

DIGITAL & TRENDS

# Artificial Intelligence: in-depth market analysis

Market Insights report



# 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. NLP deals with the interpretation and manipulation of human language by computers.

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 strong interest of Venture Capital (VC) 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 163 trillion gigabytes by 2025.

## Management summary (2/2)

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.

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. Heading into 2020, there were over 2,600 AI start-ups across 13 categories. The AI companies have cumulatively raised around US\$239.2 billion in funding during 2015-2022.

Over the years, the number of AI acquisitions have grown steadily, only to dip for the first time in 2020, as the COVID-19 outbreak prompted many businesses to prioritize core operations over new acquisitions. However, the acquisitions gained momentum and around 312 M&A deals were signed in 2021. The number of M&A deals declined in 2022 compared to the previous year and around 259 deals registered during the year.

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 ride-sharing 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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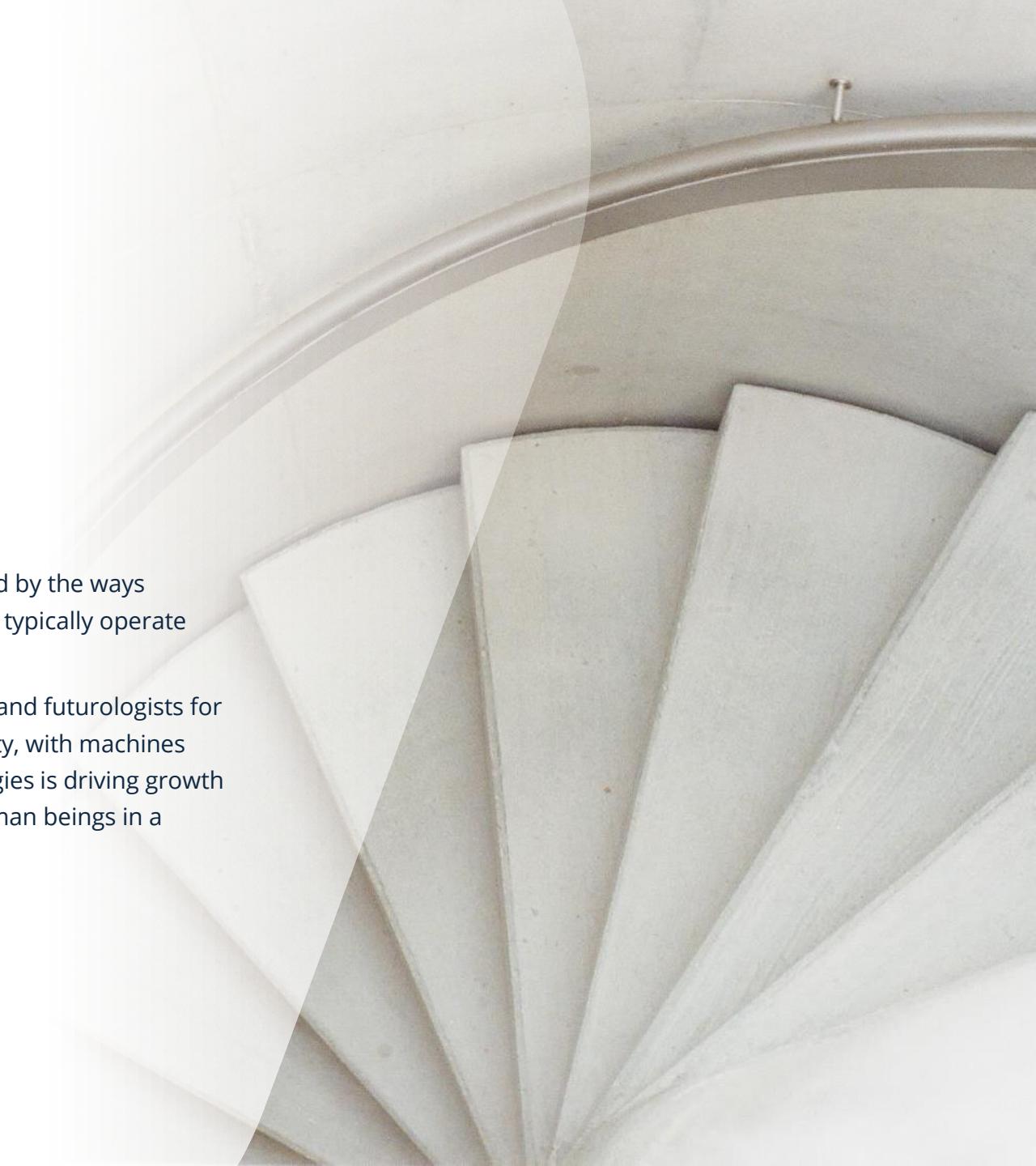
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## CHAPTER 1

# Introduction

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. 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.



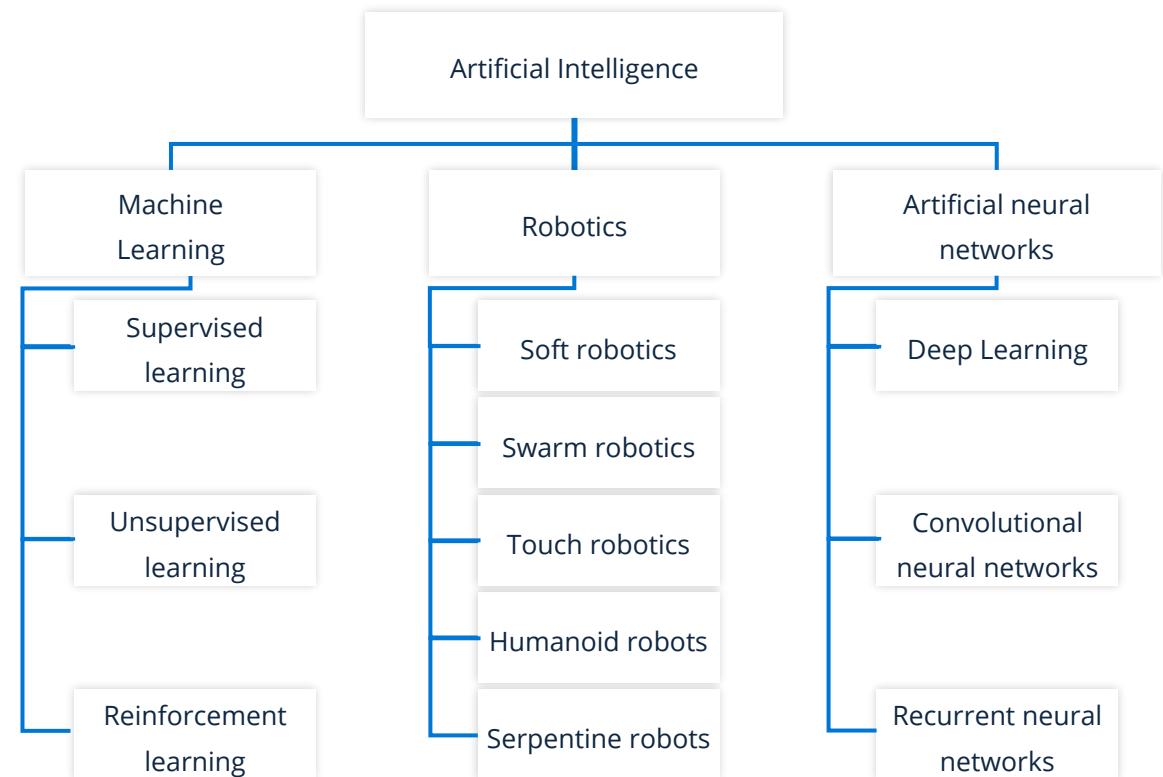
# Artificial Intelligence mimics the working of the human brain

## 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. The global market for AI is estimated to grow from US\$142.3 billion in 2022 to US\$1847.5 billion in 2030.

