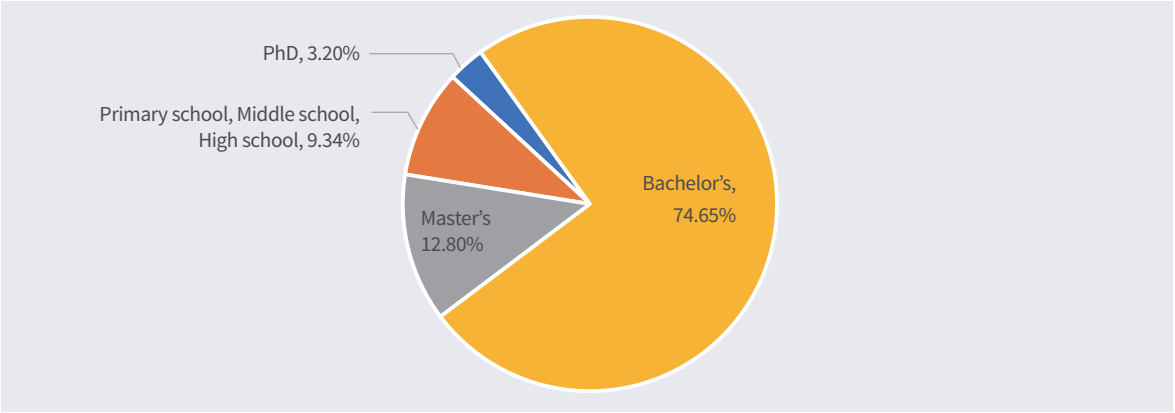
The respondents had a rather balanced gender ratio, with female respondents (approximately 53%) slightly outnumbering male respondents.

Question 14: Your age? [Single-select multiple choice question]



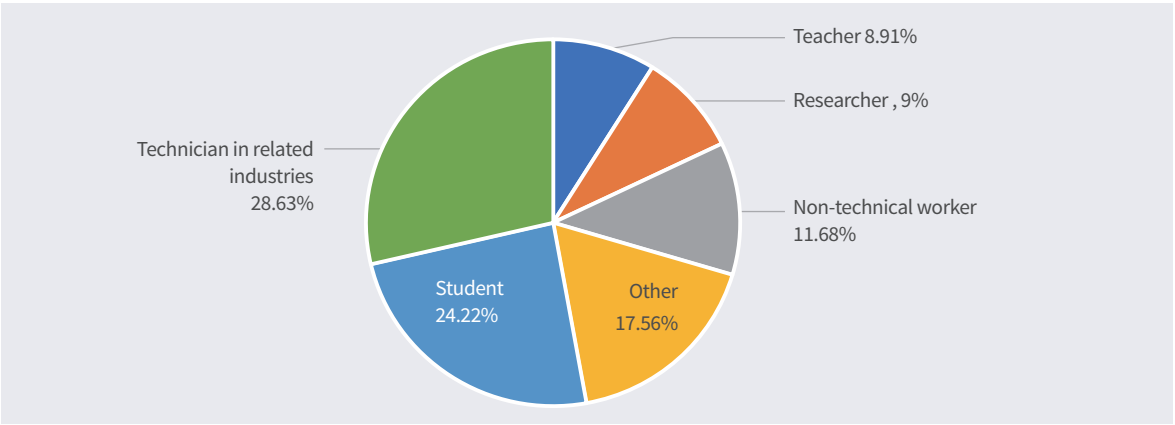
More than half of the respondents (57%) were in the 20-30 age group.

Question 15: Your education? [Single-select multiple choice question]



The majority of the respondents (approximately 75%) have a bachelor's degree.

Question 16: Your occupation? [Single-select multiple choice question]



The respondents were dominated by students (approximately 24%) and technicians (approximately 29%).

The survey found that the majority of the respondents had a strong enthusiasm for AI learning, with 61% spending 10-20 hours on AI learning per week and 85% expressing willingness to take paid courses. In terms of the channels of learning, online platforms have become an important channel of AI courses; among universities, AI courses are mainly offered by the school (department) of computer science, school (department) of automation, school (department) of science (mathematics) and school (department) of electronic information engineering. Technicians in related industries, researchers and students are the most enthusiastic groups for AI learning.

