Questel

Deep Learning

2021 Patent landscape

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Executive Summary

Artificial Intelligence (AI) has experienced a rapid expansion and started to impact numerous industries since the last decades and AI-related landscape studies have already been published. Nevertheless, AI is not a single field, indeed, it englobes many techniques and can be divided into various sub-domains.

In 2019, the World Intellectual Property Organization (WIPO) has published a landscape report on all aspects of AI, in which Deep Learning was specified as the most marked machine learning technique with an impressive average annual growth rate of 175% in patenting activity between 2013 and 2016, and a 54% share of all AI related scientific publications up to mid-2018. It is clear that Deep Learning marked the beginning of the 21st century, and this field leaped to a different level along with the emergence of Big Data.

This current report covers a global patent landscape study focused specifically on Deep Learning technologies, analyzing various trends over the last 10 years. It defines R&D origins, market countries, top players, the most popular algorithms, as well as the most impacted functional and industrial application areas. Additionally, it employs reference information from various sources to enrich the analysis, enabling to reveal business intelligence and technological insights.

As the most promising machine learning technique in the frame of AI, more than 100,000 patent families have been filed on Deep Learning related technologies all over the world since 2011. A recent surge is observed with more than 90% of these applications filed since 2017, and an extremely high compound annual growth rate (CAGR) of 106% from 2012 to 2019, completely unseen in other technical areas.

The landscape reflects high discrepancies in the levels of R&D efforts in the field between different countries and different companies.

Globally, a Chinese domination is observed in terms of patenting activities. Indeed, 3/4 of these inventions originate from China, whereas only 10% of them emanate from the USA. South Korea and Japan contribute to 5.5% and 1.7% of global patenting activities, respectively, followed by India and Europe with around 1% each.

Close competition has been observed between China and the USA with a turning point in 2013 and an increasing leading position of China since then. Nevertheless, a lower ratio of granted patent families out of the total patent applications as well as a higher abandonment rate of patents in China could mean a slightly lower number of high-quality inventions coming from China compared to the ones coming from the US.

In terms of geographical market, China stays as the most attractive market, with around 80% of patent publications, followed by 14% in the US, 7% in South Korea, and 4% in Europe. Nevertheless, most of Chinese players are not interested by abroad market, as more than 99% of the Chinese inventions are protected only in China, without any right extensions to other territories, whereas more than 50% of American inventions are also protected in one or several countries outside of the US.

In terms of players, academic players are strongly implicated in the patenting activity of Deep Learning, being at the origin of 43% of the patents. 34 out of the top 50 players are either universities or research institutes, the remaining 16 are mostly high-tech companies, such as Baidu, Samsung, IBM, etc.

43 players among the top 50 are Chinese, led by Baidu, which has filed more than 2500 inventions and follows an exponential growth (multiplicated by 4 from 2019 to 2020), followed by the State Grid Corporation of China (~1500 inventions).

Despite the academic domination from patenting perspective, some technologies have already been involved in commercial products or services. This will ensure an enormous implication of Deep Learning technologies in more and more products and services in the future, potentially impacting many industries.

The aggressiveness level of this field is incredibly low for the moment, probably due to the low maturity level of the technologies and the difficulties to detect infringement in practice. More litigations may come in the following years, and it will be interesting to observe to which extent the differences of leverage brought by the respective sizes of patent portfolios of companies could impact their future market positions.

Convolutional neural networks stand out as the main algorithm technologies with image processing & computer vision as the main functional applications. The trends show that deep learning has penetrated extensively across all fields of industries, led by transportation and healthcare. With an extremely high growth rate of patenting activity, sectors such as business intelligence, resource & energy extraction, sales & customer relationship management will receive huge impact thanks to Deep Learning related technologies.

A diverse sector focus has been observed among the top players: Baidu on transportation sector, the State Grid Corporation of China on energy management system, Siemens on healthcare solutions, Ping An and Alibaba on finance and insurance inventions, which mostly reflect their respective market positions or strategies for future business. However, most of the companies file patents targeting almost all the different industries, showing a potential interest for new markets.

AI Revolution

Major Impact

Can a machine think?

« Can a machine think? » a question asked by Alan Turing in 1950. This question led to the discovery that machines are actually able to execute tasks that in their nature required a human intelligence to perform. By publishing the first paper in this field, “Computing Machinery and Intelligence”, Turing is considered as the "father of computer science". His research was the first step in the emerging of Artificial Intelligence (AI).

From this date forward development of AI concepts kept evolving; the 1990 was a significant milestone where major advances took place in all AI’s areas: significant demonstrations in Machine Learning, case-based reasoning, multi-agent planning, scheduling, data mining (Web Crawler), natural language understanding and translation, vision (virtual reality), games.

AI's rapid expansion and impact on numerous industries lead to another legitimate question: What will be the impact of this technology on the world economy, companies, the research domain, the labor workforce, etc.?

A research from the McKinsey Global Institute in 2018[1] attempted to simulate the impact of AI on the world economy. Among their major findings were the following:

1. There is large potential for AI to contribute to global economic activity.
2. A key challenge is that adoption of AI could widen gaps among countries, companies, and workers.

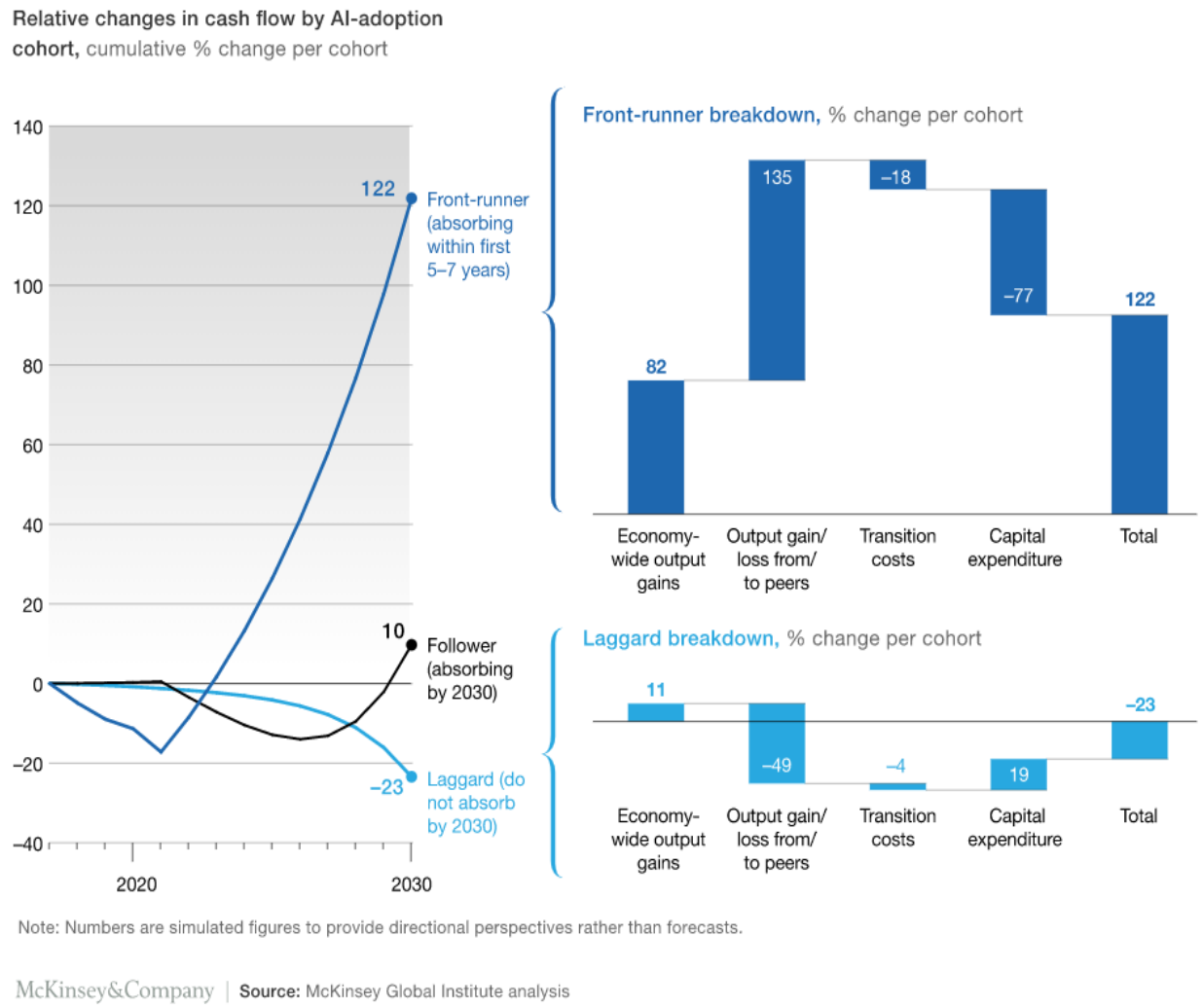
In the first point, The McKinsey Global Institute (MGI) pointed that AI has the potential to deliver additional global economic activity of around $13 trillion by 2030, or about 16 percent higher cumulative GDP compared with the date of their study. This amounts to 1.2 percent additional GDP growth per year. According to MGI Discussion Paper, the impact of AI might not be linear but could build up at an accelerating pace over time. Its contribution to growth might be three or more times higher by 2030 than it is over the next five years. They continue explaining that a slow start could be due to the substantial costs and investment associated with learning and deploying these technologies, however that it would be a misjudgment to interpret this "slow burn" pattern of impact as proof that the effect of AI will be limited. They conclude this point by saying that the size of benefits for those who move early into AI technologies will build up in later years at the expense of firms with limited or no adoption.

In their second finding MGI says that AI might widen gaps between countries, reinforcing the current digital divide. Leading AI countries could capture an additional 20 to 25 percent in net economic benefits, compared to the date of the study, while developing countries might capture only about 5 to 15 percent. They continued explaining that many developed countries might have no choice but to push AI to capture higher productivity growth as their GDP-growth momentum slows—in many cases, partly reflecting the challenge due to aging populations.

[1] Notes from the AI frontier: Modeling the impact of AI on the world economy

Moreover, in these economies, wage rates are high, which means that there is more incentive to substitute labor with machines than there is in low wage, developing countries.

The following chart from McKinsey shows the effect of AI on companies, by simulating the differences in cash flow' changes between companies that fully absorb AI tools across their enterprises over the next five to seven years (front-runners) and those who don't.



Note: Numbers are simulated figures to provide directional perspectives rather than forecasts.

McKinsey&Company | **Source:** McKinsey Global Institute analysis

Figure 1 - Relative changes in cash flow by AI-adoption

The effect on labor workforce according to the same study from MGI, expect that job profiles characterized by repetitive activities or that require a low level of digital skills could experience the largest decline as a share of total employment to around 30 percent by 2030, from some 40 percent however that the largest gain in share could be in nonrepetitive activities and those that require high digital skills, rising from roughly 40 percent to more than 50 percent. A direct consequence of this widening gap in employment and wages would be an intensifying war for talents, particularly those skilled in developing and using AI tools.

Deep learning, the most impactful AI technique

Addressing AI is not a single field to explore. AI is a general term that englobes different techniques. Each type of artificial intelligence is distinct, and some are more advanced than others just like humans' cognitive abilities differ from one person to another.

Major AI sub-domains are:

- **Machine Learning (ML):** With ML, machines learn from previous experiences to perform tasks without being programmed explicitly to execute specific instructions.

- **Natural Language Processing (NLP):** This application allows computers to process human language, without the ability to make predictions based on patterns learned from experience as Machine Learning does. Examples of NLP are found in IVR (Interactive Voice Response) used in call centers, translation services like Google Translate and text's grammar check as with Microsoft Word.

- **Automation and Robotics:** In this application of AI, robots are programed to autonomously perform high volume repetitive monotonous tasks.

- **Computer Vision:** This consists of capturing visual information and processing it such as signature identification, pattern recognition, and medical image analysis, etc. Though today, machine learning and computer vision technology are frequently used in conjunction to have accurate results, those two technologies are not the same. The purpose of Computer Vision is to mimic the powerful capabilities of human visual system in order to teach computers to interpret the visual world. ML, on the other hand, focuses on getting machines to learn from data for appropriate decisions making and by that imitating humans' behavior.

- **Data Mining:** It covers the different tools and methods used to extract knowledge from a huge volume of data to discover tendencies and correlations that cannot be found through normal analyses.