The technology's increasing use in various industries including healthcare, education, financial services, manufacturing, and entertainment is mainly due to strong research and development (R&D) by countries, educational institutions, and non-profit organizations. Despite the ongoing geopolitical tensions, the U.S. and China have the largest number of cross-country AI partnerships. In fact, the collaborative publications between the two countries increased by as much as 500% from 2010-2021. Overall, the number of AI patents filed in 2021 was over 30 times higher as compared to 2015, with the education sector dominating most of the key regions globally.

## Current artificial intelligence ecosystem



# 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 (ANNs)

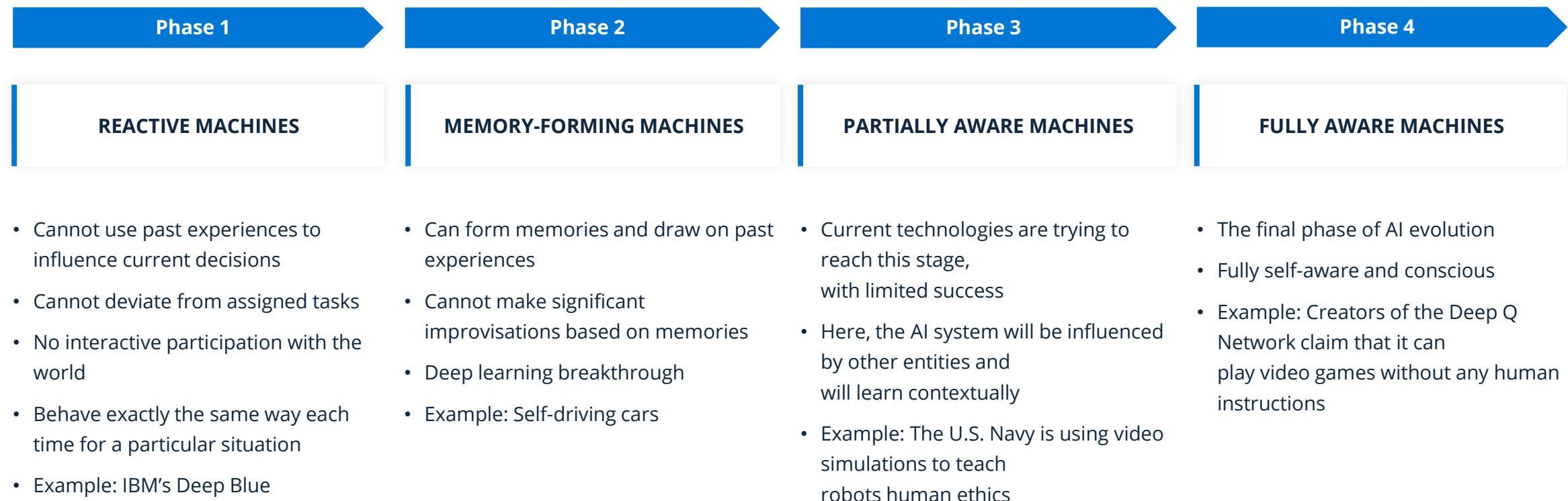
This area is concerned with developing algorithms that mimic the functioning of the neocortex area of the human brain, where all the thinking occurs. This comparison is not entirely correct because in a human brain, neurons are not arranged in a linear sequence, as is the case with ANNs.

There are three different types of ANNs:

- Deep learning
- Convolutional neural networks
- Recurrent neural network

# Artificial intelligence has evolved from being reactive to being aware

Evolution of artificial intelligence (1/4)



# AI is being deployed at scale across industries

## Evolution of artificial intelligence (2/4)

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. In fact, according to a 2020 government sponsored report by trade summit SelectUSA, a just one percent increase in robot density across global industries in 2019, resulted in a 0.8 percent jump in productivity. The biggest gains were witnessed across industries in which robot adoption was still in its nascentcy.

Even though this growth has been estimated for all the countries around the world, there are a few that are expected to witness more activity than others. According to the 2021 World Robot Report by the International Federation of Robotics (IFR), South Korea, Singapore, Japan, Germany, and Sweden are the top five countries in terms of robot density in manufacturing. In terms of regions, Asia is the leading market, followed by North America and Europe.

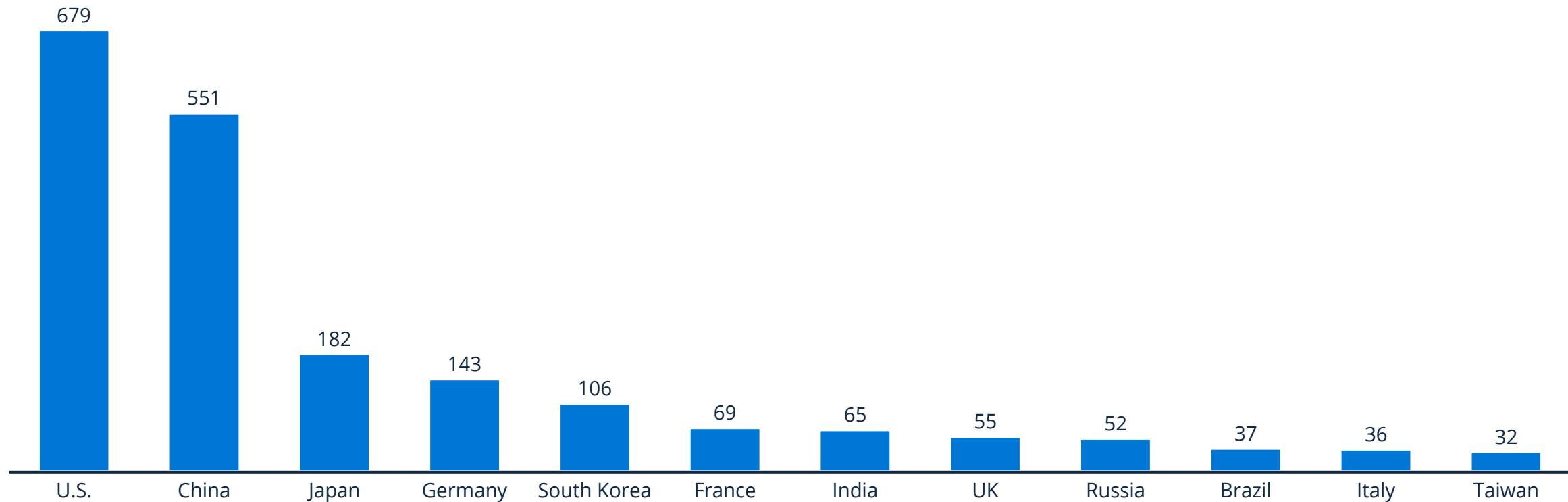
Automation potential varies across industries as well. For example, according to a McKinsey report, the manufacturing industry has an automation potential of 64%, whereas for an industry like educational services, it is 34%. The factors affecting the pace and extent of automation include openness to 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.