06

Reflection and Outlook

06 Reflection and Outlook

6.1 Summary and Reflection

Based on existing research reports and the above findings in this report, we can arrive at the following preliminary judgments and observations on China's AI development.

China has ranked among leading countries in AI technology development and market applications and is indeed in a race of "two giants" with the United States. In terms of technology output, industry development and applications, China is still significantly behind the United States overall but well ahead of other developed countries such as the United Kingdom, Germany, Japan and France. China is also behind the United States in the number of AI talents and enterprises but takes the lead in indicators such as AI papers and patents. In some specific fields like computer vision and intelligent speech recognition, China has been in an internationally leading position in both technology development and market applications. With respect to cities, Beijing has become the world's top AI city in terms of talent, enterprises, research institutions and venture capital. Overall, in the strategic field of AI, China has secured a head start and will maintain a growing momentum to achieve the goal of becoming a leading country in AI by 2030.

However, as far as the quality of development is concerned, China's AI development is far from being optimistic. China's strengths are mainly shown in AI applications and it is still weak on the front of core technologies of AI, such as hardware and algorithm, pointing to its not entirely solid foundation of AI development. Furthermore, although China's AI talents are next to the United States' in number, if only top-tier talents are considered, there is still a significant gap with the United States, the United Kingdom and Germany. As noted in Goldman Sachs' report, *China's Rise in Artificial Intelligence*[1], China's leading AI enterprises are mainly powered by returned overseas top talents. McKinsey's *Road to the Future of Artificial Intelligence*[2] report also attributed China's trailing far behind leading western countries in core algorithms to the lack of top-tier AI talents. University of Oxford's report, *Deciphering China's AI Dream*[3], which compared China and the United States on the four dimensions of hardware, data, algorithm and commercial system, found that China had a clear advantage on the data dimension only, and that its overall AI potential is only half of the United States'. *Therefore, China still faces a significant gap with the world-leading level in the core areas of AI development.*

In terms of the entities engaged in AI research, research institutes and universities are the main generators of AI knowledge in the world. According to the *Artificial Intelligence Index 2017* report[4], part of Stanford University's One Hundred Year Study

[1] Goldman Sachs. *China's Rise in Artificial Intelligence*, 2017
[2] McKinsey, *Road to the Future of Artificial Intelligence*, 2017
[3] Jeffrey Ding, University of Oxford, *Deciphering China's AI Dream—The context, components, capabilities, and consequences of China's strategy to lead the world in AI, 2018*
[4] Stanford One Hundred Year Study on AI,University, Artificial Intelligence Index 2017, 2017. http://aiindex.org/

on AI (AI100), academic activity is the main driving force of AI's stable development in its budding phase in the United States. The same thing is also true in China where research institutes and universities have generated the overwhelming majority of AI knowledge. Researchers from research institutes and universities represent 89% of all AI talents in China and are also leading forces in AI paper publication and patent application. Some research institutions and universities, such as the Chinese Academy of Sciences System and Tsinghua University, have become the powerhouses of China's AI technology development and held an important position in the world as well. However, it should also be realized that the substantial increase of scientific papers published by Chinese researchers in recent years has been on the one hand attributable to China's continuously increasing investment in R&D but on the other hand also had much to do with the over-emphasis on "papers" and "number-first" orientation in China's researcher evaluation system. In spite of the impressive growth of high-impact papers published by Chinese researchers in this field, research achievements that are original, ground-breaking or seminal, especially in basic research, are still very scarce.

China is already the world's largest patent applicant and the largest invention patent applicant and has more AI patent applications than the United States as well. However, it should be soberly realized that China's rapid patent growth—if not explosion—in recent years, while propelled by the country's economic transformation and transition from factor-driven to innovation-driven, has had much to do with all kinds of incentive policies, including performance evaluation indicators. Moreover, a large part of the patent applications in this field has been technological applications rather than underlying principles and key technologies. *Compared to their foreign counterparts, Chinese AI companies are technologically less inventive and far behind domestic universities and research institutions in AI patenting.* Even recognized domestic AI giants such as Baidu, Alibaba and Tencent (BAT) don't have an impressive performance in AI talent, papers and patents, while their U.S. competitors like IBM, Microsoft and Google lead AI companies worldwide in all indicators. Goldman Sachs' report, China's Rise in Artificial Intelligence, found that while Chinese internet giants have comparable R&D expenditure as a percentage of revenue, they are left far behind by their U.S. counterparts in terms of the absolute amount. China, though already the world's second largest AI ecosystem, still faces a significant gap with the United States.

