In-depth: Artificial Intelligence 2019

Statista Digital Market Outlook

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Management summary (1/2)

Artificial intelligence (AI) essentially refers to computing technologies that are inspired by the ways people use their brains and nervous systems to reason and make decisions, but typically they operate quite differently. The concept of AI has been the source of inspiration for many science fiction writers and futurologists for over a century. Today, advancements in computing and big data have made it a reality, with machines now being deployed at a large scale across industries. The application of AI technologies is driving growth at individual, business, and economic levels. In fact, AI has started to outperform human beings in a range of work activities, including ones requiring cognitive abilities.

The current AI ecosystem consists of machine learning, robotics, and artificial neural networks (ANNs). In machine learning, programs learn from existing data and apply this knowledge to new data or use it to predict data. The field of robotics is concerned with developing and training robots. Usually, the ability of a robot to interact with people and the world follows general rules and is predictable. However, current efforts also revolve around using deep learning to train robots to manipulate situations and act with a certain degree of self-awareness. ANNs are built to mimic the workings of a human brain. Connected units (artificial neurons) are organized in layers to process information.

Over the last few decades, the evolution of AI has mostly revolved around the advancement of linguistic, mathematical, and logical reasoning abilities. However, the next wave of AI advancements is pushing towards developing emotional intelligence. At the same time, sequential learning, another feature of Google's DeepMind, is enabling AIs to learn multiple skills. Over the last few years, deep learning has made vast improvements in enabling machines to comprehend the physical world to a certain degree and is used across industries for various tasks. Among the leading economies, China has invested a lot of research and money into AI in recent years.

One of the major factors driving the current wave of AI growth is the rapid increase in corporate venture capital (CVC) investment in AI start-ups. On the technology front, rapid advancements in computing power are driving the industry to the next level. Similarly, open source platforms are promoting and enabling collaborative learning, which is conducive for the growth of AI. The current wave of growth in the AI industry is as much about the abundant availability of big data as it is about the software and hardware. The amount of big data being generated by today's increasingly digitized economy is growing at a rate of 40% each year and is expected to reach 44 zettabytes by 2020. This growth in big data is driving the improvement of AI algorithms.

AI solutions are increasingly being customized to serve the needs of the automotive, healthcare, education, finance, entertainment, and other industries. In the automotive sector, AI is primarily used to power autonomous cars, with these systems expected to become standard in new vehicles in the medium to long term. In the healthcare industry, developments in the field of AI and machine learning have not only accelerated the pace of innovation in the industry but are also changing entire operating models. In the education industry, there are attempts to provide customized learning programs for each student using AI, while in the finance industry, AI wealth management solutions can offer higher personalization.

Management summary (2/2)

With the rise of AI, more and more start-ups venture into the market. Most of them work in the field of machine learning algorithms, followed by natural language processing. The annual global funding of AI start-ups experienced an average growth rate of almost 70%, increasing from US$0.6 billion in 2012 to US$4.9 billion in 2016. In the same time frame, the corresponding number of deals grew by 47% from 151 in 2012 to 703 in 2016. In terms of M&A, the number of deals jumped up by 38% in 2017. Looking at the most recent M&A deals, big tech companies like Google, Apple, Amazon, Microsoft, IBM, or Facebook have often been the acquirer. But Chinese tech giants like Baidu or rising stars in the start-up world like Twitter, Uber, or Spotify also acquire AI companies.

Companies from various industries are currently developing AI and related applications. Google, IBM and Microsoft are leading AI innovations in the IT industry, while Amazon and eBay are investing in AI to improve their eCommerce platform, and ridesharing company Uber is using AI on autonomous driving, food deliveries, and mapping research. Collaborative development is on the rise, and leading companies such as Amazon, Apple, Facebook, Google/DeepMind, IBM, and Microsoft are currently working in partnership towards developing AI applications. The acquisition of small-scale AI companies by tech giants like Apple, IBM, and Microsoft in relevant fields is on the rise, leading to a decreasing learning curve. Other leading companies include Baidu, Facebook, and Salesforce.

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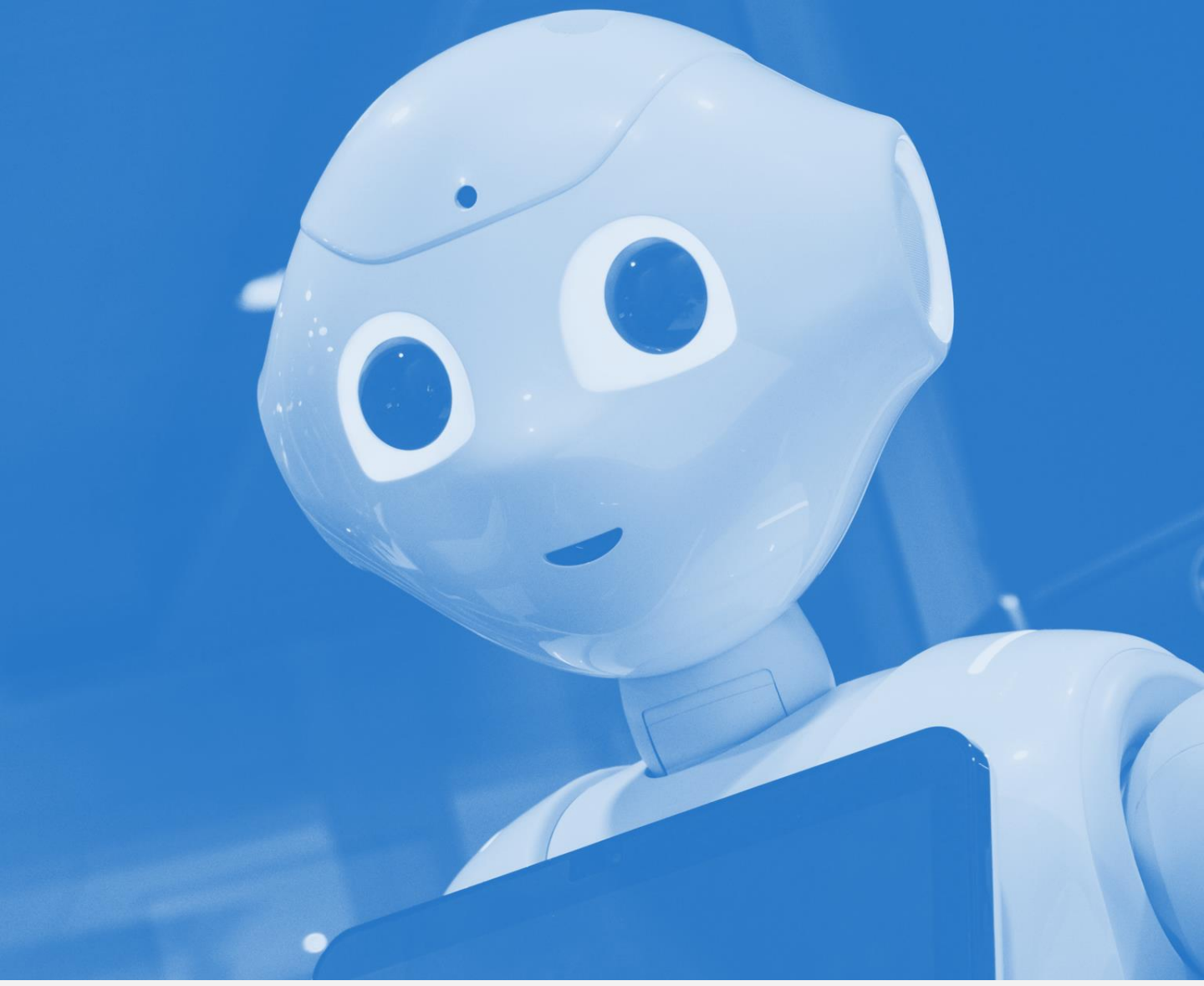

Introduction

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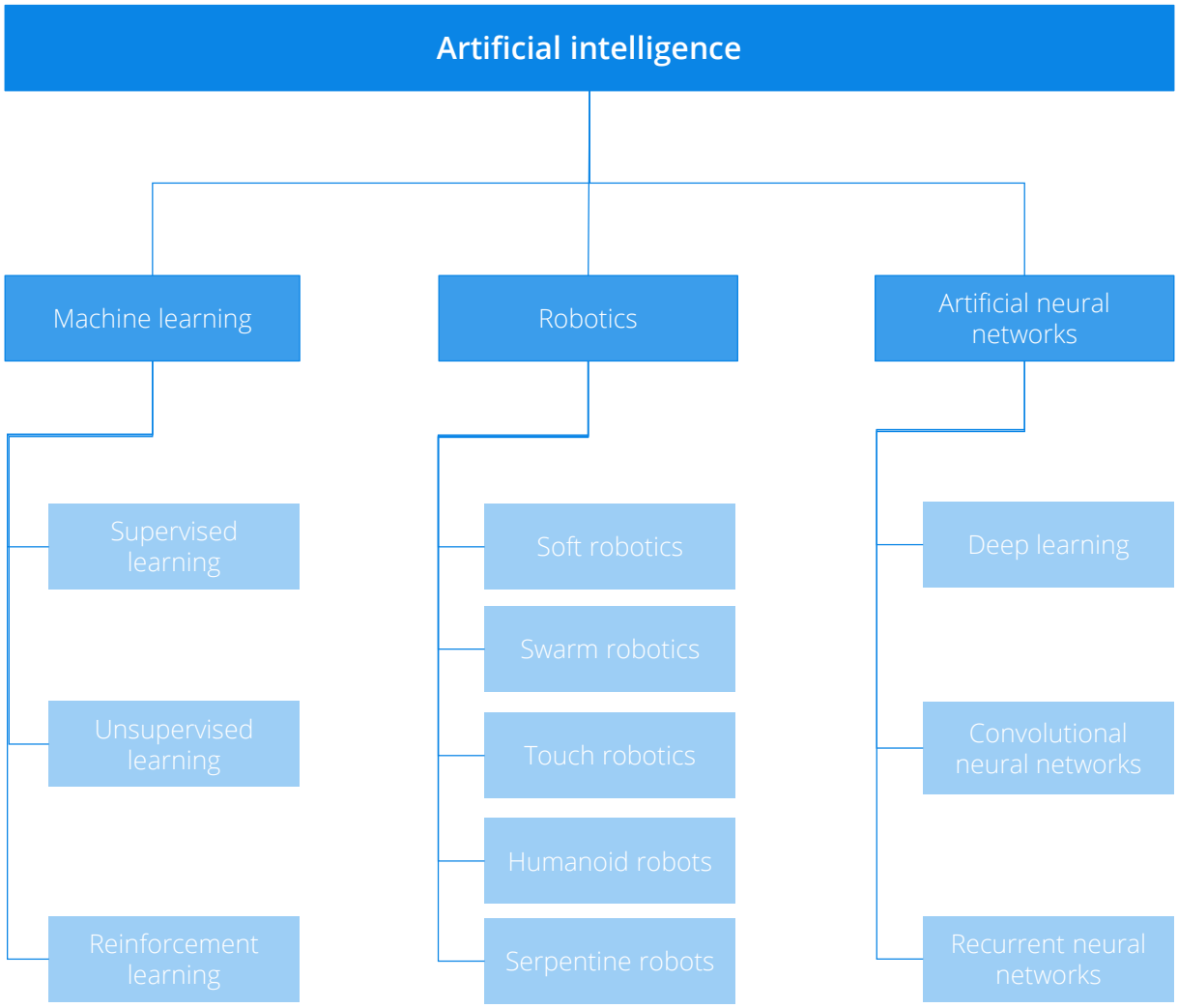
The concept of AI has been the source of inspiration for many science fiction writers and futurologists for over a century. Today, advancements in computing and big data have made it a reality, with machines now being deployed at a large scale across industries. The application of AI technologies is driving growth at individual, business, and economic levels. In fact, AI has started to outperform human beings in a range of work activities, including ones requiring cognitive abilities.

Artificial intelligence mimics the working of the human brain

Overview

Artificial intelligence (AI) essentially refers to computing technologies that are inspired by the ways people use their brains and nervous systems to reason and make decisions, but they typically operate quite differently. The concept of AI has been the source of inspiration for many science fiction writers and futurologists for over a century. Today, advancements in computing and big data have made it a reality, with machines now being deployed at a large scale across industries. In fact, AI has started to outperform human beings in a range of work activities, including ones requiring cognitive abilities.

Current artificial intelligence ecosystem



Source: McKinsey

There are three main types of artificial intelligence

Definitions

Machine learning

This involves designing new learning algorithms and improving existing ones to enable computers to act without explicit programming. These algorithms allow computers to analyze large volumes of complex data to recognize patterns and make predictions and adjustments.

The different types of machine learning are:

- Supervised learning
- Unsupervised learning
- Reinforcement learning

Robotics

This branch of technology is concerned with developing and training robots to interact with people and the world in general in predictable ways. However, current efforts also revolve around using deep learning to train robots to manipulate situations and act with a certain degree of self-awareness. The main fields within robotics are:

- Soft robotics
- Swarm robotics
- Touch robotics
- Humanoid robots
- Serpentine robots

Artificial neural networks (ANN)

This area is concerned with developing algorithms that mimic the functioning of the neocortex area of the human brain, where all the thinking occurs. This comparison is not entirely correct because in a human brain, neurons are not arranged in a linear sequence, as is the case with ANNs.

There are three different types of ANN:

- Deep learning
- Convolutional neural networks
- Recurrent neural network

Artificial intelligence has evolved from being reactive to being aware

Evolution of artificial intelligence (1/3)

Evolution of artificial intelligence

Phase 1

Reactive machines

- Most basic AI systems
- Cannot use past experiences to influence current decisions
- Cannot deviate from assigned tasks
- No interactive participation with the world
- Behave exactly the same way each time for a particular situation
- Example: IBM's Deep Blue

Phase 2

Memory-forming machines

- Can form memories and draw on past experiences
- Cannot make significant improvisations based on memories
- Example: self-driving cars

Phase 3

Partially aware machines

- Current technologies are trying to reach this stage, with limited success
- Here, the AI system will be influenced by other entities and will learn contextually
- Example: The U.S. Navy is using video simulations to teach robots human ethics

Phase 4

Fully aware machines

- The final phase of AI evolution
- Fully self-aware and conscious
- Ability to learn from scratch without instructions
- Example: Creators of the Deep Q Network claim that it can play video games without any human instructions

Source: Company information

AI is being deployed at scale across industries

Evolution of artificial intelligence (2/3)

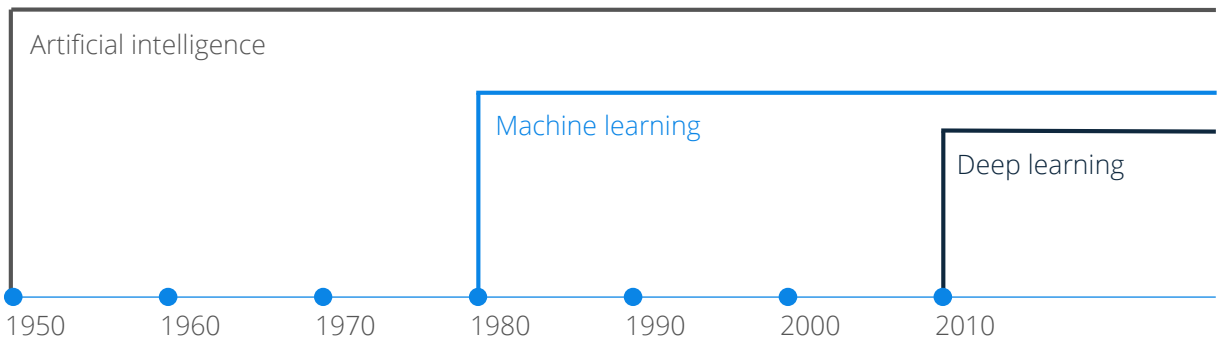
The application of AI technologies is driving growth at individual, business, and economic levels. As the percentage of the working population declines in many countries around the world, AI provides the much-needed automation to sustain and accelerate productivity growth at a micro and macro level.

At the micro level, businesses are now adopting different AI technologies to capture benefits such as lower labor costs, increased throughput, enhanced quality, and lower downtimes. At the macro level, automation is expected to result in robust productivity growth; McKinsey estimates that it will be between 0.8% and 1.4% annually.

Even though this growth has been estimated for all the countries around the world, four economies, Japan, India, China, and the U.S., which account for the majority of activities that are potentially automatable, are expected to witness the highest adoption of AI technologies.

Automation potential varies across industries as well. For example, according to a McKinsey report, the manufacturing industry has an automation potential of 64%, whereas for an industry like educational services, it is 34%. The factors affecting the pace and extent of automation include openness to change, cost of developing new technologies, labor market dynamics, the regulatory framework, and economic benefits. The highest levels of disruption can be found in industries such as healthcare, financial services, the automotive industry, and education, where advances in AI are forcing dramatic business model changes for concerned stakeholders.

Timeline: AI evolution



Source: nvidia.com

Human-machine relationships are integral to the progress of AI

Evolution of artificial intelligence (3/3)

However, in spite of these advancements, especially those involving the application of cognitive thinking, machines are still limited when it comes to improvisation. They mostly follow programmed algorithms that only allow them to act in a pre-determined manner for each conceived situation and are therefore subject to a fundamental limitation of data-driven statistical inference. They come up short when faced with a novel situation since they do not yet have the 'common sense' that is the hallmark of human experience. That said, machines are slowly but steadily starting to beat humans in a variety of fields, even in those that require superior cognitive abilities. A few examples are:

- Libratus: This is an AI developed by Carnegie Mellon University. It was the first computer to defeat four poker professionals. Owing to the margin of victory, experts were 99.98% sure that the wins were not due to chance.
- AlphaGo: This is an AI system developed by Google's DeepMind. It beat Lee Sedol, widely regarded as the world's best player of Go, an ancient Chinese board game with innumerable permutations and combinations.
- A project by Google's DeepMind and the University of Oxford, which applied deep learning to a huge data set of BBC programs to create a lip-reading system, comfortably outperformed a professional human lip-reader.

All these developments have led to much conjecture as to the future development of AI and the evolution of the man-machine relationship. Elon Musk, co-founder of Tesla, has called AI "our biggest existential threat". Stephen Hawking has strongly warned that a full AI could result in the end of mankind. Also, philosopher Nick Bostrom, in his widely acclaimed book *Superintelligence*, speaks about the possibility of computers overtaking humans in terms of cognitive capabilities. However, keeping the recent advancements and resulting benefits of AI in mind, along with the need for human intervention at various levels, the future is expected to see a collaborative approach between AI and humans.

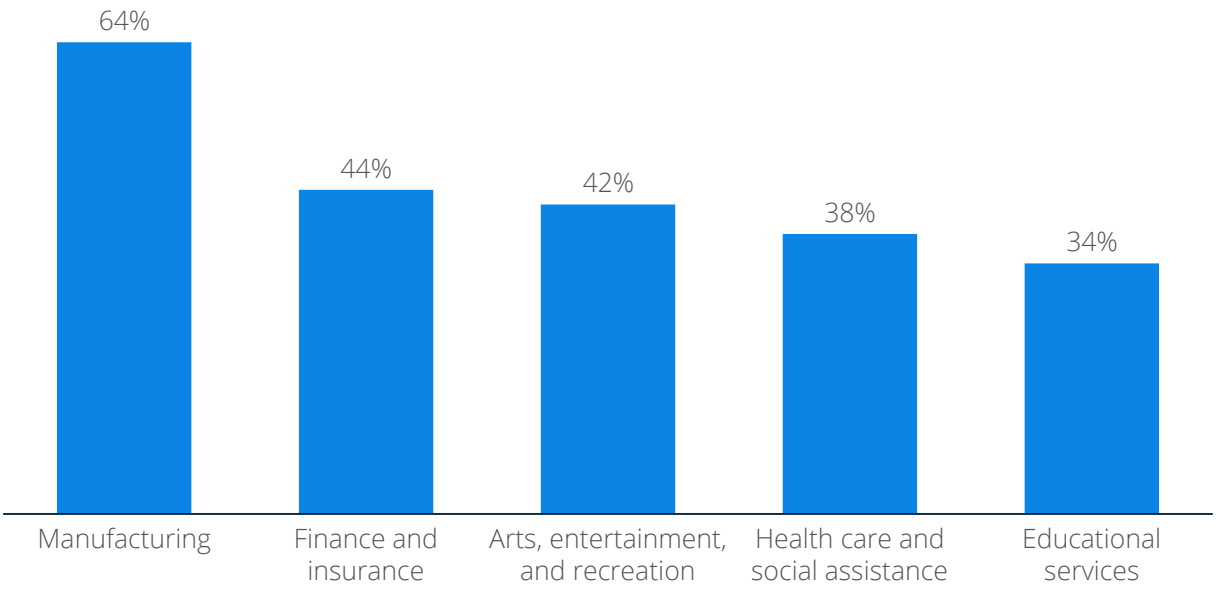
> *One of the fascinating things about the search for AI is that it's been so hard to predict which parts would be easy or hard. At first, we thought that the quintessential preoccupations of the officially smart few, like playing chess or proving theorems—the corridas of nerd machismo—would prove to be hardest for computers. In fact, they turn out to be easy. Things every dummy can do, like recognizing objects or picking them up, are much harder. And it turns out to be much easier to simulate the reasoning of a highly trained adult expert than to mimic the ordinary learning of every baby.*
>
> *Alison Gopnik, cognitive scientist*

Source: Deloitte

Automation potential differs across industries and countries

Automation potential

Automation potential across industries



Source: EMSI, Oxford Economic Forecasting, U.S. Bureau of Labor Statistics, McKinsey analysis – data as of January 2017

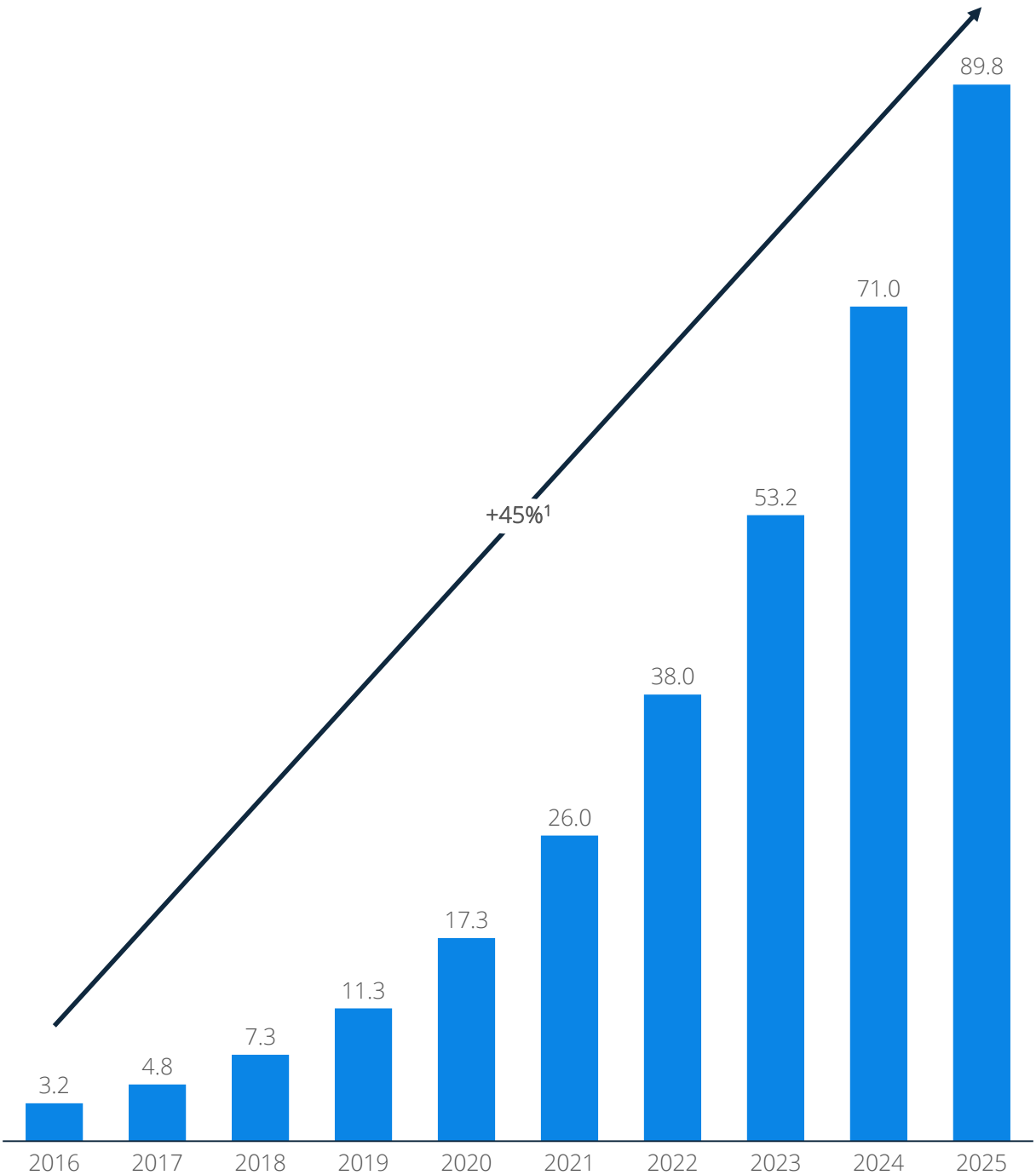
Automation potential across countries

Source: EMSI, Oxford Economic Forecasting, U.S. Bureau of Labor Statistics, McKinsey analysis – data as of January 2017

AI revenues are expected to grow at a CAGR[1] of 45%

Global revenue projection

Global revenue projection in billion US$



1: CAGR: Compound Annual Growth Rate / average growth rate per year
Source: Tractica

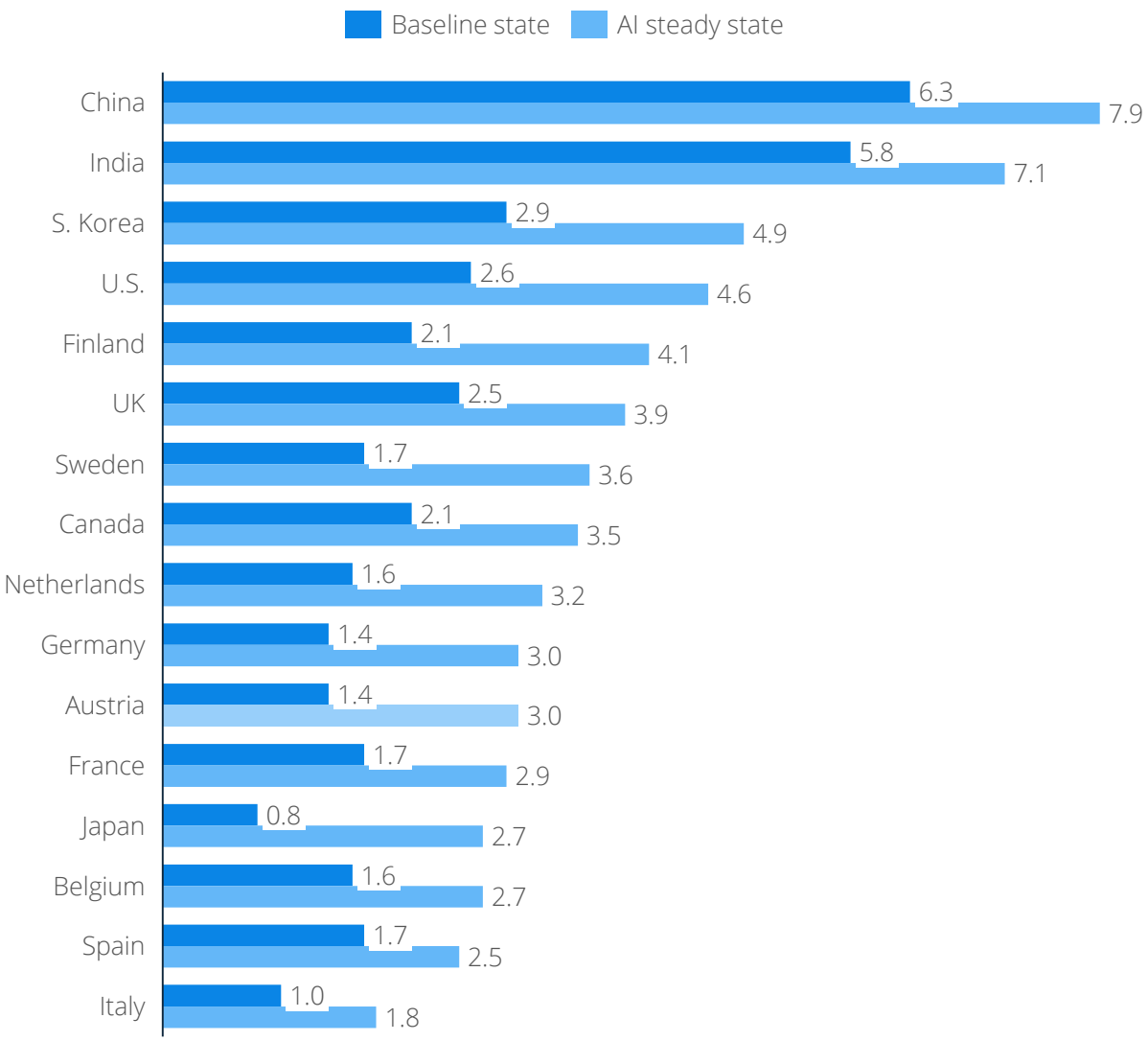
AI is expected to have a big impact on GVA[1] growth rates

Impact of AI (1/5)

A study by Accenture and Frontier Economics expects AI to have a big impact on a country's gross value added (GVA). It estimates the annual GVA growth rates in 2035 for a baseline state, based on current assumptions regarding economic growth, and for an AI steady state, assuming artificial intelligence is integrated into economic processes.

The extent of the impact depends on the country, ranging from a 0.8 percentage points increase in potential GVA growth rates in Italy or Spain to 2.0 percentage points in Finland or the U.S.