# US tops the world in terms of gross R&D expenditure

Evolution of artificial intelligence (3/4)

## Leading countries by gross R&D expenditure worldwide in 2022 in billion US\$



# Human-machine relationships are integral to the progress of AI

## Evolution of artificial intelligence (4/4)

However, despite 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.

- In May 2021, an AI computer called Dr. Fill, beat nearly 1,300 people in the annual American Crossword Puzzle Tournament to achieve top score.

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 had strongly warned that a full AI could result in the end of mankind. Philosopher Nick Bostrom, in his widely acclaimed book Superintelligence, speaks about the possibility of computers overtaking humans in terms of cognitive capabilities. Also, scientists at Google and the University of Oxford published a paper in September 2022 claiming that super-intelligent AI could go rogue and wipe out humanity over the long term. However, keeping the recent advancements and resulting benefits of AI in mind, along with the need for human intervention at various levels, the foreseeable future is expected to see a collaborative approach between AI and humans.

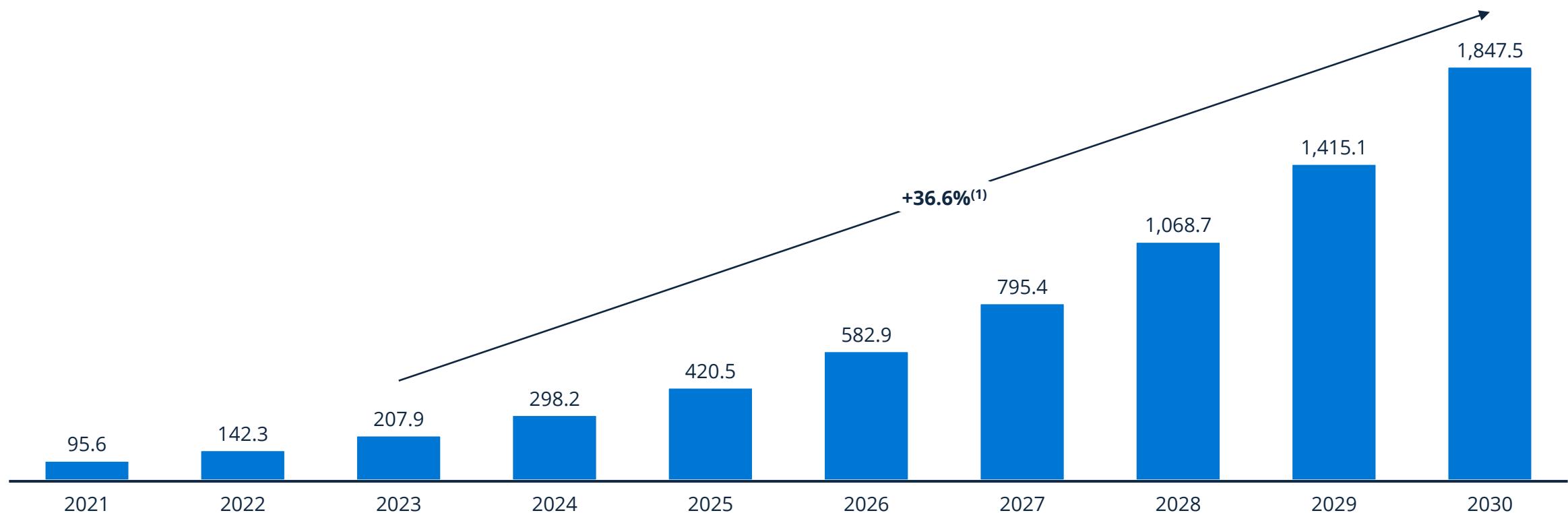
“One of the fascinating things about the search for AI is that it’s been so hard to predict which parts would be easy or hard. At first, we thought that the quintessential preoccupations of the officially smart few, like playing chess or proving theorems—the corridas of nerd machismo—would prove to be 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

# Global Artificial Intelligence market is projected to cross US\$1 trillion by 2028

Global revenue projection (1/5)

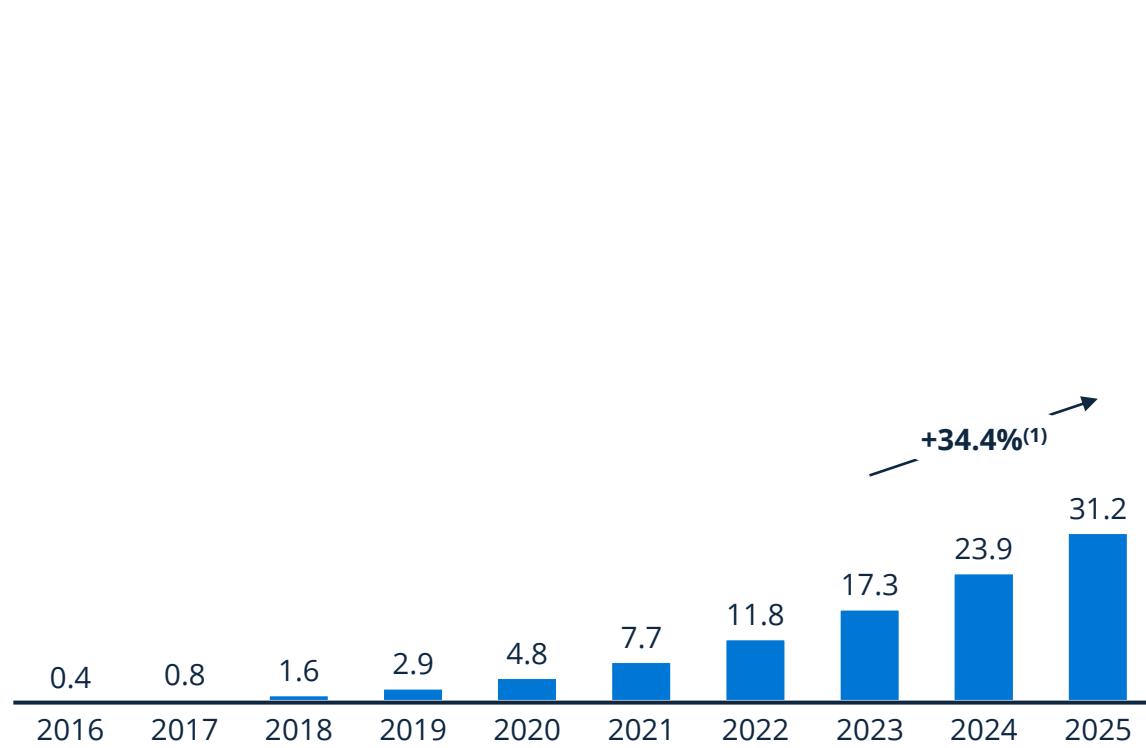
**Global Artificial Intelligence market in billion US\$**