This report will explore the Machine Learning side of the AI and more specifically Deep Learning (DL). While ML makes machines "think" and learn from experience, it still needs human intervention to correct a step until the wished result is attained. With Deep Learning, considered as a branch of ML, the machines become more "intelligent". By imitating the human brain, it leverages a series of processing through multiple layers of artificial neural networks learning from previous experiences and taking corrective measures that are used to enhance decision making and feature's transformation and extraction. Though DL is considered a subset of ML, with DL, machines do not require external intervention, they become more" independent".

Deep Learning marked the 21st century, and with the emergence of Big Data, this technology leaped to a different level. The relevant question with DL is not can machine thinks but can they increase in knowledge through experience.

Andrew Ng, the chief scientist of China's major search engine Baidu and one of the leaders of the Google Brain Project, explained how the development of Deep learning is tight up to Big Data in a great statement to Wired Magazine:

"I think AI is akin to building a rocket ship. You need a huge engine and a lot of fuel, if you have a large engine and a tiny amount of fuel, you won't make it to orbit. If you have a tiny engine and a ton of fuel, you can't even lift off. To build a rocket you need a huge engine and a lot of fuel."

The big amount of data that is available in the current century allowed therefore machines to have a huge amount of "experience" and build a level of "knowledge" that wasn't previously possible.

In 2009 Professor Fei-Fei Li, an AI professor at Stanford said, "Our vision was that Big Data would change the way machine learning works. Data drives learning". To launch her project ImageNet, Li assembled more than 14 million labeled images and used them as input to "train the neural network".

So how is it possible to “train” a machine?

Deep Learning incorporates Neural Networks within its architecture. Neural Networks is a structure consisting of layers of algorithms called neurons.

Information is passed through each layer, with the output of the previous layer providing input for the next layer. The first layer of the neural network is called the input layer, this layer processes the raw data input and passes the information to the second layer. The second continues processing the information further, it adds additional information (for example, user’s IP address) to what it received and passes it to the next layer. This process continues throughout all layers of the network until the desired result is achieved. The last layer is called an output layer while all other layers in between are referred to as hidden layers.

Just like the human brain does for decision making, the Neural Network process data and imitate the thinking process which makes it possible to "teach" machines and allow them to grow in knowledge and therefore enhance their decision making.

So far, Deep Learning architectures have found applications in many fields such as Voice Recognition, Image Processing/ Computer Vision, NLP, Knowledge Graph, Information Retrieval such as with major search engines, Personalization & Recommendation and so much more, having impact in fields as different as transportation, healthcare, entertainment, finance…

However, the Hype Cycle for AI published by Gartner in 2020[2] shows that Deep learning is exiting the Peak of Inflated Expectations[3], meaning that the use of Deep Learning will progressively be "rationalized" and show its real performances and benefits in a selection of the industries which were initially considered.

[2] https://www.gartner.com/smarterwithgartner/2-megatrends-dominate-the-gartner-hype-cycle-for-artificial-intelligence-2020/

[3] The different phases of a technology's life cycle are explained by Gartner as:

- Innovation Trigger: A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist, and commercial viability is unproven.
- Peak of Inflated Expectations: Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies act; many do not.
- Trough of Disillusionment: Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
- Slope of Enlightenment: More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots: conservative companies remain cautious.
- Plateau of Productivity: Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

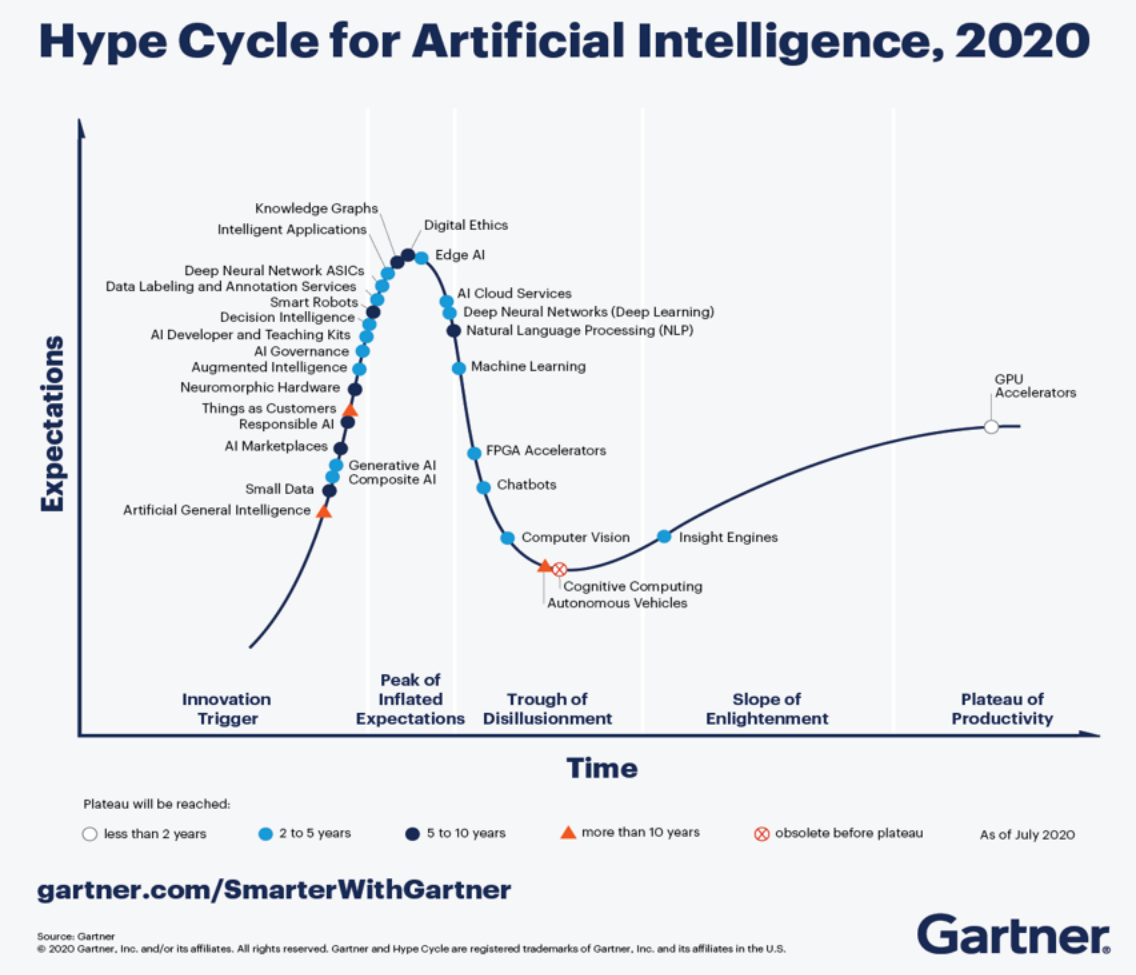
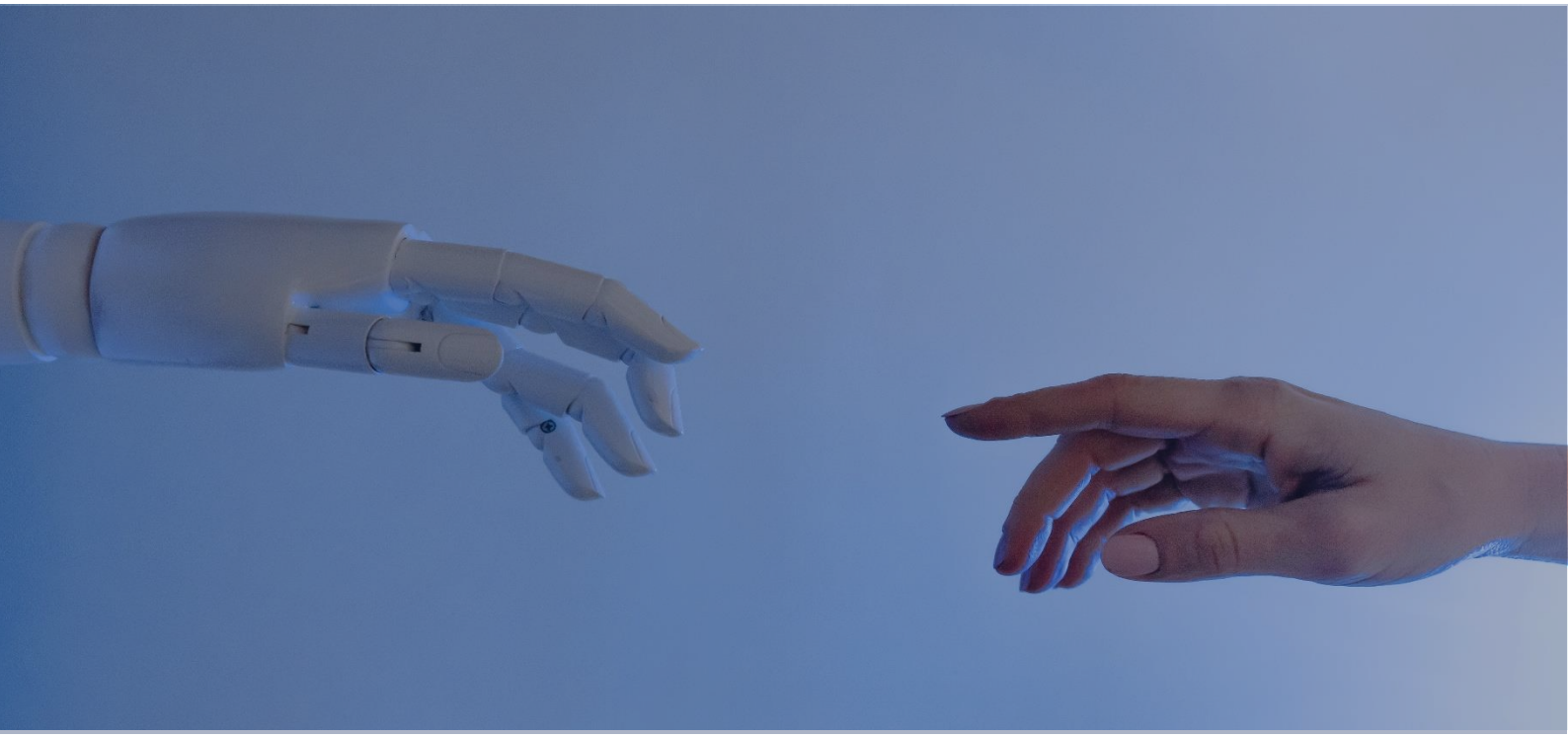


Figure 2 - Hype cycle for Artificial Intelligence

The Trough of Disillusionment is characterized by some companies keeping on investing on the technology and answering early adopters' expectations, while other companies divest the area or make bankruptcy. In terms of patents, this phase is an opportunity to acquire patents and reinforce its portfolio to increase its competitive advantages on the future market.

Thus, analyzing the current patents landscape in Deep Learning will enable to observe those trends.

Deep learning updated patent landscape: a need



AI related patent landscapes have already been published. For instance, a publication by the World Intellectual Property Organization (WIPO) on AI trends in 2019[4] displayed the following figures: nearly 340 000 patent families and more than 1.6 million scientific papers related to artificial intelligence were published from 1960 until early 2018. The number of patent applications filed annually in the AI field grew by a factor of 6.5 between 2011 and 2017. The actual number of published applications per year rose from ~8 500 in 2006 to ~12 000 in 2011 and ~56 000 in 2017 with 53 percent of all patents in the AI field published since 2013.

WIPO continued to specify in this publication that the most marked increases in patenting activity between 2013 and 2016 featured Deep learning with an average annual growth rate of 175% during this period.

[4] https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf

In scientific literature, Machine learning was also the most common field described (representing 54% of scientific publications).

As with companies, machine learning and neural networks were the most frequently mentioned AI techniques.

Deep learning appears to be the major AI technique and as predicted by McKinsey Global Institute, should have a huge impact on the global economy activity. As showed by Gartner's Hype Cycle, Deep Learning is also entering a phase of uncertainty, the Trough of disillusionment, where is real impact and applicability in various fields will be challenged.

This potential Deep learning revolution requires the innovative actors to remain at the edge and to maintain their position by protecting their inventions, notably by filing patents. Thus, a patent landscape focused on Deep Learning will, to a large extent (some inventions are protected by a secrecy and know-how policy), reflect the innovation landscape of Deep Learning.