Potential annual GVA[1] growth rates in 2035 in %



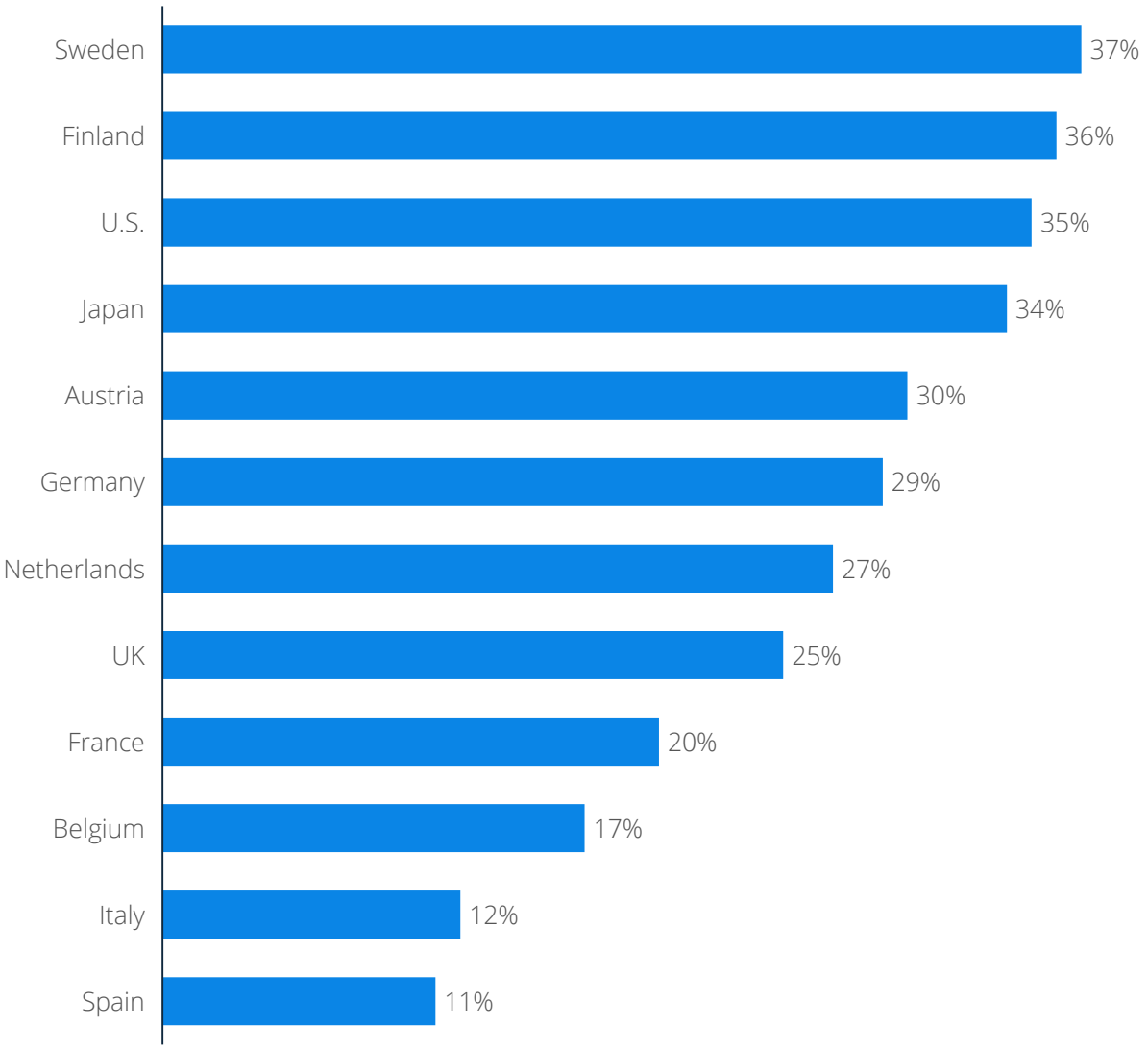
1 Gross value added: a close approximation of a country's GDP
Source: Accenture, Frontier Economics

AI has the potential to increase labor productivity

Impact of AI (2/5)

The study by Accenture and Frontier Economics also estimates that AI has the potential to increase labor productivity in countries. The impact ranges from an 11 percentage points increase in Spain to 37 percentage points in Sweden.

Impact of AI on labor productivity in developed countries in 2035



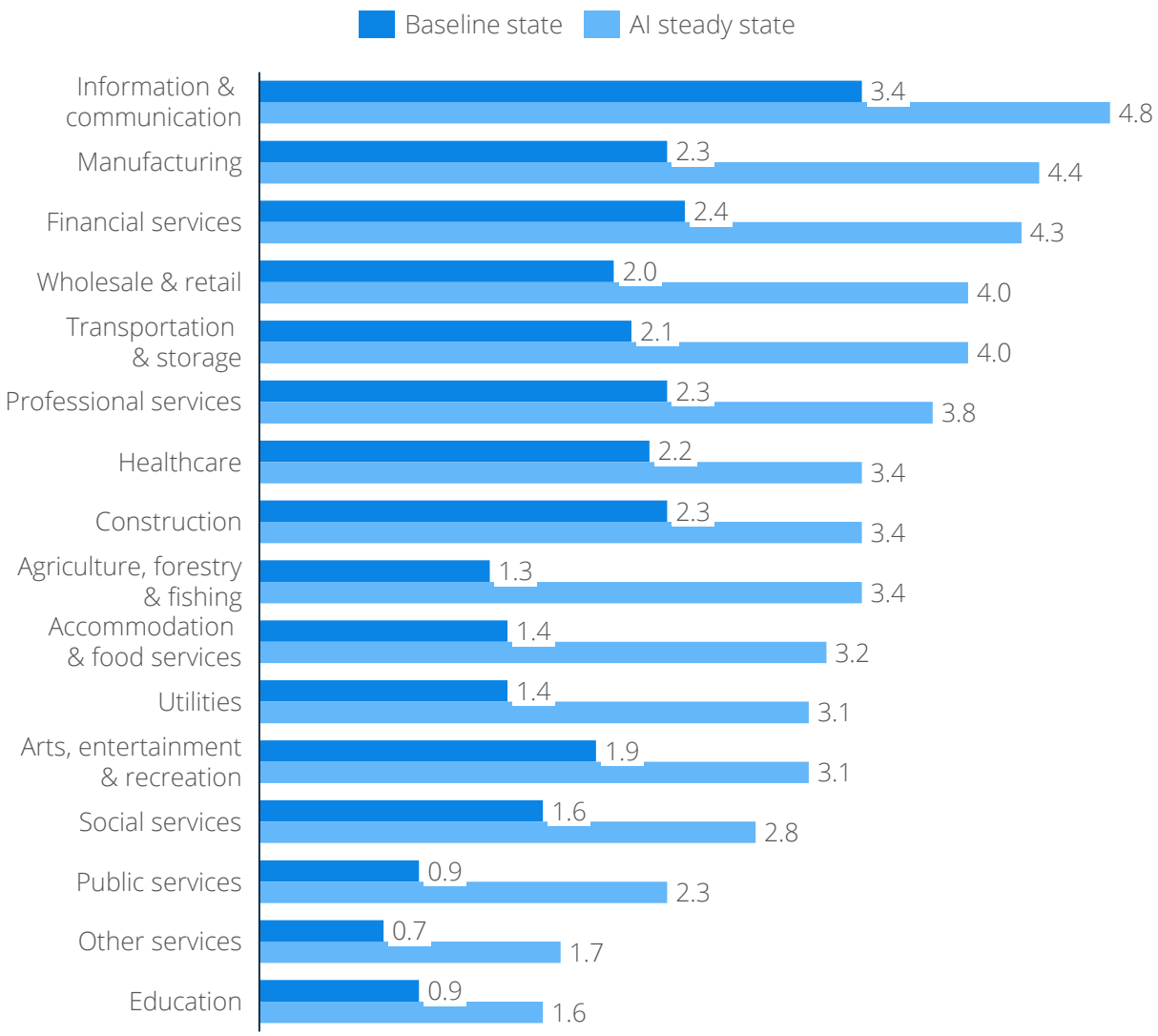
Source: Accenture, Frontier Economics

AI has the potential to increase the growth rate of industries

Impact of AI (3/5)

The study by Accenture and Frontier Economics also estimates that AI has the potential to increase economic growth rates by a weighted average of 1.7 percentage points by 2035 across 16 industries.

Impact of AI on industry growth in 2035 in %



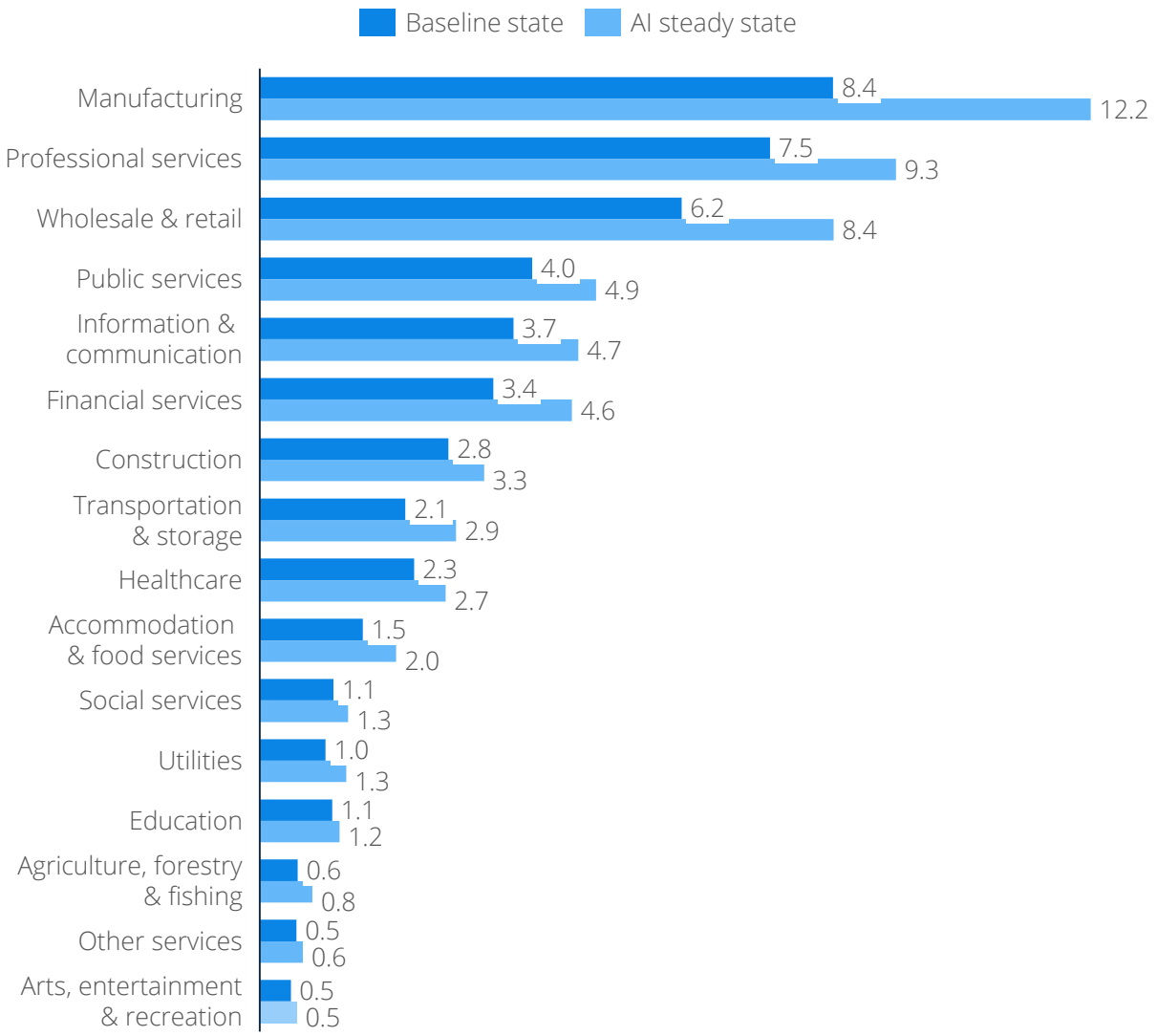
Source: Accenture, Frontier Economics

AI can boost manufacturing output by US$4 trillion

Impact of AI (4/5)

The study by Accenture and Frontier Economics also estimates that AI can substantially raise the economic output of industries. For manufacturing alone, AI can boost GVA[1] by almost US$4 trillion in 2035.

Impact of AI on industry output in 2035 in trillion US$



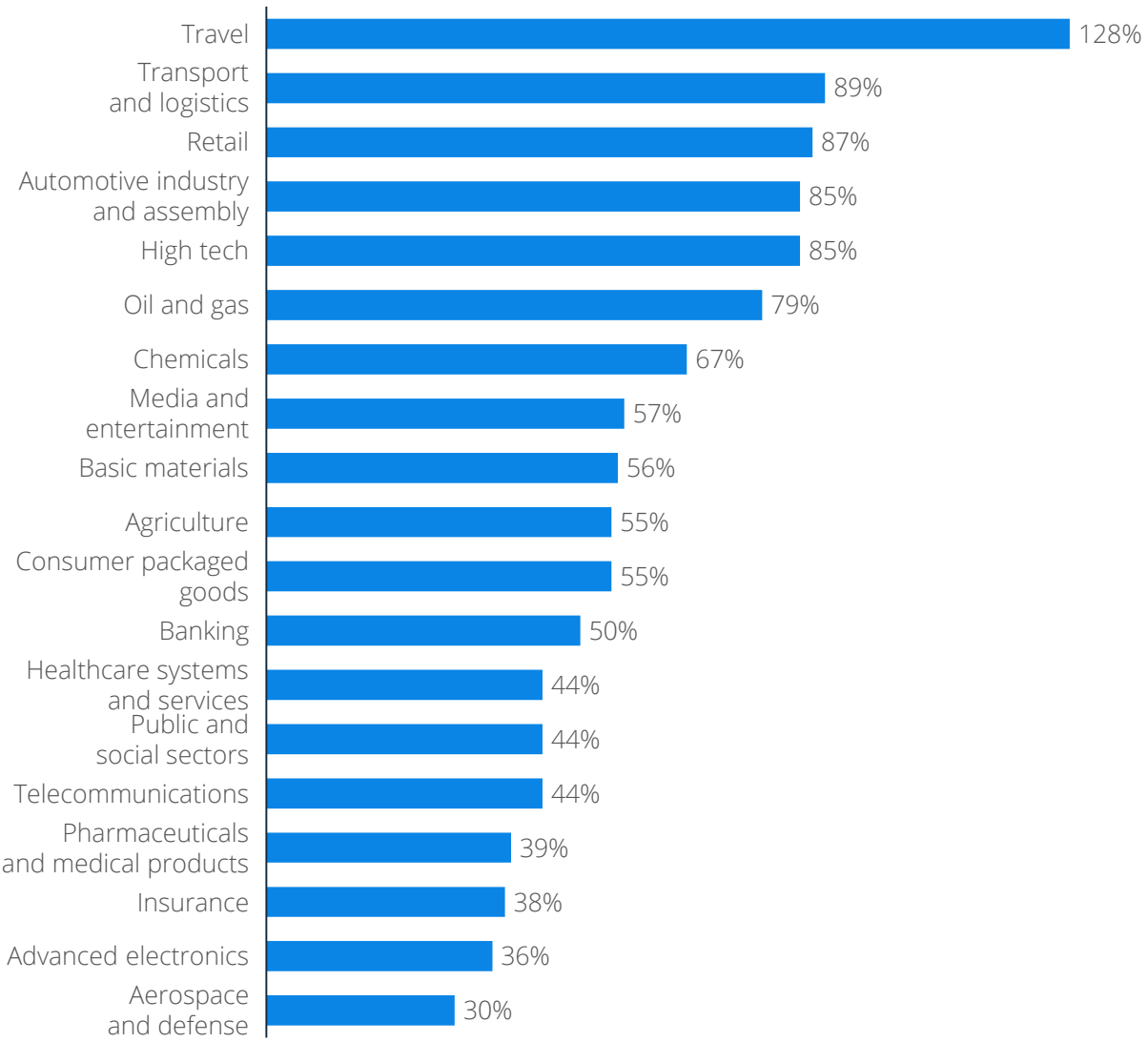
1 Gross value added – a close approximation of a country's GDP
Source: Accenture, Frontier Economics

AI has potential incremental value

Impact of AI (5/5)

A study by McKinsey on more than 400 use cases across 19 industries and nine business functions highlights the use and economic potential of advanced AI techniques. In more than two thirds of use cases, AI can improve performance as compared to other analytics techniques.

Potential incremental value of AI as compared to other analytics techniques



Source: McKinsey

Technologies

The current AI ecosystem consists of machine learning, robotics, and artificial neural networks. In machine learning, programs learn from existing data and apply this knowledge to new data or use it to predict data. The field of robotics is concerned with developing and training robots. Usually, the ability of a robot to interact with people and the world follows general rules and is predictable.

However, current efforts also revolve around using deep learning to train robots to manipulate situations and act with a certain degree of self-awareness. Artificial neural networks (ANNs) are built to mimic the working of a human brain. Connected units (artificial neurons) are organized in layers to process information.

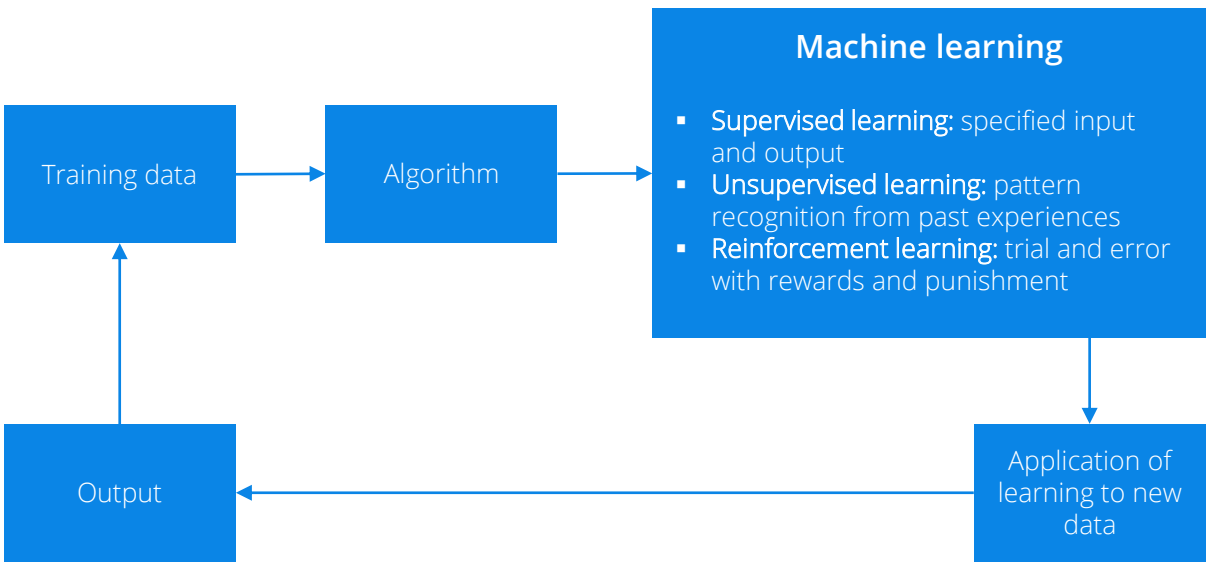
Machine learning applies insights from existing data to new data

Machine learning

In Machine learning, programs learn from existing data and apply this knowledge to new data or use it to predict data. Machine learning involves designing new learning algorithms and improving existing ones to enable computers to act without explicit programming. These algorithms allow computers to analyze large volumes of complex data and are used to complete tasks like classification, regression, clustering, etc. The different types of machine learning are:

- **Supervised learning:** These techniques train the system to respond appropriately to particular stimuli. For this, the learning algorithm is fed with a series of inputs as well as with the corresponding outputs. The algorithm then applies this same set of rules in the future.
- **Unsupervised learning:** Here, the system is not provided with the right answer but is expected to learn by itself. It does this by exploring the data on its own to find some sort of structure or patterns. In other words, the AI system uses its experience of solving one problem to solve another related problem. This type of machine learning can be applied to identify consumers with similar purchasing behaviors in order to deliver personalized marketing, for example.
- **Reinforcement learning:** Inspired by behaviorist psychology, the algorithm learns through a trial and error process in which the actions are either virtually 'rewarded' or 'punished'. It then forms a memory of each experience and uses this learning for subsequent experiences. DeepMind's (a Google AI company) win over the world champion in the game of Go is an example of reinforcement learning.

Illustration of the machine learning process



Source: sas.com, McKinsey

AI is used to advance the behavior potential of robots

Robotics

The field of robotics is concerned with developing and training robots. Usually, the capabilities of a robot to interact with people and the world follows general rules and is predictable.

However, current efforts also revolve around using deep learning to train robots to manipulate situations and act with a certain degree of self-awareness. Advances in machine learning, including computer vision and tactile perception, will continue to be key enablers in advancing the capabilities of robotics.

Currently, there are the following general types of robots:

- Soft robotics: These robots are built out of soft and deformable materials, which gives them the ability to mimic the movements of living beings. These structures can achieve complex movements and are more adaptable than traditional rigid robots. For example, Soft Robotics Inc. makes robotic grippers that are used to handle tender items such as soft foods without damaging them.
- Swarm robotics: a field of robotics that deals with the deployment of a large number of mini-robots that often mimic insects or animals which operate collectively, such as ants or bees.
- Touch robotics: Typically used to perform surgeries, these robots deliver a sense of touch, feel, and vision to the operator. They are usually designed as biologically inspired hands.
- Humanoid robots: robots similar in structure to a human being, with a torso, head, arms, and legs. Some robots might only model a part of the body, for example the upper body. Android robots resemble a male body, while Gynoids resemble a female body.
- Serpentine robots: Robots that are designed to mimic the movement of snakes in order to navigate through tightly packed spaces.

> *There is an exponential pace of improvement in hardware and machine learning algorithms. The computational power required has gone down a lot. The result is a new class of machines that can operate by themselves in human space, the advance guard of a new robot industry.*
>
> *Uriah Baalke, co-founder of Dispatch, 2016*

Source: Company information

Artificial neural networks mimic the working of a brain

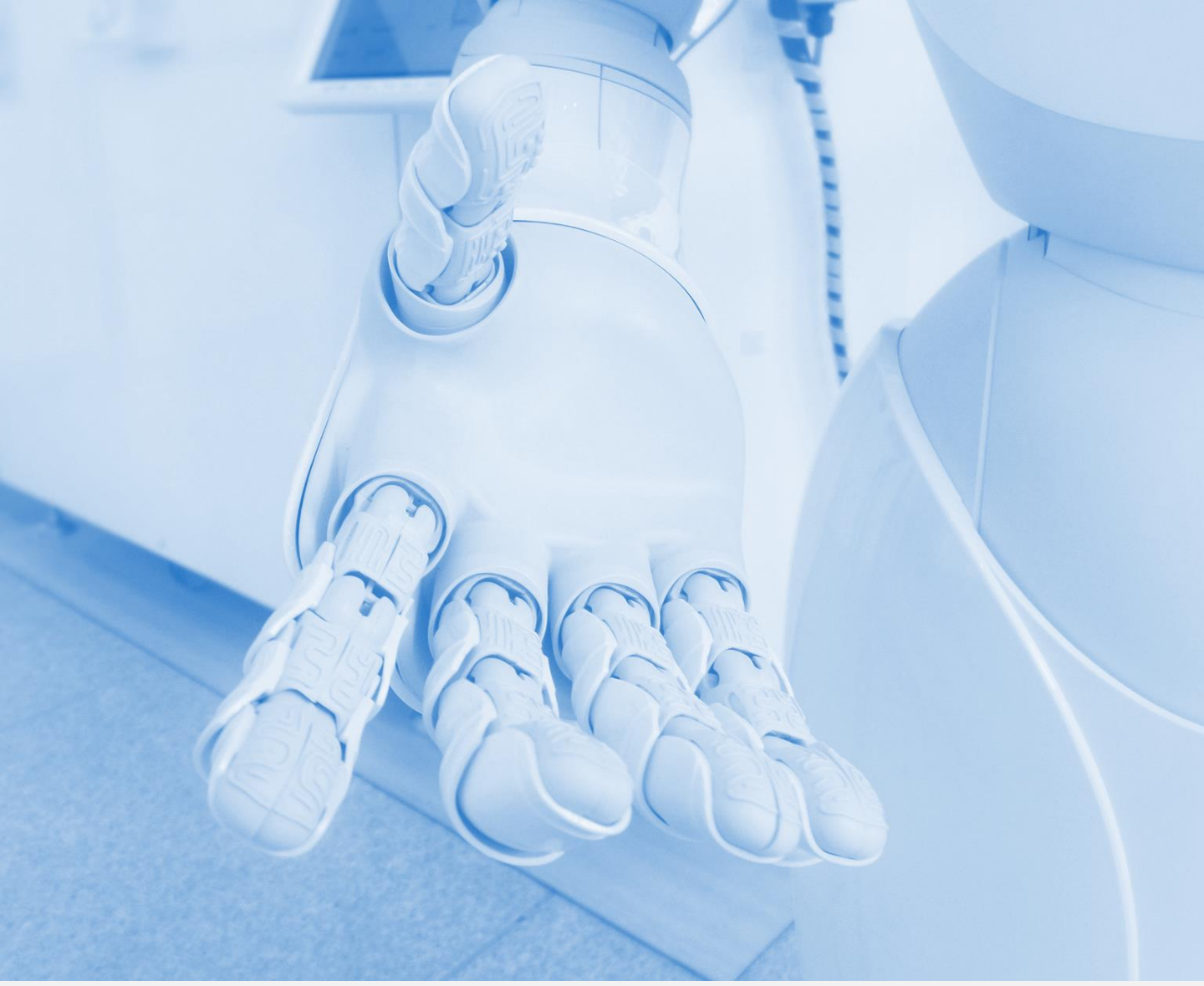
Artificial neural networks

Artificial neural networks (ANNs) are built to mimic the working of a human brain. Connected units (artificial neurons) are organized in layers to process information. Each unit can transmit a signal to another unit and thereby simulate a human brain. While neurons in a brain, however, are connected in a complex and unpredictable manner, artificial neurons are arranged in a linear sequence. The overall process of converting input into output is based on the programming of each neuron.

There are three types of artificial neural networks:

- Deep learning: These algorithms have many layers of neural networks which process information at many levels. Before the advent of deep learning, ANNs often only had three layers, unlike deep learning networks, which usually have over 10 layers. This branch of machine learning is especially important because it is the first family of algorithms that does not require manual intervention. Instead, it learns from raw data, very much like a human brain does, making use of different types of sensory inputs. Google, with vast data reserves and advanced computing resources, is the hub for deep learning across the world. The founding of Google Brain by Andrew Ng marked the beginning of deep learning at Google. The main difference between deep learning and other machine learning techniques is that larger neural networks keep improving their performance as they get access to more and more data, whereas other techniques plateau at an earlier point.
- Convolutional neural networks (CNN): These are very similar to ordinary neural networks in their overall working. The only difference is that the connections between neural layers are similar to those seen in the animal visual cortex, the part of the brain that processes images. These architectures are programmed to perceive each input as an image. In the 2012 ImageNet visual recognition contest, the only entry using a CNN achieved an 84% correct score, compared to 75% the year before. Since then, they have won all subsequent ImageNet contests, exceeding human performance in 2015 with a score of 90%.
- Recurrent neural network (RNN): These neural networks differ from others in terms of their architecture. Their neurons are connected to each other, thereby allowing them to send feedback signals to each other. Here, the information travels in loops from layer to layer so that each bit of information can be stored as memory and the network can exhibit dynamic behavior. It is due to this that RNNs have been found to be apt for natural language processing applications.

Source: Company information



Trends

Over the last few decades, the evolution of AI has mostly revolved around the advancement of linguistic, mathematical, and logical reasoning abilities. However, the next wave of AI advancements is pushing towards developing emotional intelligence. At the same time, sequential learning, another feature of Google's DeepMind, is enabling AIs to learn multiple skills.

Over the last few years, deep learning has made vast improvements in enabling machines to comprehend the physical world to a certain degree and is used across industries for various tasks. Among the leading economies, China has been investing a lot of research and money into AI in recent years.

AI moves towards artificial emotional intelligence

Artificial emotional intelligence (1/3)

Over the last few decades, the evolution of AI has mostly revolved around the advancement of linguistic, mathematical, and logical reasoning abilities. Computers have been able to make massive calculations and analyze huge amounts of data to recognize patterns much beyond the abilities of human beings. One area where they have lacked, however, is the ability to recognize and display human emotions. It has often been thought that the challenge of creating emotionally intelligent computing systems is just too big to be met anytime soon.

However, with the rising popularity of technologies such as chatbots, it is evident that humans are drawn to human-like interaction. Therefore, the next wave of AI advancements is aiming to address just that.

According to Bronwyn van der Merwe, group director at Fjord Australia and New Zealand, Accenture Interactive's design and innovation arm, the most successful AI systems in the future will be those that are able to demonstrate emotional intelligence (EI) very similar to human interaction. EI can be defined as the ability of individuals to distinguish different feelings and use those emotions to guide their thinking and behavior.

The growth of EI in machines has been aided by the advancements in our understanding of how the brain works, also called the neuroscience of EI. There is now overwhelming proof that different regions of the brain stimulate different responses and emotions. Therefore, if thinking can indeed be understood as a step-by-step process with a certain degree of sequence, AI machines can also be programmed to exhibit different emotions and achieve different levels of consciousness. EI improves an AI system's ability to not only understand input but also adapt and improvise to provide human-like responses in real time.

Interestingly, it is the very lack of inherent emotions in machines that make them such good candidates for EI. According to research, there is a direct correlation between a higher emotional quotient (EQ) in humans and lower emotional intelligence. According to Tomas Chamorro-Premuzic, Professor of Business Psychology at University College London and Columbia University, a "*higher EQ is about controlling one's impulses and inhibiting strong emotions in order to act rationally and minimize emotional interference".*

> ***As human beings, we have contextual understanding and we have empathy, and right now there isn't a lot of that built into AI. We do believe that in the future the companies that are going to succeed will be those that can build into their technology that kind of understanding.***
>
> *Bronwyn van der Merwe, group director at Fjord Australia & New Zealand, 2017*

Source: Harvard Business Review, MIT

Emotionally intelligent AI systems have various applications

Artificial emotional intelligence (2/3)

Nowadays, sensors and other devices are developing advanced abilities to observe and recognize facial features, body posture, gestures, speech, and physical states. The development of neural networks and Graphic Processing Units (GPUs) has also played a major role in integrating emotional recognition features in machines.

Examples of companies integrating varying levels of EI into their AI systems include:

Drive.ai: The autonomous car start-up Drive.ai programs vehicles to not only recognize people and other things in their environment but also to interact with the driver through lights, sounds, and movement. In August 2016, the company launched a retrofit kit complete with a sensor array, computer, and an LED sign to help vehicles communicate with pedestrians and other drivers.

Cogito Corporation: provides EI for healthcare with AI-driven real-time voice analysis for insurance call centers and other organizations. Its voice analytics tools analyze every nanosecond of the conversation and offer simultaneous recommendations and feedback, such as "you're speaking too much", "frequent overlaps," "breathe, pause between phrases", or "you're tense."

Nuralogix: has developed technology that claims to be more accurate than a polygraph owing to its EI abilities. It uses Transdermal Optical Imaging and machine learning algorithms to observe blood flow in the face to reveal hidden emotions. Law enforcement agencies would be able to use this technology to determine if a subject is lying based on the blood flow in their faces, an element which cannot be controlled physically.

Affectiva: a company that spun out of MIT's media lab, lends its emotional AI technology to over 1,400 brands worldwide, including CBS, MARS, and Kellogg's, some of whom use it to measure the emotional effects of advertisements. The technology can also be used to assess the condition of a driver before switching from autonomous to manual driving.

Source: Business Insider, Harvard Business Review, MIT

Huawei aims to build an emotionally intelligent voice assistance software

Artificial emotional intelligence (3/3)

More examples of companies integrating varying levels of EI into their AI systems include:

Huawei: is looking to develop an emotionally intelligent voice assistance software that keeps a conversation going for as long as possible in order to ensure that the user does not feel alone. According to Felix Zhang, vice president of software engineering at Huawei, the fictional character of Samantha, an EI-powered voice assistant in the Hollywood movie 'Her', is an inspiration for this technology.

Beyond Verbal: Founded in 2012, the company aims to develop a technology to decipher emotions from vocal intonations to mainly help marketing professionals improve customer experience and communication campaigns. The factors that will be assessed include valence, arousal, temper, and mood groups.

Receptiviti: Founded in 2014, this Toronto-based company has used NLP to develop a proprietary technology called Linguistic Inquiry and Word Count, or LIWC2015, which assesses an individual's handwriting to gather insights into their character, emotions, levels of deception, and decision-making ability.

BRAIQ: While most technologies related to autonomous cars are centered on how the car interacts with the environment, the technology being developed by BRAIQ focuses on how the car interacts with its passengers. This AI system looks to intuitively read a driver's emotional signals and to interact with him/her accordingly.

CrowdEmotion: Founded in 2013, this London-based company has developed a technology to gauge human emotions visually by analyzing the movements of 43 muscles on an individual's face. The company currently has a cloud-based version of the technology and has many clients, including the BBC.