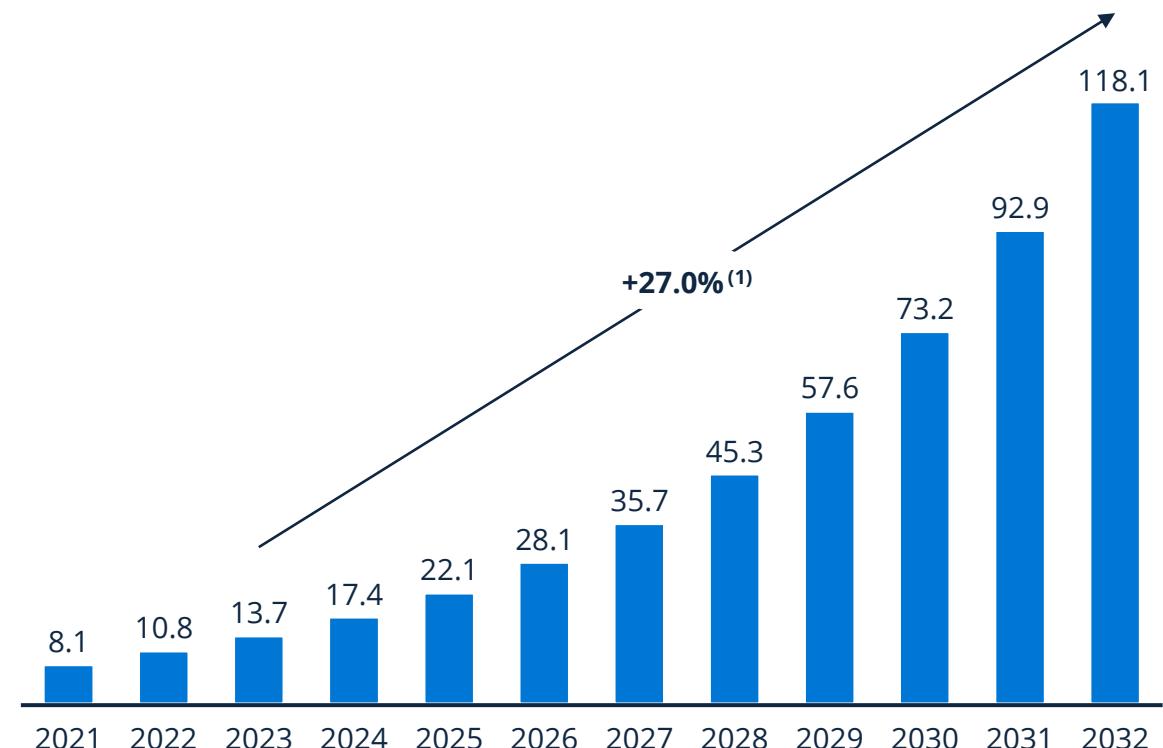
# Generative AI market is projected to surpass US\$50 billion mark by 2029

Global revenue projection (2/5)