In terms of leading enterprises, SGCC is the most prominent enterprise in both AI paper publication and AI patenting, which not only leads other Chinese enterprises by a big margin but also is high-ranked internationally. In China's AI patenting, electric power engineering is a prominent field. The fact that it has been either unmentioned or not highlighted in previous AI studies shows that the integration of AI with energy systems is likely an area that has been more or less neglected and represents a potential new direction of expansion of AI applications in China which will contribute to low-carbon transformation of the energy sector. *This example also demonstrates that it is ill-advisable to confine AI research to a number of emerging application areas and that the integration of AI with traditional sectors might represent a more promising direction.*

International collaboration and industry-university collaboration are important means of advancing AI development. As many as 42.64% of top papers on AI in the world were from international collaboration, versus 53% for China. As countries have different priorities and strength areas in AI development, international collaboration is significant by combining strengths and overcoming weaknesses and thereby promoting technological innovation

and should be encouraged and facilitated. At the same time, it should be noted that there is a lot of AI knowledge lying idle at Chinese universities and research institutions, and it is imperative to increase industry-university collaboration to promote AI knowledge application and transformation. According to the statistics, China's AI papers resulting from collaboration between research institutes and enterprises accounted for only 2.55% of its all AI papers, versus more than 6% for the United States, the United Kingdom, France and Germany. The researchers at big international technology firms represented by Microsoft, Google and IBM have not only filed for many patents, but also published a large number of papers, including high-impact papers. Some small and medium-sized technology firms, such as Deep-Mind and OpenAI, have even come to the forefront of AI research. AI is unlike traditional research areas in that the required resources such as data and computing power are controlled by large companies, meaning that they have better conditions than universities and research institutes to conduct research and tackle frontier issues. *Therefore, to advance research and applications in frontier areas of AI, China needs to not only encourage university-industry collaboration but also explicitly support enterprises to engage in basic AI research.*

With respect to the environment of AI development in China, both the central government and local governments have released policies in support of AI development; the capital market has shown a great enthusiasm for AI; most citizens have shown an optimistic attitude towards AI and a high interest in AI products; and there are all kinds of AI courses offered by universities and online education platforms which have been well received by young people. All these factors point to Chinese society's overall positive and optimistic attitude to AI, which has provided a very favorable environment in terms of policy, public opinion, market and talent for AI development. Policy keyword analysis found that local governments have shown a tendency of "following the steps of the central government" and "chasing after hot areas", raising the issue of how to avoid the problem of "redundant investment" which has frequently occurred in traditional industries and emerging strategic industries while promoting the sound development of AI, which policymakers need to come to grips with, especially in the new context of pursuing high-quality development. On the other hand, our survey has shown some worry and doubt of the public about AI development, a sentiment that has increased with media reports on relevant issues. Currently, China's AI policy has emphasized on promoting AI technological development and industrial applications and hasn't given due attention to such issues as ethics and security regulation. There are two extremes of view on AI, one considering AI as a "cure-all" and the other demonizing it. *How to properly guide the public opinion and attitude, strike a good balance between promoting AI development and putting AI development in an effective regulatory framework, and avoid the various negative issues that have previously occurred in other areas such as genetically modified food, will be a challenge and test of the government's governance ability and wisdom.*

6.2 Research Limitations and Prospect

At present, AI still lacks a clear universal definition, a tricky issue that is all too often encountered in the research of this emerging area. Although this report is based on a list of AI keywords strictly scrutinized and validated by experts, it cannot completely exclude activities which do not have much to do with core AI technologies. The use of keyword co-occurrence search as well as bibliometrics to identify AI academic output may lead to a broader, looser scope of data included. Given AI is an emerging phenomenon, a lot of industry statistics such as sales, corporate R&D, and gross product value are not up to date,

and therefore the industry development data in this report may not reflect the complete picture, which requires a set of more clear-cut criteria and more data investigation. Due to data availability, AI talent in this report is confined to researchers who have published AI papers or patents and thus AI specialists working in the industries may be less represented. Moreover, this report only examines the overall development of AI without scrutinizing its vertical areas such as infrastructure, hardware and data. All these are very important pillars of AI development and will be further examined in our future research.