Source: Business Insider, Harvard Business Review, MIT

Sequential learning enables AIs to learn multiple skills

Sequential learning

For many years, AI scientists have been trying to create 'general AI', which is essentially the ability of the AI to draw on past experiences and analyze them to come up with the best solution to a novel problem. However, this holy grail has proven to be elusive as scientists haven't been able to create an AI system with the ability to build multiple skills on top of each other. In other words, neural networks, which form the core of deep learning, can achieve excellence in learning a particular task, such as playing chess or poker, through countless rounds of trial and error. However, once the network is trained to, say, play chess, it cannot learn another game or task without overwriting its chess-playing skills. This shortcoming is called 'catastrophic forgetting'.

However, in March 2017, Google's DeepMind devised an AI technique called sequential learning that helped the computers preserve the neural connections that have been most important to learn a particular task before moving on to something else. This technique draws heavily from neuroscience studies on animals which demonstrate how they learn continually by preserving brain connections used for different skills learned in the past.

> *If we're going to have computer programs that are more intelligent and more useful, then they will have to have this ability to learn sequentially.*
>
> *James Kirkpatrick, research scientist at DeepMind, 2017*

The new AI system was put to the test by making it play 10 Atari games in random order. After many days on each game, the results showed that the AI was as good as a human player on each of those games. One of the key observations during this experiment was that while playing Enduro, a car racing game that takes place in different weather conditions and times of the day, the AI treated each environment setting as a different task.

However, the research team agreed that even though the AI learned to play different games, it did not master each one as well as a dedicated AI would have done. This was mainly because it sometimes failed to understand the importance of certain connections for a particular game. Therefore, even though this was considered to be a major breakthrough in the quest to develop human-like general AI, there is still some way to go for it to become a reality. Other companies engaged in similar research include NNaisense, SwiftKey/Microsoft Research, and Facebook AI Research.

Source: Harvard Business Review, MIT

Deep learning is used across industries for various tasks

Deep learning (1/2)

Over the last few years, deep learning has made vast improvements in enabling machines to comprehend the physical world to a certain degree. Historically, AI-powered computers have been able to perform only those tasks for which they were explicitly programmed. Even though this has worked well to make large calculations and achieve such feats as beating professionals at games like poker, chess, and Go, it has come up short when performing human-like tasks such as recognizing faces or answering novel questions.

Taking AI a step further, deep learning systems allow machines to make sense of data themselves and learn as they experience more and more. One of the major breakthroughs in the industry was made by a team at Stanford led by Andrew Ng, who figured out that graphics processing unit chips (GPUs), which were originally made to meet the visual processing demands of video games, could be repurposed for deep learning. The use of these chips to operate neural networks has increased the capabilities of deep learning manifold. Deep learning is now being used across industries for tasks such as detecting gene abnormalities, predicting weather patterns, and identifying false insurance claims.

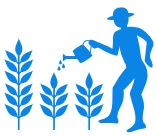
> *Deep learning is effectively a computer's version of the radioactive spider from Spider Man. If computers can be taught to see, hear and understand like humans it will become a lot easier to interact with them.*
>
> *Andrew Ng, founder of Google Brain, 2016*

Source: Harvard Business Review, MIT

One application of deep learning is to detect fraud

Deep learning (2/2)

Listed below are a few industries where deep learning is making major advances:



Agriculture: Deep learning applications are using data from drones and satellites to not only predict crop outputs but also to monitor global water levels to help detect crop diseases before they spread. They are also being used for less complex tasks, such as sorting good and bad produce in farms, as demonstrated by Makoto Koike in Japan, who made use of Google's open-sourced network TensorFlow to sort cucumbers.

Autonomous cars: Even though there are plenty of cars with driver assist features, they still require drivers to take over when an unforeseen event occurs that the car is not programmed to handle. Companies like Drive.ai and Nvidia are using deep learning to give cars full autonomy. Nvidia uses CNNs to learn the entire process of steering a car.

Cybersecurity: The application of deep learning to enable a more comprehensive and sophisticated detection of malware is the latest trend in cybersecurity solutions. Companies such as Deep Instinct and Altoros are applying deep learning techniques to not only devise protection against existing cybersecurity threats but also to recognize new ones, which have not been detected before. The deep learning systems collect a very large number of files irrespective of their type and run tests on them to classify them as either malicious or legitimate. This data is then fed into the AI engine to enable it to make predictions for future cases. According to tests conducted by Drebin University and Siemens CERT, Deep Instinct's solution was found to be 99.8% accurate as compared to the 61.5% average score for the top 10 vendors.

Healthcare: By enabling doctors to look at a person's gene sequence and molecular makeup, deep learning is facilitating personalized treatments at a very granular level. A good example is Deep Genomics, which is using large volumes of data on human cellular composition to enable machines to predict the outcomes of alterations to the genome. In drug discovery, companies like Atomwise are making use of the technique to analyze data on molecular compounds to discover drugs for new or established diseases.

Insurance: Here, deep learning techniques are used not only to assess claims at high speed but also to identify anomalies, indicating potential claims fraud, and determine payouts for legitimate claims. Tractable is an example of a company that uses images of damaged cars to teach machines how to estimate future repair costs.

Source: Company information

China is investing a lot of research and money in AI

Rise of China: overview

In October 2016, the Obama administration released a strategic plan for AI research, which mentioned that the U.S. was no longer the world leader in journal articles on deep learning. China had overtaken them. A similar study by Japan's National Institute of Science and Technology Policy found China to be a close second to the U.S. in terms of the number of AI studies presented at top academic conferences in 2015. It is not only academic research where China is making serious inroads in terms of global AI dominance. Chinese technology companies such as Baidu, Tencent, Alibaba, and Didi Chuxing have all invested significantly in setting up AI research labs with access to the huge amount of big data generated by the large Chinese digital economy.

In terms of global AI start-up funding, China ranks well above other countries, including the U.S. In fact, of the US$15.2 billion invested in AI start-ups globally in 2017, 48% went to Chinese companies, while only 38% went to companies in the U.S. China is also developing its first 'national laboratory for deep learning'. The National Development and Reform Commission (NDRC) has commissioned Baidu to create the lab in partnership with Tsinghua and Beihang universities and other research institutes. The lab's area of focus is expected to include machine-learning-based visual recognition, voice recognition, new types of human machine interaction, and deep learning intellectual property.

Another visible indication of Chinese dominance is the billions it is investing in U.S. start-ups, many of them focusing on AI. According to CB Insights, Chinese investment in U.S. technology companies totaled US$18.2 billion from 2011 to the third quarter of 2016, with US$9.9 billion being spent in 2015 alone. A KPMG study estimated that overall Chinese VC investment across all industries had hit a record US$40 billion in 2017, with a major focus on AI. Moreover, according to a 2016 study by Japanese company Astamuse, the number of AI-related patents being submitted by China have grown at a rate of 186% during the period from 2010 to 2014 as compared to just 26% for the U.S.

China's highly competitive ecosystem and a quick turnaround time from the conception of an idea to launching the product are two of the main reasons for this growth, according to Qiang Yang, computer scientist at Hong Kong University of Science and Technology. According to Andrew Ng, the founder of Google Brain, everything in China is a lot faster than in most of Silicon Valley, which means, for example, that the time you have from spotting a business opportunity to responding to it is a lot shorter.

> *Over the next year, the world will recognize how much artificial intelligence is going to transform everything we do. For example, the amount being invested in artificial intelligence in Asia is growing by the day. 2017 will be the year investors will look at AI and say, 'if you're not investing in it, you're missing the boat'.*
>
> *Egidio Zarrella, clients and innovation partner, KPMG China, 2017*

Source: CB Insights, scmp.com, technologyreview.com

Baidu adapts its structure to accommodate AI advancements

Rise of China: Baidu

Baidu is one of the big investors in AI in China. Here are some examples on how Baidu is investing and what its strategies are:

R&D spending

Apart from leading the AI lab commissioned by NDRC, Baidu is also spending as much as 15% of its entire revenue on AI-related research, according to Robin Li, the company's co-founder and CEO. From 2015 to 2017, this totaled US$2.9 billion – the highest amount in China and one of the highest amounts in the world.

High-profile appointments

In January 2017, the company appointed former Microsoft executive Qi Lu as its chief operating officer, with a mandate to focus on technologies such as deep learning, augmented reality, and image recognition. Even though Lu resigned recently, in May 2018, he was instrumental in making the company push AI by focusing on autonomous driving and conversational AI. In fact, it was during his tenure that the company was appointed by the Chinese government to spearhead the country's development in autonomous driving. Previously, Baidu had also appointed Andrew Ng as chief scientist – Andrew had earlier founded Google's first deep learning team[1].

Divestments and spin-outs of non-core businesses

In an effort to direct more of its resources towards AI, Baidu sold its food delivery business Baidu Waimai in August 2017 and span out its utility apps and its mobile ad business in May 2018. The company is now setting up a new global business unit around its AI-powered services, such as recommendation engine PopIn and keyboard app Simeji.

Baidu's current AI projects include:

- Deep learning laboratory: This is a collaboration between the Chinese government and Baidu which was launched in 2017 with an undisclosed budget. Its goal is to integrate resources from the government, industry leaders, and academic communities to improve the country's overall R&D capabilities in deep learning and AI. The main areas of focus include visual perception, speech recognition, biometrics recognition, and human-machine interaction.
- Seattle research center: In October 2017, Baidu opened a research center in Seattle, Washington, to expand its reach in AI and cloud computing.
- Xiaoyu Zaikia (Little Fish): a home robot that is capable of turning its head to listen to whoever is speaking to it.
- Autonomous cars: Baidu is also expected to begin mass production of AI-powered autonomous cars by 2021. In April 2017, the company launched a platform called Project Apollo that allows companies to manufacture autonomous vehicles faster by providing them with the tech and open-source code needed to help their vehicles perceive obstacles and plan their routes. Apart from this, Baidu is also looking to sell a range of hardware called Apollo Computing Units that can plug into cars to run its software.

1: Andrew has since left Baidu and has started various AI-related projects, including a US$175 million AI-focused fund in partnership with Greylock Partners, NEA, Sequoia, and SoftBank
Source: scmp.com, technologyreview.com, theatlantic.com, Techcrunch, Zhongguancun Science Park

Most of Tencent's AI investments are health-related

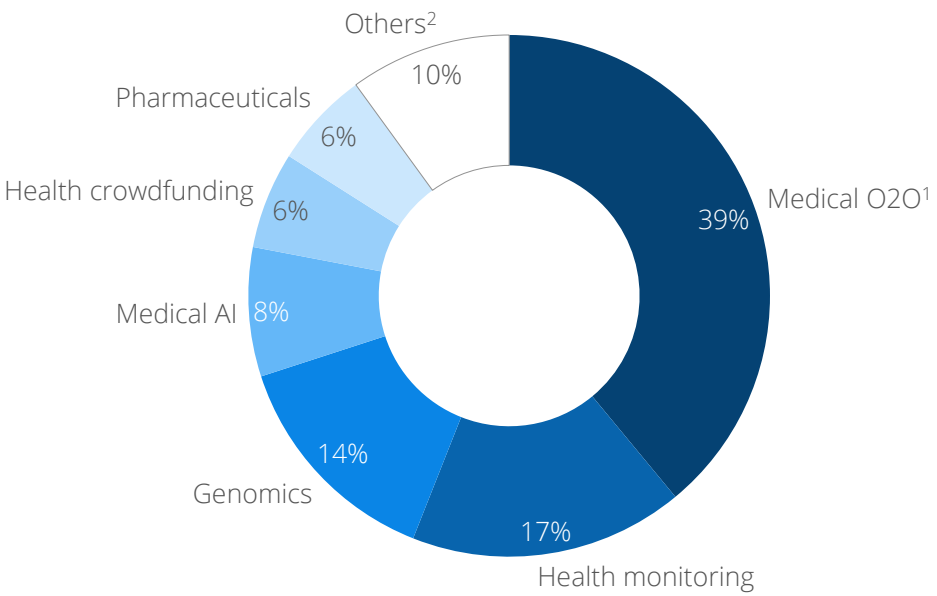
Rise of China: Tencent (1/2)

With the slogan of 'Make AI Everywhere', Tencent's AI efforts mainly focus on three areas: healthcare AI, robotics, and autonomous cars.

Healthcare

Having launched the AI Medical Innovation System, or AIMIS, an AI-powered diagnostic medical imaging service, in 2017, the company has subsequently made big investments in AI imaging technology and medical start-ups around the world. So far, AIMIS labs have been established in over 10 hospitals around the country, and agreements have been signed to increase the count to 100 hospitals in the near future. In 2014, it also launched WeChat Intelligent Healthcare, a platform that allows people to book appointments, make payments, and more at hospitals and other medical facilities through WeChat public accounts. Babylon Health, the UK-based digital healthcare start-up, has recently tied up with Tencent to deploy its AI app on WeChat. This partnership will enable WeChat's one billion users to communicate their medical symptoms directly to Babylon's mobile app, which will then send back healthcare advice on what to do next.

Share of Tencent's AI investments in 2014–2017



Source: Technode

1: Medical Online to Offline service category 2: "Others" includes investment in resuscitation training, veterinarian social network, clinic and food safety
Source: China Daily, Computer Business Review, Technode, The Drum

Tencent invested in robotics start-up UBTech

Rise of China: Tencent (2/2)

Robotics

In March 2018, the company announced the establishment of the Robotics X laboratory in Shenzhen, China, which, along with the previously set up AI lab, will work in affiliation with the Tencent Technology Engineering Group (TEG). The lab is expected to focus on various areas ranging from glasses to humanoid robots, according to the company's vice president, Yao Xing. In May 2018, Tencent also led a US$820 million funding round in robotics start-up UBTech and is expected to collaborate with the company to launch robots that can communicate and interact more naturally and intuitively.

Autonomous cars

In a bid to develop AI-powered level 3 and level 4 autonomous cars, Tencent has made a string of partnerships with automotive companies such as BYD, Changan, Dongfeng Liuzhou Motor, GAC Group, Geely, and FAW China. In October 2017, the company launched an AI system that facilitates the manufacture of cars capable of calculating the best route, ordering food, and searching for parking lots with minimum human intervention. These features are expected to be seen in the next line of autonomous cars launched by companies such as GAC Group, BYD Co, and Zhejiang Geely Holding Group Co, all backed by Tencent's proprietary technologies. Tencent has also invested in Tesla and two other EV start-ups: Nio and Weltmeister.

Source: China Daily, Computer Business Review, Technode, The Drum

AI hardware is growing at a similar pace to AI software

Growth in hardware and software (1/2)

While software seems to be getting all the attention in the AI industry, the market for related hardware is also witnessing robust growth. According to estimates by IDC, even though software will account for the highest share of AI revenues, hardware revenues are estimated to grow nearly as fast as software at an average annual growth rate of over 60% during the period of 2016 to 2020.

Many industry experts consider hardware to be a huge differentiator for AI companies. According to Sam Altman, co-chairman of OpenAi, the organization has been focusing on building better AI algorithms until now, but its next phase of growth will come from building better hardware.

Companies like Nvidia, Intel, Qualcomm, AMD and a number of start-ups are also developing chips to make machine and deep learning faster, cheaper, and more powerful. Even though Nvidia is primarily associated with the development of video cards for the gaming industry, it has also been focusing on improving its GPUs to meet advanced AI requirements.

GPUs, which have begun to play a significant role in training large deep neural networks, are expected to be a major catalyst for AI progress. This is because GPUs offer a huge parallel architecture that has the ability to handle multiple tasks simultaneously. Since neural networks are required to process enormous amounts of data, with much of it being high-dimensional, training on CPUs is simply not adequate.

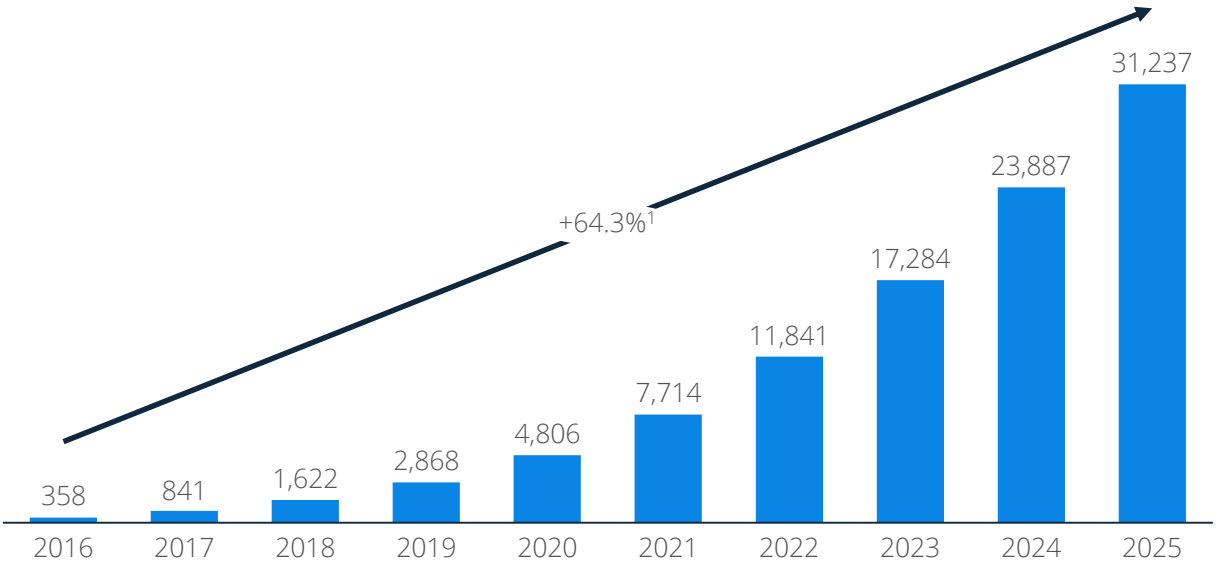
However, since GPUs were originally not built for neural network training, they experience challenges related to memory bandwidth and data throughput or end up wasting their high computational precision, which is not always required. This has resulted in new hardware innovation by companies such as Google, Graphcore, Intel, and Scortex, which are developing chips with larger memory bandwidth, higher compute density, efficiency, and performance per watt. These chips can be used in various areas such as cloud infrastructure as a service, self-driving vehicles, UAVs, and robotics.

Source: medium.com, fortune.com

AI software and hardware market to register robust growth

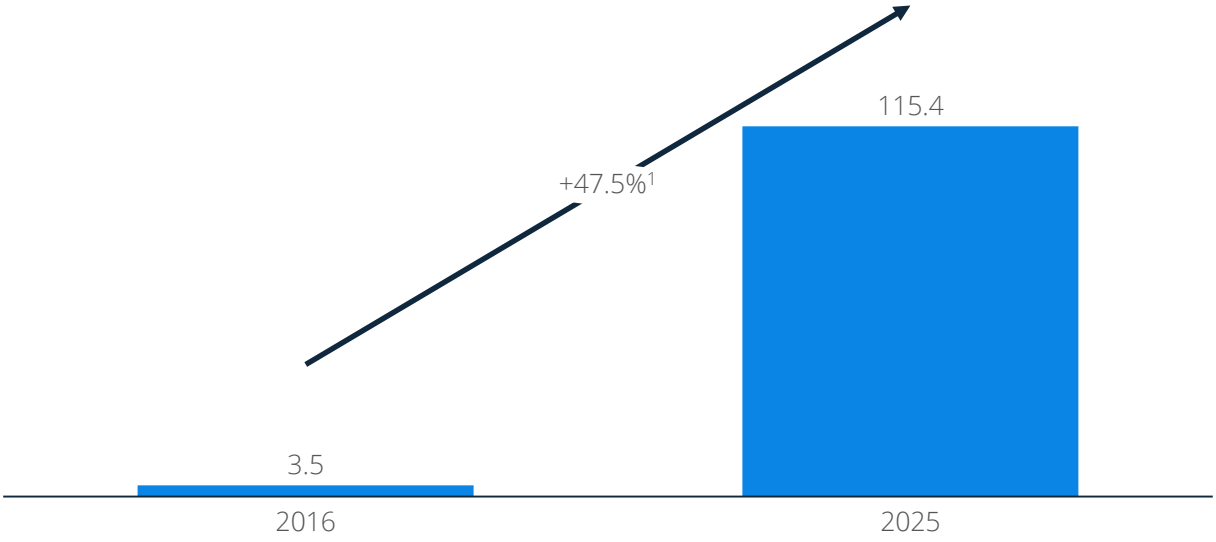
Growth in hardware and software (2/2)

Worldwide AI for enterprise applications market in million US$



Source: Tractica

AI-driven hardware sales growth in million US$



Source: Tractica

1: CAGR: Compound Annual Growth Rate / average growth rate per year

Transfer learning enables AI models to train on less data

Transfer learning

Deep learning is the branch of AI currently receiving maximum attention globally and has applications in almost all industries. However, for deep learning models to achieve the desired results, the neural networks need to be trained with huge amounts of data. For example, in the annual ImageNet Large Scale Visual Recognition Challenge, which requires teams to challenge their image recognition models, 1.2 million images across 1,000 object categories were used to train the AI programs. Until recently, such volumes of data have been imperative in order for deep learning models to perform well on complex tasks such as speech recognition or machine translation. This has often proven to be costly and time-consuming and therefore unsuitable for many use cases.

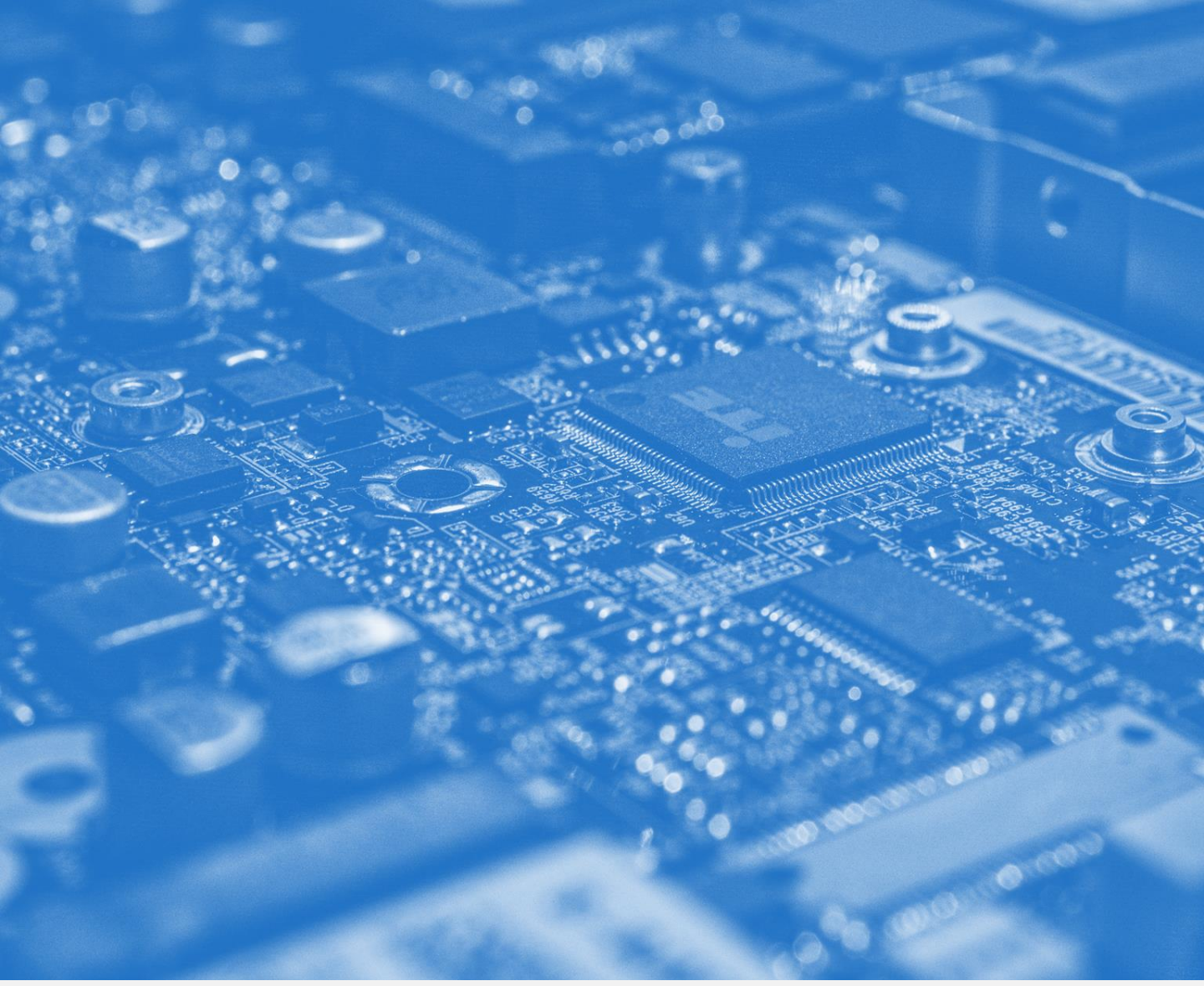
Transfer learning is a new technology developed by AI researchers that enables deep learning models to train on small data sets by transferring the learnings from a previous task to be reused for different problems in the same domain. Importantly, this smaller neural network only needs specific data about the current problem as it has already learned about the overall patterns from the pre-existing data.

Examples of related start-ups are:

- Geometric Intelligence: a start-up acquired by Uber, has developed a machine learning software called XProp, which requires much less data to learn a new visual task. In a demonstration, CEO Gary Marcus compared XProp to another deep learning program in a test to recognize handwritten digits. In this test, XPropr needed only 150 examples to achieve an accuracy of 98% as compared to the 700 examples required by the other software for a similar level of accuracy.
- Owkin: a start-up that uses AI technology to make accurate medical predictions, is building a platform to enable healthcare professionals to create and share a new transfer-learning-powered classification algorithm. Interestingly, it requires a data set of medical images that have a minimum of only two different labels, whether it is for diagnosis, prognosis, or drug response prediction.

> *Transfer learning can help data scientists mitigate the risks of machine-learning-driven predictions in any problem domain susceptible to highly improbable events. For example, cross-fertilization of statistical knowledge from meteorological models may be useful in predicting "perfect storms" of congestion in traffic management. Likewise, historical data on "black swans" in economics, such as stock-market crashes and severe depressions, may be useful in predicting catastrophic developments in politics and epidemiology.*
>
> *James Kobielus, lead analyst for data science, deep learning, and app development at SiliconANGLE Media, 2017*

Source: CB Insights, scmp.com, technologyreview.com



Drivers

One of the major factors driving the current wave of AI growth is the rapid increase in corporate venture capital (CVC) investment in AI start-ups. On the technology front, rapid advancements in computing power are driving the industry to the next level. Similarly, open source platforms are promoting and enabling collaborative learning, which is conducive for the growth in AI.

The current wave of growth in the AI industry is as much about the abundant availability of big data as it is about software and hardware. The amount of big data being generated by today's increasingly digitized economy is growing at a rate of 40% each year and is expected to reach 44 zettabytes by 2020. This growth in big data is driving the improvement of AI algorithms.

Corporate venture capital funding for AI increased by 81% in 2017

Corporate VC investment (1/2)

One of the major factors driving the current wave of AI growth is the rapid increase in corporate venture capital (CVC) investment in AI start-ups. Even as global CVC funding recovered across industries to increase to US$31.2 billion in 2017 from US$26.5 billion in 2016, the AI sector also continued its upward trajectory. According to CB Insights, CVC funding for AI companies nearly doubled in 2017, increasing from US$2.1 billion to US$3.8 billion. The total funding over the period 2013–2017 increased at a huge CAGR of 88.7%, while the number of deals increased from 36 to 198.

In May 2017, Salesforce Ventures announced its fourth investment fund, the Salesforce platform fund, which will focus on AI start-ups. Notably, the largest CVC funding deal for 2017 was for Nio, a Chinese electric vehicle start-up which received US$1 billion from Tencent and Lone Pine Capital, CITIC Capital, and Scottish fund manager Baillie Gifford.

Below is a selected list of corporate investments:

Alphabet: One of the most active AI investors, Alphabet's largest and most famous AI investment has been the acquisition of DeepMind Technologies for US$600 million. The company has made various AI investments over the last few years, in companies such as BenchSci, Calico, DNNresearch, Jetpac, Moodstocks, Kaggle, Api.ai, and Granata.

Apple: The company has been on the bleeding edge of AI since the launch of Siri in 2012. Since then, it has made a number of significant acquisitions, such as Novauris (speech recognition), Perceptio (image recognition), VocalIQ (natural language processing), Emotient (face expression recognition), Turi (wide range of machine learning applications), and RealFace (facial recognition).

Facebook: AI has become vital for Facebook in its efforts to scale up and match the growing prowess of Google and Microsoft. Its acquisitions include Face.com (facial recognition), Jibbigo (speech translation), Wit.ai (speech recognition), and Zurich Eye (computer vision).

Source: CB Insights, GCV Analytics, singularityhub.com, company sources

SoftBank to heavily invest in AI with its US$100bn vision fund

Corporate VC investment (2/2)

Intel: The most significant of Intel's AI acquisitions is Nervana Systems, a deep learning start-up, for US$408 million as it ups the ante in its competition with Nvidia. Others include Itseez (computer vision), Movidius (computer vision processors), Indisys (natural language processing), and Saffron (cognitive computing platform).

Microsoft: Even though Microsoft has been making AI-related investments for over two decades, its latest initiative, the launch of an AI fund by Microsoft Ventures, reinforces the company's commitment to developing its AI capabilities and to compete with other technology giants. The first investments of the fund were in the Montréal-based start-up Element AI, an incubator co-founded by Yoshua Bengio, who is often called "the godfather of machine", and in Tact, an AI-powered assistant for salespeople. The company also acquired AI scheduling tool Genee and deep learning research lab Maluuba. In addition, Envisagenics (healthcare), Hazy (data sharing), ZenCity (data analytics) and Voiceitt (speech recognition) are the first winners of Innovate.AI, the AI start-up competition announced by the company in October 2017.

SoftBank: is expected to make the biggest investments in AI over the coming years, mainly with its US$100 billion vision fund. The company's founder Masayoshi Son has often spoken about the concept of Singularity – the time when AI will become smarter than humans – and has thus been investing in AI-related businesses for the last few years. His most significant buys include the US$32 billion acquisition of semiconductor maker ARM Holdings, insurtech start-up Lemonade for US$120 million, and US$93 million for Petuum, an AI solution development platform.

Source: CB Insights, GCV Analytics, singularityhub.com, company sources

Rapid advancements in computing power are driving the industry

Computing power (1/2)

The exponential increase in big data and sophistication of analytical capabilities has mandated significant advancements in computing power. Just to give an idea of the progress chip makers have made over the years: The current generation of microprocessors delivers over 4 million times the performance of the first single-chip microprocessor introduced in 1971. It is because of developments like this that AI scientists are now able to create advanced system designs such as those supporting multi-core and parallel processing.

According to Dileep George, co-founder of the machine learning start-up Vicarious, at least 80% of the recent advances in AI are due to advancements in computing power. Moreover, distributed computing network systems can seamlessly interface with infrastructure platforms and cloud applications as well as analyze streamed data from sources such as the IoT, sensors, and embedded intelligent devices.

Below are examples of what some of the key companies are doing in this area:

Google: In May 2016, Google launched its own computer chip for driving deep neural networks. Called the Tensor Processing Unit (TPU), the chip requires fewer transistors per operation, which helps it get results more rapidly. In February 2018, the company made the chip available to other companies through its cloud computing service.

Intel: recently launched a new range of CPUs called Knights Mill, specially designed for AI applications. These include the next generation of Intel Xeon Phi co-processors, whose performance is expected to be up to four times better than the performance of the previous generation of deep learning. The company is also considering melding its CPUs with reprogrammable field programmable gate arrays (FPGA) processors that, as the name suggests, can be reprogrammed after they are made to carry out specific tasks. In October 2017, Intel launched a new family of chips called Nervana Neural Network Processors (NNPs), specially designed for deep learning. The first version of the chip set, code-named Lake Crest, is currently made available only to a select set of customers like Facebook to train complex neural networks to share insights on the performance of the chips.