Worldwide AI for enterprise applications market in billion US\$

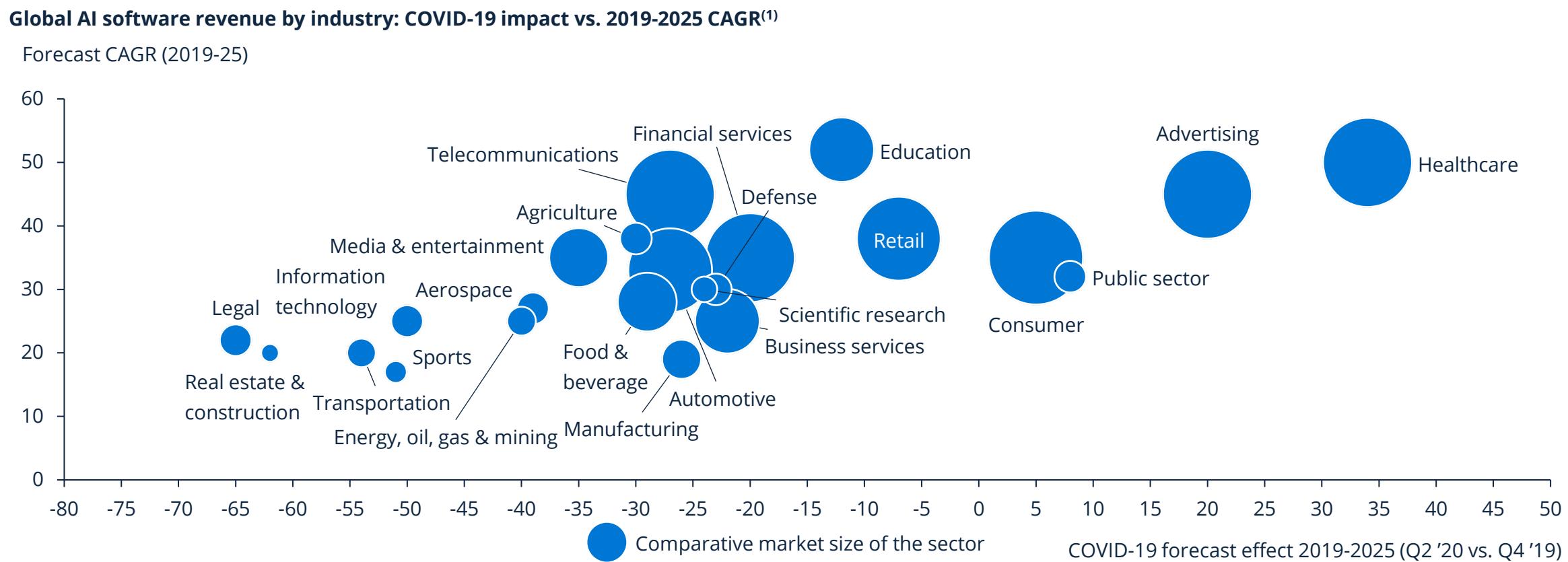


Global Generative AI market in billion US\$



# Healthcare industry to generate maximum revenue

## Global revenue projection (3/5)



16

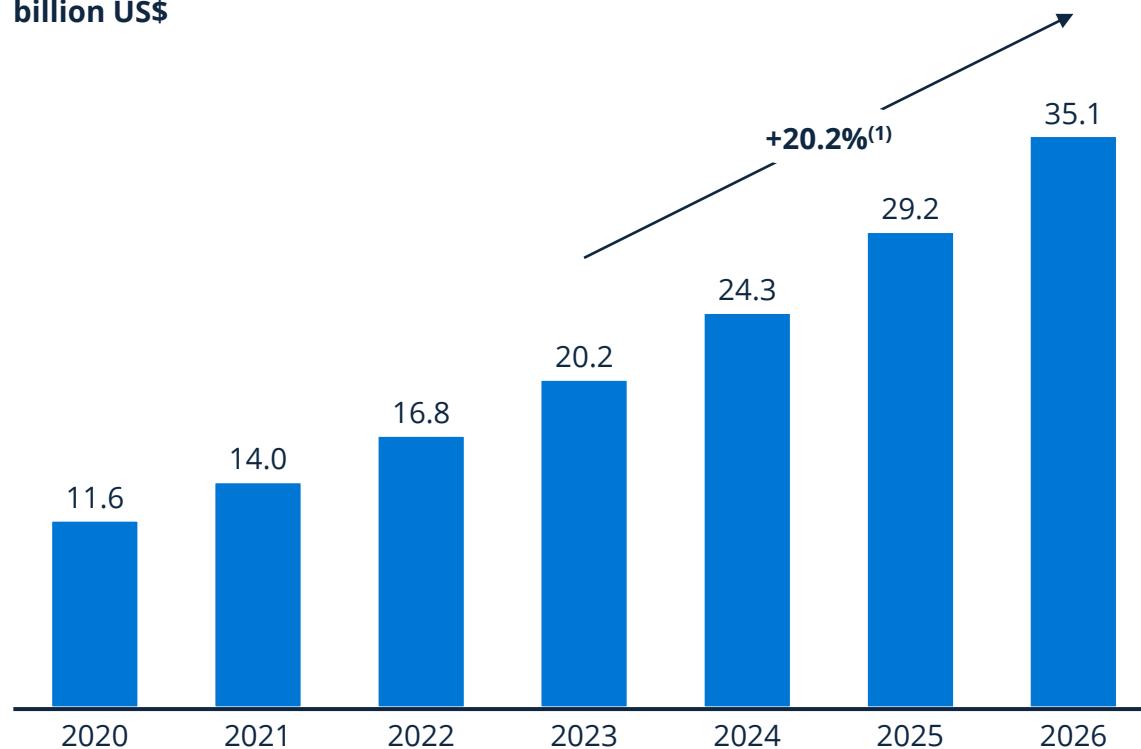
**Notes:** (1) CAGR: Compound Annual Growth Rate / average growth rate per year

**Sources:** Tractica; Omdia

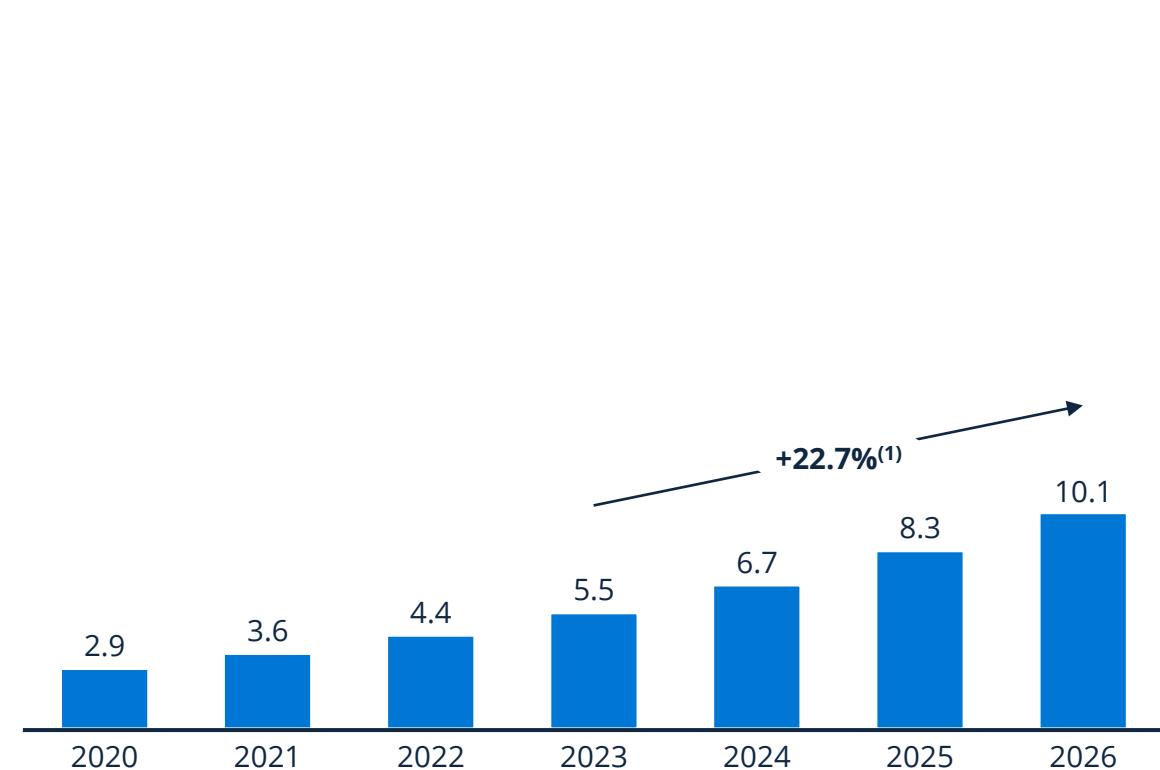
# The chatbot market revenue is forecast to cross US\$10 billion by 2026

Global revenue projection (4/5)