Deep learning technologies are developed by many different players, coming from different horizons, and operating in various fields, which makes therefore identifying the leading players, new entrants, and technological trends difficult. Thus, the purpose of this study is to identify the actual state of this prominent field by identifying innovative trends, major contributors, fields of applications and industries which drive the innovation.

Methodology

Patents search strategies

Data source

The data source used in this study is FamPat worldwide database search tool Orbit Intelligence. FamPat is a global collection of patent applications and granted patents organized by simple patent families, covering more than 100 patent authorities all over the world, including searchable full text from 63 patent offices, provided by Questel.

As each Fampat record contains potentially many individual publication events all with different dates, the report uses the earliest known office of first filing date for each patent family. This is considered as the representative patent family member which is being used to refer to the patent family. The office of first filing (OFF) or priority, refers to the first application for a particular invention which, when filed at any patent office becomes the “priority application”, with the date of this event defining the priority date. The country of the first filing is defined as the first priority country.

The tables and charts included in the report use this priority date, unless otherwise noted, because it provides the most accurate indication of the inventive activity. The definition of patent sources, i.e., the location from which patent families are emanating, is based on the Office of First Filing (OFF). It should be noted that this definition is not 100% accurate, nevertheless, it provides a useful and fair method of identifying the usual country of first filling of entities, which typically coincides with their home patent office.

As mentioned previously, the current study focuses on deep learning technologies, a popular branch of machine learning technologies within AI field.

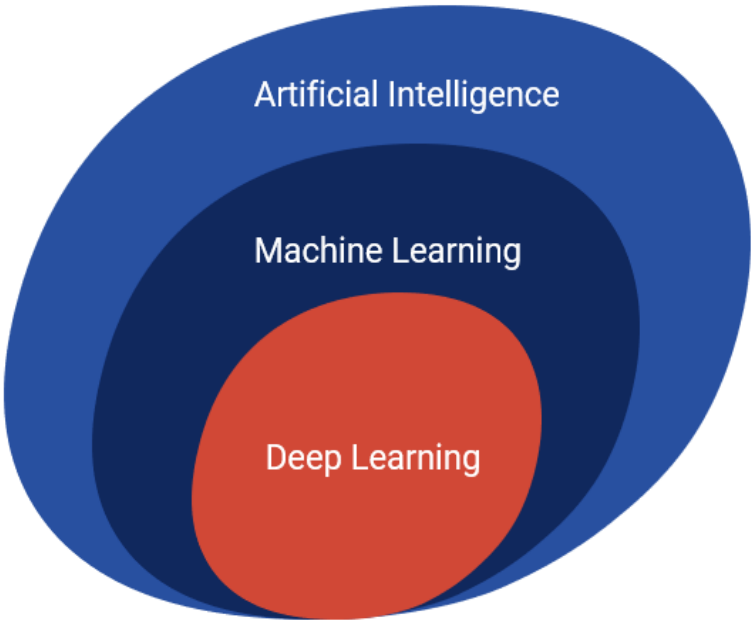
The search was performed by employing several strategies, using deep learning and their associated techniques keywords as well as relevant patent classifications (such as G06N 3/02: computer systems using neural network models). The relevance of the results is guaranteed between exhaustivity and accuracy thanks to the proper use of Boolean operators and an iterative search process.

Methodology

Taxonomy

Studied area

The core subject of this patent landscape is Deep Learning being the most prominent field of AI in the 21st century.



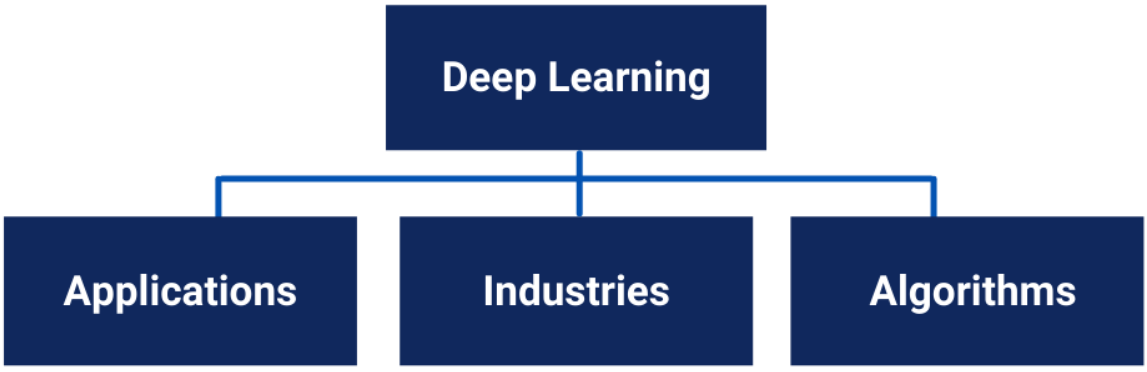
Definition of the taxonomy to segment the patent dataset

Deep Learning is a subject that carries excessive concepts. The analyses of the theme can be approached from several angles, therefore a clearly defined and a focused study is fundamental. For clarity and simplicity, the report will focus on three axes that were found providing the wider and the most global view. The segmentation (See Annex A) can be summarized in three key areas: Applications, Industries, and Algorithms.

- **Applications:** These are the functional applications defining the general DL domain such as Voice Recognition or Computer Vision with no connection to any specific industry or methodology.

- **Industries:** To fully understand the influence of DL, it must be tied to the industries that are targeted the most. It is interesting to view its impact on fields such as healthcare, telecommunications and many more.

- **Algorithms:** Deep Learning is based on Neural Networks; however, those networks do not imply a single architecture for every application and do not involve a common methodology for processing data. Many algorithms have been developed and analysis on the implication of each one of them in the current DL era highlights the recent technological evolution in this field.



To have a structured approach, a few subjects have been selected for each axis based on the most known in each branch. However, this selection is not exhaustive; developments and innovation are also taking place in other applications such as Robotics and Data Mining, and in other industries such as Government, Travel & Tourism, Legal…

Patent landscape

Filing trends

An explosive growth

The analysis' timeframe of this report was from mid-July 2011 to August 2021. During this period, a total number of 107423 Deep Learning related patent families was found. The acceleration in DL's patent numbers can be clearly seen in the following figure, showing the timeline of patenting activity from 2011 to 2019[5]:

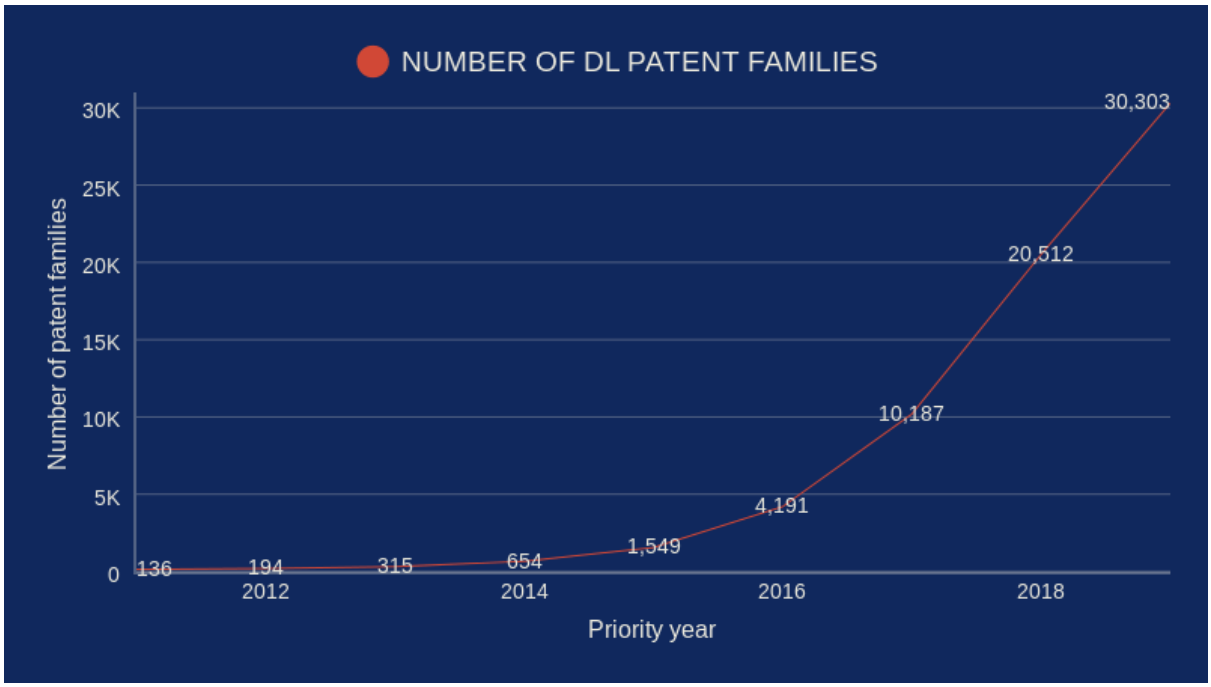


Figure 3 - Number of DL related patent families

The huge impact of Deep Learning in the last 10 years can clearly be seen in the increase of the number of patent families filed between 2011 and 2019.

[5] Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2019.

The average yearly growth for this period is 106% with a continuous increase in yearly growth percentage.

The yearly growth rate peak was reached in 2016 with a value of 171% compared to 2015. However, starting 2017, a decline in this percentage began to be observed reaching a yearly growth rate of 48% in 2019.

A global look at the growth over the last 10 years, more specifically between 2011 and 2019 shows that the number of patent filings has been multiplied by almost 200, a remarkable value for any new technology.

The patent filing dynamic in Deep Learning is globally very high. Comparing the global patent filing with all technologies combined, for the period between 2012 and 2019 with DL specific patents, the following has been noticed: A 17% global growth rate has been observed for China with 136% growth rate in the DL field, in India a 12% global growth rate corresponded to 130% for DL and with 1 % global growth rate for South Korea a remarkable 121% rate was observed for DL.

On the other hand, even the countries with a negative or null global growth rate, DL was still increasing at a high pace. For the U.S.A for instance, the global growth rate decreased by -2% while Deep Learning growth rate increased by 76%.

The same pattern has been observed for many other regions or countries such as Taiwan (-4% / +89%), United Kingdom (-3% / 88%) and Germany (0% / 53%). This analysis demonstrates how Deep Learning has been a major innovation area in the last decade comparing to any other innovation field.

Patent landscape
Inventions' origin

More than two thirds of DL patent filings coming from China

Normally the priority country data provide information on the patenting strategy in the sector and is a good indicator of the main R&D locations, as most players file priority patent application locally.