IBM: IBM's new hardware suite, called PowerAI, contains the Power8 server run by the Nvidia Tesla GPUs. In December 2017, the company launched the Power9 chip, specially designed to improve the performance of common AI frameworks like Chainer, TensorFlow, and Caffe. IBM intends to sell the chips to third-party manufacturers and to cloud vendors, including Google.

Source: queue.acm.org, company sources

Microsoft is building the world's first AI supercomputer

Computing power (2/2)

Microsoft: In March 2017, Microsoft, in partnership with Nvidia, unveiled a new hyperscale GPU accelerator called HGX-1, designed for AI workloads in the cloud. It is an open-source design that enables a CPU to connect to multiple GPUs, thereby allowing cloud service providers to offer a number of CPU and GPU machine instance configurations.

In September 2016, the company installed FPGAs across its Azure cloud computing platform consisting of servers in 15 countries to build what it called "the world's first AI supercomputer". To showcase its power, the company demonstrated its ability to translate 5 billion words into another language in less than one-tenth of a second.

Nvidia: Its GPU technology has had the maximum impact on advancements in global deep learning. Its Volta GPU computing architecture, launched in May 2017, consists of 21 billion transistors providing a deep learning performance equivalent to 100 CPUs. In April 2016, Nvidia released the Tesla P100 GPU with 12 times as much processing power as its previous system. It also launched the 'world's first deep learning supercomputer': NVIDIA® DGX-1.

Source: queue.acm.org, company sources

Open-source platforms promote and enable collaborative learning

Open platforms (1/2)

Even though AI scientists have made considerable progress in their efforts to make algorithms learn from patterns, progress has been a bit slow. This is why major technology companies with considerable proficiency in this domain, including Google, Facebook, and OpenAI, have decided to move from intellectual property protection to open and free software.

The AI community usually operates in this way and shares its learnings with all its members. In fact, deep learning came into existence when academics, including University of Toronto professor Geoff Hinton, openly shared ideas.

Google started this trend in November 2015, when it made its AI engine TensorFlow open source, freely sharing the underlying code with the world at large. In December 2016, Google again made its entire DeepMind Lab training environment codebase open source, sharing it on GitHub for anyone looking to train their own AI systems. The company uses 3D gaming environments to train AI agents to behave more like human beings. According to team members of DeepMind, this move was necessary because despite using its AI lab for some time now, DeepMind has "only barely scratched the surface of what is possible".

> *Google is five to seven years ahead of the rest of the world. If they open source their tools, this can make everybody else better at machine learning.*
>
> *Chris Nicholson, co-founder at Skymind, 2015*

At the same time, Elon Musk's OpenAI also released its Universe platform for other researchers to test their agents.

Facebook, which had open sourced its AI hardware design in 2015, did the same with some of its AI software, such as DeepMask, SharpMask, and MultiPathNet. These tools are essentially used for segmenting objects within images.

More recently, in April 2017, Chinese internet giant Baidu announced that it would be sharing its autonomous driving platform, Project Apollo, in an effort to speed up developments in the sector. According to a company press release by Project Apollo, Baidu will make its software code and capabilities in various areas, such as obstacle perception, trajectory planning, vehicle control, and vehicle operating systems, open source as well.

The rise of open-source AI is driving research in the community by providing software developers and start-ups with tools and resources that were not available to them previously. One benefit of this can be observed in the personal robots market, where manufacturers now have access to quality AI software, which had heretofore been a weak point.

Source: singularityhub.com, company sources

TensorFlow and Torch are two popular open AI frameworks

Open platforms (2/2)

- TensorFlow: Developed by Google, this open-source software library is made for deep learning or artificial neural networks and allows users to create neural networks and computation models using flowgraphs. It is available in C++ and Python.
- Theano: Only available in Python, Theano is designed especially for deep learning and supports platforms like Linux, Mac OS X, and Windows. It allows users to define and evaluate mathematical calculations, including multi-dimensional arrays.
- Torch: an open-source computing framework for machine learning algorithms which offers GPU support, N-dimensional arrays, numeric optimization routines and linear algebra routines. It is based on a scripting language called Lua and supports major platforms such as Linux, Android, Mac OS X, iOS, and Windows.
- Caffe: Developed by then UC Berkeley PhD candidate Yangqing Jia, Caffe is a deep learning framework which can process over 60 million images in a single day using just one NVIDIA K40 GPU. One of its main features is that it allows the user to apply neural networks to the problem using text without writing code. It supports operating systems such as Ubuntu, Mac OS X, and Windows.
- Microsoft CNTK: a deep learning framework that is billed to be faster than TensorFlow and supports distributed learning with built-in data readers. The tool supports Windows and Linux.
- Deeplearning4j: an open-source deep learning library for the Java Virtual Machine (JVM). It runs in distributed environments and integrates with both Hadoop and Apache Spark.
- Distributed Machine Learning Toolkit (DMTK): Another open-source AI tool developed by Microsoft, the DMTK consists of three key components: the DMTK framework, the LightLDA topic model algorithm, and the Distributed (Multisense) Word Embedding algorithm.
- Azure ML Studio: used to develop larger machine learning models in the cloud, owing to its wide range of modelling options and algorithms. It can be used with R and Python programs.
- Amazon Machine Learning (AML): a machine learning tool that can be connected to data stored in Amazon S3, Redshift, or RDS.
- MLlib: Another machine learning tool offered by Spark, MLlib integrates with Hadoop and interoperates with both NumPy and R. It includes various machine learning algorithms for classification, regression, decision trees, recommendation, clustering, topic modeling, feature transformations, model evaluation, ML pipeline construction, ML persistence, survival analysis, frequent itemset, and sequential pattern mining.

Source: Datamation, DZone

The growth of big data is driving the improvement of AI algorithms

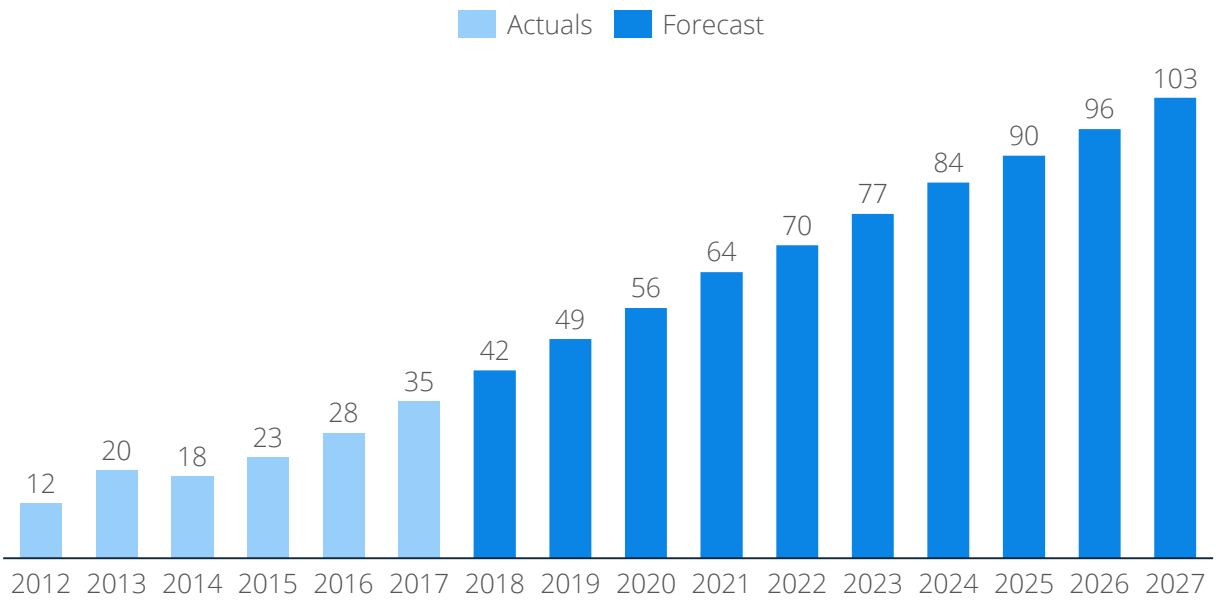
Big data

The current wave of growth in the AI industry is as much about the abundant availability of big data as it is about software and hardware. This is because AI applications, especially deep learning, need large volumes of data to deliver accurate results.

According to a study conducted by International Data Corporation (IDC), the amount of big data being generated by today's increasingly digitized economy is growing at a rate of 40% each year and is expected to reach 44 zettabytes or 44 trillion gigabytes by 2020.

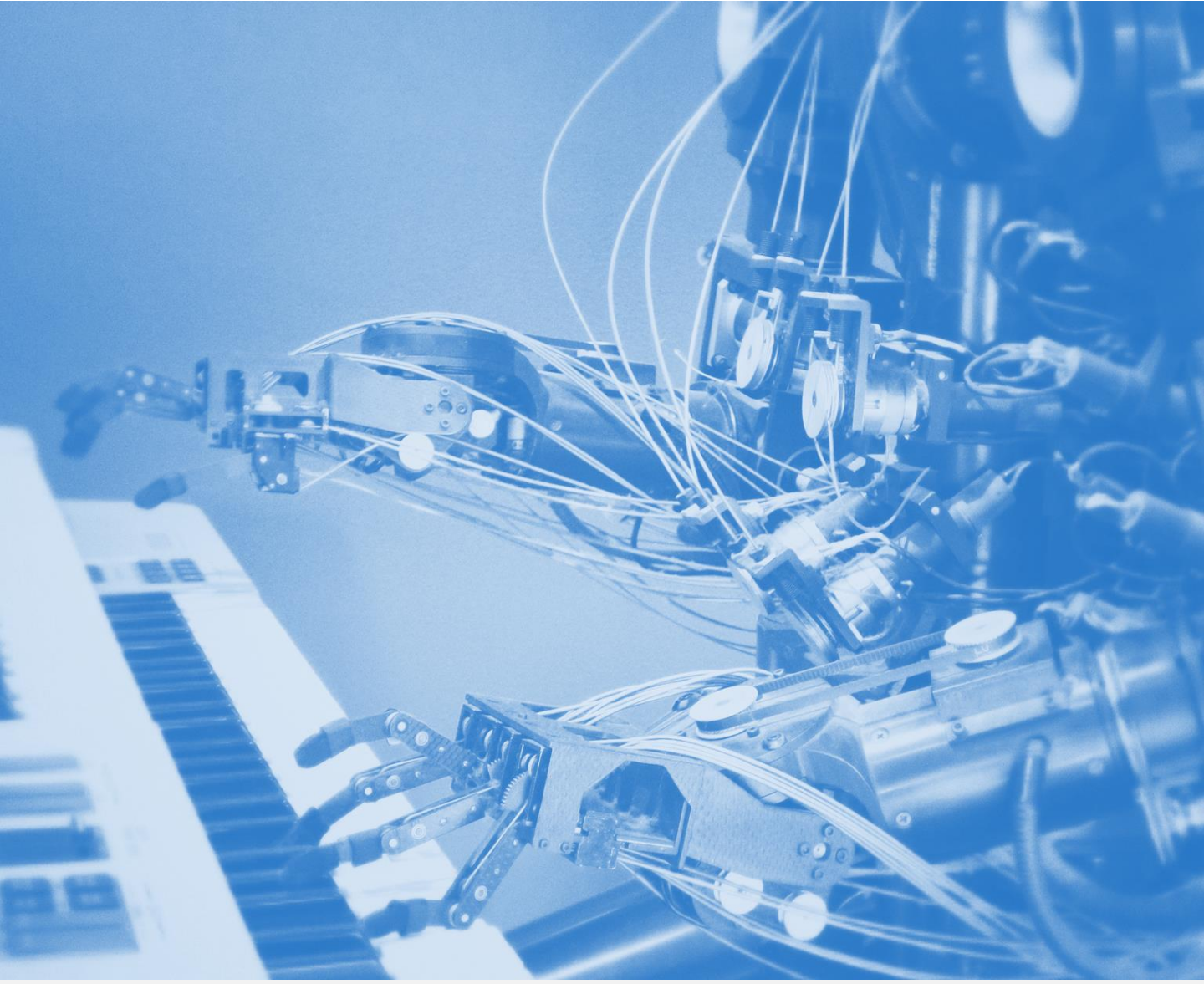
This huge growth, which is driven mainly by the proliferation of smart devices, the Internet of Things (IoT) and social media, is absolutely critical to the growth of AI applications across industries. After all, AI systems get 'smarter' in direct proportion to the amount of data they consume.

Worldwide big data revenue in billion US$



Source: Wikibon; SiliconANGLE

Source: IDC



Applications

AI solutions are increasingly being customized to serve the needs of the automotive, healthcare, education, finance, entertainment, and other industries.

In the automotive sector, AI is primarily used to power autonomous cars, with these systems expected to become standard in new vehicles in the medium to long term. In the healthcare industry, developments in the field of AI and machine learning have not only accelerated the pace of innovation in the industry but are also changing entire operating models. In the education industry, there are attempts to provide customized learning programs for each student using AI, while in the finance industry, AI wealth management solutions can offer higher personalization.

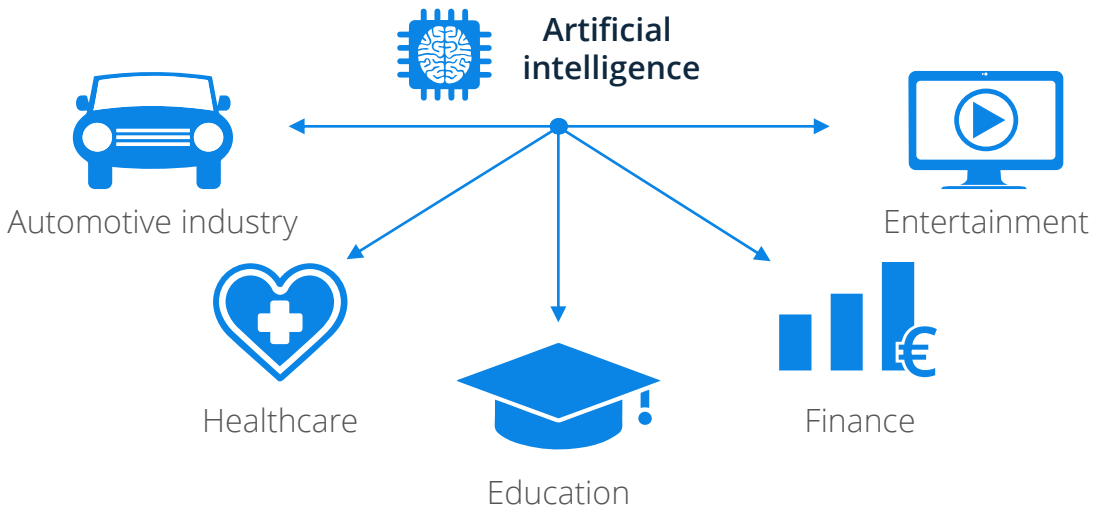
AI applications are used in multiple industries

Overview

AI solutions are increasingly being customized to serve the needs across the automotive, healthcare, education, finance, entertainment, and other industries.

In the automotive sector, AI is primarily used to power autonomous cars, with these systems expected to become standard in new vehicles in the medium to long term. Even though most automotive manufacturers are developing AI-powered cars, Google and Tesla are currently the front-runners in the field.

Healthcare is another major area of AI disruption, with applications in the fields of diagnostics, drug discovery, personalized treatment plans, and robotic patient care. One of the major breakthroughs brought about by AI is the shift in approach from treating diseases to preventing them.



Source: Company information

AI disrupts many elements of the automobile industry's ecosystem

Automotive industry: overview (1/2)

The application of AI in the automotive industry can be traced back to 1962, when the first industrial robot started working at a General Motors (GM) plant in New Jersey. At the time, Japan was the only other country to recognize the true potential of this new technology and the benefits it would provide.

One of the major breakthroughs was made in 1981, when Takeo Kanade developed the world's first direct drive arm, with motors installed directly into the joints of the robot arm. This marked the beginning of an era where robots began to replace humans in the car manufacturing process on a large scale. Since then, advances in computing power and the proliferation of big data have resulted in deeper penetration of AI in the automotive industry, from driving to design to manufacturing. Areas such as automotive assemblies, displays on dashboards, and even overall vehicle conceptualization are all experiencing robust innovation aided by faster computing systems like GPUs.

Today, many cars are equipped with sensors in the front, back, and sides, along with rear- and front-facing cameras, to capture real-time data. This data is then used to identify anomalous patterns, which the AI system uses to relay precautionary measures to the driver in real time. The AI-powered adaptive cruise control systems are another feature gaining significant traction, according to Anand Rao, partner and innovation lead of PwC Data & Analytics.

> *If you set your speed to 70 miles an hour and the car in front of you is going 50, as you approach it within a safe distance, you'll start slowing down automatically.*
>
> Anand Rao, partner and innovation lead, PwC Data & Analytics, 2016

AI is not only changing the entire driving experience but also every other element of the automobile ecosystem, including on-demand mobility, connected cars, insurance, electric vehicles, advertising, etc. For example, the pay-per-use consumption model pioneered by companies such as Zipcar, Uber, and Lyft is evolving towards an autonomous model. Ford has earmarked a US$1 billion investment over the next five years in AI company Argo AI to develop autonomous vehicles and use them in areas such as ride sharing and ride hailing. In addition, insurance companies are gradually using real-time data on driving behavior to deliver highly personalized policies.

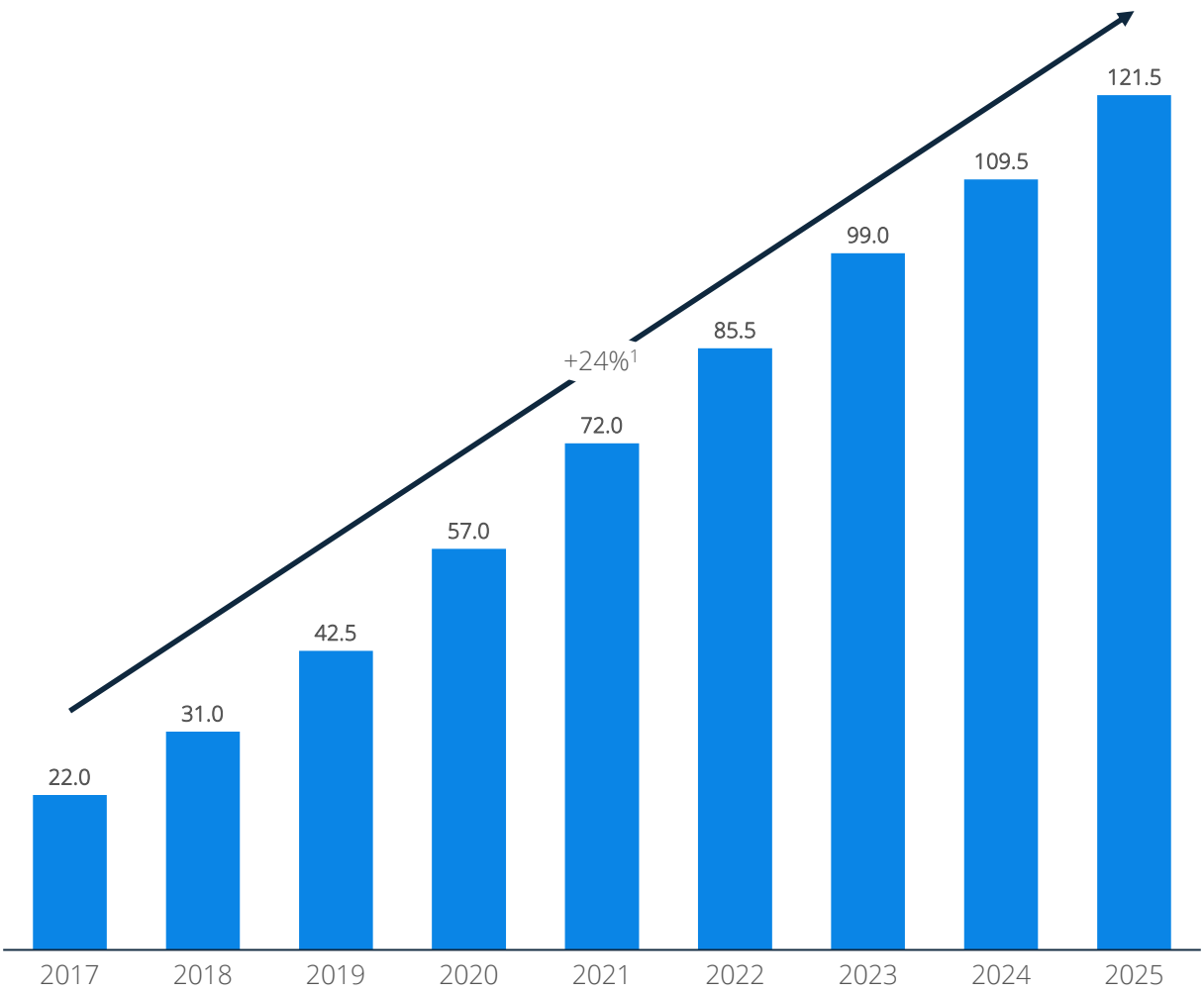
Source: Company information

Shipments of AI-based systems for automotive industry are growing

Automotive industry: overview (2/2)

The worldwide number of unit shipments of AI-based systems for the automotive market is expected to register robust growth up to 2025. The global automotive market is expected to ship 121.5 million AI-based systems in 2025, growing at a CAGR[1] of 24% from 22 million units in 2017.

Unit shipments of AI-based systems for automotive industry in millions



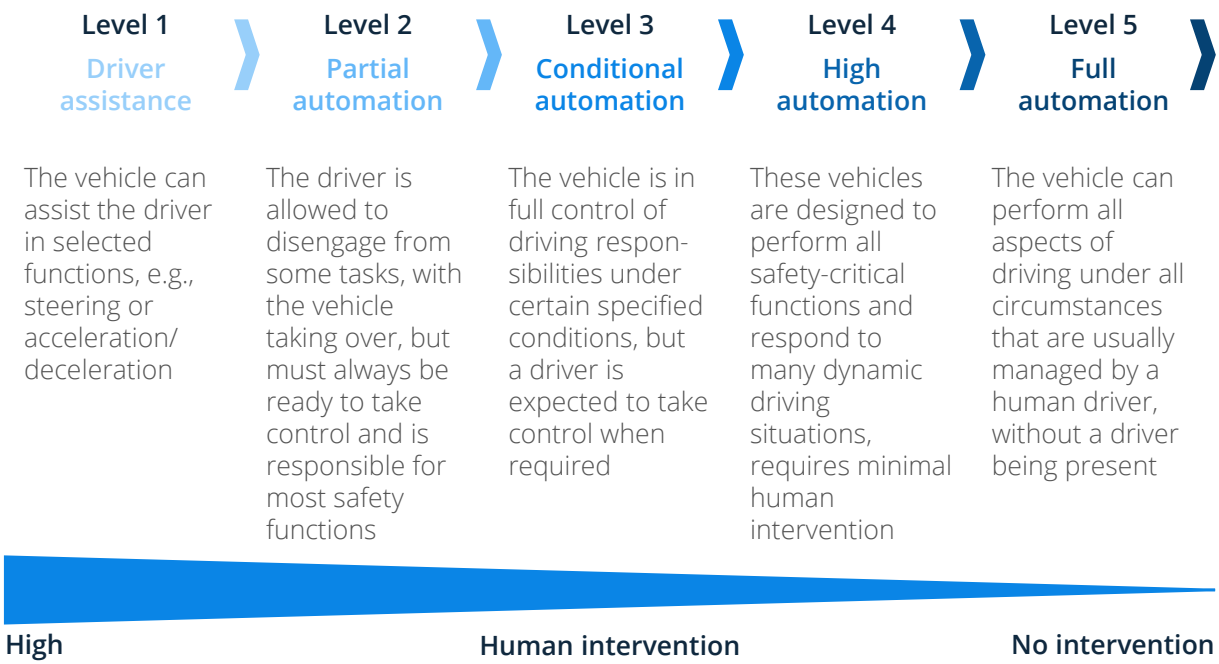
1: CAGR: Compound Annual Growth Rate / average growth rate per year
Source: Statista estimates, IHS

Deep learning makes fully autonomous cars a reality

Automotive industry: autonomous driving (1/5)

According to a study by Garret/Galland Research, the number of self-driving cars on the road is expected to reach 10 million by 2020. Another report by IHS estimates the annual sales of self-driving cars to reach approximately 33 million units by 2040, with nearly 76 million vehicles with some level of autonomy sold by 2035. Even though the required hardware, such as sensors, cameras, radars, and ultrasound systems, has contributed a lot to making autonomous cars a reality, it is really the developments in AI that play the most pivotal role.

Impact of deep learning on autonomous driving



Source: SAE International, KPMG, Techrepublic, Medium, IHS

Deep learning architectures enable cars to learn from their experiences and adapt to real-time situations without human intervention. This is particularly important because it is impossible for software engineers to write programs to cover every variable or driving situation a car may face. In fact, deep learning is solely responsible for the evolution of cars from driver assist technologies to fully autonomous vehicles.

Source: Garret/Galland Research, IHS

Overview of autonomous cars and their autonomy level

Automotive industry: autonomous driving (2/5)

Company	Model	Autonomy level	Range in miles	Launch year
Alphabet	Waymo	Level 4	n/a	2018
Audi	aicon	Level 5	500	Undecided
	A9 e-tron	Level 4	311	2020
	Q6 e-tron	Level 4	310	2018
	Elaine	Level 4	311	2019
Baidu-BAIC Group	n/a	Level 4	n/a	2021
BMW	iNext	Level 3 at launch, upgrade to level 4 a year later	435	2021
Faraday Future	FF-91	Level 4	300	2018
Fisker	EMotion	Level 4	400	2019
Future Mobility Corp	Byton	Level 3	250	2019
General Motors	Chevrolet Bolt	n/a	238	2020
Jaguar Land Rover / Waymo	Jaguar I-Pace	Level 5	298	2020
Kia	Niro EV	n/a	238	n/a
Mercedes-Benz	V-Class	Level 3	n/a	2021
Navya	Autonom Cab	Level 4	n/a	2018
Porsche	Mission E	Level 4	310	2020
Renault	SYMBIOZ	Level 4	n/a	Concept
	Easy Drive	Level 2	n/a	2019
	Easy Drive	Level 4	n/a	2022
Toyota	Concept-i	Level 5	186	2020
Volkswagen	I.D. VIZZION	Level 5	n/a	n/a
	I.D. Buzz	Level 5	370	2022

Source: autocar.co.uk, autocarpro.in, Bloomberg, carwow.co.uk, businessinsider.in, CNN, digitaltrends.com, greencarcongress.com, greentechmedia.com, theverge.com, topgear.com

Google and Tesla are leaders in driverless car development

Automotive industry: autonomous driving (3/5)

For deep learning to be successful, it is imperative that the algorithms are fed with large amounts of data. One of the most important trends driving automation in the industry is the growth in the number of connected cars. As autonomous cars share driving experiences and readings with each other, algorithms use that data to adapt to various situations without having to experience them firsthand.

Google, the global leader in self-driving technology, recently launched the testing phase of its self-driving car called Waymo, which is powered by over 2 million miles of real-world driving data. Elon Musk, co-founder and CEO of Tesla, has also announced the rollout of a completely autonomous car by the end of 2017, equipped with Nvidia's Drive PX 2, a supercomputer that uses deep learning to teach the car to handle itself.

Even though Google and Tesla are the most visible brands chasing driverless technology, a host of auto manufacturers and other technology companies are also partnering with each other to develop cars with varying levels of autonomy. A few key examples can be found in the following table.

> *Deep learning is the best enabling technology for self-driving cars. You hear a lot about all these things on a car: the sensors, the cameras, the radar, and LIDAR[1]. What you need are the brains to make an autonomous car work safely and understand its environment.*
>
> *Sameep Tandon, CEO and co-founder of Drive.ai*

1: Light Detection and Ranging is a remote sensing method that uses light in the form of a pulsed laser to measure ranges

Car companies' activities in autonomous driving (1/2)

Automotive industry: autonomous driving (4/5)

Company	Description	AI platform	Other partnerships
Audi	▪ Launched a level 3 autonomous vehicle in 2017 and is expected to a level 4 vehicle by 2020	▪ Nvidia – DRIVE PX 2	n/a
BMW	▪ BMW's iNEXT project to be launched in 2021; will consist of fully electric and connected 7 series cars with level 4 autonomous technology	▪ Intel Nervana – incl. machine & deep learning training and simulation infrastructure	▪ Mobileye[1] – EyeQ5 processor, 360° camera system, and a sensor fusion solution ▪ Intel – Intel GO automated driving solutions
GM	▪ GM spent US$600 million on autonomous vehicle development in 2017 ▪ In 2016, it spent US$581 million to acquire Cruise Automation, a start-up that specializes in developing software to operate self-driving cars ▪ Had 30 self-driving all-electric Chevrolet Bolt vehicles on the road in October 2016	▪ IBM's Watson – OnStar Go	▪ IBM – to develop OnStar's touch screen interfaces

1 Mobileye was acquired by Intel in March 2017
Source: Company sources, press releases

Car companies' activities in autonomous driving (2/2)

Automotive industry: autonomous driving (5/5)

Company	Description	AI platform	Other partnerships
TOYOTA	▪ Spending US$1 billion on developing self-driving cars ▪ Launched the next-generation autonomous customized Lexus in March 2017 with two platforms: Chauffeur – Level 4 and 5 autonomy; Guardian – driver-assist	▪ Yui – an AI assistant made by Toyota	▪ NTT – to develop technology for connected cars utilizing fifth-generation signals, big-data analysis, and AI applications ▪ Stanford and MIT – to develop AI applications for use in its autonomous cars
	▪ Launched its first autonomous concept car Sedric in March 2017 ▪ Its 2025 strategy focuses on developing electric vehicles and autonomous driving technology	▪ Nvidia – Drive ▪ PX 2	▪ Mobvoi – voice recognition and language processing technologies ▪ Mobileye[1] – to integrate its Road Experience Mgmt mapping service into VW cars by 2018
VOLVO	▪ Launched a fleet of 100 autonomous Volvo XC90 SUVs by the end of 2017	▪ Nvidia – DRIVE PX 2	▪ Microsoft – to install Skype for Business on new Volvo 90 Series cars

1 Mobileye was acquired by Intel in March 2017
Source: Company sources, press releases

Cloud computing augments AI in the automotive industry

Automotive industry: cloud computing

Rapid advancements in technology have resulted in a closer relationship between AI and cloud computing. Since AI works primarily by analyzing huge volumes of data, companies (including AI developers and end users) are quickly realizing the benefits of moving away from the confines of internal IT structures and into the vast computing power and data that the cloud has to offer.

According to Eric Schmidt, chairman of Google's parent company Alphabet, companies tapping into cloud computing will also get access to crowdsourced data, which, when combined with advanced AI technologies, will lay the platform for truly disruptive businesses across many industries.

Therefore, companies in the automotive industry are using data from the cloud to deliver various services, including marketing, navigation, and payments.