China's AI development already enjoys very favorable conditions in the form of not only a vast application market and rich data but also strong policy support from the central government and local governments. But for China to become an AI superpower, the journey ahead is long and arduous. China must strengthen basic research, optimize the research environment, develop and attract top-tier talent, and make breakthroughs in core basic areas of AI to put the country's development on a solid foundation. Meanwhile, China needs to encourage university-industry collaboration to make enterprises a major force in AI innovation. China's AI policy research, which has so far tilted towards industry development and industry progress, should be more focused on the social impact and ethical implications of AI. AI technology development should be accompanied by social foresight with a view to supporting policymaking that steers AI development in anticipation of the technology roadmap and potential social impacts. Meanwhile, it is important to create mechanisms of public engagement in policy-making so that policies reflect and incorporate inputs from all sectors of society. Universities, research institutions and specialized research teams should also organize seminars and create relevant technical standards and norms and incorporate them in their educational or research activities. Finally, China should get actively involved in the global governance of AI and play a prominent role in relevant areas such as AI technology development, risk prevention and formulation of AI ethics norms to advance AI development for a beautiful future of human society.

Appendix 1: List of Main AI Conferences

Abbreviation	Full Name
AAAI	AAAI Conference on Artificial Intelligence
ICML	International Conference on Machine Learning
IJCAI	International Joint Conference on Artificial Intelligence
NIPS	Annual Conference on Neural Information Processing Systems
ACL	Annual Meeting of the Association-for-Computational-Linguistics
COLT	Annual Conference on Learning Theory
EMNLP	Conference on Empirical Methods in Natural Language Processing
ICPAS	International Conference on Automated Planning and Scheduling
ICCBR	International Conference on Case-Based Reasoning
KR	International Conference on Principles of Knowledge Representation and Reasoning
AAMAS	International Joint Conference on Autonomous Agents and Multiagent Systems
COLING	International Conference on Computational Linguistics
UAI	International Conference on Uncertainty in Artificial Intelligence
CVPR	Conference on Computer Vision and Pattern Recognition
ECAI	European Conference on Artificial Intelligence
ICRA	International Conference on Robotics and Automation
ICLR	International Conference on Learning Representations
IROS	International Conference on Intelligent Robots
NIPS	Neural Information Processing Systems

Appendix 2: Category Description

Computer Science, Artificial Intelligence

Computer Science, Artificial Intelligence covers resources that focus on research and techniques to create machines that attempt to efficiently reason, problem-solve, use knowledge representation, and perform analysis of contradictory or ambiguous information. This category includes resources on artificial intelligence technologies such as expert systems, fuzzy systems, natural language processing, speech recognition, pattern recognition, computer vision, decision-support systems, knowledge bases, and neural networks.