**Revenues from the natural language processing (NLP) market worldwide in billion US\$**



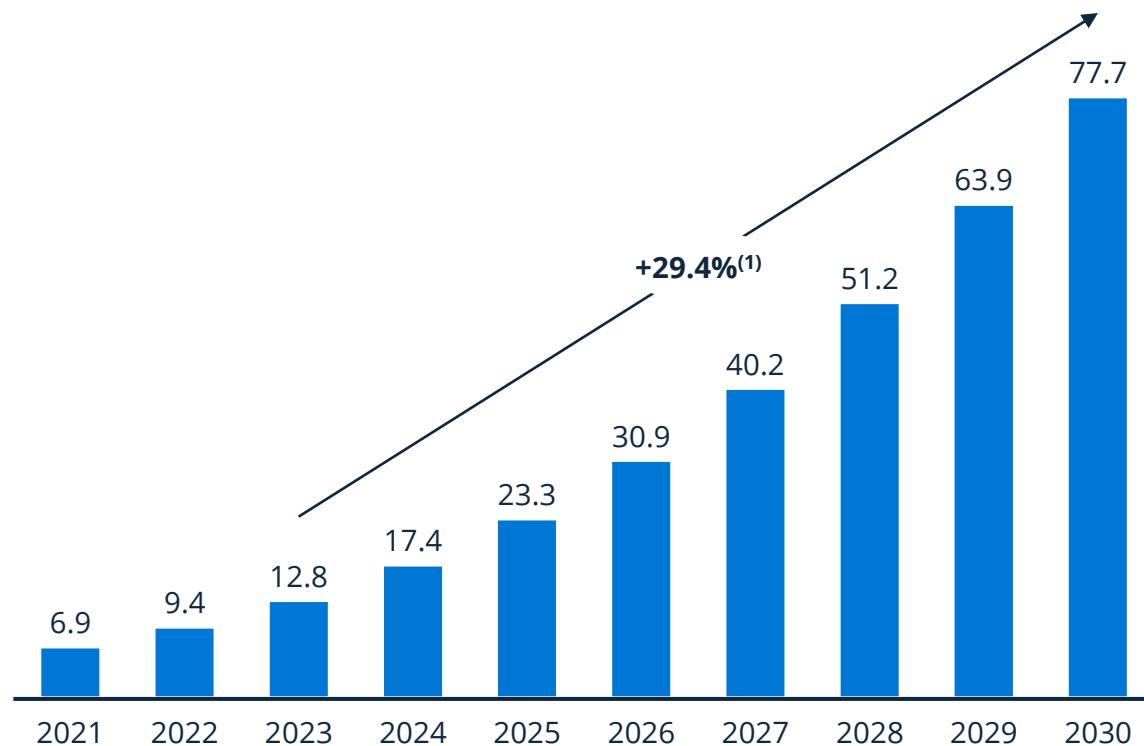
**Chatbot market revenue worldwide in billion US\$**



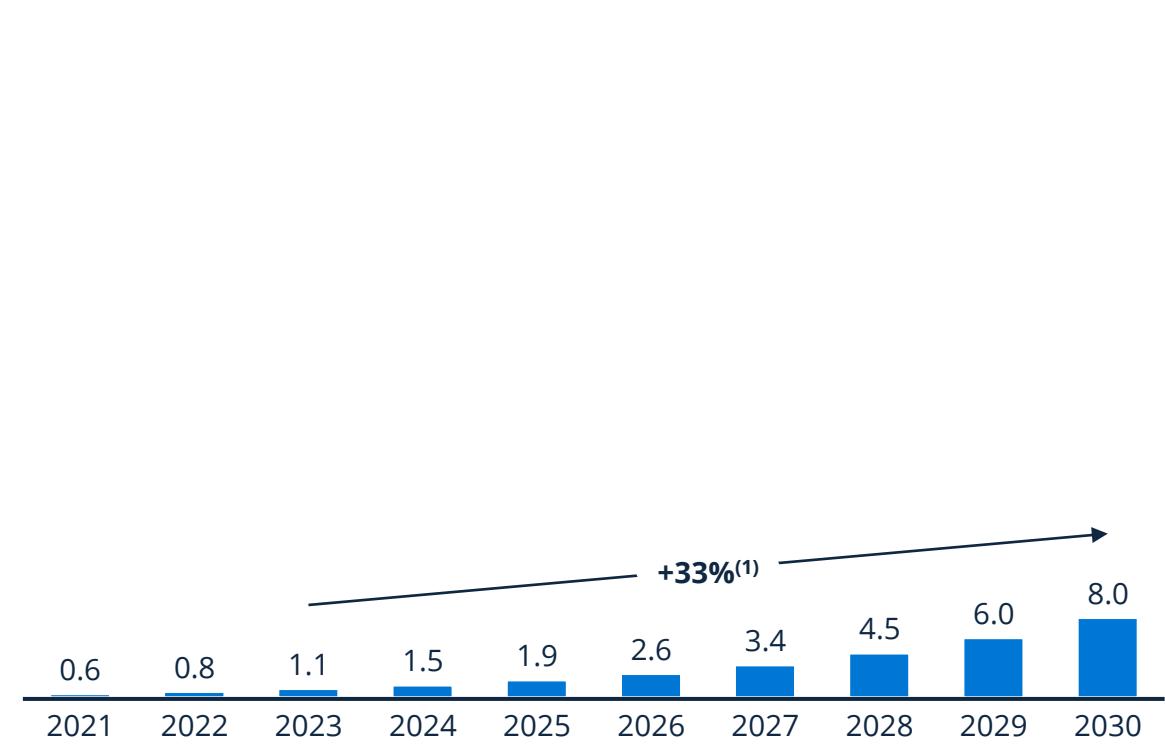
# Global Robotic AI market to be worth US\$78 billion by 2030

Global revenue projection (5/5)

**Global Robotic AI market in billion US\$**



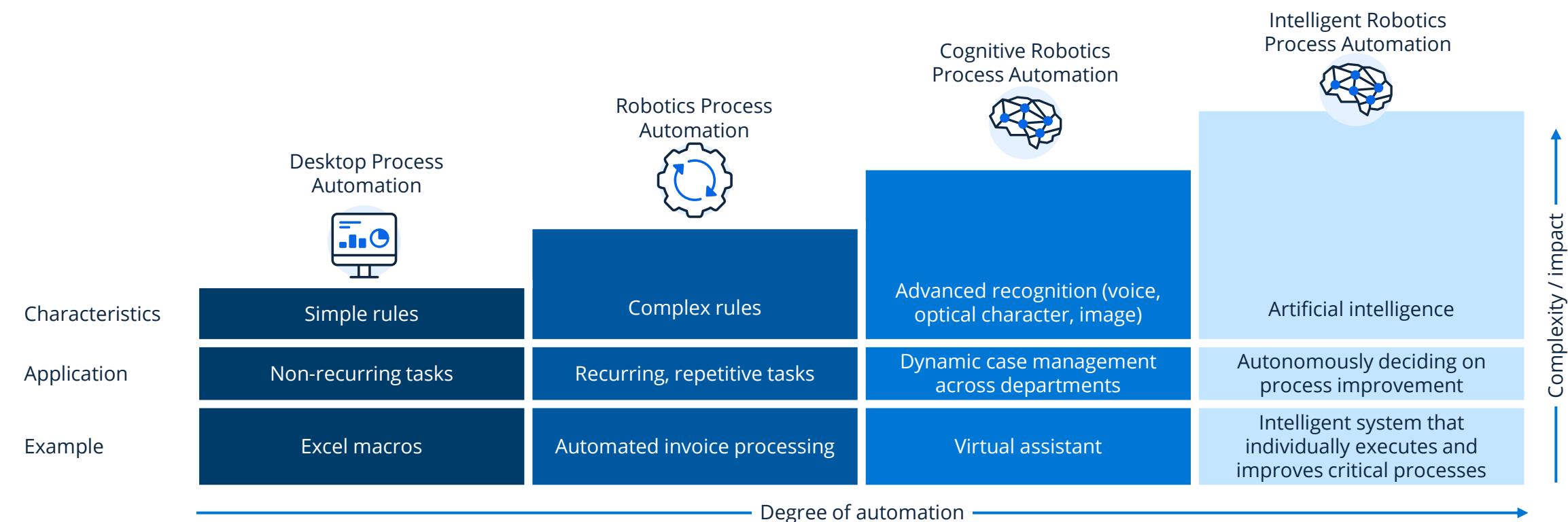
**Global collaborative robots' market in billion US\$**