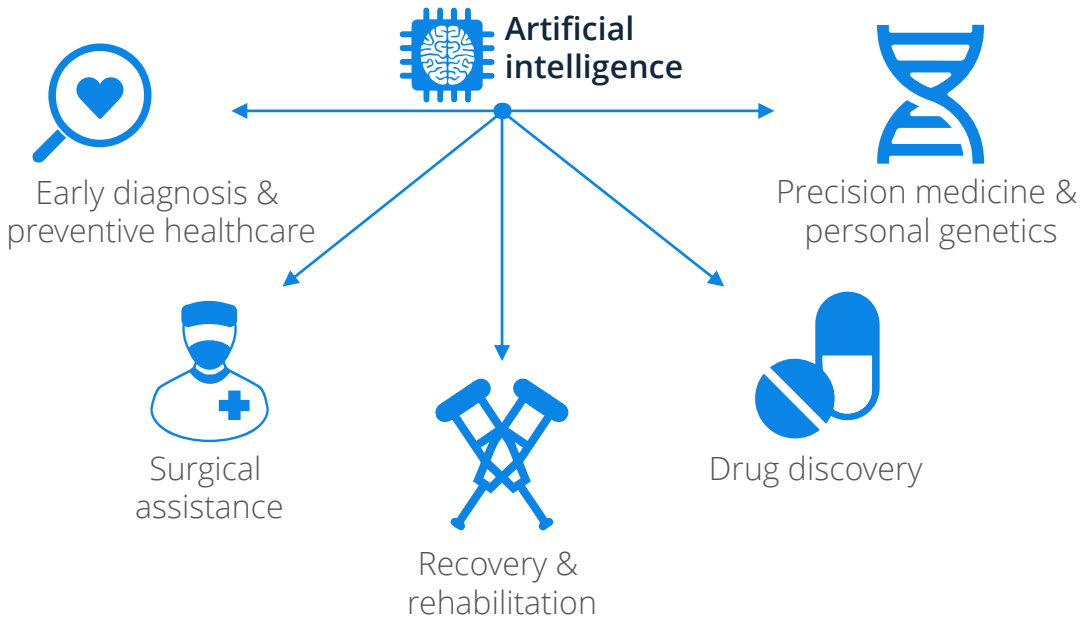
Examples of such collaborations are below:

- GM and IBM have partnered to enable IBM's AI supercomputer Watson to power GM's upgraded onboard car system called OnStar Go. This platform now uses data from the cloud to offer recommendations to drivers on places to eat, shop, or fill gas. Moreover, when drivers are nearing a preferred location, say a fast food joint, they have the option to pre-purchase their order before their arrival.
- Researchers at the NYU Tandon School of Engineering are developing an AI system which enables self-driving cars to combine the information retrieved from cloud-based maps with their onboard sensors to achieve enhanced navigation, maneuverability, and ability to adapt to changing road conditions.
- Nvidia and Baidu have partnered to develop an AI-powered cloud computing platform for autonomous vehicles. They plan on integrating Baidu's cloud platform and mapping technology with Nvidia's self-driving computing platform to create solutions for high-definition maps, Level 3 autonomous vehicle control, and automated parking.

Source: cloudwedge.com, company sources

AI impels transition from reactive to proactive healthcare

Healthcare: overview



In the past, innovations in the healthcare industry have been restricted to the digitization of manual tasks in order to save on time and effort. However, developments in the field of AI and machine learning have not only accelerated the pace of innovation in the industry but are also changing entire operating models.

One of the major changes brought about by AI is the shift from mere treatment of diseases (reactionary mindset) to a treatment that focuses on diagnosing illnesses at an early stage or before they occur (preventive mindset). According to Praveen Soti, general manager for healthcare and life sciences at Wipro, the future of healthcare lies in moving away from the present conditions, in which hospitals are incentivized to fill beds, prescribe tests, and perform surgeries, to actually keeping patients away, with AI playing a pivotal role in this transition.

As computing power becomes more advanced and algorithms become smart enough to spot patterns in digital data and images, the process for diagnosing and treating illnesses is becoming more of a data-driven practice.

- KenSci: a Washington-based start-up which is using AI to track the onset and progress of a disease, along with predicting chronic and critical illnesses within a group of patients.
- Pathway Genomics: a genetic testing lab which is developing an AI-powered application to provide customized preventive health advice based on a user's genetic makeup.
- IBM and Under Armour: They have partnered to develop an AI-powered 'cognitive coaching system' which processes data from over 200 million people to develop personalized advice on sleep, fitness, and nutrition.

Source: ai100.stanford.edu, Wipro

AI enables personalized medical advice without seeing a doctor

Healthcare: new market creation

AI is also creating new markets in the healthcare industry. For example, Norwegian company Your.MD has developed an AI-powered mobile app that matches a patient's symptoms to publicly available data collected from various sources and offers them personalized advice regarding their ailments. This mainly works by filtering out people who do not need primary care and letting the doctors focus on those who need the most attention.

This has resulted in the creation of a new healthcare market called 'pre-primary care', in which the patient ends up doing more for themselves and acts as a driver for large-scale behavioral change.

> *In 20 to 30 years, we really will be living in the Jetson era. By then, big data, the internet of everything, precision medicine and AI will have converged. A body scan will verify what we can already predict based on genetic mapping. Therapy, diet, and treatment will all be personalized to the individual and treatments like chemotherapy will seem as barbaric as leeching. Some of the greatest advances will be in neuroscience. We'll have the ability to map the billions of neuron firings for personalization and unique mental health therapies.*
>
> *Al Babbington. CEO of PrescribeWellness, 2017*

Source: Company sources

AI applications facilitate early and accurate diagnosis

Healthcare: early diagnosis (1/2)

According to a 2017 study conducted by the Mayo Clinic, a non-profit medical practice and research group, original diagnoses in the U.S. are revised by a second medical professional 88% of the time. A previous study conducted by National Academies of Medicine in 2015 revealed that diagnostic errors were responsible for up to 10% of all patient deaths and for up to 17% of all hospital complications.

Advancements in AI have resulted in early detection of diseases through the use of deep learning to analyze huge amounts of data and recognize patterns, a process especially useful in diagnostics. Some examples of AI systems designed for early diagnosis are listed here:

IBM Watson

The supercomputer analyzes large volumes of internal and external data to detect early signs of cancer or vascular diseases.

Google DeepMind

Google has teamed up with the NHS in the UK to build a machine learning system with the ability to recognize vision-threatening conditions simply by conducting a digital scan of the eye.

Pathway Genomics

Is developing a simple blood test to detect or predict certain cancers by tracking minute levels of cancerous cells that have been cast off from tumors into the bloodstream.

Lumiata

Uses machine learning to identify patients who need early hospitalization or medication plans.

> *If you miss something and a patient develops cancer five years later, there's no systematic routine that tells you how to correct yourself. But you could build in a system to teach the computer to achieve exactly that.*
>
> Geoffrey Everest Hinton, The New Yorker, 2017

Source: Company sources

AI applications are driving early and accurate diagnosis

Healthcare: early diagnosis (2/2)

Microsoft

It has gone a step further by developing an AI system that interprets online search engine behavior, e.g., people researching symptoms of diseases long before they actually occur, and takes necessary pre-emptive measures.

University of Malaga and the University of Granada

Both have jointly developed an AI technique to detect Alzheimer's by revealing brain patterns associated with the disease. The technique models different regions of the brain and uses deep learning to compare it with the brain of a healthy person.

Langone Medical Center (New York University)

It has developed a machine learning algorithm to detect Post Traumatic Stress Disorder (PTSD), simply by listening to an individual's speech pattern. The AI has a success rate of 77%.

Source: Company sources

Robots aid in surgical assistance, rehabilitation, and research

Healthcare: robotics (1/2)

Just fifteen years ago, the field of healthcare robotics was mostly science fiction. A company called Robodoc, an IBM spinoff, was the first to develop a robotic system for orthopedic surgeries. Even though the technology worked, the company could not achieve commercial success and eventually shut down. However, recent advancements in robotics and AI have resulted in a strong increase in the research and practical use of healthcare robotics.

These systems are increasingly being used in various medical fields and across the entire spectrum of user populations:

- Surgical assistance: This area of healthcare robotics has received the maximum attention over the years. One of the first companies to gain substantial market traction was Intuitive Surgical, which launched the 'da Vinci' system, a technology initially meant to support minimally invasive heart bypass surgery, which also went on to aid in the treatment of prostate cancer. Now in its fourth generation, the 'da Vinci' provides assistance in multiple laparoscopic procedures through not only a physical platform but also a data platform which is used to study the entire surgical process. Other companies making surgical robots include Verb Surgical (a start-up spun out of Google and Johnson & Johnson) and Dublin-based Medtronic.

- Recovery and rehabilitation: A patient suffering from neuromuscular diseases or injuries, such as those that occur after a stroke, can benefit from robot-assisted sensory motor therapy. Such systems are also capable of assisting people with behavioral disorders like Autism Spectrum Disorder and Attention Deficit Hyperactivity Disorder (ADHD). Another important role is to help neuroscientists improve their general understanding of brain function. Robots analyze data on stimulus-response recordings to get insights into the relationship between external mechanical forces and neural plasticity. An example of such robots is the MIT-Manus rehabilitation robot, which has helped to bring about improved recovery of both acute and chronic stroke patients.

- Research: One of the growing areas of robotics technology is its application to conducting research for overall human health. To achieve this, scientists are trying to create a robotic system that is similar to human biology in order to simulate its workings in an artificial setting. Furthermore, robots, such as those that work with people with neurodevelopmental disorders, can collect data on patient behavior that can be analyzed to develop personalized treatment.

A report by the Robotics Business Review segments the healthcare robotics market into:

- Direct patient care robots
- Indirect patient care robots
- Home healthcare robots

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Source: Company sources

The three market segments of healthcare robots

Healthcare: robotics (2/2)

Direct patient care robots

- Surgical robots (to carry out clinical procedures)
- Exoskeletons (mechanical suits that bolster patient strength)
- Prosthetics (replacements for lost limbs)

One example is the nursing care robot ROBEAR

Indirect patient care robots

- Pharmacy robots (mainly used to reduce labor costs)
- Delivery robots (autonomous delivery of medical products)
- Disinfection robots (to interact with patients with infectious ailments)

Panasonic Autonomous Delivery Robots such as HOSPI are an example

Home healthcare robots

- Robots that provide assistance to the elderly or chronically ill people

An example is the home healthcare robot Pillo

Source: Indiegogo, Panasonic, Phys.org

AI systems reduce time and costs to develop novel drugs

Healthcare: drug discovery

According to a study conducted by the Tufts Center for the Study of Drug Development (CSDD), the average cost of developing a drug that gains market approval is US$2.6 billion, and the process takes more than 10 years. Even then, less than 10% of potential medicines make it to market, according to Jackie Hunter, CEO of BenevolentBio, the life sciences arm of London's BenevolentAI. Apart from being time-consuming and expensive, this process also limits the number of diseases scientists can focus on.

Machine learning algorithms can play a very important role in reducing the time and cost by using previously generated data to establish patterns and decipher which experiments need to be done. Other algorithms can also be used to predict the side effects of certain chemical compounds on humans, thereby speeding up the approval process.

Key developments in this area include:

- Atomwise: This start-up uses machine learning and 3D neural networks to accelerate drug discovery for diseases like Ebola, multiple sclerosis, and leukemia. In 2015, the company's solution discovered two new drugs to combat the Ebola virus, with the analysis finishing in just one day.
- twoXAR: It leverages big biomedical data such as gene expression measurements, protein interaction networks, and clinical records to discover drugs that treat diseases like glaucoma and liver cancer.
- Berg Health: This Boston-based start-up has an inverse approach to drug discovery. It analyzes data to determine why some people survive diseases and then applies the results to improve current therapies or create new ones.
- Stanford University: For situations where a small amount of data hampers the effectiveness of conventional deep learning algorithms, scientists at Stanford University have developed 'one-shot learning', a new kind of deep learning that requires only a small number of data points (usually hundreds). Even though the researchers were skeptical about the efficacy of this method, test results published in ACS Central Science in April 2017 were very positive.
- Insilico Medicine: This company uses a new deep learning technique known as a generative adversarial network (GAN) that uses historical biological and chemical data to 'imagine' new cancer-like molecules with specific properties.

Source: news.stanford.edu, techcrunch.com

AI is used to map the human DNA to deliver precision medicine

Healthcare: precision medicine and personal genetics

Precision medicine has been available for some time now in the form of low-tech therapies like allergy treatments and blood transfusions. Even genetic targeting of tumors has become more commonplace now, spawning medications such as the famous Herceptin[1], which targets the HER2 protein associated with an aggressive form of breast cancer.

However, AI technologies such as deep learning and natural language processing are now being combined with big data from consumer wearables, sensors, and connected devices to detect patterns for mutations and linkages in diseases. This is then used to deliver precision medicine down to the familial and individual level.

One of the most significant uses of AI in the healthcare industry is to understand the human DNA. Greater insights into an individual's genetic makeup are providing the opportunity to deliver personalized healthcare for each person based on their biological disposition.

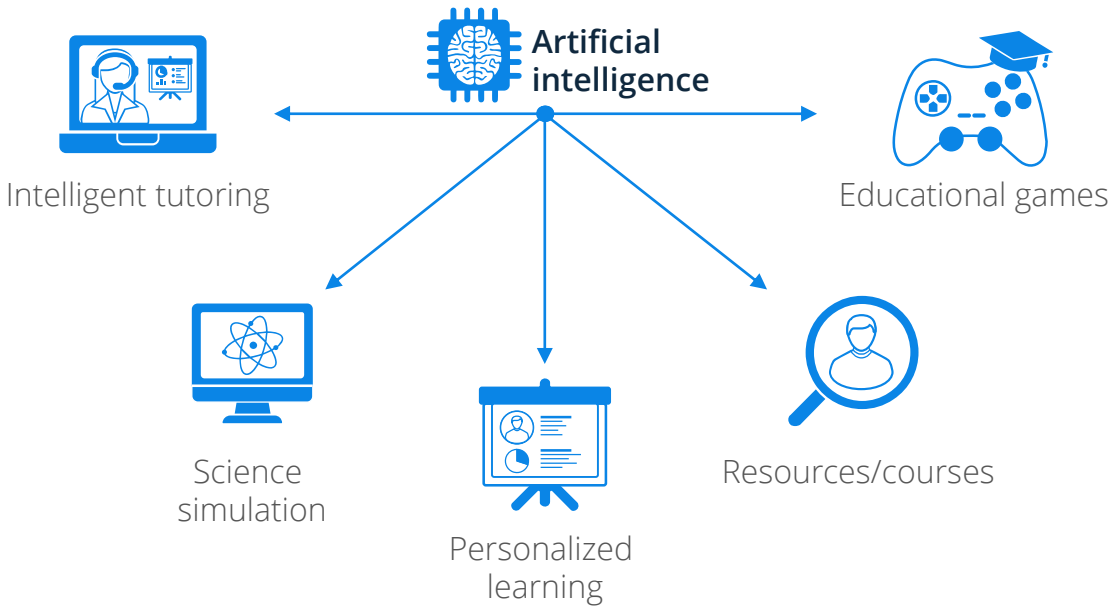
Even though much of the research in this field is still in its early stages, a few promising projects are:

- Flow Health: is building a knowledge graph of medicine and genomics using over 30 petabytes (30 million gigabytes) of longitudinal clinical data of 22 million veterans collected over 20 years. The goal is to determine how each gene variant in the genome affects phenotype[2].
- Human Longevity: co-founded by Craig Venter, the man credited with mapping the human genome. The company is aiming to sequence at least one million genomes and use the data generated from them, along with DNA-related information, to offer better precision medicine for ailments such as cancer and heart diseases.
- Deep Genomics: a Toronto-based start-up which applies GPU-based deep learning to determine how strongly genetic variants affect RNA splicing[3], a contributing factor for many diseases. The company's database is aiming to be able to explain how hundreds of millions of genetic variations can impact a human's genetic code.
- University of Toronto: A team is developing a GPU-powered genetic interpretation engine that could identify cancer-causing mutations for individual patients.
- Editas Medicine: specializes in a process called gene editing using a technology called CRISPR/Cas9. The company aims to use this tool to treat genetic diseases such as eye disease, cancer, sickle-cell anemia, and Duchenne muscular dystrophy. One of its initial plans is to inject a virus containing Cas9 into the eyes of people suffering from a rare form of progressive blindness caused by a specific gene mutation. The enzyme would then cut the faulty sequence, triggering a natural DNA response in which the cell repairs the deficit itself.

1: Has been used to treat more than two million patients worldwide and has generated global sales of >US$64 billion for Swiss pharma company Roche 2: The total set of observable characteristics displayed by an individual under a particular set of environmental factors 3: The removal of certain DNA sequences
Source: techcrunch.com, company sources

AI is driving the personalized learning industry

Education: overview



The universal approach to education has mostly remained the same, with a single teacher delivering the same message to a large group of students, with little attention being paid to their individual progress. It is the desire to create customized learning programs for each student that is currently the biggest driver of AI in education and learning.

Machine learning capabilities embedded in online learning programs track the entire learning process of an individual, diagnose misconceptions, and provide timely guidance, feedback, and explanations.

For example, if a student misunderstands a particular mathematical concept, the AI system could send an alert to the teacher before it becomes a bigger issue later in their education.

Recent years have witnessed an influx of heavy investment in the personalized learning space, the most notable being the US$240 million made by the Bill and Melinda Gates foundation. This initiative consists mainly of investments in private companies that analyze big data to develop software that creates individual learning plans for students based on their performance with a special focus on their weak areas.

Other interactive educational technologies that have gained traction over the last few years include homework support systems, science simulations, and virtual labs, educational games, online resources, and open online courses.

Source: ai100.stanford.edu

ITS are one of the most popular AI applications used in education

Education: intelligent tutoring (1/2)

Intelligent Tutoring Systems (ITS) are the most widely used AI applications in the education industry. They are educational applications of AI and machine learning technologies that emerged as a scholarly discipline over 40 years ago. Central to every ITS is its ability to gather in-depth data on an individual level and use it to assess the level of progress and offer feedback to promote productive learning behaviors such as self-regulation, self-monitoring, and self-explanation.

ITS are now widely used in K-12[1] schools and colleges, especially in the U.S. The One Hundred Year Study on Artificial Intelligence by Stanford University in 2016 states that the use of intelligent tutors and other AI technologies to assist teachers in the classroom and at home in a typical North American city is likely to expand significantly over the next 15 years.

Examples of intelligent tutoring systems that are already being used are:

- Cognitive Tutor: Developed by Carnegie Learning, this software is primarily used in U.S. high schools to learn mathematics from grade 9 to 12. It has two major analytics components: 'Skillometer' and the teacher reports. The 'Skillometer' uses data generated from student interaction with the software to visually indicate the current and future levels of mastery on a particular subject. Teachers are also provided with detailed information on each student's progress.
- SHERLOCK: It is used to teach Air Force technicians to diagnose electrical system problems in aircraft.
- University of Southern California: The Information Sciences Institute at the University of Southern California has created avatar-based training modules to train military personnel being sent to international posts in appropriate behavior when dealing with people from different cultural backgrounds.

Other ITS have been used in other disciplines, such as geography, circuits, medical diagnosis, computer literacy and programming, genetics, and chemistry.

> *AI will not replace tutors, it will support them and it will guide them to be better teachers.*
>
> *Tom Hooper, founder of Third Space Learning, 2016*

1: Kindergarten (K) and the 1st through to the 12th grade (1-12) in school
Source: ai100.stanford.edu, bdtechtalks.com, ewise.com, forbes.com, Narrative Science, National Business Research Institute, wired.com

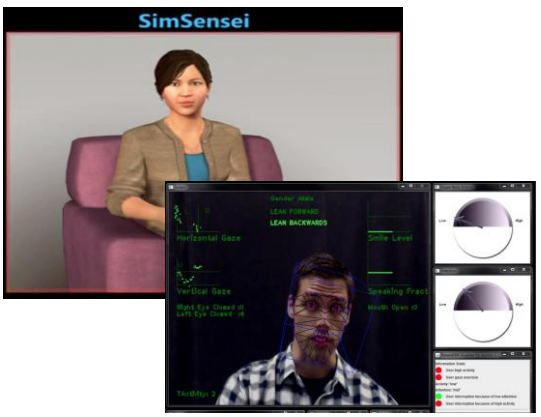
Virtual humans can be used to coach people in different ways

Education: intelligent tutoring (2/2)

Even though Apple's Siri, Microsoft's Cortana, Amazon's Alexa and Google's Assistant have already given us a peek into what virtual humans can do, scientists are still a long way from developing characters that possess the required degree of social intelligence to perform mainstream tasks.

Two examples of how virtual humans are used in education are SimSensei and Kaspar:

Kaspar – a robot developed by the University of Hertfordshire that helps autistic children deal with personal interactions. It uses touch sensors and the ability to detect gestures and eye gaze to teach them how to make eye contact and when it is appropriate to touch others



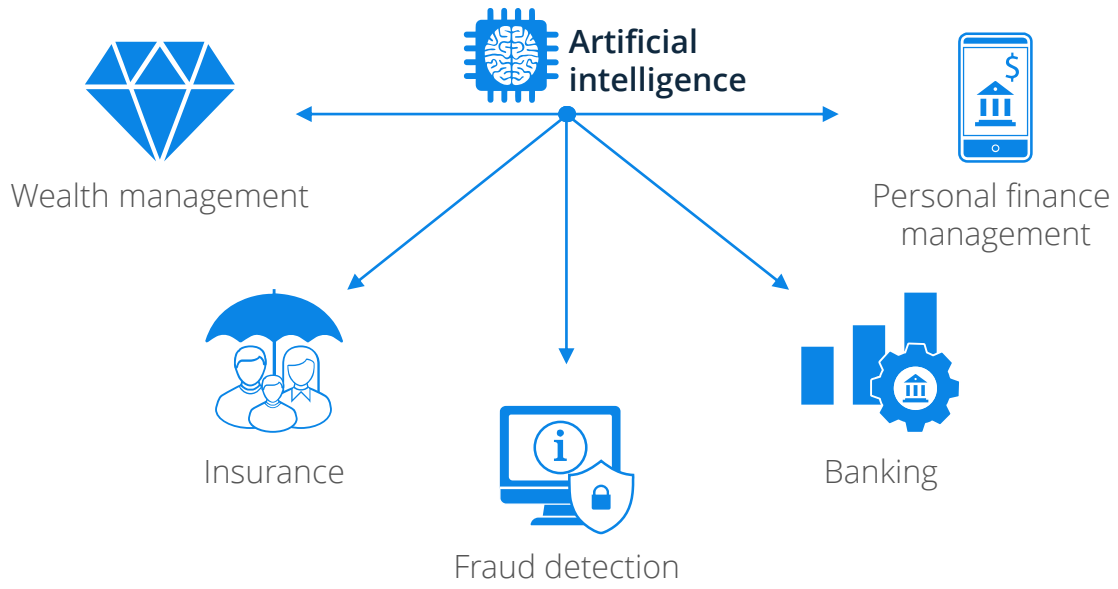
SimSensei – One of the pioneering efforts to create socially intelligent virtual humans is the SimSensei program being developed by the University of Southern California. It is an autonomous system that is able to interpret a person's mood just by observing their behavior, like where one is looking, the tilt of the head or if someone is frowning. It essentially records and analyzes behavior in order to establish a personal rapport with humans. SimSensei has been used by people to further their public speaking skills and their handling of job interviews. The U.S. military has also used it for leadership training.

> *Within 15 to 20 years, artificially intelligent tutors will be as common as car insurance, and these tutors will engage with a child's emotions through speech interaction, support problem-solving, and develop much more targeted learning paths for each student.*
>
> *Tom Hooper, founder of Third Space Learning, 2016*

Source: ai100.stanford.edu, bdtechtalks.com, forbes.com, ewise.com, Narrative Science, National Business Research Institute, wired.com

Its wealth of date makes the finance industry perfect for the use of AI

Finance: overview



Owing to its heavy reliance on large volumes of numbers and data, the financial services industry is ripe for the disruption offered by AI. Large volumes of historical data on banking, insurance, mortgages, and financial trading have been integrated with deep learning algorithms to automate routine tasks, mitigate risk, prevent frauds, and generate new insights.

According to a survey conducted by Narrative Science and the National Business Research Institute, 32% of financial services executives surveyed confirmed using AI technologies such as predictive analytics, recommendation engines, voice recognition and response.

Besides general AI applications in the insurance and banking industry, two areas that are gaining a lot of traction are especially suited for AI:

- Wealth management: Private wealth management used to be only an option for an elite group with lots of funds because an actively managed portfolio usually involves high management fees. By using AI, there is now the possibility of offering wealth management with very low fees as the algorithm, often called a robo-advisor, decides or suggests changes in the portfolio.
- Fraud detection: Detecting fraudulent cases was always a high priority in the financial industry. By using algorithms that analyze a huge amount of data, potential fraud cases can be found a lot easier and faster than before.

Source: Narrative Science Report, medium.com

AI wealth management solutions offer higher personalization

Finance: wealth management

Even though the rapid growth of robo-advisors is a good example of the increased penetration of AI in the wealth management industry, it represents only a fraction of the technology's potential.

Robo-advisors have simple and rule-based algorithms that select exchange-traded funds (ETFs) based on information such as age, risk appetite, income, etc. However, the next generation of AI-powered wealth management solutions will also have the ability to self-learn and therefore offer higher degrees of personalized advice for each consumer.

Australian bank ANZ was among the first to explore the potential of AI when it started using IBM's Watson supercomputer to aid financial advisors. Since then, many other firms, such as Goldman Sachs, BlackRock, UBS, Deutsche Bank, and Bridgewater Associates, either have built their own AI engines or are investing in third-party developers.

Below is a list of some key developments:

Bridgewater Associates: The world's largest hedge fund is building an AI engine to automate the entire functioning of the company and eliminate human emotional volatility. Called the "Book of the Future", the system is being run by David Ferrucci, one of the leading developers on IBM's Watson computer.

Aladdin (BlackRock): It is based on open-source technology and uses NLP to analyze large volumes of data from documents such as news stories and broker reports. For example, it analyzes data on trade activity in order to detect complex patterns and predict the transactions most likely to fail. It can also gather satellite images to see how full a retailer's parking lot is and then correlate that data to the company's revenue and stock price.

Kensho (Goldman Sachs): It uses machine learning to help find correlations responsible for movements in stock and currency prices. The engine answers questions such as "How do defense stocks react to terrorism incidents in Europe?" or "How do populist votes affect local currencies?".

Sqreem (Wells Fargo, BlackRock, UBS, and Deutsche Bank): It uses deep learning to analyze data on people's digital activity to predict which products and services they are most likely to want. It also protects companies against financial crimes through algorithms that can detect anomalies relating to illicit behavior.

Source: americanbanker.com

Cybercrime costs the economy several hundred billions

Finance: fraud detection (1/2)

The proliferation of connected devices and mass digitization of companies has increased the risk of fraud, hacking, data compromise, and other cyber-vulnerabilities. According to McAfee, cybercrime costs the global economy over US$400 billion annually, with credit card fraud accounting for a large portion of this cost.

PwC's 19th Annual Global CEO Survey found that 69% of financial services CEOs reported that they were either somewhat or extremely concerned about cyberthreats, compared to 61% of CEOs across all sectors.

In order to combat this and detect patterns of anomalies, many financial institutions are turning to machine learning techniques such as logistic regression, decision tree, random forest, neural networks, and clustering. These AI techniques help financial institutions to study the buying behavior of each customer and then compare it to other indicators to build a complete picture of a transaction.

Detecting fraud is especially important in areas such as online shopping, online payment, and credit card usage, and there are many examples of companies in those areas.

> *We estimate that in the U.S. alone, the value of false declines is more than 13 times the total amount lost to actual card fraud. Applying machine learning to decision-scoring is a new way of creating a positive consumer experience, while also minimizing fraud.*
>
> *Al Pascual, senior vice-president, research director, and head of fraud and security at Javelin Strategy & Research, 2016*

One good example is PayPal, which has used machine learning to bring its fraud rate down to just 0.32% as compared to the industry average of 1.32%. It applies machine learning to study users' purchase history and detect patterns, which can then be used to implement new rules that prevent scams being repeated.

More examples can be found on the next page.

Source: aibusiness.org

Several finance institutions use AI to combat and prevent fraud

Finance: fraud detection (2/2)

CO-OP Financial Services has partnered with Feedzai, a provider of AI-powered payment applications, to develop a machine-learning-based risk management tool. The company works across all payment types, including cards, vouchers, prepaid card tokens, or bitcoin.

Lloyd's Banking Group recently partnered with Pindrop to combat fraud. Pindrop's software creates a sort of audio profile by identifying 147 different features of a human voice from a single call. This is then used to detect any unusual activity and potential fraud.

Mastercard has launched Decision Intelligence, an AI-powered decision and fraud detection service. It leverages account information such as customer value segmentation, risk profiling, location, merchant, device data, time of day, and type of purchase made to examine how a specific account is used over time to detect normal and abnormal shopping spending behaviors. According to Johan Gerber, EVP of Security and Decision Products for Enterprise Security Solutions, the company has "seen a 40% increase in the accuracy of detecting fraud with Decision Intelligence, compared with the old algorithms, and a 50% reduction in false positives".

ThetaRay provides an AI-powered platform to combat lending frauds, ATM hacks, money laundering, and cyber attacks. The company has recently partnered with ING to detect SME lending fraud.

Westpac is working with start-up Red Marker to use NLP techniques to detect content at risk of breaching legal regulations as it is being created.

Source: Company information

AI tools 'learn' patterns to deliver personalized financial advice

Finance: banking, personal financial management (1/3)

Robotic Process Automation (RPA): One of the most widespread applications of AI in the banking industry is RPA, which eliminates much of the analysis work currently carried out by both junior and senior employees. Even though these processes are highly standardized and formulaic, they still require a large number of people performing low value-added tasks such as reconciliation and consolidation.

RPA helps with lower transaction processing time, enhanced productivity, redeployment of staff to higher-skilled roles, and elimination of manual errors.

However, such basic automation, which is the work of business process management and rule engine software, is limited by its inability to adapt to change. An emerging trend, however, is the combination of RPA and cognitive technologies such as machine learning and NLP to automate perceptual tasks usually requiring human intervention. This integration is helping financial institutions extend automation to all areas of their business, such as lending, card operations, risk & compliance, and core banking operations, as they transition towards a fully digital operating model.

A few examples are:

feedzai

Feedzai: It helps with transaction monitoring and fraud prevention by recognizing behavior patterns that could indicate fraudulent payment activity.

FinGenius

FinGenius: an NLP system used not only to interpret and answer employee or customer questions but also to suggest answers.

fonetic

Fonetic: It offers speech recognition technology to automate customer interactions on the telephone.

Source: Ewise.com, Narrative Science, National Business Research Institute, wired.com

AI tools use predictive analytics to offer real-time financial advice

Finance: banking, personal financial management (2/3)

Personal Financial Management: Another area in financial services where AI is making a mark is personal financial management (PFM). Over the last two years, there have been a number of PFM tools which mostly use cloud-based AI, predictive analytics, and chatbot messaging to track consumer purchases and offer real-time advice on spending and saving habits.

For example, if someone makes a purchase, an AI application can let that person know how this affects their monthly budget or how their current monthly expenditure stacks up against their historical average. This is especially applicable to millennials who have low trust in banks, have a mobile-first expectation regarding their products, and are generally more willing to try new products and services.

Pefin

Pefin: Launched by Ramya Joseph, a former investment banker, the online platform can sync its data with a consumer's financial institution to get a more holistic view of how much they should spend and invest.

SIMPLE

Simple: uses machine learning combined with behavioral economics to understand a user's individual earning and spending patterns and offer personalized advice.

WALLET.AI

Wallet.Ai: an app that monitors a consumer's spending habit and alerts them on how to restrain their needs and improve their saving behaviors.