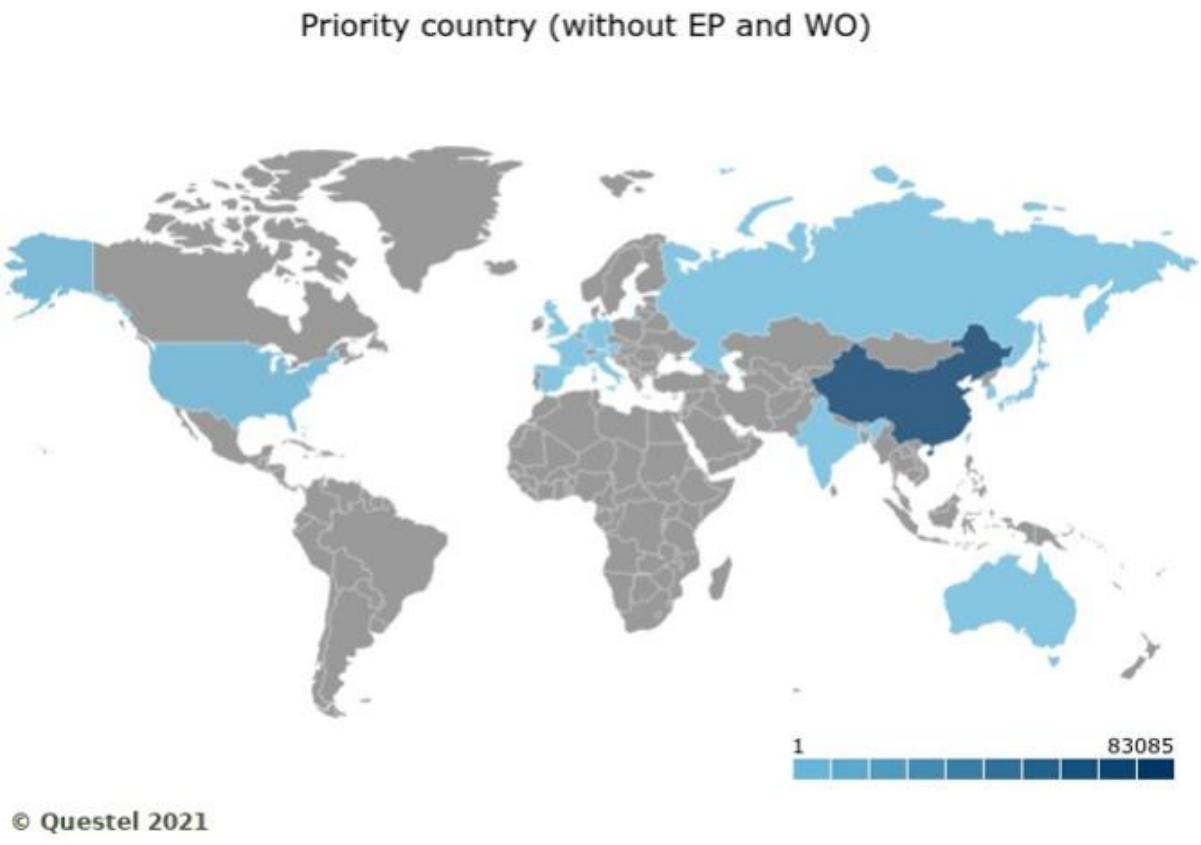


Figure 4 - Worldwide patent priority country map

Globally speaking, 77% of DL related patent applications worldwide in the last ten years originated from China, whereas only 10% of them emanated from the USA. South Korea and Japan contributed to 5.5% and 1.7% of global patent filing, respectively, followed by India and Europe with around 1% each.

In 2011, Chinese patent applications accounted for 28% of world patent filings; whereas in 2016, 50% of DL related patent applications came from China; and in 2019, this percentage surpassed two thirds.

We have observed strong competitions between China and the USA from 2011 to 2013. And the number of Chinese patents applications surpassed those from the USA for the first time in 2013. Ever since, this field has been led by Chinese applicants, with a continuous growing disparity, reaching more than seven times patent applications (almost three times granted patent families) compared to American ones in 2019. Nevertheless, a lower granted patent families / total patent applications ratio is observed in China compared to the US, in which only 28% of Chinese patent applications are granted whereas 46% of American ones are granted from 2011 to 2019. This phenomenon is partially explained by the fact that Chinese patents are younger than American ones, thus examination procedures still ongoing, and by the abandonment of patent by Chinese applicants, especially universities, even when they already have been granted. Moreover, there are almost 2,900 PCT applications from China, accounting for 3% of its total applications since 2011, whereas almost 4300 PCT applications from USA at the same period of time, which is 40% of its total applications.

Please note that the data in 2020 and 2021 are incomplete due to the 18 months of publication delay of patent literature. Nevertheless, some patents are included in the search results due to early publication policies, especially in China. There are very few utility models (<1%) among the Chinese patent families, in contrary to the presence of a huge number of Chinese utility models in other fields.

The growth rate in the past few years shows an extremely strong filing activities from Asia, confirmed by a CAGR of 140% from 2012 to 2019 in China, and similar growth rate from South Korea and India. A relatively lower and still significant growth rate is observed in USA, Europe, and Japan.

In terms of legal state, around 95% of DL related patent families are alive[6], with almost no difference from the top filing countries.

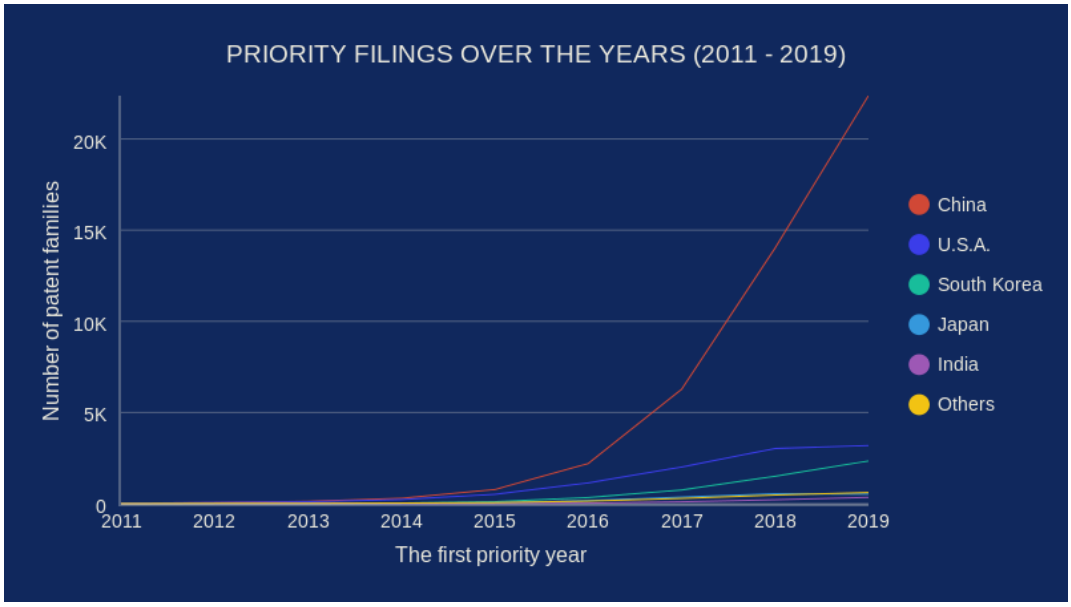


Figure 5 - Top 5 priority country patent filing dynamics

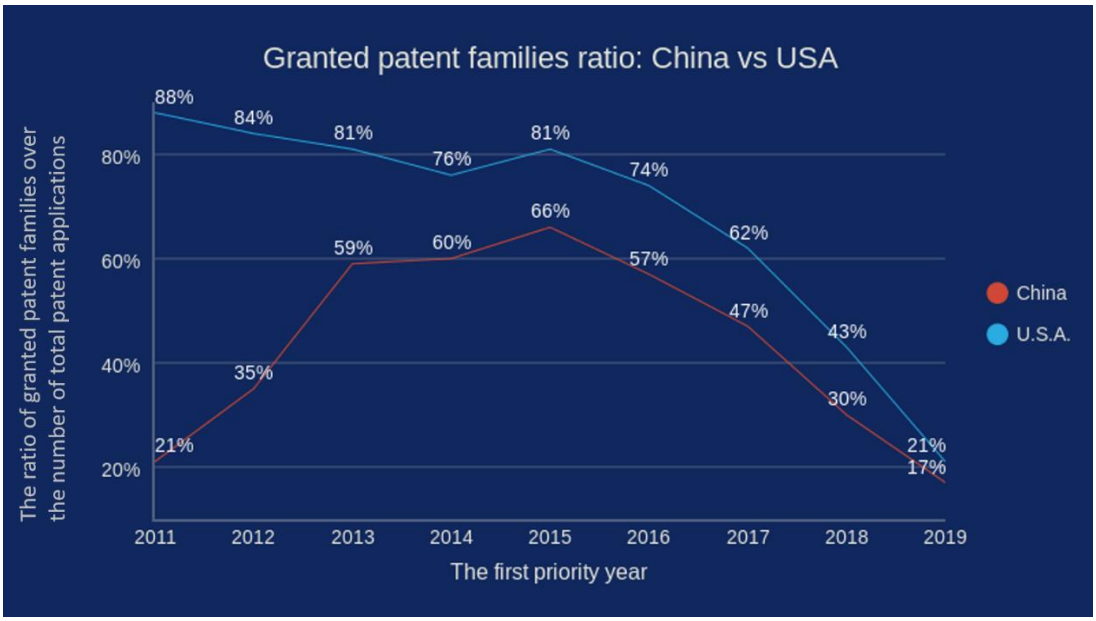


Figure 6- Granted patent families ratio China vs USA comparison

[6] Patent families where at least one member is still a patent application or a granted patent are considered as alive.

This strong position of China in the AI world was explained by Boi Faltings, EPFL in the following statement: “Since AI-related innovations are enabled by data, the organizations that generate the most AI-related patents are often the ones that own the most data. This explains many of the observations, in particular, the surprisingly strong position of China – there are far fewer obstacles to collecting vast amounts of data in China than in other countries, and China has the best training data collections for speech recognition, human behavior modelling and medical data, for example”

Indeed, there are three main factors behind China's rise on the global AI scene[7]:

- **The possibility to have access to a huge domestic market:** China's population of 1.4 billion consumers is the largest domestic market worldwide. There is a plethora of potential AI applications for this market. This makes China fertile ground for AI companies to thrive.

- **Policy stimulus and guidance:** AI is a top priority for the leadership, and the Chinese government has formulated a clear and ambitious mission for artificial intelligence. The government and business sector understand that AI is revolutionizing virtually every aspect of consumers' lives, and they are embracing this new technology and providing strong strategic guidance to innovative AI technology companies.

- **Favourable market environment:** China is a self-sufficient market, relying on its own and sole local supply for a huge domestic market. This is another important factor for innovation to flourish, representing a great incentive for domestic contribution in this field.

[7] https://www.forbes.com/sites/bernardmarr/2021/03/15/china-poised-to-dominate-the-artificial-intelligence-ai-market/?sh=1b9870541b38

Patent landscape

Market countries

China as the main market country

The number of documents published in the various national offices reflects the patent strategies of the actors in the sector, as the national filings are a good indicator of the markets that need to be protected. Please note that some players also target a protection in the geographical areas where the manufacturing sites of their competitors are located. The graph below is based on patent publication numbers and is dependent on the practices of the Offices. Thus, some offices, such as Germany, republish a document after the grant of the European patent, whereas France does not. Other offices publish only the granted patents and not the applications.

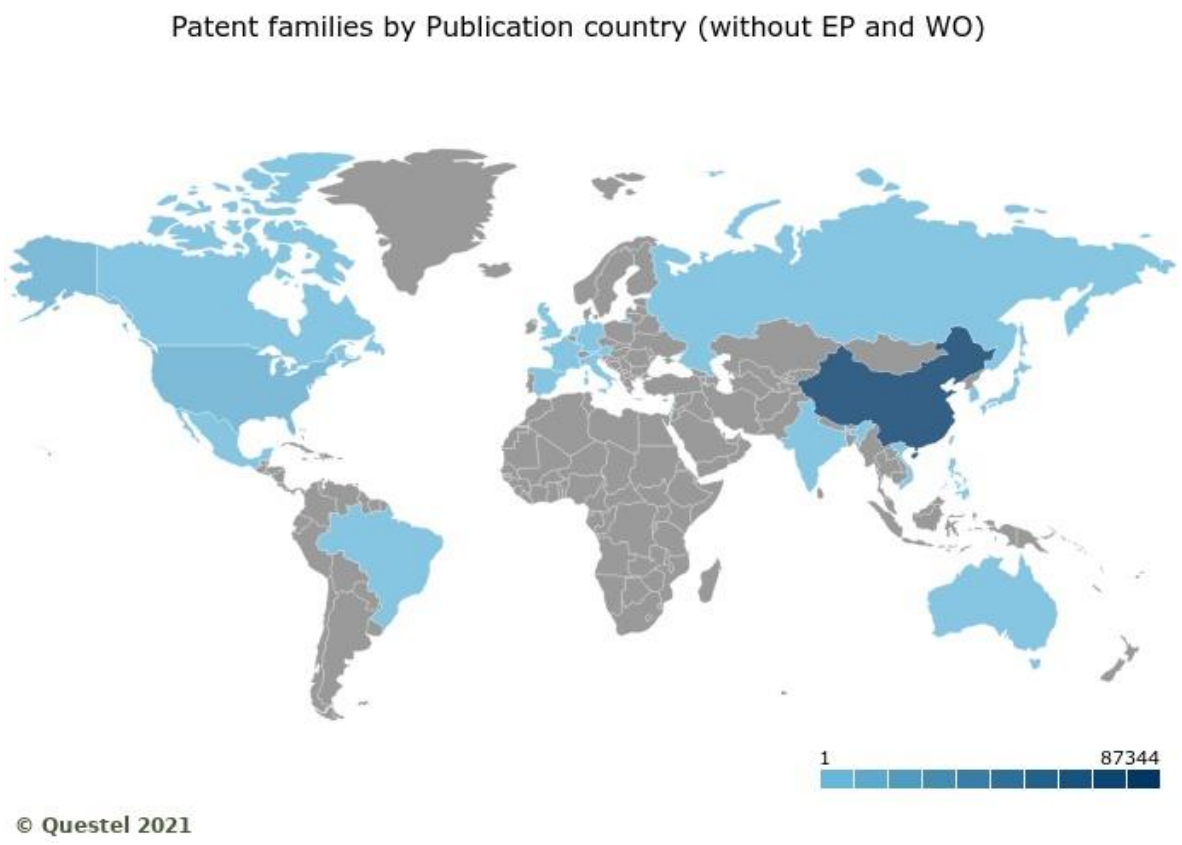


Figure 7 - Worldwide patent families by publication country

Not surprisingly, 81% of patent publications have been published in China, showing its position as the major market. This position is further enhanced by the intensive patent filings from China (Figure 7). Indeed, most of the Chinese patent applications are only published in China, and only 1.7% of Chinese applications are extended in the USA, which is the largest Western market country for Chinese patents, far ahead of other territories, such as Europe, Japan and South Korea. On the other side, 26% of American patents have been extended in China, whereas 22% have been published in Europe. Interestingly, other countries, such as Korea, Japan, India and UK tend to protect their inventions more than twice as often in the USA than in China.