Appendix 3: Two Dimensions of AI Enterprise Identification

Technical Dimensions	
Speech	Speech recognition, speech synthesis, speech interaction, speech evaluation, human-machine dialogue, voiceprint recognition
Vision	Biometrics (face recognition, iris recognition, fingerprint recognition, vein recognition, etc.), affective computing, emotion recognition, expression recognition, behavior recognition, gesture recognition, body recognition, video content recognition, object and scene recognition, mobile vision, optical character recognition (OCR), handwriting recognition, text recognition, image processing, image recognition, pattern recognition, SLAM, spatial recognition, 3D scanning, 3D reconstruction, etc.
Natural language processing	Natural language interaction, natural language understanding, semantic understanding, machine translation, text mining (semantic analysis, semantic computing, classification, clustering), information extraction, human-machine interaction
Basic algorithm and platform	Machine learning, deep learning, open source framework, open platform
Basic hardware	Chips, lidars, sensors, etc.
Basic enabling technology	Cloud computing, big data
Product and Industry Dimensions	
Intelligent robotics (including solutions)	Industrial robotics (focusing on production processes such as handling, welding, assembly, palletizing and painting), service robotics (for banks, restaurants, hotels, shopping malls, exhibition halls, hospitals, logistics), personal/home robotics (virtual assistants, emotional support robot, child robot, educational robot, domestic robot (for floor and window cleaning, etc.), home security robot, in-vehicle robot)
Smart driving (including solutions)	Intelligent driving, driverless driving, autonomous driving, assisted driving, advanced driver assistance system (ADAS), laser radar, ultrasonic radar, millimeter wave radar, GPS positioning, high-precision map, vehicle chip, human-car interaction, etc.
Drone (including solutions)	Consumer drones (entertainment, aerial photography) Professional drones (agriculture, forestry, electric power, logistics, security, etc.)
AI+	Finance, insurance, judiciary administration, entertainment (social, games), tourism, healthcare, education, logistics and warehousing, smart home, smart city (traffic, electricity, environment), network security, video surveillance, commerce (marketing, retail, advertising) , human resources, corporate services

Appendix 4: AI Standards and Norms

	Organization	Main Research Areas	Main Standards
International	International Organization for Standardization / International Electrotechnical Commission (ISO/IEC) Joint Technical Committee (JTC) 1	Key areas such as AI terminology, human-computer interaction, biometrics and computer image processing, as well as in AI enabling technologies such as cloud computing, big data and sensor networks	ISO/IEC2382-34:1999 Information technology – Vocabulary – Part 34: Artificial intelligence – Neural networks ISO/IEC 19794-2:2005 Information technology – Biometric data interchange formats – Part 2: Finger minutiae data ISO/IEC 29794-6:2015 Information technology – Biometric sample quality – Part 6: Iris image data ISO/IEC 8632-3 Information technology – Computer graphics – Metafile for the storage and transfer of picture description information – Part 3: Binary encoding
	International Organization for Standardization (ISO)	Industrial robots, smart finance, smart driving	ISO 11593:1996 Manipulating industrial robots – Automatic end effector exchange systems – Vocabulary and presentation of characteristics ISO 9946:1999 Manipulating industrial robots – Presentation of characteristics ISO 14539:2000 Manipulating industrial robots – Object handling with grasp-type grippers – Vocabulary and presentation of characteristics ISO 19092:2008 Financial services – Biometrics – Security framework ISO 14742:2010 Financial services – Recommendations on cryptographic algorithms and their use
	International Electrotechnical Commission (IEC)	Wearable devices	No specific standard released for the moment
	International Telecommunication Union (ITU)	At the AI for Good Global Summit held in June 2017, ITU-T put forward AI proposals on “Artificial Intelligence and Internet of Things” (ITU-T Y.AI4SC) and “Requirements of machine learning based QoS assurance for IMT-2020” (ITU-T Y.qos-ml).	No specific standard released for the moment
Overseas	Institute of Electrical and Electronics Engineers (IEEE)	Focused on research on AI ethical standards	IEEE P7000 Model Process for Addressing Ethical Concerns During System Design; IEEE P7001 Transparency of Autonomous Systems; IEEE P7002 Data Privacy Process; IEEEP7003 Algorithmic Bias Considerations; IEEE P7004 Standard for Child and Student Data Governance; IEEE P7005 Standard for Transparent Employer Data Governance IEEE P7006 Standard for Personal Data Artificial Intelligence (AI) Agent.
	National Institute of Standards and Technology (NIST)	NIST has conducted research in various AI areas including AI acquisition and analysis tools, future expert systems, AI-based collective production quality control, high-throughput material discovery and optimization, and optimized applications of machine learning	No specific standard released for the moment
China	Standardization Administration of China (SAC)	Focused on vocabulary, human-machine interaction, biometrics, big data, cloud computing, etc.	Information technology – Vocabulary – Part 31: Artificial intelligence – Machine learning Information technology – Vocabulary – Part 34: Artificial intelligence – Neural networks Specification of programming interface for Chinese speech recognition internet service Specification of programming interface for Chinese speech synthesis internet service