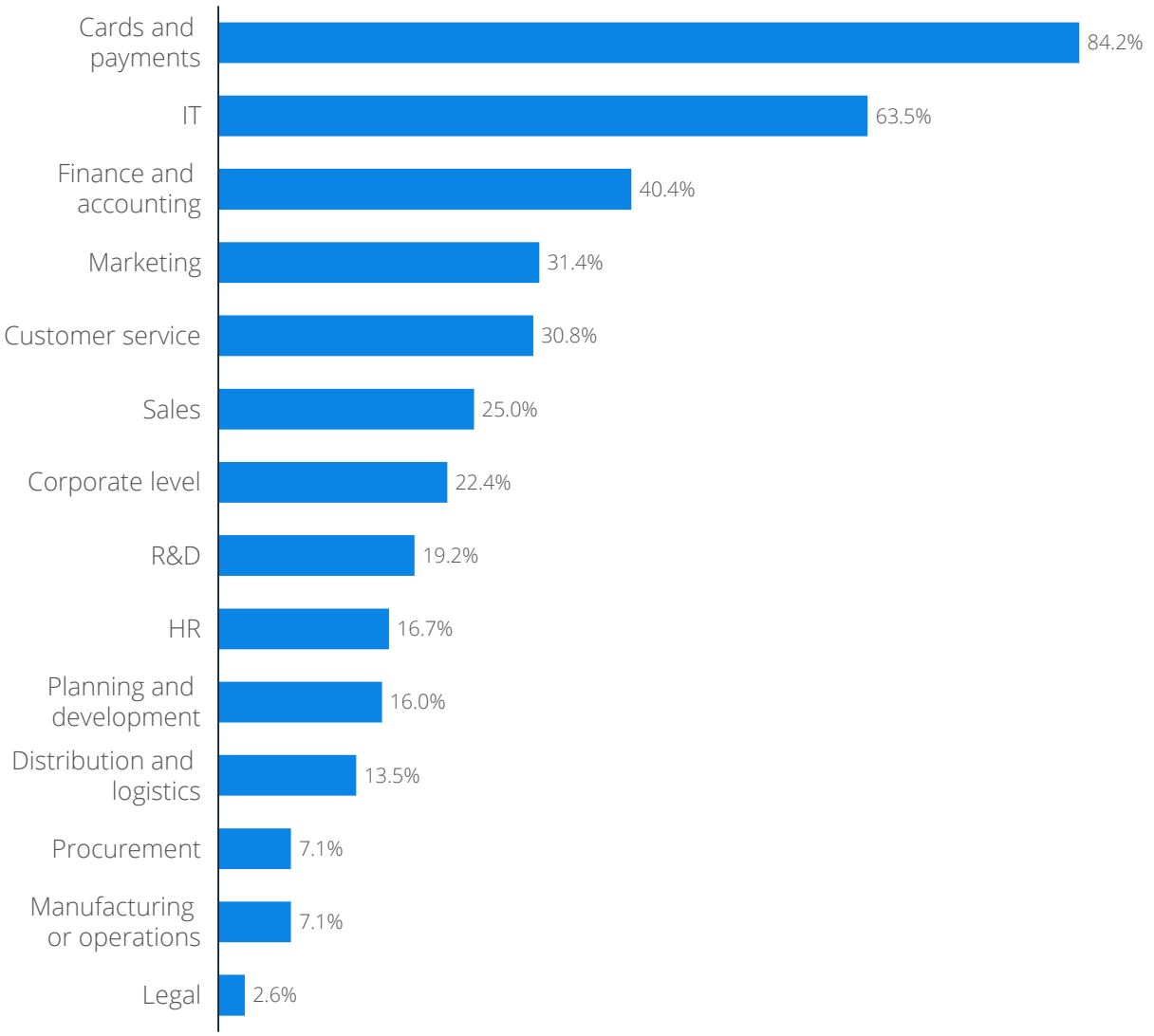
Source: Ewise.com, Narrative Science, National Business Research Institute, wired.com

Cards and payments are the leading banking sector regarding AI usage

Finance: banking, personal financial management (3/3)

The banking industry is using AI for various purposes, depending on the feasibility and complexity of the processes. According to a study by Consultancy.uk, 84.2% of cards and payments divisions used artificial intelligence in 2017.

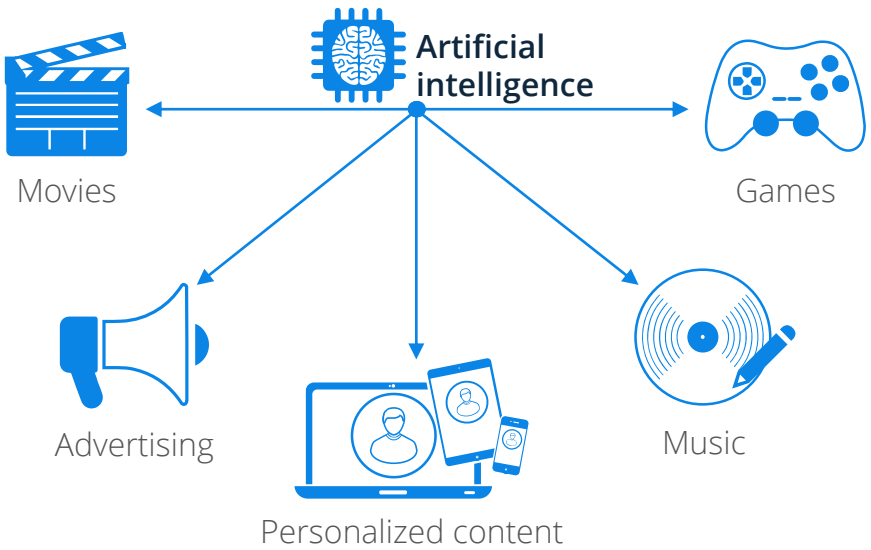
Banking sectors using artificial intelligence worldwide in 2017



Source: Statista estimates, IHS

A major use of AI in entertainment is the creation of original content

Entertainment: overview (1/2)



The entertainment industry profits from AI applications in various segments, such as movies, advertising, personalized content, music, and games. The applications range from creating original content and personalizing the offered content to developing serious opponents in the gaming context. There are several possible applications of AI in the movie segment. One of them is the use of AI to support with tasks which used to be primarily manual, e.g., reviewing a movie to select the clips for a trailer. Another application is the creation of original content and scripts based on the analysis of previous movie performances.

Two examples are:

- IBM Research and 20th Century Fox – recently collaborated to create what they called the 'first ever cognitive movie trailer', for the movie *Morgan*. IBM's Watson platform analyzed hundreds of horror movie trailers to determine what type of content elicited the fear response in people. It then used the insights gained to select the 10 clips used in the trailer, after which a human editor created the final version. Moreover, the entire process took only 24 hours, as opposed to the usual 10–30 days of manual editing.
- Benjamin – Jack Zhang is taking the use of AI in movies even further. His company Greenlight Essential has developed an AI software called Benjamin that has co-written the script for a horror movie titled 'Impossible Things'. According to Zhang, this is the first instance of AI creating original content in collaboration with humans. The software essentially used NLP to analyze thousands of movie plot summaries in correlation to box office performance. *Sunspring* is an example of a movie entirely written by AI without any human intervention. The software is a recurrent neural network that is usually used for text recognition. The movie was placed in the top 10 out of hundreds of entries at the Sci-Fi London contest in 2016.

Source: theguardian.com

AI enables gaming characters to develop their own personalities

Entertainment: overview (2/2)

Netflix is a good example of AI driving personalized content in the entertainment industry. The company's AI framework called Meson provides recommendations based on the viewer's previous viewing activity and behavior.

Apart from simple recommendations, Meson also uses data such as subscription history, previous interactions with content, type of device, and time of day to create personalized homepages for each user.

The company recently announced that it was using AI to enable users to enjoy uninterrupted viewing even on a slow internet. An AI-powered system called Dynamic Optimizer reviews each frame of a video and compresses it only as much as required, without compromising on image quality. This differs from previous technology that compressed the entire stream but could cause fuzzy, pixelated or unclear images.

Gaming: Until recently, AI in gaming was restricted to characters following a predetermined script. However, developers are now trying to create AI-powered characters that actually think, learn, and have the potential to develop their own personalities. Two examples are:

- Google AlphaGo used machine learning to beat Lee Sedol, one of the world's best players of Go, an ancient Chinese board game, a feat that was never previously achieved by a computer program. The main reason why this win was important was that, in addition to advanced calculation, the algorithm also exhibited original and creative thinking.
- Libratus Poker AI, developed at Carnegie Mellon University, defeated four of the world's best heads-up poker players by a huge margin. What made this win particularly interesting for the AI world was that Libratus did not utilize neural networks but reinforcement learning, where it learned from trial and error at a massive scale.

Source: theguardian.com

Start-ups: funding and M&A

With the rise of AI, more and more start-ups venture into the market. Most work in the field of machine learning algorithms, followed by natural language processing. The annual global funding of AI start-ups experienced an average growth rate of almost 70%, increasing from US$0.6 billion in 2012 to US$4.9 billion in 2016. The corresponding number of deals grew by 47% in the same time frame, from 151 in 2012 to 703 in 2016.

In terms of M&A, the number of deals jumped up by 38% in 2017. Looking at the most recent M&A deals, big tech companies like Google, Apple, Amazon, Microsoft, IBM, or Facebook have often been the acquirer. But Chinese tech giants like Baidu or rising stars in the start-up world, like Twitter, Uber, or Spotify, also acquire AI companies.

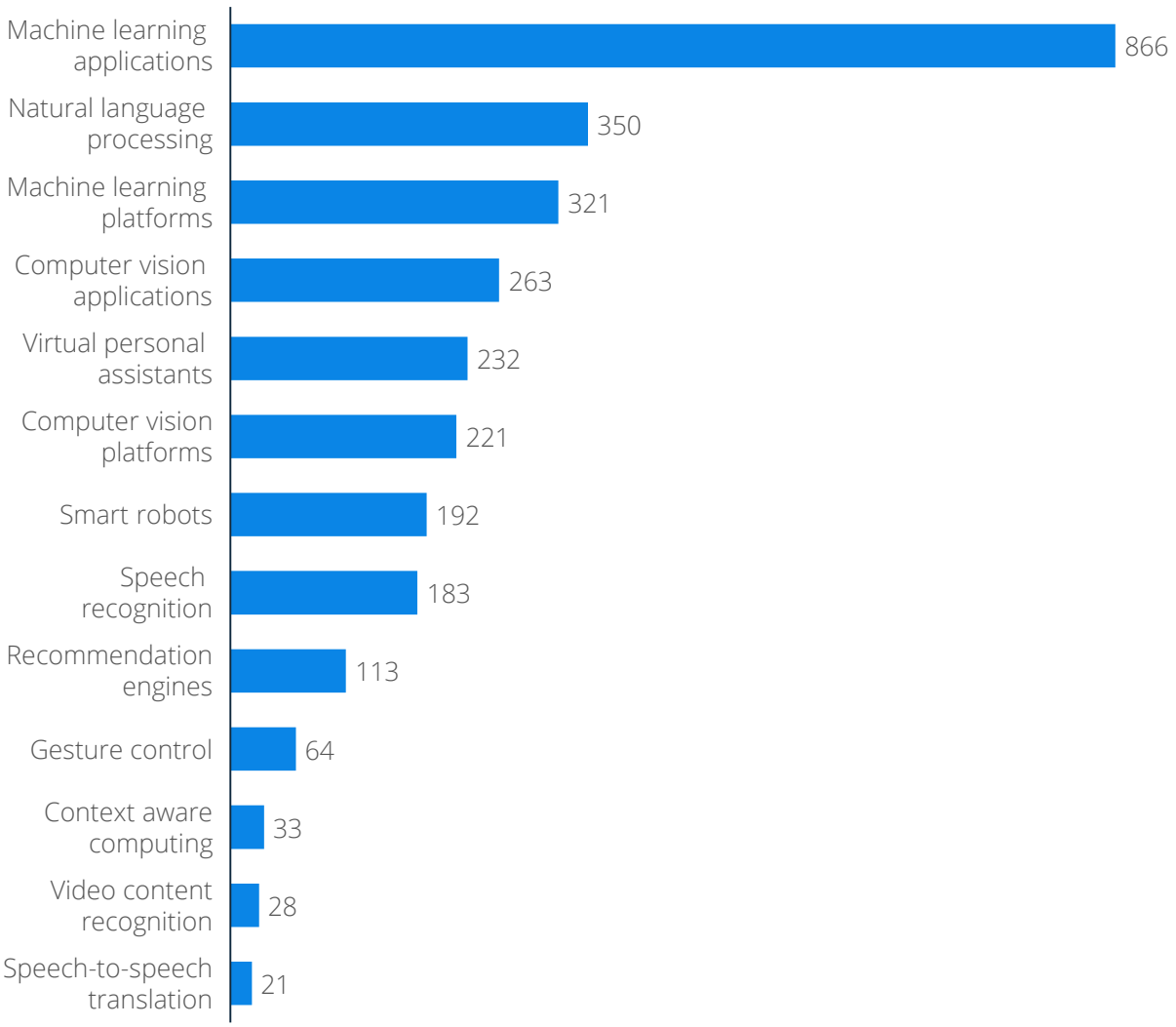
Highest number of AI start-ups in machine learning applications

Overview (1/2)

With the rise of AI, more and more start-ups venture into the market. Most work in the field of machine learning applications, followed by natural language processing. As of March 2018, start-ups focusing on applications for machine learning also received the most funding with almost US$19 billion.

The annual global funding of AI start-ups experienced a high growth of almost 72% CAGR[1], from US$1.7 billion in 2013 to US$15.2 billion in 2017. The corresponding number of deals grew by 44% in the same time frame, from 310 in 2013 to 1349 in 2017.

Number of AI start-ups as of October 2018

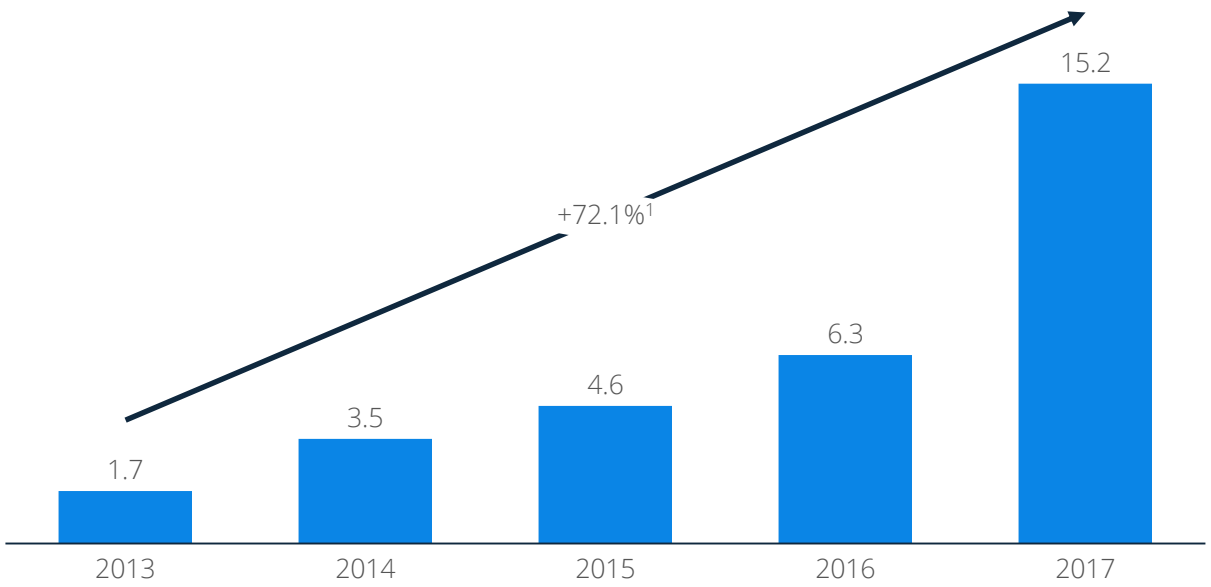


1: CAGR: Compound Annual Growth Rate / average growth rate per year
Source: Venture Scanner, as of Oct 2018

Funding of AI start-ups grew at a CAGR[1] of about 72% up to 2017

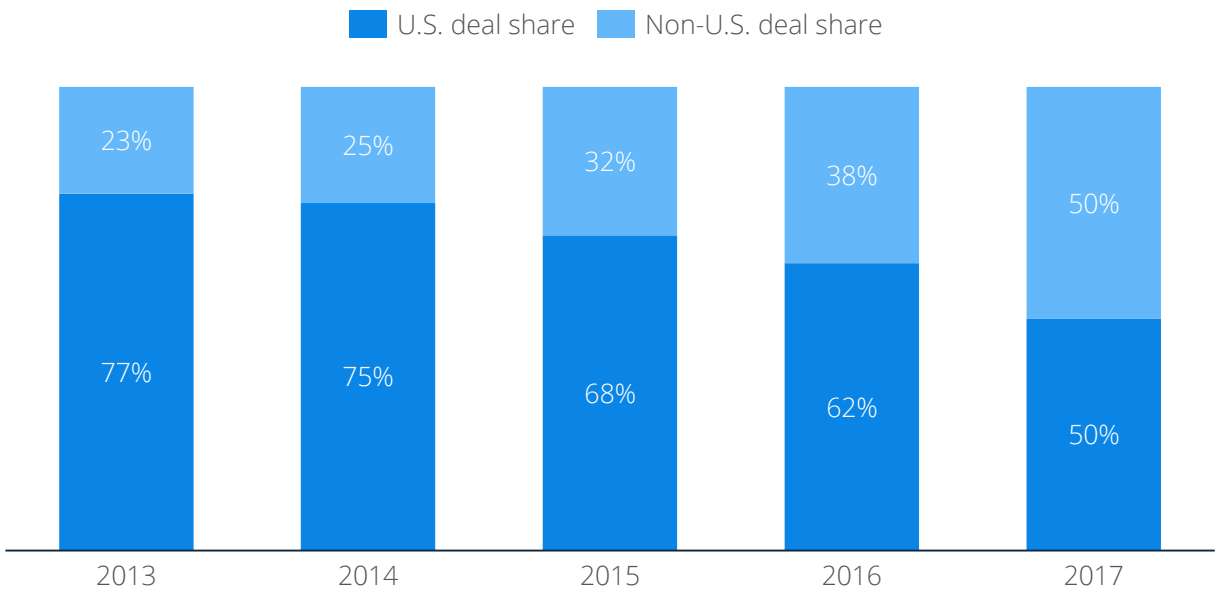
Overview (2/2)

AI start-ups: annual global funding in billion US$



Source: CB Insights

AI start-ups: global deal share U.S. vs. non-U.S. deals



Source: CB Insights

AI start-ups ranked by funding (1/13)

#	Company	Funding in mUS$	Investors	Headquarter
1	ByteDance	3105	TCV, General Atlantic, SoftBank, KKR & Co., Primavera Capital Group	Beijing, China
2	SenseTime	2600	Alibaba Group, Fidelity International, HOPU Investment Management Company, Qualcomm Ventures, Temasek Holdings, Tiger Global Management, SBCVC, Silver Lake Partners, Suning.com	Beijing, China
3	UBTECH Robotics	940	CDH Investments, CITIC Securities, CreditEase, Green Pine Capital, Haier Group, Telstra, Tencent Holdings, Qiming Venture Partners	Shenzhen, China
4	Zoox	790	AID Partners Capital, ARCHina Capital Partners, Blackbird Ventures (Australia), Composite Capital Management, Draper Fisher Jurvetson (DFJ)	Menlo Park, California, U.S.
5	Affirm	720	Caffeinated Capital, Founders Fund, GIC, Khosla Ventures, Lightspeed Venture Partners, Morgan Stanley, Ribbit Capital	California, U.S.
6	Face++	607	Alibaba Group, Ant Financial, Boyu Capital, SK Group, China State-Owned Assets Venture Investment Fund, Foxconn Technology Group, Qiming Venture Partners	Beijing, China
7	Megvii	607	Ant Financial, CCB International, Foxconn Technology Group, Russia-China Investment Fund, Sinovation Ventures, Sunshine Insurance Group, SK Group	Beijing, China

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (2/13)

#	Company	Funding in mUS$	Investors	Headquarter
8	Dataminr	577	Andreas, BoxGroup, Credit Suisse, Deep Fork Capital, Fabrice Grinda, GSV Capital, Richmond Global Ventures	New York, U.S.
9	Zymergen	574.1	5 Prime Ventures, AME Cloud Ventures, Data Collective, Draper Fisher Jurvetson, ICONIQ Capital, Innovation Endeavors, Obvious Ventures, Prelude Ventures, SciFi VC, SoftBank Vision Fund	California, U.S.
10	CrowdStrike	481	Accel, CapitalG, Cloud Apps Capital Partners, General Atlantic, IVP (Institutional Venture Partners), Instant Scale Ventures, Telstra Ventures, Warburg Pincus	California, U.S.
11	WuXi NextCODE	455	3W Partners, Amgen Ventures, ARCH Venture Partners, Ireland Strategic Investment Fund, Polaris Partners, Sequoia Capital, Temasek Holdings, YF Capital	Massachusetts, U.S.
12	UiPath	448	Accel, CapitalG, Credo Ventures, Earlybird Venture Capital, Kleiner Perkins Caufield & Byers, Sequoia Capital	New York, U.S.
13	Tempus Labs	320	Baillie Gifford, New Enterprise Associates, Revolution Growth, T. Rowe Price	Illinois, U.S.
14	Flatiron Health	313	Allen & Company, Baillie Gifford, Casdin Capital, First Round Capital, GV, LabCorp, Roche, Stripes Group, SV Angel	New York, U.S.
15	Graphcore	310	Amadeus Capital Partners, Atomico, BMW i Ventures, C4 Ventures, Dell Technologies Capital, Microsoft, Samsung Catalyst Fund, Sequoia Capital	Bristol, UK

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (3/13)

#	Company	Funding in mUS$	Investors	Headquarter
16	Cylance	297	Blackstone, Capital One Growth Ventures, Dell Ventures, DFJ Growth, Draper Nexus Ventures, Fairhaven Capital Partners, Insight Venture Partners, TenEleven Ventures	California, U.S.
17	Mobvoi	252.7	Google, Sequoia Capital, SIG China, Volkswagen Group, ZhenFund	Beijing, China
18	InsideSales.com	251.2	Acadia Woods Partners, EPIC Ventures, HWVP, Irish Strategic Investment Fund, Kleiner Perkins Caufield & Byers, Microsoft, Polar Capital Management, Polaris Partners, QuestMark Partners, Salesforce Ventures, Shares Post Investment Management, USVP	Utah, U.S.
19	Darktrace	230.5	Hoxton, Invoke Capital, Insight Venture Partners, KKR & Co., SoftBank, Summit Partners, Vitruvian Partners, Taliz Capital, Ten Eleven Ventures	Cambridge, UK
20	C3 IoT	228.5	Breyer Capital, Sutter Hill Ventures, Pat House, Pat House, The Rise Fund, TPG Growth	California, U.S.
21	DataRobot	224.6	Accomplice, Atlas Venture, IA Ventures, Intel Capital, Meritech Capital Partners, New Enterprise Associates, New York Life Insurance Co, Recruit Strategic Partners, Right Side	Massachusetts, U.S.
22	ZestFinance	217	Baidu, Eastward Capital Partners, Flybridge Capital Partners, Fortress Investment Group, Founders Fund, Kensington Capital Partners Limited, Lightspeed Venture Partners, Matrix Partners, Northgate Capital, Oakhouse Partners	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (4/13)

#	Company	Funding in mUS$	Investors	Headquarter
23	SoundHound	215	Daimler, France Telecom (now Orange S.A.), Global Catalyst Partners, Hyundai Motor Company, Kleiner Perkins, Midea Group, MKaNN, Nvidia GPU Ventures, RSI Fund	California, U.S.
24	BenevolentAI	207	Lansdowne Partners, Lundbeck, Upsher Smith Laboratories, Woodford Investment Management	London, UK
25	Cambricon Technologies	200	Alibaba, CAS Investment Management, China State-Owned Assets Venture Investment Fund, CMB International Capital, Group, Oriza Seed Capital, SDIC Venture Capital, Turing	Beijing, China
26	iCarbonX	200	China Bridge Capital, Tencent Holdings, Zhongyuan Union Cell & Gene Eng	Shenzhen, China
27	Afiniti	197.2	Daniel Klueger, Frederick Ryan, Global Asset Management, Ivan Seidenberg, TRG (The Resource Group), Zeke Capital Advisors	Washington D.C., U.S.
28	Cybereason	188.6	SoftBank, Spark Capital	Massachusetts, U.S.
29	Nauto	182.6	Allianz Ventures, BMW i Ventures, Draper Nexus Ventures, General Motors Ventures, Greylock Partners, Index Ventures, Playground Global, SoftBank, Toyota AI Ventures	California, U.S.
30	Anki	182	Andreessen Horowitz, C4 Ventures, Index Ventures, JP Morgan Chase & Co., Silicon Valley Ventures, Two Sigma Ventures	California, U.S.
31	Sentient Technologies	174.4	Access Industries, BlackPine PE Partners, Horizon Ventures, NJF Capital, Tata Communications	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (5/13)

#	Company	Funding in mUS$	Investors	Headquarter
32	Rokid Corporation	158.3	Advantech Capital, CDIB Capital, Credit Suisse, IDG Capital Partners, Linear Venture, Temasek Holdings, Vision Plus Capital, Walden International	Hangzhou, China
33	Shape Security	132	Baseline Ventures, EPIC Ventures, Focus Ventures, JetBlue Technology Ventures, Kleiner Perkins, Norwest Venture Partners, Singtel Innov8	California, U.S.
34	CloudMinds	130	Foxconn Technology Group, Keytone Ventures, SoftBank, Walden International	California, U.S.
35	Preferred Networks	129.9	FANUC, Hakuhodo, Hitachi, Mitsui & Co, Mizuho Corporate Bank, Nippon Telegraph and Telephone Corporation, Toyota Motor	Tokyo, Japan
36	Liulishuo	128.9	Cherubic Ventures, China Media Capital (CMC), Hearst Ventures, GGV Capital, IDG Capital, RTA Capital, Trustbridge Partners	Shanghai, China
37	Brain corporation	125	Qualcomm Ventures, SoftBank Vision Fund	California, U.S.
38	Trifacta	124.3	Accel, Cathay Innovation, Columbia Pacific Advisors, Deutsche Börse, Ericsson, Google, Greylock Partners, Ignition Partners, New York Life Ventures, Ridge Ventures	California, U.S.
39	Vicarious Systems	122	Felicis Ventures, Fenox Venture Capital, Iconical, Khosla Ventures, Morpheus Ventures, Samsung NEXT, Wipro Ventures	California, U.S.
40	WorkFusion	121.3	Alpha Intelligence Capital, Declaration Partners, Hawk Equity, iNovia Capital, Georgian Partners, Guardian, iNovia Capital, New York Presbyterian Ventures, NGP Capital	New York, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (6/13)

#	Company	Funding in mUS$	Investors	Headquarter
41	Cerebras Systems	112	Benchmark	California, U.S.
42	Endgame	111.4	Bessemer Venture Partners, Columbia Capital, Edgemore Capital, Kleiner Perkins, Paladin Capital Group, Tech Operators, Top Tier Capital Partners	Virginia, U.S.
43	Petuum	108	Advantech Capital, Northern Light Venture Capital, Oriza Ventures, SoftBank, Tencent Holdings	Pennsylvania, U.S.
44	Element AI	107	Business Development Bank of Canada, Canadian Government, Data Collective, Hanwha Investment Corp, Intel Capital, M12, National Bank of Canada, Nvidia, Real Ventures	Montréal, Canada
45	Ayasdi	106.3	Centerview Capital, Citi Ventures, Draper Nexus Ventures, FLOODGATE, GE Ventures, IVP, Khosla Ventures, Kleiner Perkins, Caufield & Byers	California, U.S.
46	Recursion Pharmaceuticals	105.4	Bill & Melinda Gates Foundation, CRV, Data Collective DCVC, EPIC Ventures, Felicis Ventures, Lux Capital, Menlo Ventures, Mubadala Investment Company	Utah, U.S.
47	Digital Reasoning	104	Barclays, BNP Paribas, Credit Suisse, Goldman Sachs, HCA, In-Q-Tel, Lemhi Ventures, NASDAQ, Square Capital	Tennessee, U.S.
48	BloomReach	97	Bain Capital Ventures, Battery Ventures, Chris Dixon, Lightspeed Venture Partners, New Enterprise Associates	California, U.S.
49	Benson Hill Biosystems	94.7	Alexandria Venture Investments, Collaborative Fund, GV, iSELECT FUND, Lewis & Clark Ventures, Mercury Fund, Mercury Fund, Prelude Ventures LLC	North Carolina, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (7/13)

#	Company	Funding in mUS$	Investors	Headquarter
50	MOOGsoft	92.9	Goldman Sachs, HCL Technologies, Northgate Capital, Redpoint, Singtel Innov8, ST Telemedia, Wing Venture Capital	California, U.S.
51	Conversica	87	Ben Brigham, CIBC, Green D Ventures, Kennet Partners, Providence Strategic Growth, Savano Capital, The Yard Ventures, Toba Capital	California, U.S.
52	OrCam Technologies	86.4	Clal Insurance Enterprises Holdings, Intel Capital, Meitav Investment House, Moshe Gaon	Jerusalem, Israel
53	Upstart	85.7	Alumni Ventures Group, Blue Ivy Ventures, Collaborative Fund Collaborative Fund, Green D Ventures, First Round Capital, Khosla Ventures, Rakuten, Third Point Ventures	California, U.S.
54	Babylon Health	85	Adam Balon, Demis Hassabis, Hoxton Ventures, Jon Wright, Kinnevik AB, Mustafa Suleyman, NNC Holdings, Richard Reed, Vostok New Ventures	London, UK
55	Dynamic Yield	83.3	Bessemer Venture Partners, Deutsche Telekom Capital Partners, Global Founders Capital, Innovation Endeavors, Marker, Naver Corporation, Union Tech Ventures, Vertex Ventures, Viola Growth	New York, U.S.
56	Appier	81.5	EDBI, FirstFloor Capital, Media-Tek, Naver Corp, LINE Corp, Pavilion Capital, Qualgro VC, Sequoia Capital, Translink Capital, UOB Venture, WI Harper Group	Taipei, Taiwan
57	Orbital Insight	78.7	Balyasny Asset Management, Clearvision Ventures, CME Ventures, Geodesic Capital, GV, Intellectus Partners LLC, Lux Capital, Sequoia Capital	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (8/13)

#	Company	Funding in mUS$	Investors	Headquarter
58	Freenome	77.6	Andreessen Horowitz, Anne Wojcicki, Asset Management Ventures (AMV), Data Collective DCVC, Founders Fund, GV, Innovation Endeavors, Polaris Partners, Section 32, Verily	California, U.S.
59	Drive.ai	77	GGV Capital, HOF Capital, InnoSpring Seed Fund, New Enterprise Associates, Manicv Mobility, Northern Light Venture Capital, Nvidia GPU Ventures, Oriza Ventures	California, U.S.
60	Algolia	74.3	Accel, Aglaé Ventures, Alven Capital, Clark Valberg, Point Nine Capital, SaaStr Fund, Storm Ventures	California, U.S.
61	H2O.ai	73.6	Capital One Growth Ventures, Nexus Venture Partners, Nvidia, Paxion Capital Partners, Transamerica, Transamerica Ventures, Wells Fargo & Co	California, U.S.
62	MAANA	71.2	Accenture Technology Ventures, Chevron Technology Ventures, CICC, Eight Capital, GE Ventures, Global Bridge Capital, Intel Capital, Saudi Aramco Energy Ventures, Shell Technology Ventures, Sino Capital Group	California, U.S.
63	Tamr	69.2	GE Ventures, GV, Granite Hill Capital Partners, Hewlett Packard Ventures, MassMutual Ventures, New Enterprise Associates, Pear Tree Partners, SBI Investment, SineWave Ventures, Thomson Reuters, Work-Bench	Massachusetts, U.S.
64	Drawbridge	68.7	Ericsson Ventures, Kleiner Perkins Caufield & Byers, Mitsui & Co, Northgate Capital, Sequoia Capital	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (9/13)