Patent landscape

Players

A different field typology than AI's one

A Chinese academic domination

In the general field of AI (not focused on Deep Learning), WIPO's patent landscape (published in 2019) stated that out of the 30 top patents players:

- companies represented 26 of them
- most of them were Japanese conglomerates
- the two biggest AI portfolios belonged to US companies (IBM with ~9000 patent families, dominating the field with 1,5 times more patents than the second player Microsoft)
- there were only 4 Chinese players.

The present Deep Learning patent landscape in 2021 shows a significantly different typology of top players, as out of the top 50:

- there are 34 academic actors and only 16 companies
- 43 players are Chinese
- The top patent filer is Baidu, with more than 2,500 inventions (almost 3% of the total patent inventions), dominating the field with 1,6 times more than the second one, the Chinese electric utility State Grid Corporation of China (SGCC)
- The rest of the players are from the US (4), South Korea (2) and Germany (1).

Moreover, WIPO's report stated that out of the top 20 universities and public research organizations in the AI field, the vast majority (17) were in China and the remaining three in the Republic of Korea.

Today, top academic players in Deep Learning are mostly Chinese: 20 out of the 20 first, 49 out of the 50 first, and 93 out of the 100 first (representing 97.5% of the patents). 43% of all the patents are originated from academic players, 91% of them being Chinese. A few collaborations happened between some universities (Tsinghua University, Southeast University Nanjing, Wuhan University, Zhejiang University…) and SGCC, and between Chinese Academy of Sciences (Institute of Automation) and Tencent.

Thus, Deep Learning seems to be a less mature AI technique than others, with a strong implication of academic players. More surprisingly, the ratio of patents from academic players increases over time, which is very specific to this technological field. However, this statement may hide different situations, with already mature technologies in some industries, as most of the top industrial players, such as Baidu, Ping An Technology, Alibaba or Google, already use Deep Learning technologies in their respective commercialized solutions.

If companies appearing within the top 50 players are not surprising, the absence of some of them was unexpected. Within the BATX galaxy, Xiaomi appears "only" at the 62nd position, despite its late but massive investment of $1.5 billion in artificial intelligence and Internet of Things[8]. Within the GAFAM universe, Amazon (116th position), Facebook (128th) and Apple (162nd) are far behind but compensate this "low" activity by being the most active in AI companies' acquisitions[9].

[8] https://www.bloomberg.com/news/articles/2019-01-11/china-s-xiaomi-places-a-1-5-billion-bet-on-ai-and-smart-devices

[9] https://www.sofrecom.com/en/news-insights/gafa-batx-and-operators-on-the-hunt-for-data-and-ai.html

TOP-50 PATENT APPLICANTS LIST

Assignee	Number of inventions	Country	Player Typography
BAIDU	2522	China	Internet & Search Engine
CHINESE ACADEMY OF SCIENCES	2415	China	Academic
ZHEJIANG UNIVERSITY	2169	China	Academic
NANJING UNIVERSITY	1887	China	Academic
STATE GRID CORPORATION OF CHINA (SGCC)	1577	China	Electric Utility
PING AN TECHNOLOGY	1382	China	AI & Cloud
UNIVERSITY OF ELECTRONIC SCIENCE & TECHNOLOGY OI	1114	China	Academic
BEIJING UNIVERSITY OF TECHNOLOGY	1089	China	Academic
SAMSUNG	1079	S. Korea	Conglomerate
CHONGQING UNIVERSITY	1025	China	Academic
SOUTH CHINA UNIVERSITY OF TECHNOLOGY	935	China	Academic
TENCENT	925	China	Conglomerate
TSINGHUA UNIVERSITY	924	China	Academic
ALIBABA	921	China	E-commerce & Retail
TIANJING UNIVERSITY	823	China	Academic
WUHAN UNIVERSITY	806	China	Academic
XIDIAN UNIVERSITY	791	China	Academic
IBM	768	US	IT
SUN YAT SEN UNIVERSITY	686	China	Academic
SOUTHEAST UNIVERSITY NANJING	655	China	Academic
HANGZHOU DIANZI UNIVERSITY	636	China	Academic
BEIHANG UNIVERSITY	619	China	Academic
GOOGLE	612	US	Internet & Search Engine
GUANGDONG UNIVERSITY OF TECHNOLOGY	571	China	Academic
SHANGHAI JIAO TONG UNIVERSITY	551	China	Academic
SHANDONG UNIVERSITY	543	China	Academic
HUAWEI	501	China	Consumer Electronics & Telecom
HUAZHONG UNIVERSITY OF SCIENCE & TECHNOLOGY	484	China	Academic
XI'AN JIAOTONG UNIVERSITY	479	China	Academic
SIEMENS	450	Germany	Conglomerate
HARBIN INSTITUTE OF TECHNOLOGY	446	China	Academic
BEIJING UNIVERSITY OF POSTS & TELECOMMUNICATION	430	China	Academic
NORTHWESTERN POLYTECHNICAL UNIVERSITY	406	China	Academic
MICROSOFT	395	US	IT
INTEL	390	US	Semiconductors
SENSETIME	366	China	AI
LG	366	S. Korea	Consumer Electronics & Telecom
SICHUAN UNIVERSITY	343	China	Academic
FUDAN UNIVERSITY	339	China	Academic
CENTRAL SOUTH UNIVERSITY	339	China	Academic
HOHAI UNIVERSITY	338	China	Academic
NATIONAL UNIVERSITY OF DEFENSE TECHNOLOGY	335	China	Academic
TONGJI UNIVERSITY	334	China	Academic
FUZHOU UNIVERSITY	328	China	Academic
OPPO	308	China	Consumer Electronics & Telecom
DALIAN UNIVERSITY OF TECHNOLOGY	305	China	Academic
NORTHEASTERN UNIVERSITY OF CHINA	298	China	Academic
HARBIN ENGINEERING UNIVERSITY	290	China	Academic
HIKVISION	279	China	Videosurveillance
SHENZHEN UNIVERSITY	269	China	Academic

Trends in the industrial sector

A focus on the 50 top industrial players (corresponding to the ones having at least 100 patents families related to Deep Learning) shows that Chinese companies are still a majority (29), but companies from other countries (U.S.A., Japan, South Korea, Germany, The Netherlands, Sweden) also appear.
The market fields of non-Chinese companies are quite similar to Chinese companies' ones: IT, search engine, e-commerce, transportation, electronics, telecommunication… This shows the great diversity of the applicative areas of Deep Learning, as it will be observed later by analyzing the industries targeted by patents.

Indus. rank	Player	Patents
7	IBM	768
8	GOOGLE	612
11	MICROSOFT	395
12	INTEL	390
16	ADOBE SYSTEMS	233
38	GENERAL ELECTRIC	135
43	NVIDIA	130
44	QUALCOMM	126
49	AMAZON TECHNOLOGIES	103
50	FORD	100

Indus. rank	Player	Patents
10	SIEMENS	450
22	ROBERT BOSCH	186
26	PHILIPS	178
48	ERICSSON	109

Indus. rank	Player	Patents
17	FUJITSU	227
21	NEC	193
29	CANON	163
32	NIPPON TELEGRAPH & TELEPHONE	154

Indus. rank	Player	Patents
4	SAMSUNG	1079
13	LG	366
46	STRADVISION	115

Indus. rank	Player	Patents
1	BAIDU	2522
2	STATE GRID CORPORATION OF CHINA	1577
3	PING AN TECHNOLOGY	1377
5	TENCENT	925
6	ALIBABA	921
9	HUAWEI	501
14	OPPO	303
15	HANGZHOU HIKVISION DIGITAL TECHNOLOGY	243
18	BEIJING JINGDONG SHANGKE INFORMATION TECHNOLOGY	225
19	BEIJING SENSETIME TECHNOLOGY DEVELOPMENT	214
23	GREE ELECTRIC APPLIANCES	184
24	BEIJING DIDI INFINITY TECHNOLOGY & DEVELOPMENT	180
25	SHANGHAI EYES CONTROL TECHNOLOGY	178
27	SHENZHEN WEITESHI TECHNOLOGY	167
28	BEIJING ZIJIE TIAODONG NETWORK TECHNOLOGY	167
30	JINAN INSPUR HIGH & NEW TECHNOLOGY INVESTMENT DEVELOPMENT	157
31	SUZHOU LANGCHAO INTELLIGENT TECHNOLOGY	154
33	BOE TECHNOLOGY	149
34	SICHUAN CHANGHONG ELECTRIC	145
35	BEIJING DAJIA INTERCONNECTION INFORMATION TECHNOLOGY	144
36	DAHUA TECHNOLOGY	143
37	BEIJING XIAOMI MOBILE SOFTWARE	142
39	INDUSTRY & COMMERCIAL BANK CHINA	132
40	BEIJING QIYI CENTURY SCIENCE & TECHNOLOGY	132
41	ONECONNECT TECHNOLOGY	131
42	GUANGDONG POWER GRID	131
45	BEIJING KUANGSHI TECHNOLOGY	125
47	BEIJING SCIENCE & TECHNOLOGY THREE FAST ONLINE	112

Figure 9 - Ranking of top industrial players

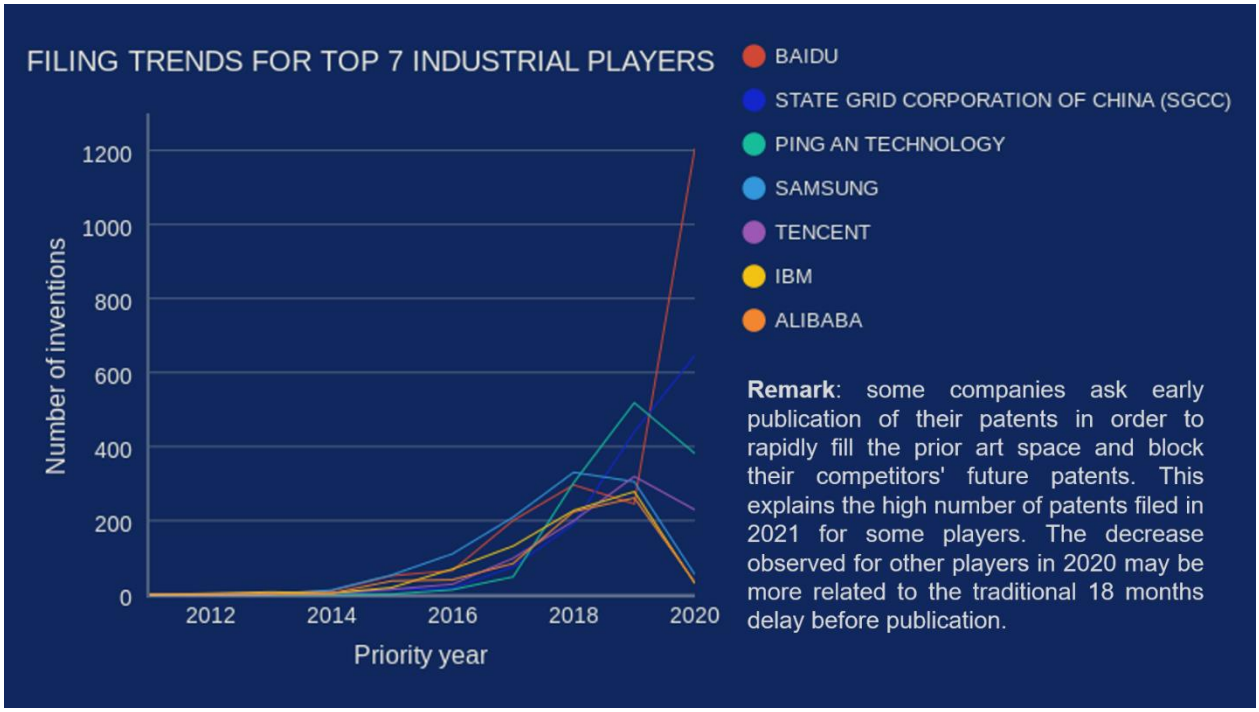


Figure 10 - Filing trends for top 7 industrial players

All top 7 companies have followed approximately the same rapid increase of patent filings from 2011 until 2018. Except for SGCC and Ping An Technology, the filing trend has slowed down in 2019. And in 2020 (even if not all the patents filed have been published), Baidu showed a radical change of the filing trend, with a remarkable number of filings, which is multiplied by 4 in only one year.