# AI can autonomously decide process improvement

Robotic process automation (1/3)

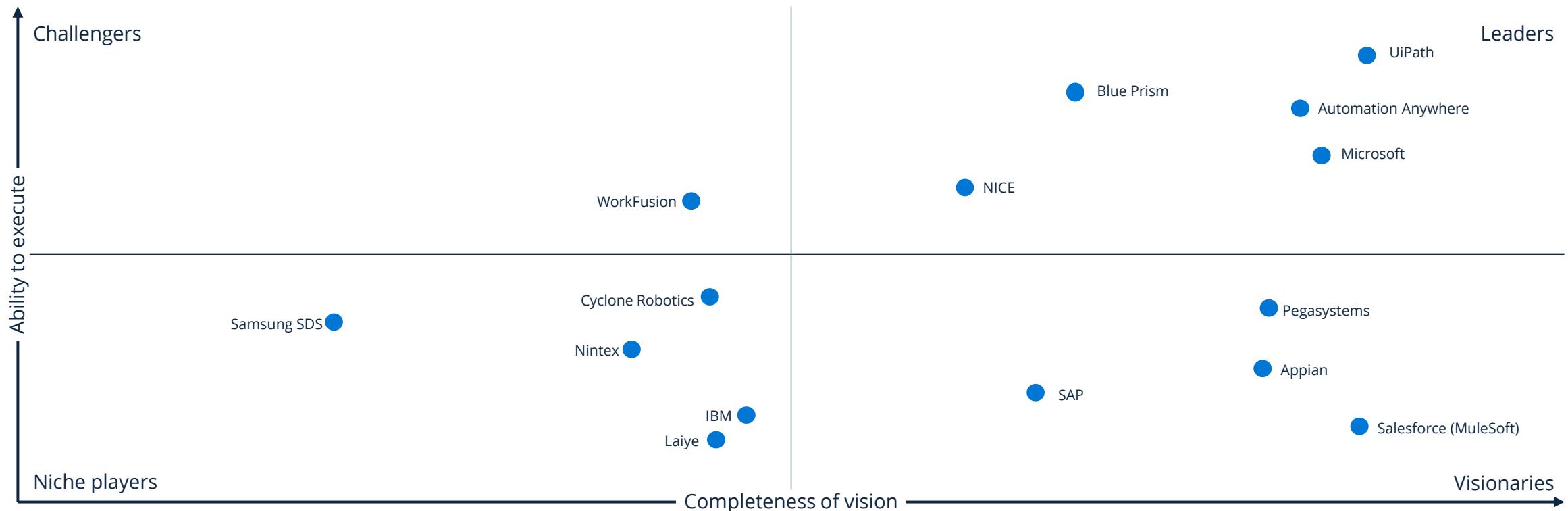
## Stages of robotic process automation



# Key players in RPA are UiPath and Automation Anywhere

Robotic process automation (2/3)

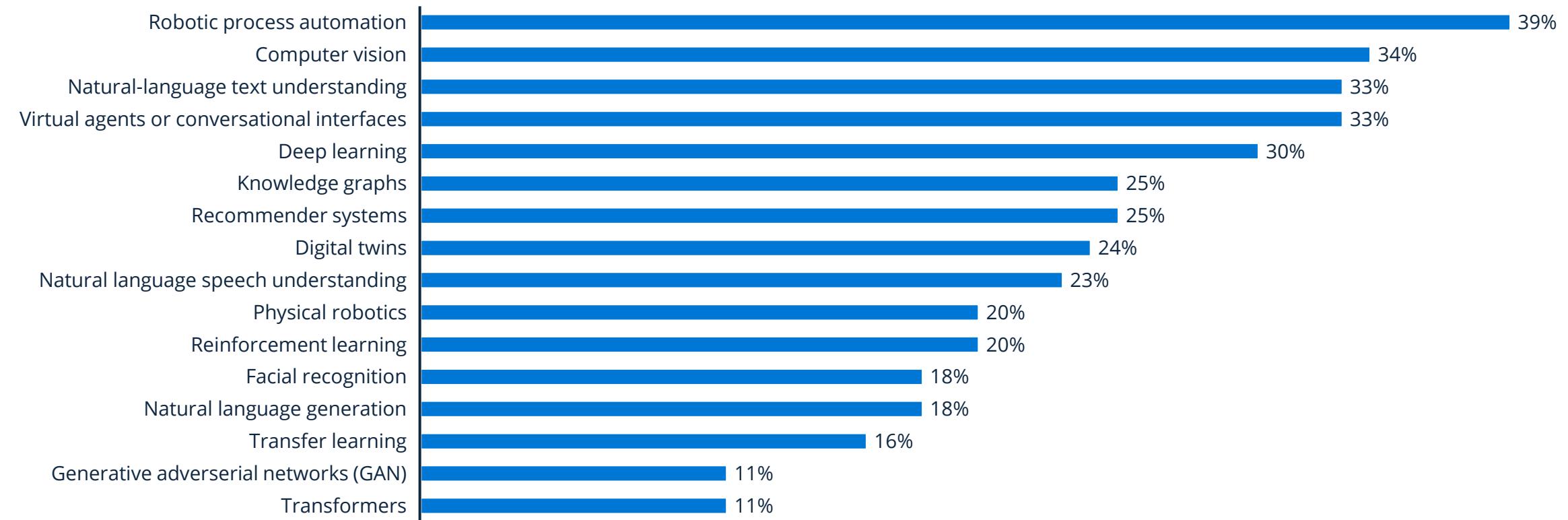
Gartner's magic quadrant for RPA<sup>(1)</sup> as of July 2022



# Most businesses are incorporating Robotic Process Automation and Computer Vision technologies

Robotic process automation (3/3)