#	Company	Funding in mUS$	Investors	Headquarter
65	Spark Cognition	63.2	Alameda Ventures, CME Ventures, The Entrepreneurs' Fund, US Department of Energy, Verizon Ventures	Texas, U.S.
66	Paxata	61	Accenture, Accel, AirTree Ventures, Cisco, Deutsche Telekom Capital Partners, EDBI, EDB Investments, In-Q-Tel, Synapse Partners, Toba Capital, Walden Riverwood Ventures	California, U.S.
67	Invoca	60.8	Accel, Morgan Stanley Alternative Investment Partners, Rincon Venture Partners, Salesforce Ventures, StepStone Group, Upfront Ventures	California, U.S.
68	Onfido	60.3	Christian Faes, CreditEase Fintech Investment Fund, David Rowan, Jon Reynolds, Khaled Helioui, Plug and Play, Salesforce Ventures, Taavet Hinrikus	England, UK
69	AEYE	59.1	Airbus Ventures, Intel Capital, Kleiner Perkins, R7 Partners, Taiwania Capital, Tyche Partners	California, U.S.
70	CrowdFlower	58	Canvas Ventures, Industry Ventures, M12, Promus Ventures, Salesforce Ventures, Trinity Ventures	California, U.S.
71	Figure Eight (formerly CrowdFlower)	58	Bessemer Venture Partners, Canvas, Felicis, Harmony Partners, Industry Ventures, K9 Ventures, Microsoft Venture, Promus Ventures, Trinity Ventures	California, U.S.
72	Versive (formerly Context Relevant)	57	Bank of America Merrill Lynch, Bloomberg, Goldman Sachs. Formation 8, Madrona Venture Group, New York Life Insurance Co, Rolling Bay Ventures, Work Bench	Washington, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (10/13)

#	Company	Funding in mUS$	Investors	Headquarter
73	Chorus.ai	55.3	Emergence Capital Partners, Georgian Partners, Redpoint	California, U.S.
74	Mythic	55.2	AME Cloud Ventures, Andreas Bechtolsheim, Data Collective DCVC, DFJ, Lockheed Martin Ventures, Lux Capital, SoftBank Ventures Korea	Texas, U.S.
75	Captricity	51.9	Accomplice, Atlas Venture, Knight Foundation, Social Capital, White Mountains Insurance Group	California, U.S.
76	Atomwise	51.3	AME Cloud Ventures, B Capital Group, Baidu Ventures, Data Collective, Draper Associates, Draper Fisher Jurvetson (DFJ), Dolby Family Ventures, Farzad (Zod) Nazem, Grand Challenges Canada, OS Fund, Tencent Holdings, Y Combinator	California, U.S.
77	Zebra Medical Vision	50	aMoon Fund, Aurum Ventures, Deep Fork Capital, Dolby Family Ventures, Intermountain Healthcare, Khosla Ventures, OurCrowd-GCai	Shefayim, Israel
78	Narrative Science	47.87	Battery Ventures, In-Q-Tel, Jump Capital, Northwestern University, Sapphire Ventures, USAA	Illinois, U.S.
79	AImotive	47.5	B Capital Group, Day One Capital Fund Management, Draper Associates, Inventure Oy, Nvidia, Prime Ventures, PortfoLion, Robert Bosch Venture Capital, Samsung Catalyst Fund, Tamares	Budapest, Hungary
80	Foghorn Systems	47.5	Darling Ventures, Dell, General Electric (GE), Honeywell Venture Capital, Intel Capital, March Capital Partners, Saudi Aramco Energy Ventures, The Hive Group,Yokogawa Electric Corp.	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (11/13)

#	Company	Funding in mUS$	Investors	Headquarter
81	Nexar	44.5	Aleph, Alibaba Innovation Ventures, Mosaic Ventures, Nationwide Ventures, Ibex Ventures, True Ventures, Expansion Venture Capital, Tusk Ventures	Tel Aviv, Israel
82	Kindred Systems	44	11.2 Capital, Bold Capital Partners, Data Collective DCVC, Eclipse, First Round Capital, Tencent Holdings	California, U.S.
83	Arterys	43.7	DNA Capital, Emergent Medical Partners, GE Ventures, MedTech Innovator, Morado Ventures, New York Presbyterian Ventures, Northwell Ventures, ORI Capital, Temasek Holdings, Varian Medical Systems	California, U.S.
84	Reflektion	42.8	Battery Ventures, Clear Ventures, Hasso Plattner Ventures, Intel Capital, Nike	California, U.S.
85	Applitools	41.8	Bessemer Venture Partners IAngels, La Maison Compagnie d'Investissement, Magma Venture Partners, OpenView, Sierra Ventures	Tel Aviv, Israel
86	Clarifai	40	Corazon Capital, GV, LDV Capital, Lux Capital, Menlo Ventures, Union Square Ventures	New York, U.S.
87	CognitiveScale	40	IBM, Intel Capital, M12, Microsoft Ventures, Norwest Venture Partners, The Westly Group, USAA	Texas, U.S.
88	Prophesee (formerly Chronocam)	40	360 Capital Partners, Bosch, CEA Investissement, iBionext Growth Fund, Intel Capital, Nissan-Renault, Robert Bosch Venture Capital	Paris, France

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (12/13)

#	Company	Funding in mUS$	Investors	Headquarter
89	Shift Technology	39.8	Accel, Elaia Partners, General Catalyst, Iris Capital, Microsoft Accelerator Paris	Paris, France
90	KONUX GmbH	38.5	Greenbay Ventures, FOUNDER.org, MIG, New Enterprise Associates, Unternehmertum Venture Capital Partners, Upbeat Ventures	Munich, Germany
91	Descartes Labs	38.3	Correlation Ventures, Crosslink Capital, Cultivian Sandbox Ventures, Data Collective, Expansion Venture Capital, March Capital Partners, Milliways Ventures, TenOneTen Ventures, ValueStream Labs	New Mexico, U.S.
92	AlphaSense, Inc.	37.1	First Fellow Partners, Quantum Strategic Partners, Tom Glocer, Triangle Peak Partners, Tribeca Venture Partners	California, U.S.
93	Aquifi	36.8	Benchmark, Binux Capital, Plug and Play, Shenzhen O-film Technology	California, U.S.
94	RapidMiner	36	Ascent Venture Partners, Earlybird Venture Capital, Longworth Venture Partners, Nokia Growth Partners (NGP), OpenOcean	Massachusetts, U.S.
95	Twiggle	35	Alibaba Capital Partners, Gigi Levy Weiss Korea Investment Partners, MizMaa Ventures, Naspers,Sir Ronald Cohen, State of Mind Ventures, Yahoo! Japan, YJ Capital	Tel Aviv, Israel
96	Tractable	34.9	415, Acequia Capital (Acecap), Greg Gladwell, Ignition Partners, Insight Venture Partners, Plug and Play, Scott Roza, Zetta Venture Partners	England, UK

Note: Data as of December 2018
Source: CB Insights, Crunchbase

AI start-ups ranked by funding (13/13)

#	Company	Funding in mUS$	Investors	Headquarter
97	PerimeterX	34.5	Andreas Bechtolsheim, Canaan Partners, Data Collective DCVC, Vertex Ventures, Vertex Ventures US	California, U.S.
98	Affectiva	34.3	Fenox Venture Capital, Horizons Ventures, Kantar Consulting, Kleiner Perkins Caufield & Byers, Myrian Capital, WPP	Waltham, Massachusetts, U.S.
99	Osmo	32.5	Accel, Collaborative Fund, Houghton Mifflin Harcourt,K9 Ventures, Mattel, Sesame Workshop, Shea Ventures, StartX (Stanford-StartX Fund), Upfront Ventures	California, U.S.
100	Mya Systems	32.4	Emergence, Foundation Capital	California, U.S.

Note: Data as of December 2018
Source: CB Insights, Crunchbase

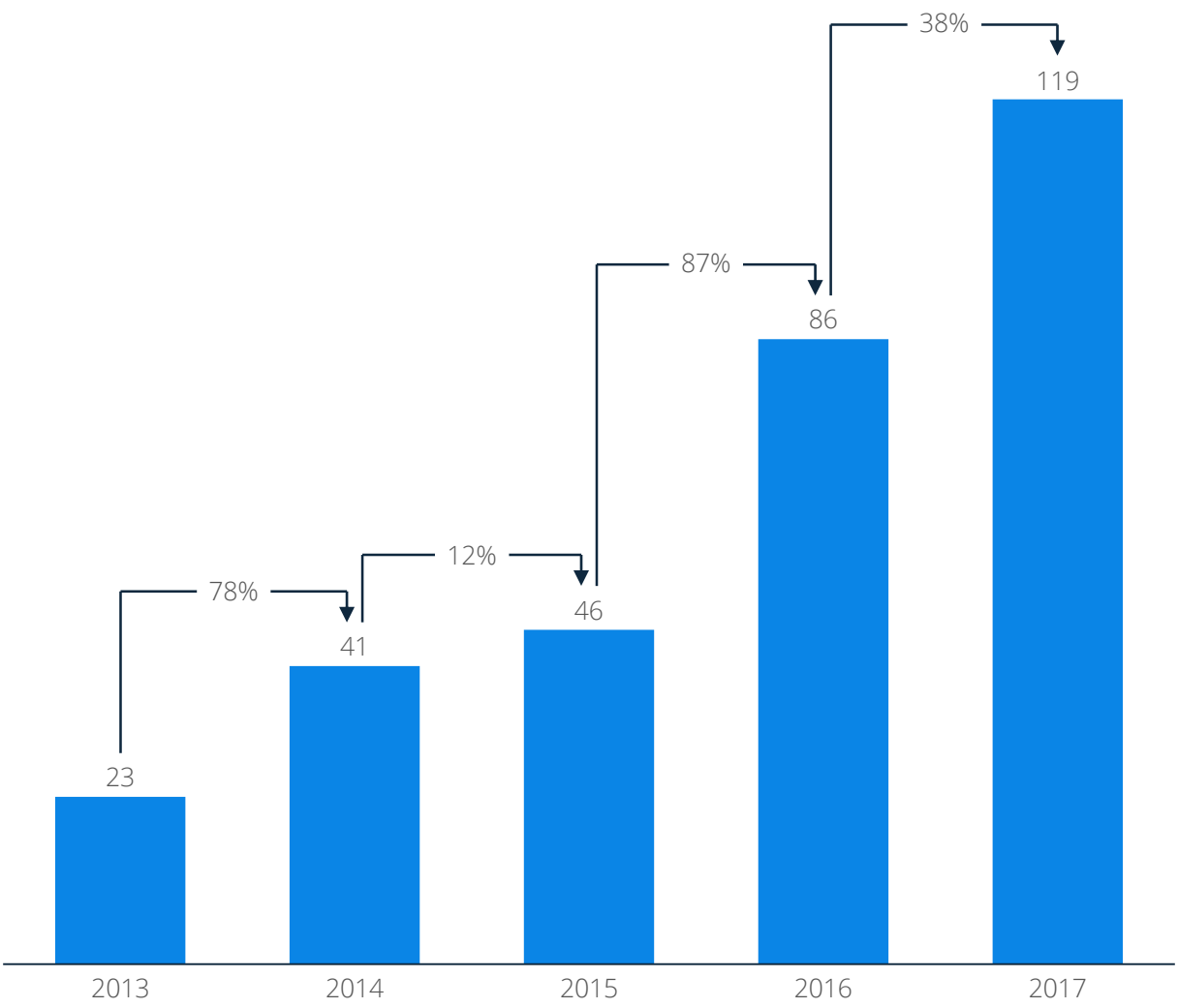
Number of M&A deals grew by 38% from 2016 to 2017

Mergers & acquisitions

After a robust growth from 2015 to 2016, the number of M&A deals jumped up by 38% in 2017. Looking at the most recent M&A deals, big tech companies like Google, Apple, Amazon, Microsoft, IBM, or Facebook have often been the acquirer. But Chinese tech giants like Baidu or rising stars in the start-up world, like Twitter, Uber, or Spotify, also buy AI companies.

The biggest deal (with announced deal size) has been Microsoft's acquisition of GitBub – a company that provides a large code repository that is used by developers and companies for hosting projects, documentation, and code for US$7,500 million in October 2018.

Number of M&A deals



Source: CB Insights

Recent M&A deals (1/9)

Company	Description	Deal value in mUS$	Acquirer	Date
GitHub	Provides a large code repository that is used by developers and companies for hosting projects, documentation, and code	7500	Microsoft	Oct 2018
DataFox	Provides an AI-based engine which automatically locates and pulls the most current information available on public and private businesses	n/a	Oracle	Oct 2018
Lobe	Provides easy-to-use deep learning development tools	n/a	Microsoft	Sep 2018
Vertex.AI	Focused on deep learning compilation tools and associated technology	n/a	Intel	Aug 2018
Datorama	Provides cloud-based, AI-powered marketing intelligence and analytics platform for enterprises, agencies, and publishers	n/a	Salesforce	July 2018
Bonsai	Offers an AI platform that empowers enterprises to build and deploy intelligent systems	n/a	Microsoft	June 2018
Semantic Machines	Provides conversational AI technology to be used in customer service and home automation	n/a	Microsoft	May 2018
Velostrata	Cloud workload mobility software that helps organizations move workloads to and from public cloud	n/a	Google	May 2018

Source: CB Insights, company websites

Recent M&A deals (2/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Sqrrl	Provides a data analytics tool to combat cybersecurity threats	40	Amazon	Jan 2018
Pop Up Archive	An online platform of tools for organizing and searching digital spoken words	n/a	Apple	Dec 2017
Banter	A conversational commerce platform to connect businesses with customers via messaging apps	n/a	Google	Nov 2017
Init.ai	A platform that enables its users to design and develop natural-language conversational mobile apps	n/a	Apple	Oct 2017
Regaind	Uses AI to analyze pictures	n/a	Apple	Sep 2017
Cosmify	Provider of data analytics	n/a	Meltwater	Aug 2017
Algo	AI-based news and data tracker	n/a	Melwater	Aug 2017
AIMatter	A neural network-based AI platform and SDK to quickly detect and process images on mobile devices	n/a	Google	Aug 2017
Halli Labs	A company that provides solutions based on artificial intelligence and machine learning	n/a	Google	July 2017
Ozlo	An intelligent assistant for iOS and the Web	n/a	Facebook	July 2017

Source: CB Insights, company websites

Recent M&A deals (3/9)

Company	Description	Deal value in mUS$	Acquirer	Date
KITT.AI	A machine learning start-up that works on natural language understanding technologies	n/a	Baidu	July 2017
SensoMotoric Instruments	Provides eye-tracking technology useful for VR and AR applications	n/a	Apple	June 2017
Lattice Data	Uses AI to turn dark or unstructured data into structured data	200	Apple	May 2017
Niland	A machine learning start-up specializing in music search and recommendations	n/a	Spotify	May 2017
x Perception	Develops vision perception software and hardware with applications in robotics and virtual reality	n/a	Baidu	Apr 2017
Kaggle	An online service that hosts data science and machine learning competitions	n/a	Google	Mar 2017
Wrapidity	Uses AI to automate the extraction of data from unstructured web-based content	n/a	Meltwater	Feb 2017
RealFace	A cybersecurity and machine learning firm specializing in facial recognition technology	2	Apple	Feb 2017
Raven Tech	A company that specializes in AI voice assistant platform development	n/a	Baidu	Feb 2017
Maluuba	Natural language processing	n/a	Microsoft	Jan 2017

Source: CB Insights, company websites

Recent M&A deals (4/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Harvest.ai	Provides cybersecurity solutions	20	Amazon	Jan 2017
Yodil	Develops enterprise data management software	n/a	Duck Creek Techno-logies	Dec 2016
Geometric Intelligence	Develops machine learning techniques	n/a	Uber	Dec 2016
Bit Stew Systems	An AI platform that solves the data integration needs of utilities, aviation, oil and gas, and manufacturing industries	153	General Electric	Nov 2016
Wise.io	Develops machine learning applications for the customer experience market	n/a	General Electric	Nov 2016
Zurich Eye	A computer vision company that develops accurate position information for robots to navigate in indoor and outdoor environments	n/a	Facebook	Nov 2016
Tuplejump	Provider of big data	n/a	Apple	Sep 2016
Angel.ai	Provider of natural language processing	n/a	Amazon	Sep 2016
API.AI	Provides a conversational UX platform enabling natural language interactions	n/a	Google	Sep 2016
Movidius	Manufactures computer vision processors used in drones and virtual reality devices	n/a	Intel	Sep 2016

Source: CB Insights, company websites

Recent M&A deals (5/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Tuplejump	A machine learning company that simplifies the handling of big data	20	Apple	Sep 2016
Genee	Provides natural language processing to schedule meetings	n/a	Microsoft	Aug 2016
Otto	Provides self-driving technology	680	Uber	Aug 2016
SAIPS	Provides computer vision solutions	n/a	Ford	Aug 2016
Nervana Systems	Provides deep learning algorithms	350+	Intel	Aug 2016
BeyondCore	Designs and develops automated analytics software	110	Salesforce	Aug 2016
Turi	Provides a machine learning platform to help other developers embed its capabilities into their own applications	200	Apple	Aug 2016
Sales Predict	Provides technology to predict consumer buying behavior and sales conversion	n/a	eBay	July 2016
Mood stocks	Develops machine-learning-based image recognition technology for smartphones	n/a	Google	July 2016
Magic Pony Techno logy	Provides computer vision solutions	150	Twitter	June 2016
Itseez	A machine vision company that builds algorithms that help vehicles avoid obstacles and collisions	n/a	Intel	May 2016

Source: CB Insights, company websites

Recent M&A deals (6/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Expert maker	Develops cloud-based data technology solutions that help automate and optimize data-driven decisions and processes	n/a	eBay	May 2016
Crosswise	Provides machine-learning-based cross-device mapping data	50	Oracle	Apr 2016
MetaMind	Provides natural language processing and image recognition solutions	n/a	Salesforce	Apr 2016
Prediction IO	Provides an open-source-based machine learning server	n/a	Salesforce	Feb 2016
SwiftKey	Provides AI-powered smartphone keyboards	250	Microsoft	Feb 2016
Nexidia	Develops dialogue and audio analysis products and technologies for optimizing audio and video media	135	NICE Systems	Jan 2016
Emotient	Uses AI to detect emotion from facial expressions	n/a	Apple	Jan 2016
Hunch	Provides recommendation and predictive analytics technology	n/a	n/a	Jan 2016
Saffron Technology	Provides a cognitive computing platform for industries	n/a	Intel	Oct 2015
Perceptio	A deep learning company that uses AI to classify photos on smartphones	n/a	Apple	Oct 2015

Source: CB Insights, company websites

Recent M&A deals (7/9)

Company	Description	Deal value in mUS$	Acquirer	Date
VocalIQ	Provides AI software that helps computers and people speak to each other in a more natural dialogue	n/a	Apple	Oct 2015
Orbeus	Offers a cloud-based image analysis solution that identifies faces, scenes, and objects	n/a	Amazon	Sep 2015
deCarta	Provides geospatial software platforms	n/a	Uber	Aug 2015
Whetlab	Develops machine learning technologies based on artificial intelligence software	n/a	Twitter	June 2015
Taboola	A content discovery platform	n/a	Baidu	May 2015
Timeful	Uses machine learning to help people manage their schedules better	n/a	Google	May 2015
Tempo AI	Designs and develops enterprise mobility management solutions	n/a	Salesforce	May 2015
TellApart	Operates a personalized predictive marketing platform that helps companies leverage customer data to drive sales through personalized marketing	n/a	Twitter	May 2015
Explorys	Provides a secure cloud computing platform for the healthcare industry	n/a	IBM	Apr 2015
AlchemyAPI	Provides natural language processing services through a SaaS API for various businesses and computing applications	n/a	IBM	Mar 2015

Source: CB Insights, company websites

Recent M&A deals (8/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Sociocast	Provides actionable social intelligence for web and mobile platforms	n/a	AOL	Mar 2015
Wit.AI	Provides natural language solutions for apps or devices	n/a	Facebook	Jan 2015
Granata Decision Systems	Provides prescriptive analytics technology to organizations and individuals	n/a	Google	Jan 2015
Equivio	Develops text analysis software for the legal market	200	Microsoft	Jan 2015
Wit.AI	Enables developers to build a Siri-like speech interface for apps and devices	n/a	Facebook	Jan 2015
Vision Factory	Provides object recognition and text recognition systems based on deep learning	n/a	Google	Oct 2014
Dark Blue Labs	Engaged in deep learning technologies to understand natural language	n/a	Google	Oct 2014
Jetpac	Creates visual city guides by analyzing photos from social media to infer key information about the places they were taken	n/a	Google	Aug 2014
Emu	An AI-powered assistant that can schedule appointments and sets reminders	n/a	Google	Aug 2014
Freshplum	Develops revenue analytics solutions for eCommerce companies	n/a	TellApart	July 2014

Source: CB Insights, company websites

Recent M&A deals (9/9)

Company	Description	Deal value in mUS$	Acquirer	Date
Madbits	Develops a visual artificial intelligence software that understands, organizes, and extracts relevant information from raw media	n/a	Twitter	July 2014
Medio Systems	Provides predictive analytics products to Fortune 500 and emerging growth companies	n/a	HERE Holding	June 2014
Cogenea	Provides a cognitive computing and conversational AI platform	n/a	IBM	May 2014
Novauris Technologies	Provider of voice recognition software for mobile devices	n/a	Apple	Apr 2014
DeepMind	An AI platform that performs a variety of AI tasks; it is not pre-programmed and can learn from experience	600	Google	Jan 2014
Causata	Develops software that connects, assembles, and transforms customer data into portable real-time intelligence	n/a	NICE	Aug 2013
DNN research	Develops voice and image recognition solutions	n/a	Google	Mar 2013

Source: CB Insights, company websites

Competitive landscape

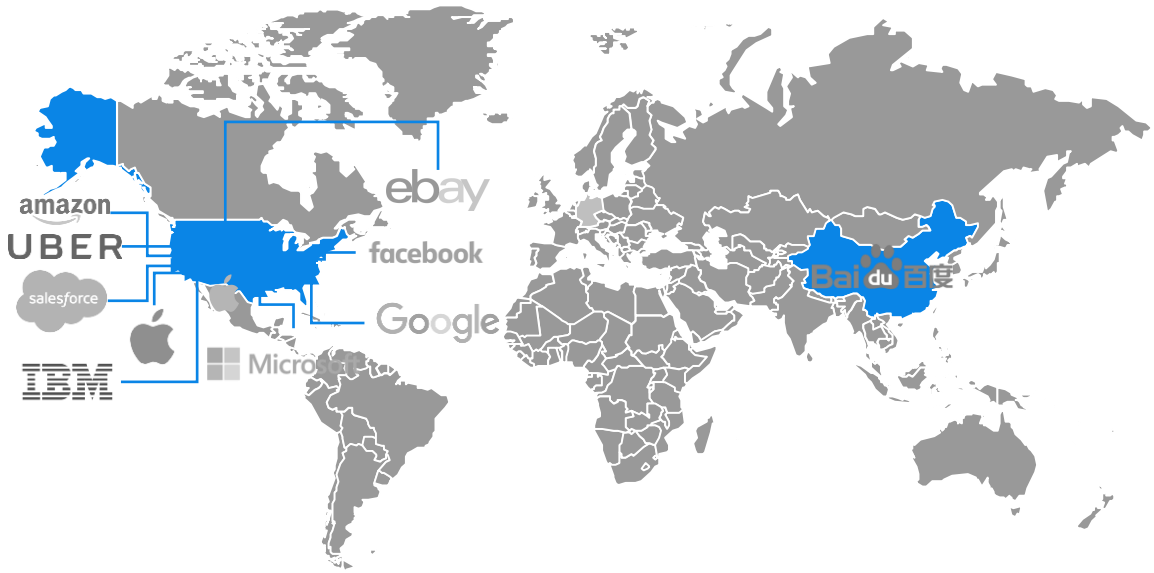
Companies from various industries are currently developing AI and related applications. Google, IBM and Microsoft are leading AI innovations in the IT industry, whereas Amazon and eBay are investing in AI to improve their eCommerce platform, and ridesharing company Uber is using AI for autonomous driving, food deliveries, and mapping research.

Collaborative development is on the rise, and leading companies such as Amazon, Apple, Facebook, Google/DeepMind, IBM, and Microsoft are currently working in partnership towards developing AI applications. The acquisition of small-scale AI companies in relevant fields by tech giants like Apple, IBM, and Microsoft is decreasing the learning curve. Other leading companies include Baidu, Facebook, and Salesforce.

Most of the leading AI companies are from the U.S.

Company comparison

Location of selected leading AI companies



Comparison of selected leading AI companies

Company	Headquarter	Revenue in bnUS$[1]	Key AI areas
Amazon	Washington, U.S.	177.9	Text-to-speech, computer vision, deep learning, NLP
Apple	California, U.S.	265.6[2]	Machine learning
Baidu	Beijing, China	13.0	Machine learning, robotics
eBay	California, U.S.	9.6	Predictive analytics, cloud-based AI, big data
Facebook	California, U.S.	40.6	Language technology, machine learning, computer vision
Google	California, U.S.	110.9	Machine learning, deep learning, automotive industry
IBM	New York, U.S.	79.1	Machine learning, cognitive architectures
Microsoft	Washington, U.S.	110.4[3]	Machine vision, machine learning, healthcare
Salesforce	California, U.S.	10.5[4]	Machine learning, analytics
Uber	California, U.S.	7.5	Voice and image recognition, machine learning, automotive industry

1: As of Dec 2017 2: As of Sep 2018 3: As of June 2018 4: As of Jan 2018
Source: Annual reports, corporate news letters

Amazon works in various areas to advance Alexa's capabilities

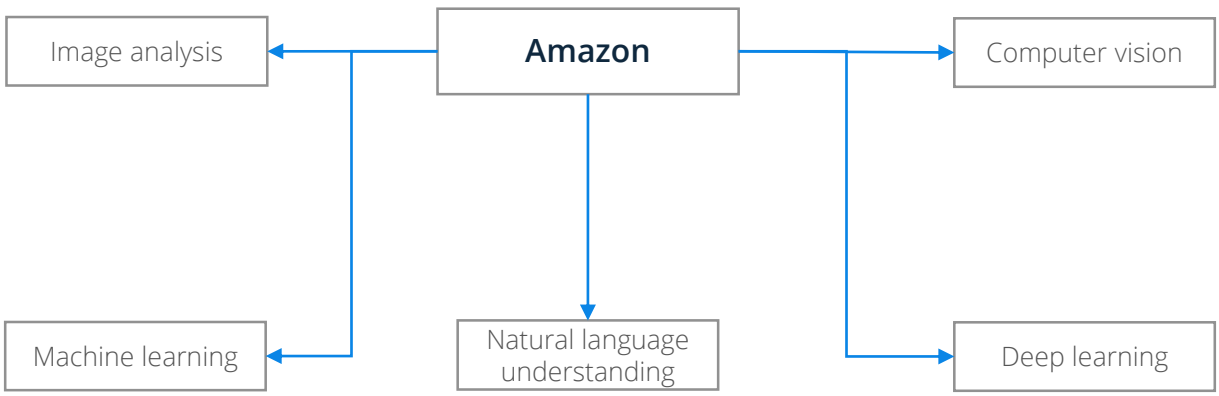
Amazon (1/2)

Amazon.com, Inc., incorporated in 1996, is a Seattle-based company that primarily sells a range of products and services through its online retail platform. In addition, the company also manufactures and sells electronic devices, including the portable reading devices Kindle eReaders and Fire tablets, Fire TVs, and Echo. It provides online direct publishing platforms for independent authors and publishers to publish books in the Kindle Store, an online repository of eBooks.

In November 2016, Amazon launched its AI platform, which consists of new services such as Rekognition, Amazon Polly, and Lex for enterprises. The company has invested US$100 million in the Alexa Fund, which has so far invested in 22 start-ups working at various stages of product development. In addition, Amazon has created the Alexa Prize in the field of conversational AI, challenging university students to develop bots that can hold human conversation.

- Year incorporated: May 1996
- Revenue: US$177.9 billion (Dec 2017)
- Profit before tax: US$3.8 billion (Dec 2017)
- Market capitalization: US$563.5 billion (Dec 2017)
- Employees: 566,000 (Dec 2017)

R&D areas



Source: Annual report, company information, press releases

Amazon's AI research is used in several services and features

Amazon (2/2)

Amazon's current AI service initiatives are focused around natural language understanding (NLU), automatic speech recognition (ASR), visual search and image recognition, text-to-speech (TTS), and machine learning (ML).

The company aims at using the outcomes of AI research in the following services:

Amazon Rekognition: Launched in November 2016, mainly for enterprises, it provides image recognition, categorization, and facial analysis. It can, for example, recognize human faces, detect emotion, and tell whether a particular subject is wearing glasses or not.

Amazon Polly: a deep-learning-powered text-to-speech (TTS) service, mainly for enterprises, that converts a text input into an MP3 stream that sounds like an actual conversation.

Amazon Go: In December 2016, Amazon launched Amazon Go, a retail store which uses AI techniques like computer vision, sensor fusion, and deep learning to expedite the shopping process. Using the Amazon Go app, the shopper simply walks into the store, scans the products, and walks out, paying via the Amazon Go app.

Amazon Alexa: a natural language processing system that can answer questions, provide weather reports, play music, and control the lighting in the house. The voice assistant powers various Amazon products, including Echo (hands-free speaker), Echo Dot (hands-free, voice-controlled device with a built-in speaker), Amazon Tap (a portable Bluetooth and Wi-Fi enabled speaker) and Amazon Fire TV.

Cybersecurity: In January 2017, Amazon acquired harvest.ai, a provider of AI-powered cybersecurity solutions. The company uses machine learning to track changes in user behavior, business systems, and applications and to prevent data theft.

Source: Company information, press releases, CB Insights

One focus area of Apple's AI initiatives is enhancing battery life

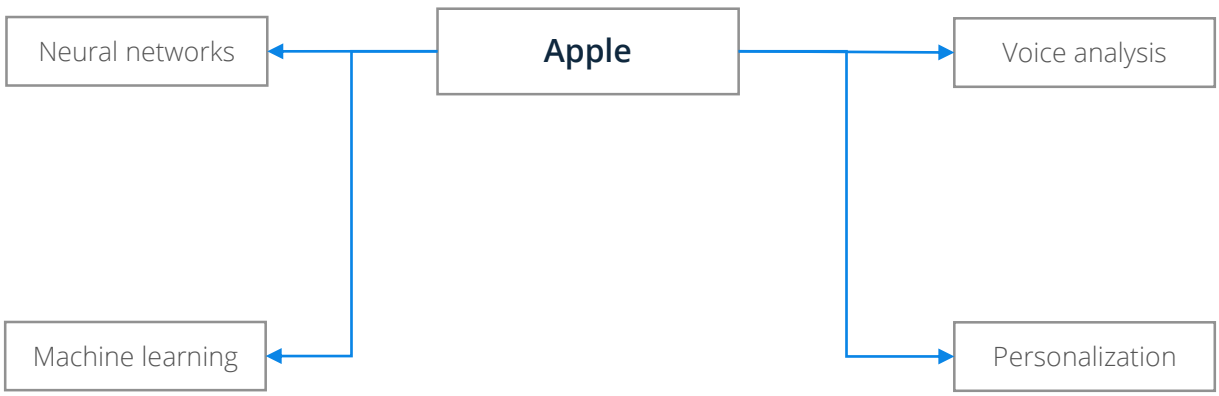
Apple

Apple, headquartered in Cupertino, California, is a technology company that designs, manufactures, and markets personal computers, related software, services, peripherals, networking solutions, portable digital music players, mobile communication, and media devices, as well as third-party digital content and applications.

Over the years, Apple has kept its AI projects and research publications shrouded in secrecy. However, in December 2016, the company published its first AI paper, describing how image recognition training can be enhanced by using computer-generated images over real-world images. Since then, Apple has joined the Partnership on AI, which has Amazon, Facebook, Google/DeepMind, IBM, and Microsoft as its members. Apart from advances in Siri, Apple currently uses AI and machine learning to improve the battery life across its product line, based on consumer usage patterns and data on how to manage power consumption at a component level.