Baidu is one of the largest AI and internet companies in the world, known for their highly popular search engine. Over 70% of Chinese search inquiries are performed through Baidu's search engine.
Haifeng Wang, chief technology officer at Baidu, declares that: "In 2013, Baidu announced the world's first in-house institute focusing on the study of deep learning." And that "Baidu is now among the top AI players in the world, with more than 10 000 R&D engineers. Its annual R&D investment is about US$2 billion, and AI R&D accounts for a large proportion of that". Like Google, China's number one search engine obviously uses artificial intelligence at the heart of its historical platform to manage natural and paid referencing.

But in AI, Baidu has attracted most attention for its initiatives in autonomous cars, with massive investments in this area. In 2017, it published the open-source software platform resulting from its work: Apollo. A turn of strength which allows it to federate nearly 500 players in the sector. The same year, it launched a $1.52 billion fund with the aim of supporting a hundred or so projects in the field over three years.

At the same time, Baidu is also opening up the sources of its historical AI algorithms. This is the case of its image processing and language models from the R&D of its search engine. These are grouped together in the open-source project AI Open Platform. Mid-2020, open developer accounts on the platform jumped 37% in one year, to 1.3 million.

Another open-source project launched by Baidu is the deep learning infrastructure PaddlePaddle. In its latest iteration, it introduces bricks-oriented NLP, video recognition, recommendation... In total, PaddlePaddle has 200 pre-configured machine learning models and is used by more than 1.9 million developers and 84,000 enterprises globally[10].

Industries throughout China are using the platform to create specialized applications for their sectors, from the automotive industry's acceleration of autonomous vehicles to the health-care industry's applications for fighting covid-19. Baidu for instance developed an AI multi-body temperature measurement system based on image recognition technology and infra-red thermal imaging technology.

However, Baidu's domination in the patent landscape should not hide the current commercial importance of US companies in this field, even if they do not appear among the top patents' players. TensorFlow, an open-source platform from Google published in 2015 that quickly became a reference Framework in DL, has indeed an actual market share of 65%[11] in data-science-machine-learning market and its similar platform PyTorch, developed by Facebook's AI Research lab, owns 25%[12] of the market share (September 2021).

This large gap between current market shares and patent ownership in deep learning raises questions about who the future leaders in this field will be. It will be very interesting to observe to which extent the leverage brought by the respective patent portfolios will impact market positions.

But whatever the answer, the patent landscape already reflects the different levels of R&D efforts in the field between different countries and between companies. And there is no indication at this time that the differences observed today will be reduced in the future.

[10] https://www.technologyreview.com/2020/06/22/1004251/baidus-deep-learning-platform-fuels-the-rise-of-industrial-ai/
https://www.asiafinancial.com/chinas-old-dragon-baidu-leading-the-pack-in-ai-technologies
[11] https://www.slintel.com/tech/data-science-machine-learning/tensorflow-market-share#compare
[12] https://www.slintel.com/tech/data-science-machine-learning/pytorch-market-share

The other BATX' development

Alibaba started by using AI for its services (robotization of its supply chain, chatbot...). Its recommendation engine of its e-commerce site, for instance, relied on machine learning to link visitors' interests to its media and entertainment platforms.

In 2015, Alibaba Cloud introduced a platform dedicated to machine learning. It covers classification, clustering and logistic regression algorithms. But also neural networks, especially tailored for natural language and image recognition. These services are used in China, for example, in the industrial, transport and medical sectors, for decision support and predictive analysis scenarios. Like IBM with its Watson offering, Alibaba Cloud has built verticalized AI solutions, grouped under the ET Brain brand. It covers smart cities, manufacturing, healthcare, air transport and the financial sector[13].

Tencent, the Chinese internet and mobile services specialist entered AI in the health sector. Capitalizing on the success of WeChat, it markets an offer to tens of thousands of Chinese medical facilities[14], allowing them to manage their appointments online via chatbots. Tencent is also developing AI solutions to help with medical diagnoses, especially cancer screening.

This is a mission entrusted by the Chinese industry and Internet regulatory authorities. Building on this first step, the group has been extending its AI offering since 2017 to other fields: road transport optimization, voice recognition and translation. These technologies are also used by WeChat.

Unaggressive field so far

Only 5 infringement related litigations have been observed, in the US and in UK. Out of more than 100 000 patents families, this number is incredibly low, respectively 80 times lower than the global AI landscape which in 2019 showed more than 1200 litigation cases and was already considered as not aggressive[15].

[13] https://www.sofrecom.com/en/news-insights/gafa-batx-and-operators-on-the-hunt-for-data-and-ai.html
[14] https://www.journaldunet.com/solutions/dsi/1446945-les-batx-investissent-massivement-dans-l-ia/

[15] https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf

This low litigation level is linked to the low maturity of Deep Learning, meaning than a lot of technologies are still not commercialized, but also that players on the market compete on technologies performances and data volumes to earn market shares. Patent litigation could arrive later, when the market growth will slow down.

Additionally, potential infringements related to Deep Learning technologies would be very complicated to detect. Therefore, this questions on the willingness of players to build so impressive patents portfolios. Those ones indeed appear to be players' pride in the geopolitics competition on the one hand, and weapons against competitors which can become a threat or a leverage only if they are massive on the other hand.

Patent landscape

Segmentation analysis

Algorithms

CNNs as the most popular algorithm technology

75 491 patent families (70% of the global database) involve at least one type of algorithm technologies.

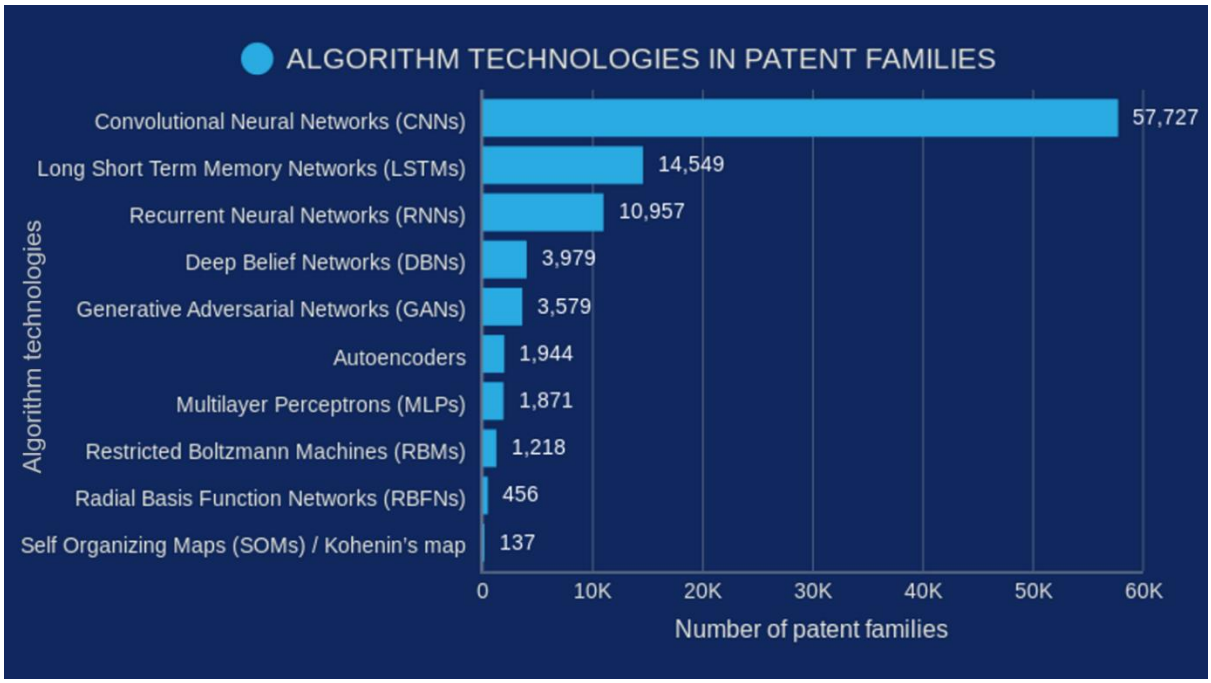


Figure 11 - Patent volumes concerning algorithm technologies

Among the ten algorithm technologies investigated, the convolutional neural networks (CNNs) seem to be the most popular one, mentioned by 76% of the documents. Chinese players are the main contributors of this technology, owning 80% of the inventions.

Indeed, China stays at a dominate position, for most of the algorithm technologies, including long short-term memory networks, radial basis function networks, restricted Boltzmann machines, etc. Their position is less strong in other technologies, such as recurrent neural networks, self-organizing maps and autoencoders, where the landscape is also occupied by US players, or even players from other countries.

All the top three players filing the algorithm technologies are academic, Chinese Academy of Science, Zhejiang University and Nanjing University, with more than 1500 patent families each. Baidu is ranged at the 7th position, Samsung and Google are the only two non-Chinese players, ranking in 16th and 20th position, respectively.

CNNs' major role in computer vision

CNNs played a major role in the advancement and perfection of Computer Vision with time. The pre-processing required in this type of network is much lower as compared to other classification algorithms which encouraged its usage in the new inventions for this specific application. This influence is clearly reflected in this present analysis as Image Processing/Computer Vision and CNN algorithms were jointly mentioned in almost 40,000 inventions.
The CAGR for Image Processing/Computer Vision between 2012 and 2019 is 144 % interestingly associated with a Growth value of 128 % for CNNs, with the emergence of variant CNN architectures, both concepts following a very close dynamics in their increase. Common applications of computer vision today can be seen in industries such as Automotive (21% of transportation inventions mentioning CNN), Healthcare (14 %) or Entertainment (9%).

CNN, LSTM and GAN algorithms on a strong rise, SOM, Kohenin's map and RBM slowing down

Comparing the different growth rate of the addressed DL algorithms, Long Short-Term Memory Networks (LSTMs) presented a remarkable CAGR value rate of 171% for the period between 2012 and 2019, the highest value between the algorithms, with a growth of 71% from 2018 to 2019. Generative Adversarial Networks (GANs) had also an interesting growth rate of 150% over the same period of time, however it had the highest growth between 2018 and 2019 with 75%, therefore exceeding LSTM's and showing that there was an increased interest in the innovation field for GAN in the latest years. On the other hand, though CNN was mentioned by 76% of the documents, its CAGR wasn't the highest (128 %) compared to other algorithms, but this cannot deny it's big part in the innovation field.

An interesting observation was also noticed for 2 other algorithms, Self-Organizing Maps (SOMs) / Kohenin's map and Restricted Boltzmann Machines (RBMs), which both had a negative growth rate between 2018 and 2019 with a value of -26% and -10% respectively though their global CAGR value represented a growth from 2012 to 2019 (31% for SOM and 56% for RBMs). This clearly shows a decrease of interest in the development for those algorithms in the latest years.