Appendix 5: AI Policy Data Sources

The U.S. AI policy documents are mainly from the Executive Office of the President and the National Science and Technology Council and Office of Management and Budget under it. Their websites are as follows:

Policy documents of the Executive Office of the President of the United States and its functions	https://www.whitehouse.gov
U.S. Networking and Information Technology Research and Development (NITRD) Program	https://www.nitrd.gov
U.S. Department of Homeland Security	https://www.dhs.gov
U.S. National Science and Technology Council (NSTC)	http://www.nstc.org.zm

The AI policy documents for other countries or regions are from their relevant government authorities, parliaments, national academies of sciences and related councils. Their websites are as follows:

European Union	https://www.eu-robotics.net/
German Federal Government	https://www.bundesregierung.de/Content/Infomaterial
German Federal Ministry for Economic Affairs and Energy	https://www.bmwi.de/Redaktion
German Academy of Science and Engineering	http://www.acatech.de/
German Federal Ministry of Education and Research	https://www.bmbf.de
French Parliament	https://www.aiforhumanity.fr
UK Engineering and Physical Sciences Research Council	http://hamlyn.doc.ic.ac.uk/ https://subtleengine.org/ https://assets.publishing.service.gov.uk/government
UK Parliament Science and Technology Committee	https://publications.parliament.uk
UK AI experts	https://assets.publishing.service.gov.uk/government
Prime Minister of Japan and His Cabinet	https://www.kantei.go.jp
Artificial Intelligence Technology Strategy Council	http://www.nedo.go.jp/

Data source of China's AI policy documents: China's AI policy documents are retrieved from the Government Documents Information System (GDIS) of Tsinghua University School of Public Policy and Management.

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World Economic Forum	Mr. Danil Kerimi

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China Academy of Information and Communications Technology (CAICT), established in 1957, is a public research institution directly under the Ministry of Industry and Information Technology. Positioned as a national high-level specialized think tank and an industry innovation and development platform and steeped in the core values of "solid research for long-term industry development", CAICT has provided a strong support in many aspects including major strategies, plans, policies, standards, testing and certification of industry development and played an important role in driving the leap-frog development and take-off of China's ICT industry.

ByteDance 字节跳动

Beijing Bytedance Technology Co., Ltd., founded in March 2012, is the world's first company to apply AI to its main products. With the migration of reading behavior to mobile devices, Bytedance has achieved rapid development and established a superb reputation and influence in the industry. Bytedance allows content creators to distribute content more conveniently and helps all types of media better adapt to the mobile Internet era. While consolidating its position in the domestic market, Bytedance has proactively made deployments internationally and aims to become a world-leading mobile Internet company that provides advanced mobile Internet-based information distribution services globally.

Advisory Organization: Chinese Institute of Engineering Development Strategies (CIEDS)

中国工程院 Chinese Academy of Engineering

清華大學 Tsinghua University

About CIEDS: The Chinese Institute of Engineering Development Strategies (CIEDS) was jointly established by the Chinese Academy of Engineering and Tsinghua University in April 2011 to improve the level of research on engineering development strategies in China and create a first-rate engineering thinktank platform. Oriented to high-level, open-ended and forward-looking development with the focus on holistic, general and strategic research projects in engineering science and technology

development based on theoretical and applied research, policy advice, pre-planning research and personnel training, CIEDS strives to build a leading strategy research institute featuring "small entity, large alliance, network-based collaboration" and a top-level thinktank in engineering science and technology and an important member of China's high-level thinktank network. Its main functions include 1) undertaking engineering development strategies advisory research projects of the Chinese Academy of Engineering and providing advisory services for the strategic policymaking of the state and relevant ministries and commissions; 2) conducting research on important theoretical issues of engineering development and building a database of engineering development strategy and policy documents; 3) conducting research on theories, methods and processes of engineering development strategy formation and advancing relevant disciplines relating to engineering development; 4) developing research, teaching and management personnel in engineering development strategies; 5) providing engineering strategy advisory services for large enterprises, public institutions and social organizations; and 6) advancing international exchange and cooperation in engineering development strategy research.

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