- Year incorporated: Apr 1976
- Revenue: US$265.6 billion (Sep 2018)
- Profit before tax: US$72.9 billion (Sep 2018)
- Market capitalization: US$748.5 billion (Dec 2018)
- Employees: 132,000 (Sep 2018)

R&D areas



Source: Annual report, company information, press releases

Baidu's Big Data Lab works in several AI areas

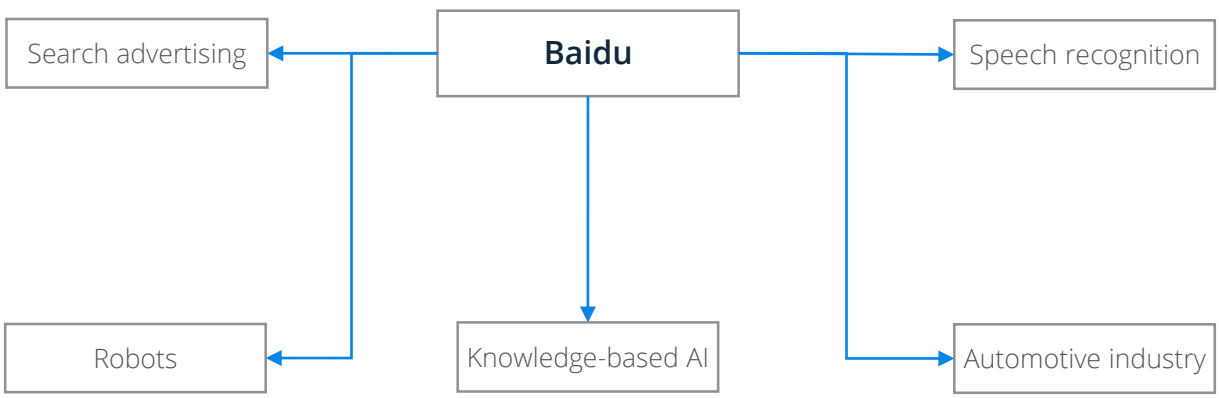
Baidu (1/2)

Baidu was incorporated in 2000 and is a Beijing-based technology company that primarily provides a Chinese-language internet search platform. In addition, the company also offers, among other things, social networking, photo sharing, entertainment, security, music products, software, mapping services, and mobile applications. The company sells its products through its direct sales team and third-party distributors.

Baidu formed its Big Data Lab in July 2014, which focuses on developing large-scale AI algorithms and applications in areas such as predictive analytics, large data structure algorithms, and intelligent systems research. The lab's AI projects include core search technologies, robots, and knowledge-based AI.

- Year incorporated: Jan 2000
- Revenue: US$13.0 billion (Dec 2017)
- Profit before tax: US$3.3 billion (Dec 2017)
- Market capitalization: US$81.3 billion (Dec 2017)
- Employees: 39,343 (Dec 2017)

R&D areas



Source: Annual report, company information, press releases

One area of Baidu's AI research is robots

Baidu (2/2)

The AI projects of Baidu's Big Data Lab include:

- Core search technologies: Current research includes fundamental hashing techniques, hashing-based large-scale machine learning, hashing-based indexing, and fast similarity search, image search, web search, and ranking.
- Robots: Baidu is developing intelligent robots that can not only have a one-on-one conversation with humans but can also ask questions to get a better understanding of their latent intentions. DuNurse is an example of a robot developed for healthcare applications. It can diagnose potential medical conditions and make recommendations on the line of treatment.
- Knowledge-based AI: using voice and language recognition to analyze large volumes of unstructured data for use in domains such as professional query-answering, high quality web search, and automated legal advice.
- Other initiatives:
  - Baidu is developing a speech recognition engine with an expected accuracy of 99%. Its latest product, called Deep Speech 2, uses deep learning to recognize words spoken in English and Mandarin and is currently used in several Baidu apps such as Duer (Siri equivalent) and Melody (a chatbot that assists doctors with recommendations and treatment options).
  - Partnered with zaijia.com, a manufacturer of home appliances, to launch an AI-based home assistant robot. Apart from communicating with humans, the robot offers security monitoring and entertainment services.
  - In April 2017, Baidu open sourced its self-driving platform, called Project Apollo, to enable other automobile companies to develop their own autonomous driving systems.
  - In February 2017, Baidu acquired Raven Tech, an AI start-up developing a voice recognition assistant.
  - Baidu developed PaddlePaddle, its open-source deep learning platform, in 2016.
  - In September 2016, Baidu partnered with Nvidia to jointly develop a platform for semi-autonomous vehicles.
  - In September 2016, Baidu launched a US$200 million venture capital fund to invest in AI projects.

Source: Company information, press releases, CB Insights

eBay's AI efforts aim to improve communication in eCommerce

eBay (1/2)

eBay Inc., headquartered in San Jose, California, provides an online platform that connects buyers with sellers worldwide. The platform enables registered sellers to create a virtual online store from where buyers can search and select products to buy. The company offers a retail platform via the web and also through mobile applications. In addition, the company also sells tickets to sports events, concerts, and live shows through its online ticketing platform stubhub.com.

eBay aims at improving buyer/seller communications through the use of AI. The company made many AI-related acquisitions in 2016 in the areas of predictive analytics, cloud-based AI, and big data.

- Year incorporated: Sep 1995
- Revenue: US$9.6 billion (Dec 2017)
- Profit before tax: US$2.3 billion (Dec 2017)
- Market capitalization: US$39.4 billion (Dec 2017)
- Employees: 14,100 (Dec 2017)

R&D areas

Source: Annual report, company information, press releases

eBay's AI initiatives focus on buyers and sellers

eBay (2/2)

eBay's current area of focus in AI is to achieve real-time customer behavior analysis to deliver personalized experiences to its customers.

Its key AI initiatives are:

eBay ShopBot BETA

eBay ShopBot: an AI-powered smart personal shopping assistant, currently in beta stage, which is integrated with the Facebook messenger. It interacts with buyers to help them select the best deal for a particular product.

Inventory solutions: an AI-powered retail platform that helps sellers to identify inventory gaps for a particular product and sends alerts to stock up.

Source: Company information, press releases

Facebook created its AI research group in 2013

Facebook (1/2)

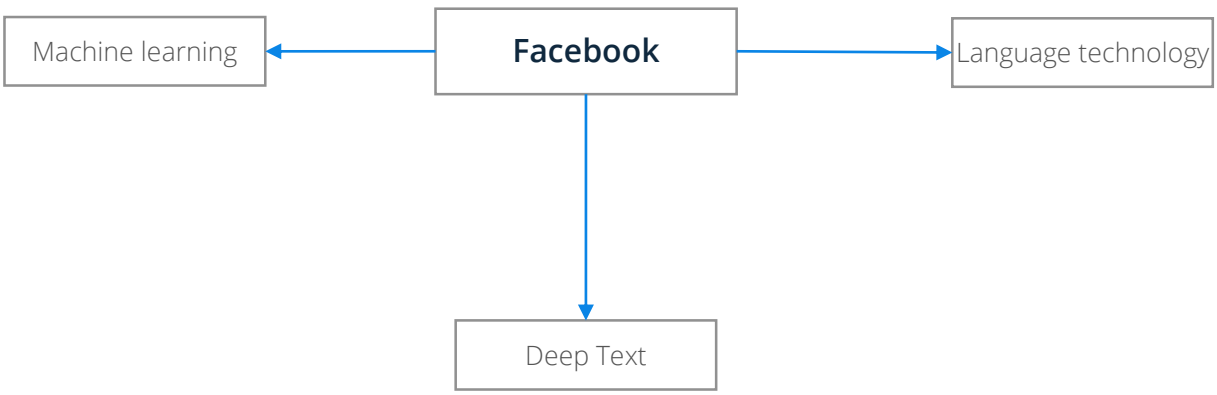
Facebook, founded in 2004, is a technology company that provides social media, mobile application, and communications platforms. It owns several other popular social media platforms, such as the photo-sharing platform Instagram and the instant communication application WhatsApp, which allows people to connect and interact with each other. The company also offers a virtual reality platform, Oculus VR, that allows users to play games, consume content, and connect with others in an immersive and interactive environment.

In 2013, the company created the Facebook Artificial Intelligence Research group (FAIR), which is run by neural networks expert Yann LeCun and has over 60 researchers and scientists. In 2015, Facebook launched the Applied Machine Learning (AML) group, which is helmed by Joaquin Candela and integrates its overall AI efforts into the company's products. The division looks after language technology, core machine learning, computational photography, computer vision, and image recognition.

- Year incorporated: Feb 2004
- Revenue: US$40.7 billion (Dec 2017)
- Profit before tax: US$20.6 billion (Dec 2017)
- Market capitalization: US$512.8 billion (Dec 2017)
- Employees: 25,105 (Dec 2017)

facebook

R&D areas



Source: Annual report, company information, press releases

Facebook's AI initiatives focus on enhanced text understanding

Facebook (2/2)

Facebook is currently working on the following areas in terms of AI research and development:

FBLearner Flow: is its machine learning platform, which can reuse algorithms across various products to deliver a unique personalized experience for every user. According to a company post, the AI system, which is used by more than 25% of its engineering team, is used, among other things, to rank and personalize News Feed stories, filter offensive content, highlight trending topics, and rank search results.

Language technology: One of Facebook's core area of focus with regards to AI integration is language technology. The company started to develop its Language Group after the 2013 acquisition of Mobile Technologies, a developer of voice recognition and translation tools. Currently, the group is focused on developing Facebook's first AI-powered speech recognition and conversational understanding capabilities.

Deep Texts

Deep Text: The company's latest AI offering, DeepText, is based on deep neural networks and helps it to analyze each news story, public post, and even text messages, to determine the context of the content and then make suggestions accordingly. For example, if a user posts a status update saying that he/she needs a ride, the AI system will suggest using services such as Uber or Lyft. DeepText uses deep neural network architectures such as convolutional and recurrent neural nets.

Source: Company information, press releases

Google's AI efforts touch various industries and services

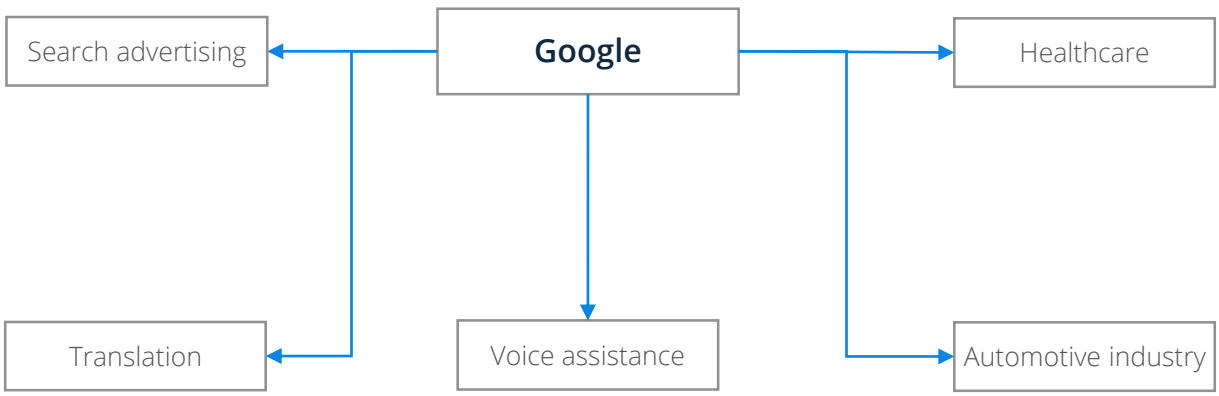
Google (1/3)

Google, a global technology company founded in 1998, offers search, advertising, operating systems and platforms, enterprise, and hardware products. The company operates as a subsidiary of Alphabet Inc. and is headquartered in Mountain View, California. Even though Google started its AI research many years ago, it was the acquisition of British AI company DeepMind in 2014 for over US$600 million that marked the beginning of the next era of AI development in the company. Since then, Alphabet has been one of the biggest spenders on AI development in the world. DeepMind is currently focused on developing AI applications to help manage energy infrastructure, hone health-care systems, and improve access to clean water.

Google Brain handles all aspects of AI development and application, with the technology now touching almost all areas of its business, including vehicles, healthcare, translation, photography, and advertising.

- Year incorporated: Sep 1998
- Revenue: US$110.9 billion (Dec 2017)
- Profit before tax: US$27.2 billion (Dec 2017)
- Market capitalization: US$729.5 billion (Dec 2017)
- Employees: 80,110 (Dec 2017)

R&D areas



Source: Annual report, company information, press releases

Google is using AI to upgrade its traditional offerings

Google (2/3)

Google is currently working on the following areas in terms of AI research and developments:

Search advertising: Google Search, which generated over 90% of the company's revenues, is reinventing itself through AI and machine learning. In 2015, Google launched a deep learning system called RankBrain, which delivers more accurate search results by teaching itself to interpret queries based on a person's intent as opposed to a predefined program. The algorithm is essentially capable of guessing words or phrases with a similar meaning and of filtering the results accordingly, thereby enabling it to deliver accurate results, even for novel queries.

Google Translate: In September 2016, Google launched the Google Neural Machine Translation (GNMT) system, which uses deep learning to translate entire sentences and not just phrases, as was the case earlier. The main difference in this approach is that the system now does not only translate parts of a sentence piece by piece but instead looks at the sentence as a whole to figure out the broader context and deliver the most accurate translation. It also keeps learning continuously as it gets access to more data, thereby resulting in improved and more natural translations.

Voice assistance: Google takes on Siri (Apple), Cortana (Microsoft), and Alexa (Amazon) with the launch of its own voice assistance service called Google Assistant. It essentially takes the features of Google's existing 'OK Google' or 'Hey Google' voice controls and fuses them with an AI-powered system which is designed to deliver a more human-like interactive experience. Google Assistant is currently available on the Google Pixel smartphones, Google Home (a smart speaker), and the Google Allo app (smart messaging). The company plans on launching it on Android Wear devices via Android Wear 2.0, on Android TV, in a few cars, and on smartphones running on Marshmallow and Nougat (new Android operating systems).

Source: Company information, press releases

Besides healthcare, Google's AI efforts also include automobiles

Google (3/3)

Healthcare: Google DeepMind has formed a research partnership with the radiotherapy department at University College London Hospitals (UCLH) NHS Foundation Trust, a provider of cancer treatment. The main goals of this partnership are two-fold: to use machine learning to reduce the amount of time needed for radiotherapy treatment for head and neck cancers and to develop a radiotherapy-segmentation algorithm that can potentially be used for other body parts as well. Another partnership with Moorfields Eye Hospital in the UK is applying AI to spot early signs of visual degeneration just by using images of eye scans. DeepMind has also developed an app called Streams, which uses deep learning to detect early signs of kidney injury in a patient's blood test data.

Automobiles: Google's autonomous car division Waymo[1] recently began testing its service to members of the general public in Phoenix, Arizona. The company is essentially focused on building an AI-powered platform consisting of sensor hardware (vision cameras, radars, and LIDAR), sensor fusion software, and image recognition systems. According to Waymo CEO John Krafcik, the company now has access to 2 million self-driven miles, which translates into about 'over 300 years of human driving experience'. This data is what powers Waymo's self-driving algorithm, and it is directly responsible for the company witnessing a 400% drop in disengagement rates, or the number of times human intervention was needed, between 2015 and 2016.

1: Waymo is a subsidiary of Alphabet, Google's parent company
Source: Company information, press releases

IBM's AI efforts started in the 1950s with an AI checkers player

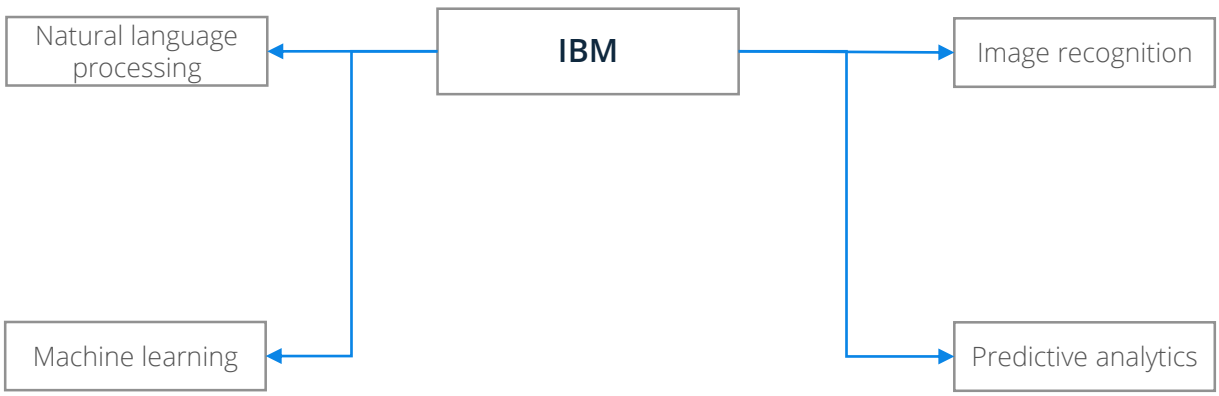
IBM (1/2)

International Business Machines Corporation (IBM), incorporated in 1911, is an information technology (IT) company headquartered in New York. The company has five key operating segments: Software, Global Business Services (GBS), Global Technology Services (GTS), Systems Hardware, and Global Financing.

IBM's AI efforts date back to the 1950s, when it created a checkers player that learned from experience. The company's AI initiatives gained prominence with the development of the AI-powered Deep Blue computer platform, which defeated chess grand master Garry Kasparov in 1997. Currently, IBM's AI initiatives are focused on search and planning optimization, machine learning, deep question answering, knowledge representation, and cognitive architectures.

- Year incorporated: Jun 1911
- Revenue: US$79.1 billion (Dec 2017)
- Profit before tax: US$11.4 billion (Dec 2017)
- Market capitalization: US$142.0 billion (Dec 2017)
- Employees: 366,000 (Dec 2017)

R&D areas



Source: Annual report, company information, press releases

Watson is one of IBM's main AI projects

IBM (2/2)

IBM is currently working on the following areas in terms of AI research and developments:

Watson: a supercomputer that applies NLP, information retrieval, knowledge representation, automated reasoning, and machine learning technologies to answer questions. The intelligence platform was originally developed to answer questions on the quiz show Jeopardy. The Watson platform can now be used in retail, healthcare, hospitality, entertainment, aerospace, and other sectors.

- **Watson's use in CRM:** In March 2017, IBM partnered with Salesforce to enable it to use data from IBM's Watson AI platform, such as the weather or local shopping patterns.
- **Watson's use in cybersecurity:** IBM partnered with eight universities in January 2017 to provide Watson with the data necessary to expand its security protocol to be used in the cybersecurity domain. Around 40 companies are now part of Watson's cybersecurity beta program.

Bluemix (PaaS[1]) cloud services: Along with Watson, IBM is also working on machine learning initiatives to expand the Bluemix (PaaS) cloud services. The company is working towards integrating natural language pattern recognition, predictive analytics, and image recognition under Bluemix service offerings.

1: Platform as a Service, in which the service provider rents out platforms such as application servers, databases, and mobile back-end services as a service
Source: Company information, press releases

Microsoft's AI efforts include education, healthcare, and training

Microsoft (1/2)

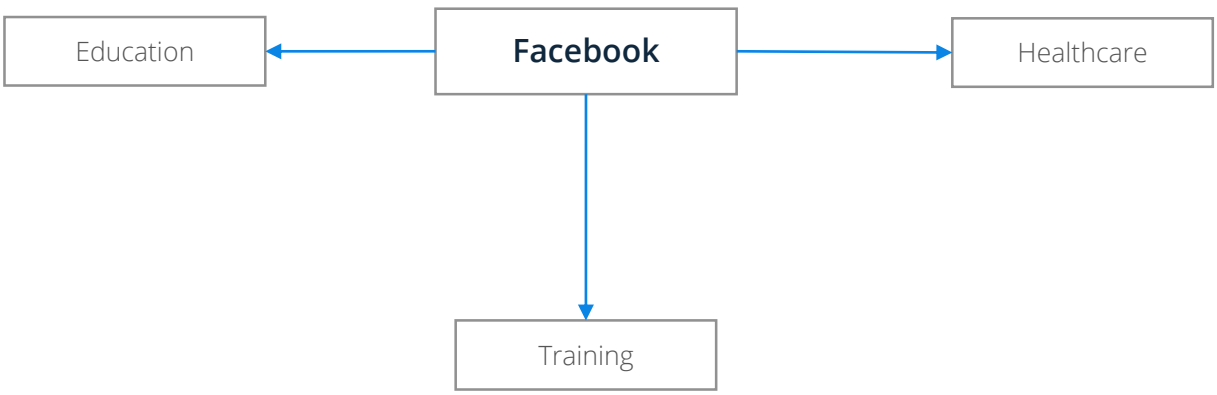
Microsoft, headquartered in Redmond, Washington, develops and supports software products, services, and devices. The company offers a range of server applications, business solution applications, operating systems, desktop and server management tools, video games, and training and certification services.

In September 2016, Microsoft announced that it had formed the Microsoft AI and Research Group, which consists of over 5,000 computer scientists and engineers and includes product engineering, basic and applied research labs, and New Experiences and Technologies (NExT). Led by Harry Shum, the division focuses on building AI capabilities across various areas, including agents (Cortana), apps (Skype, Office 365, and Microsoft Photo), services (vision, speech, and machine analytics), and infrastructure (AI supercomputer Azur). In December 2016, the company launched an investment fund, a part of Microsoft Ventures, to make AI-related investments in areas such as education, healthcare, and training.

- Year incorporated: Apr 1975
- Revenue: US$110.4 billion (Jun 2018)
- Profit before tax: US$36.5 billion (Jun 2018)
- Market capitalization: US$779.7 billion (Dec 2018)
- Employees: 131,000 (Jun 2018)

Microsoft

R&D areas



Source: Annual report, company information, press releases

Various Microsoft AI projects focus on healthcare applications

Microsoft (2/2)

In healthcare, Microsoft's AI efforts are concerned with:

- Developing machine learning techniques to analyze tumors and design new medication regimes
- Developing simulations which detail the progress of cancer in different patients' bodies
- Creating programmable biological cells
- InnerEye: an AI tool that uses machine vision to give radiation oncologists a 3D view of CT scans of tumors
- Project Hanover: personalizing medicine using AI
- Developing a new chatbot with the ability to help people assess their symptoms before going to a clinic
- Healthcare NExT: integrate work from Microsoft's Research and AI units and other industry participants to reduce data entry tasks, diagnostic procedures, and ease outpatient care

Source: bloomberg.com, fortune.com, company information, press releases

In 2016, Salesforce acquired several companies specialized on AI

Salesforce

Salesforce.com, headquartered in San Francisco, California, is a technology company that primarily provides cloud-based software solutions on a subscription basis. Its flagship product, on-demand customer relationship management (CRM) solutions, enables users to connect, engage, sell, service, and collaborate with their customers. The company, together with its subsidiaries, provides services to industries spread across the globe, including healthcare, the automotive industry, media, finance, life sciences, retail, manufacturing, and communications.

Salesforce's AI platform Einstein integrates its AI capabilities with its CRM tools to make it more useful for clients to improve their sales pitches. In 2016, the company made significant acquisitions, including PredictionIO, which specializes in machine learning and predictive analytics, MetaMind, which specializes in NLP and image recognition, and beyondCore, which develops automated analytics software.

- Year incorporated: 1999
- Revenue: US$10.5 billion (Jan 2018)
- Profit before tax: US$202.1 million (Jan 2018)
- Market capitalization: US$73.8 billion (Dec 2017)
- Employees: 29,000 (Jan 2018)

R&D areas

Source: Annual report, company information, press releases

Uber seriously committed to develop its AI capabilities in 2016

Uber (1/2)

Uber is a technology start-up that connects drivers with people who need a drive through a mobile application. The company operates in the Americas, Europe, the Middle East, Africa, and Asia-Pacific. Uber is headquartered in San Francisco, California, whereas its engineering center is based in Bengaluru, India.

Uber's acquisition of Geometric Intelligence, a provider of advanced machine learning techniques, in December 2016 marked the beginning of its serious commitment towards developing its AI capabilities. The company appointed its then CEO, Gary Marcus, to lead its newly launched AI research lab in Silicon Valley. The primary aim of the lab is to develop powerful speech- and image-recognition software which can be trained on less data.

- Year incorporated: 2009
- Revenue: US$11.1 billion (Dec 2017)[1]
- Profit before tax: n/a
- Valuation: US$68.0 billion (Apr 2017) [2]
- Employees: 16,000 (Dec 2017)

UBER

R&D areas

1: CNBC 2: PitchBook
Source: Annual report, company information, press releases

One of Uber's focus areas regarding AI research is autonomous driving

Uber (2/2)

Uber's AI lab is focused on developing advanced algorithms that will enable machine learning with fewer data requirements and training AI systems using both data and explicit rules.

Below are Uber's areas of AI focus:

UBER ATG

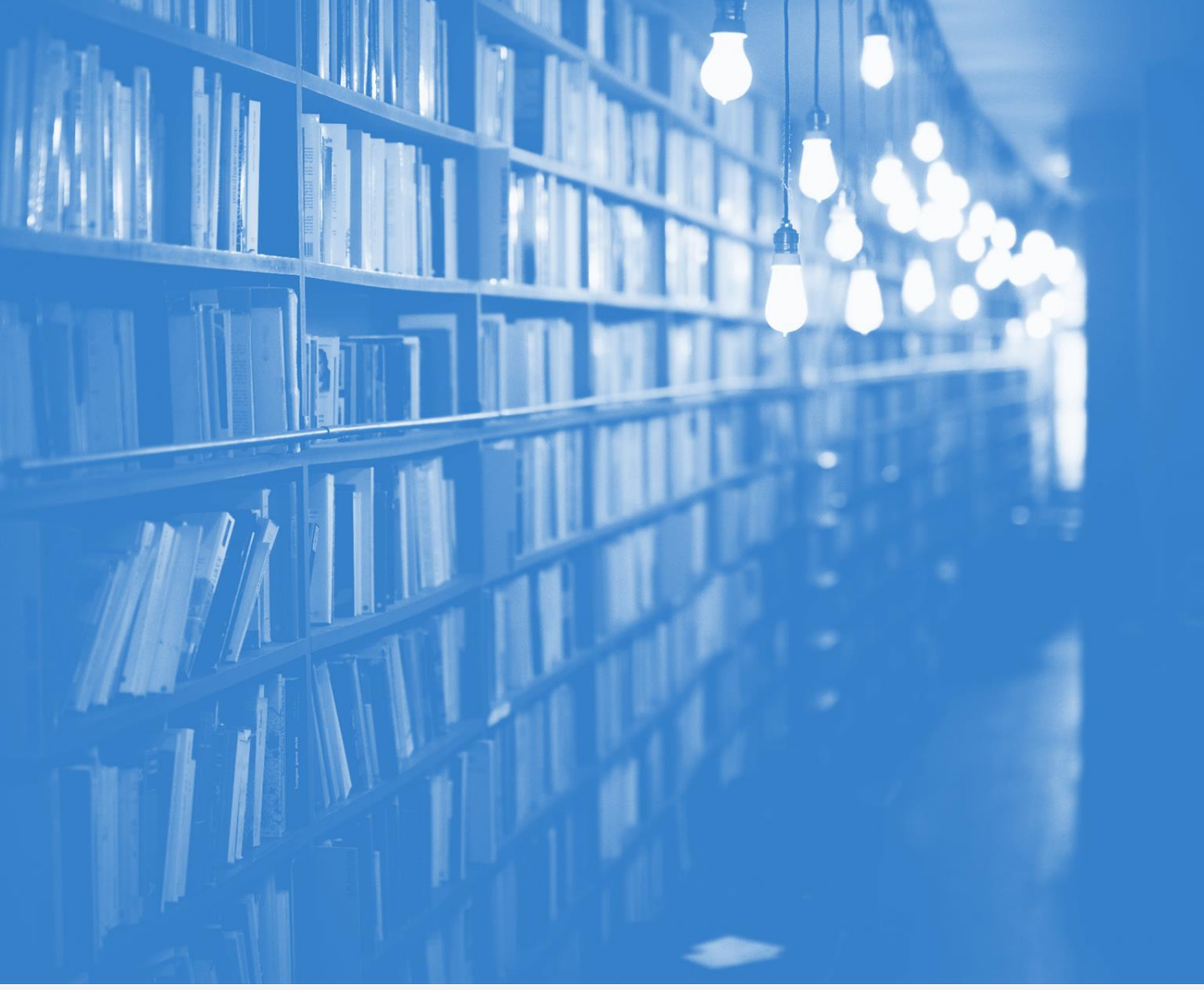
Autonomous driving: Uber's autonomous car development initiative, led by the company's Advanced Technologies Group (ATG), began testing its service in September 2016 by picking up passengers in Pittsburgh, Pennsylvania. During the trial period, selected Volvo SUVs were fitted with sensors (cameras, radars, and LIDARs) and processing units to provide necessary AI, and a Uber test engineer accompanied the safety driver to monitor progress with the tests and handle manual driving when needed. The pilot program expanded to San Francisco, California, in December 2016. However, the company suspended the program in March 2017 following an accident that happened in Arizona. The company is expected to continue the trials after fixing the errors in the coming months.

UBER EATS

Food deliveries: Uber started its food delivery service UberEats as a pilot program in 2014, which was offered in more than 26 countries in March 2017. The company uses AI to calculate delivery time considering the traffic, vehicle position, and type of food ordered. In addition, machine learning is being used to generate restaurant recommendations and to integrate popular payment options to make transactions quickly and easily.

Mapping research: The company uses AI for analyzing traffic signs and the number of traffic signals on a particular road to improve mapping research, which can be used for predicting the arrival and total travel time of vehicles.

Source: Company information, press releases



Appendix

Glossary

Term	Abbreviation	Explanation
Artificial intelligence	AI	Artificial intelligence (AI) essentially refers to computing technologies that are inspired by the ways people use their brains and nervous systems to reason and make decisions, but they typically operate quite differently.
Medical Online to Offline	Medical O2O	Medical O2O is the platform connecting those transforming the medical and wellness world through cutting-edge technology.
Machine learning	Machine learning	Involves designing new learning algorithms and improving existing ones to enable computers to act without being programmed explicitly. These algorithms allow computers to analyze large volumes of complex data to recognize patterns and make predictions and adjustments.
Robotics	Robotics	It is concerned with developing and training robots to interact with people and the world in general in predictable ways. However, current efforts also revolve around using deep learning to train robots to manipulate situations and act with a certain degree of self-awareness.
Artificial neural networks (ANN)	ANN	This area is concerned with developing algorithms that mimic the functioning of the neocortex area of the human brain, where all the thinking occurs. This comparison is not entirely correct because in a human brain, neurons are not arranged in a linear sequence, as is the case with ANNs.

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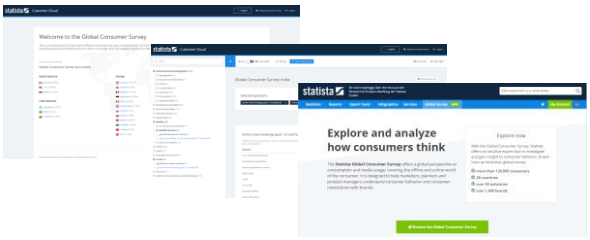

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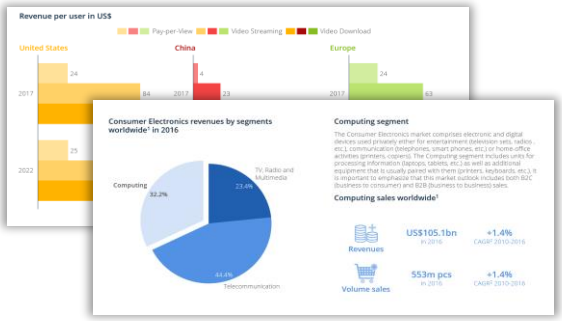

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