Deep Belief Networks (DBNs) and Restricted Boltzmann Machines (RBMs) had a close value of CAGR (2012-2019), 55% and 56% respectively, however DBN kept its growth between 2018 and 2019 (22%) unlike RBM (-10%).

Image processing /computer vision as the most popular functional application

~74 000 patent families (69% of the global database) concern at least one type of functional technologies.

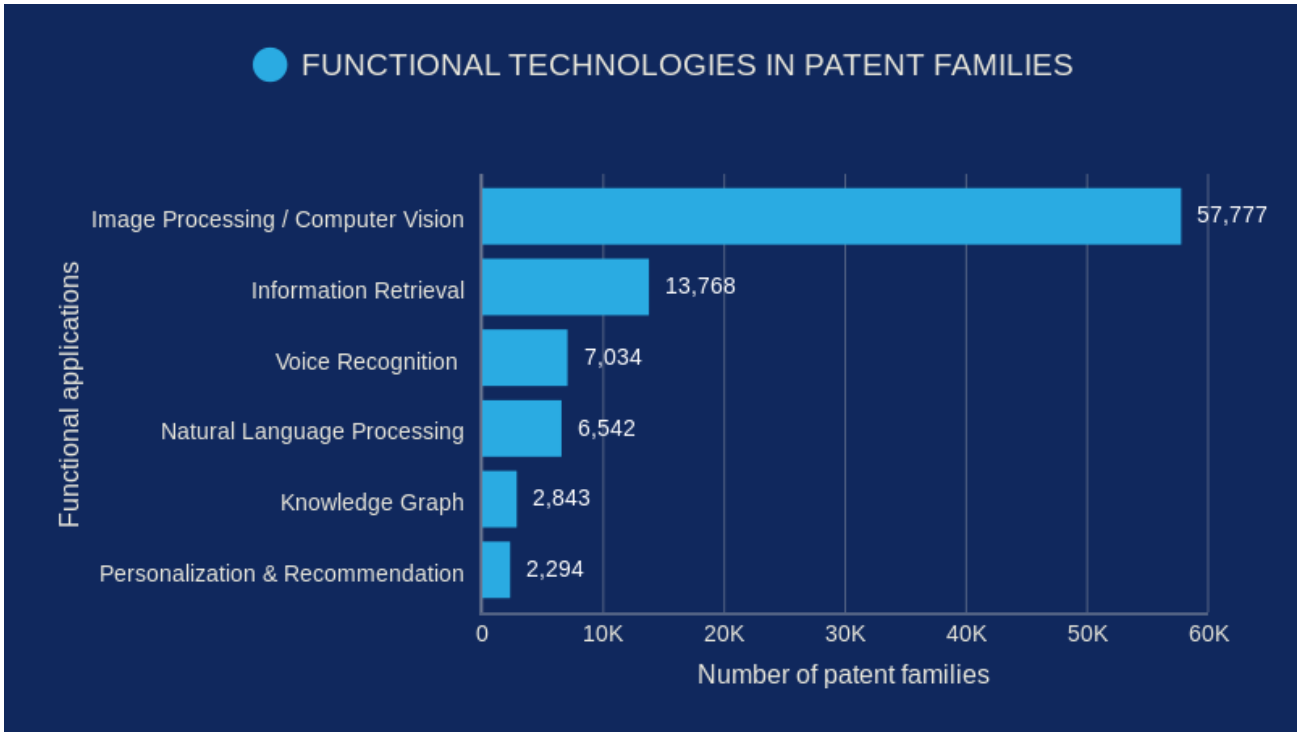


Figure 12 - Patent volumes concerning functional applications

The image processing / computer vision is the most popular functional application, mentioned in 78% of the documents. China is the main contributor of this technology, owning 79% of the inventions of this application. Indeed, China stays at a dominate position for almost all the six functional applications, followed by US players and South Korean ones, but with a prominent gap; a closer look at the patenting strategy of China and US, we notice that Chinese players have a strong focus on information retrieval, whereas American ones tend to patent more on voice recognition and knowledge graph.

Baidu appears as the top player concerning functional applications, with a clear focus on image processing / computer vision. Similar trends have also been observed among the top academic players, Chinese Academy of Science, Zhejiang University and Nanjing University, with more than 70% of their patent families on image processing applications. Samsung and IBM are the only two non-Chinese players, ranking in 6th and 20th position, respectively.

Transportation and healthcare as the most promising application fields

~46 000 patent families (43% of the global database) concern at least one type of application fields or industries.

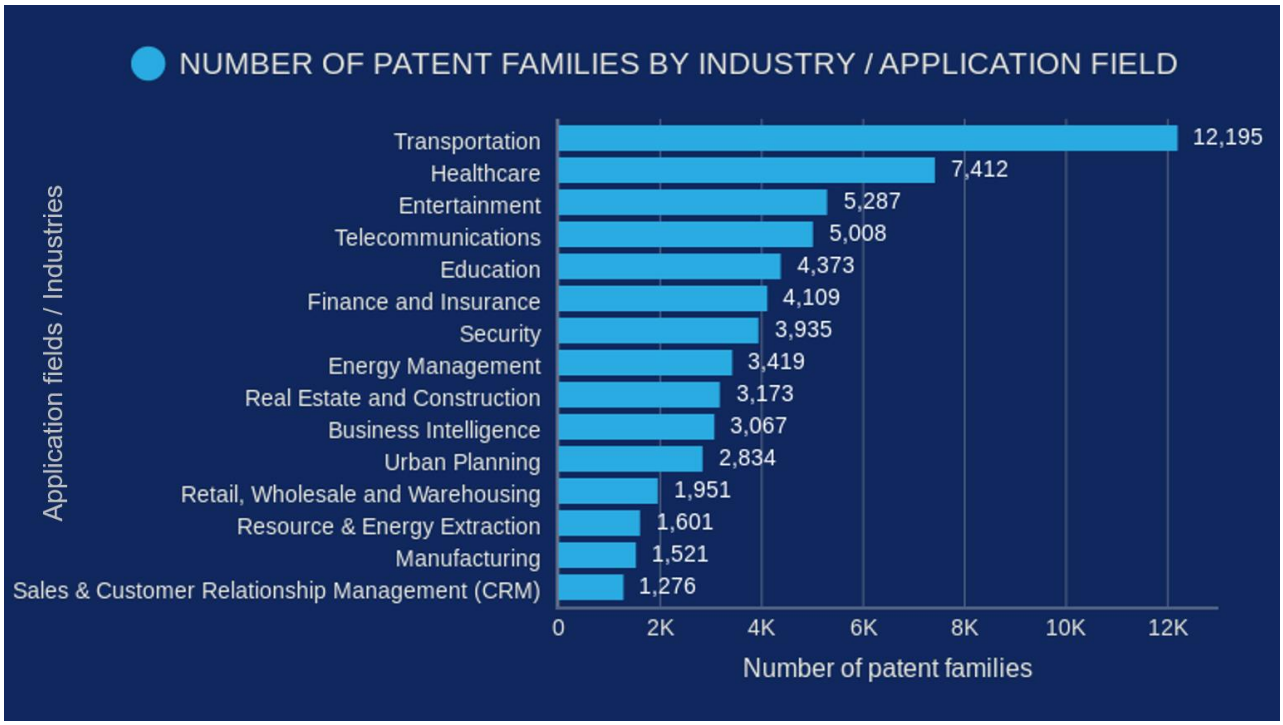


Figure 13 - Patent volumes concerning industrial applications

Transportation and healthcare are the two most popular industrial application fields, mentioned in 26% and 16% of the documents, respectively. China is the main contributor of industrial application inventions, with a dominating position in fields, such as energy management or business intelligence.

The analysis of industries targeted by each player highlights what their markets or projects are, with different focus observed among the top players. Many highly visible positions reflect the market position of companies, as the State Grid Corporation of China focused on energy management, Siemens' main position on Healthcare, Ping An's and Alibaba's (coming from Alipay payment platform) positions on Finance and Insurance, LG and Huawei's positions on Telecommunications or Baidu's top position on Transportation.

The high number of patents in Transportation from Baidu and LG shows their respective projects in the vehicles' autonomy: Baidu develops robocar concept, with level 5 autonomous driving capabilities. Robin Li, Baidu's CEO, announced that "these robocars will drive autonomously, act as both an intelligent assistant and loyal companion, and be self-learning"[16].

On its side, LG has developed deep learning for advanced driver assistance system and fully autonomously vehicles. In March 2021, LG Electronics also invested in the US start-up CerebrumX, which develops an augmented deep learning platform for connected vehicles, enabling real-time processing of driving data to help prevent accidents and reduce travel time[17].

Despite those main positions of companies in their original market industry, most of the companies file patents targeting almost all the industries, showing a potential interest for new markets.

Chinese universities like Zhejiang University, Nanjing University, Beijing University of Technology or Chongqing University, as the Chinese Academy of Sciences, show a very diverse activity among the different industries, and seem to be partners of choice for different companies originated from varied industries.

[16] https://techwireasia.com/2021/08/baidu-leads-the-self-driving-race-with-an-ai-packed-robocar/
[17] https://pulsenews.co.kr/view.php?year=2021&no=224817

Top-20 Assignees	Transportation	Healthcare	Entertainment	Telecommunications	Finance & Insurance	Retail, Wholesale & Warehousing	Education	Energy Management	Real Estate & Construction	Business Intelligence	Urban Planning	Resource & Energy Extraction	Sales & Customer Relationship Management (CRM)	Security	Manufacturing
BAIDU	243	42	66	12	65	17	58	29	24	39	70	13	10	12	11
STATE GRID CORPORATION OF CHINA (SGCC)	134	12	46	104	54	26	19	406	57	194	37	22	34	113	12
ZHEJIANG UNIVERSITY	173	116	107	76	51	28	59	61	76	45	86	29	9	66	36
CHINESE ACADEMY OF SCIENCES	166	111	85	30	60	14	70	60	81	32	75	41	4	63	19
NANJING UNIVERSITY	222	64	88	120	39	17	39	65	57	34	81	17	6	49	10
PING AN TECHNOLOGY	75	97	82	5	177	17	30	7	19	79	49	10	42	43	5
BEIJING UNIVERSITY OF TECHNOLOGY	95	55	78	37	28	5	28	32	58	23	45	15	4	47	12
CHONGQING UNIVERSITY	142	41	50	64	33	11	32	35	37	25	26	28	6	27	14
SAMSUNG	76	79	54	85	30	21	47	26	42	11	22	1	3	22	3
TSINGHUA UNIVERSITY	78	48	20	26	24	7	32	29	21	18	23	3	1	16	13
UNIV. OF ELECTRONIC SCIENCE & TECHNOLOGY OF CHINA	93	52	39	52	21	6	24	19	52	14	20	3	2	39	6
ALIBABA	53	6	25	19	103	11	20	8	21	49	16	1	43	30	6
WUHAN UNIVERSITY	106	41	17	24	20	6	25	20	39	18	49	15	6	29	13
SOUTH CHINA UNIVERSITY OF TECHNOLOGY	84	36	59	14	30	8	23	15	53	10	16	9	5	20	7
IBM	40	75	50	27	21	11	61	4	10	18	10	6	9	23	8
SOUTHEAST UNIVERSITY NANJING	111	21	21	64	11	6	11	40	28	13	43	6	0	10	7
XIDIAN UNIVERSITY	53	19	23	88	24	3	21	15	44	5	27	3	0	25	5
SIEMENS	34	177	5	3	0	11	15	17	18	13	7	4	3	8	12
LG	132	16	28	163	3	15	11	16	8	6	12	0	2	8	0
HUAWEI	46	4	18	153	4	20	9	13	4	7	17	3	2	27	1
BEIHANG UNIVERSITY	127	28	22	10	11	4	10	10	27	8	43	7	0	21	4

Figure 14- Top players per targeted industry

Appendices

ANNEX A – TAXONOMY

Applications explained

Voice Recognition	Voice recognition is a computational linguistics subfield that develops methodologies and technologies that enables the recognition and translation of spoken language and voice by computer such as Speech Synthesis / Speech Recognition / Speech Modeling / Voice Analytics / Speaker recognition / Speech & Audio processing / Speech Enhancement / Phonology / Speech-to-Speech / Speech-to-Text etc.
Image Processing/ Computer Vision	Image processing techniques in computer vision that includes Image & Video segmentation / Image Classification / Visual Recognition / Facial Recognition / Computer Vision / Character Recognition / Scene Understanding / Multimedia data analysis / Image Coloring / Colorization of Black and White Images / Image-to-Language Translations / Pixel Restoration etc.
Natural Language Processing	Natural Language Processing or NLP is a technique that gives the machines the ability to read, understand and derive meaning from human languages. It includes NLP / Machine Translation / Information Extraction / Dialogue / Natural language Generation / Sentiment analysis / Sentence Classification / Natural Language Understanding / NLU / Natural language Interpretation / Language Modeling etc.
Knowledge Graph	In knowledge representation and reasoning, knowledge graph is a knowledge base that uses a graph-structured data model or topology to integrate data. It gathers contextually relevant information and then translates data and knowledge into insights. Knowledge Graph includes technique such as Knowledge Representation & Reasoning / Knowledge Scouting.
Information Retrieval	Information retrieval includes method that search and rank results from a database in response to a query. A majority of search engines use ranking algorithms to provide users with accurate and relevant results.
Personalization & Recommendation	A technique that transforms unstructured data into structured representations that highlight resemblance or patterns upon which a recommendation can be made. Deep-learning can be used to recommend the best choices in complex situations, based on historical data.

Industries explained

Transportation	Automobiles, vehicles, Unmanned Aerial Vehicle (UAV) etc.
Healthcare	Health monitoring, Elder/Child/Pet Care, Indoor Air Quality Monitoring, Water Monitoring, Smart Toilet, Tele-Medicine / Medicine, Diagnostic, Biotech, Pharma, etc.
Entertainment	Arts, recreation, games, culture etc.
Telecommunications	3G, 4G, 5G networks, Internet of Things (IoT) etc.
Finance and Insurance	Finance. Bank, Insurance, Stocks, Cashflow, Investment Management etc.
Retail, Wholesale and Warehousing	Store, warehouse logistics / transportation / transit of goods, planogram organization and management etc.
Education	E-Learning, Digital Library, Learning Management system, Learning/Training etc.
Energy Management	Smart grids, smart city, energy storage systems etc.
Real Estate and Construction	Real estate, Properties, Rental, leasing etc.
Business Intelligence	Business Data Collection/ Intelligence, BI Tools, Decision-making, Hiring, Access Management, Human Resource (HR) etc.
Urban Planning	Roads, traffic, streets, commuting, zoning, land use, physical layout, town, city, urban and rural planning and design.
Resource & Energy Extraction	Mining, Quarrying, Oil and Gas Extraction, Agriculture, Forestry, Fishing, Hunting etc.
Sales & Customer Relationship Management (CRM)	Covering sales or client-associated monitoring, acquisition, maintaining relations etc.
Security	Security , cameras, video surveillance, theft, break-ins, Privacy, Cybersecurity etc.
Manufacturing	Include technologies such as 3D printing, Factory automation etc.

Algorithms explained

Convolutional Neural Networks (CNNs)	A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm which is mainly used for image processing and object detection to segment or to identify images and/or objects.
Long Short-Term Memory Networks (LSTMs)	Long Short-Term Memory Networks (LSTMs) are a type of Recurrent Neural Network (RNN) that can learn and memorize long-term dependencies. LSTMs are useful in time-series prediction because they remember previous inputs. LSTMs are typically used for speech recognition, music composition, and fault/fatigue diagnosis.
Recurrent Neural Networks (RNNs)	Recurrent Neural Networks (RNNs) are type of neural networks used for sequential data processing. In deep-learning, they are commonly used for image captioning, time-series analysis, natural-language processing, handwriting recognition, and machine translation.
Generative Adversarial Networks (GANs)	Generative Adversarial Networks (GANs) are generative deep learning algorithms that create new data instances that resemble the training data. GANs help generate realistic images and cartoon characters, create photographs of human faces, and render 3D objects.
Radial Basis Function Networks (RBFNs)	Radial Basis Function Networks (RBFNs) are special types of feedforward neural networks that use radial basis functions as activation functions. They are mostly used for classification, regression, and time-series prediction.
Multilayer Perceptrons (MLPs)	A multilayer perceptron (MLP) is a feedforward artificial neural network that generates a set of outputs from a set of inputs. An MLP uses backpropagation as a supervised learning technique. Since there are multiple layers of neurons, MLP is a deep learning technique. They are used to build speech-recognition, image-recognition, and machine-translation software and services.
Self Organizing Maps (SOMs) / Kohenin's map	A self-organizing map (SOM) is a type of artificial neural network (ANN) that is trained using unsupervised learning to produce a low-dimensional, discretized representation of the input space of the training samples, called a map. They are used in data visualization of high-dimensional information.
Deep Belief Networks (DBNs)	A deep belief network (DBN) is a generative graphical model, or alternatively a class of deep neural network, composed of multiple layers of latent variables. Deep Belief Networks (DBNs) are used for image-recognition, video-recognition, and motion-capture data.
Restricted Boltzmann Machines (RBMs)	Restricted Boltzmann Machines (RBMs) are stochastic neural networks that can learn from a probability distribution over a set of inputs. This deep learning algorithm is used for dimensionality reduction, classification, regression, collaborative filtering, feature learning, and topic modeling.
Autoencoders	Autoencoders are a specific type of feedforward neural network in which the input and output are identical. Autoencoders are used for purposes such as pharmaceutical discovery, popularity prediction, and image processing.

ANNEX B – GLOSSARY

- **Patent family (Fampat)**: defined as an "invention-based family", this family definition from Questel incorporates the EPO's strict family rule (same priority application(s)) with additional rules (applications falling outside the 12 months filing limit; links between EP and PCT publications…) etc. A reasonable compromise between strict family and extended family.
- **Patent application**: to obtain a patent, an application must be filed in the appropriate Patent Office with all the necessary documents and fees. The patent office will conduct an examination to decide whether to grant or reject the application. Patent applications are generally published 18 months after the earliest priority date of the application. Prior to that publication, the application remains confidential.
- **Granted patent**: once examined by the patent office, an application becomes a granted patent or is rejected. If granted, the patent gives his owner a temporary right for a limited time period (normally 20 years) to prevent unauthorized use of the technology outlined in the patent. Procedure for granting patents varies widely between countries according to national laws and international agreements. Note that in the same patent family, an application can be granted in one country and rejected in another.
- **PCT (WO)**: The Patent Cooperation Treaty (PCT) is an international patent law treaty concluded in 1970, administered by the World Intellectual Property Organization (WIPO), between more than 140 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single "international" patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices in which is called the "national phase".
- **European patent (EP)**: a European patent can be obtained for all the EPC countries by filling a single application at the EPO in one of the three official languages (English, French or German). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). A granted European patent is a "bundle" of national patents, which must be validated

- at the national patent office to be effective in member countries. The validation process could include submission of a translation of the specification, payment of fees and other formalities at the national patent office. Once a European patent is granted, competence is transferred to the national patent offices. Other regional patents or procedures also exist: the Eurasian patent (EA), ARIPO patent (AP) for English-speaking Africa and OAPI patent (OA) for French-speaking Africa.
- **Patent classifications**: patent classification is a system for examiners of patent offices or other people to code documents, such as published patent applications, according to the technical features of their content. The International Patent Classification (IPC) is agreed internationally. the European Patent Office (EPO) and USPTO launched a joint project to create the Cooperative Patent Classification (CPC) in order to harmonize the patent classifications systems between the two offices.
- **Patent applicant/assignee**: when a person is applying for a patent, the word "applicant" refers to the assignee, the person to whom the inventor is under an obligation to assign the invention, or the person who otherwise shows sufficient proprietary interest in the matter. We call it also patent owner or patent assignee; typically, it is the inventor's employer.
- **Priority filling**: the first location in which a particular invention has a patent application filed, also known as the office of first filing.
- **Average family size**: average number of granted or pending patents in each patent family in an assignee's portfolio.
- **Geographic coverage**: the total number of granted or pending patents in Tier1 and BRIC regions or countries (Taiwan, Australia, Republic of Korea, China, India, Brazil, France, Germany, Japan, USA).
- **CAGR**: compound annual growth rate, initially used to calculate and determine the rate of investment return, it represents the average annual growth rate between two dates in the study.

About Questel's Consulting team

Questel's Consulting team combines skills in IP, technology, and market to provide various kind of data-driven projects enabling innovative organizations to make strategic decisions: Patent Landscapes, Tech & Competency mapping, IP due diligence and IP roadmap, Patent portfolio assessment for pruning or licensing, Technology scouting, etc.

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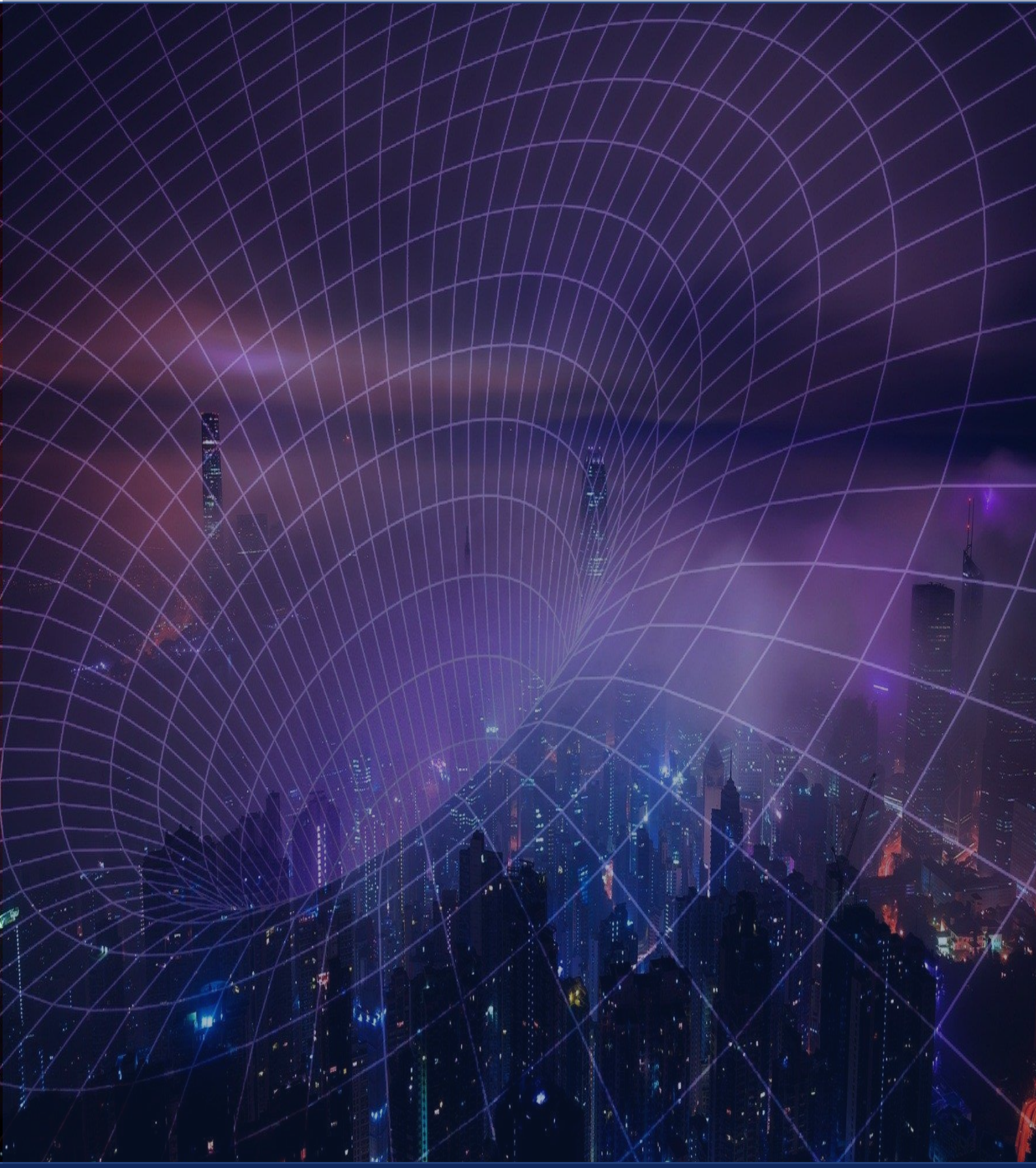

Our insights can help you be ahead of market trends and challenges.

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