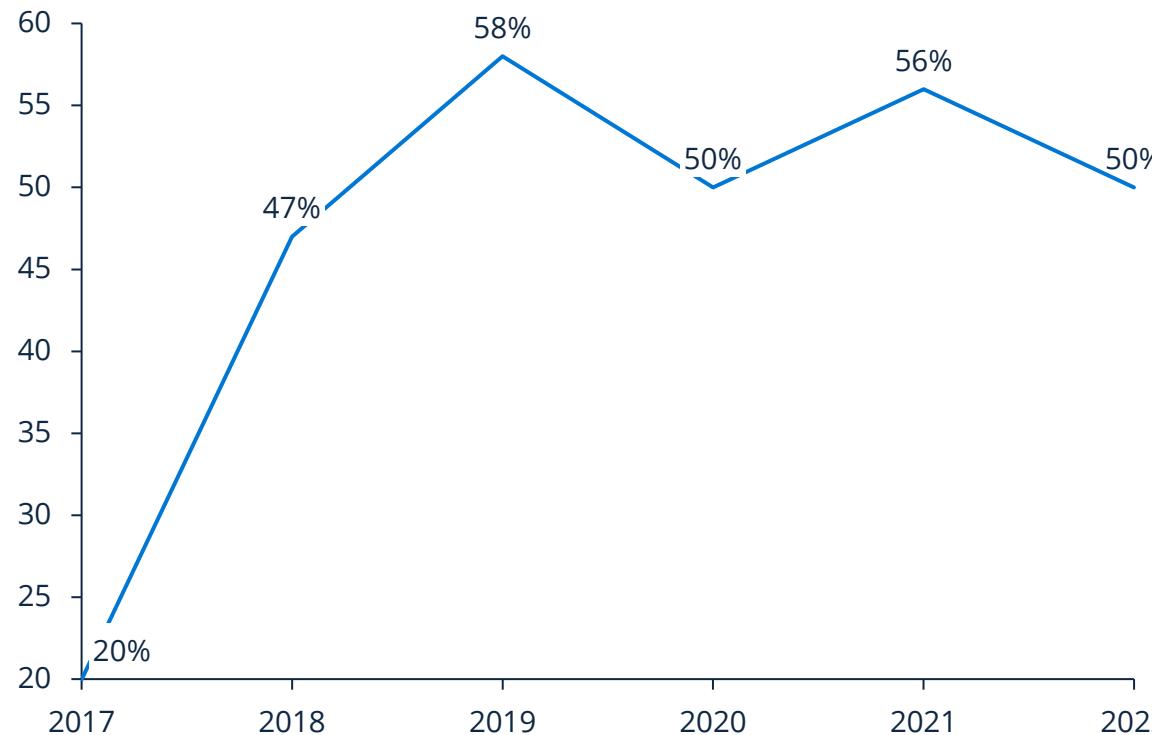
## Leading AI capabilities adoption rate in business 2022



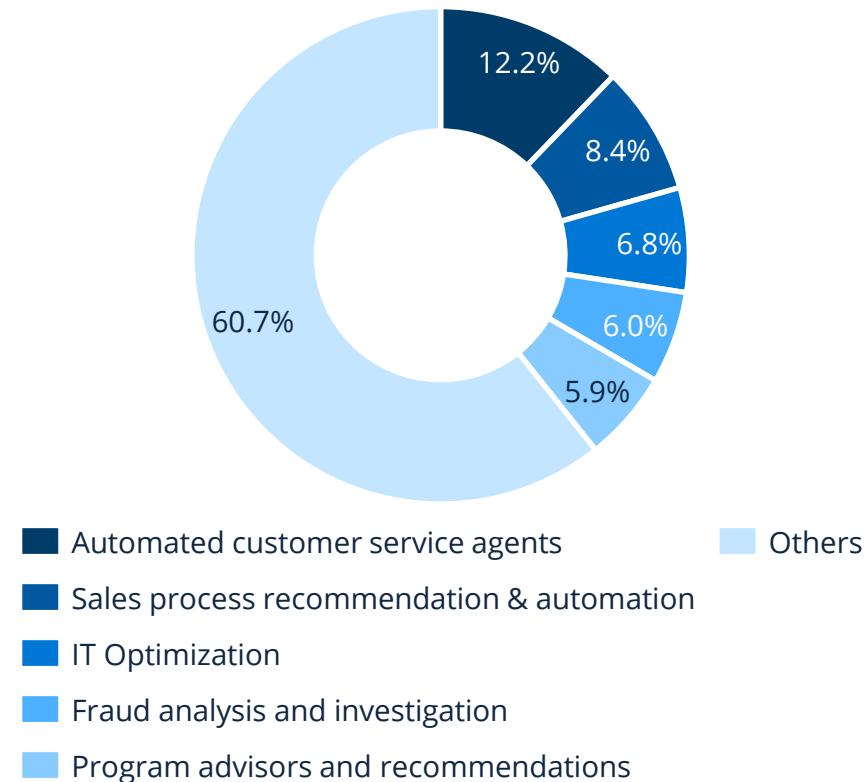
# AI is mostly used as automated customer service agents in 2022

AI adoption

Global AI adoption rate in businesses



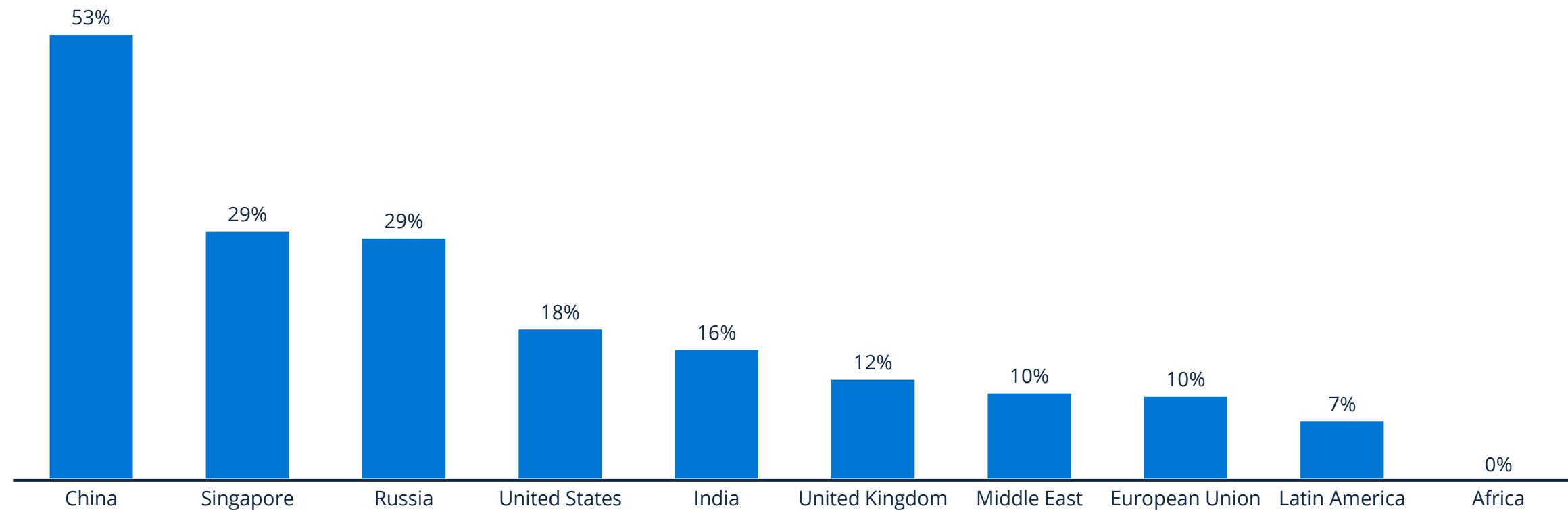
Leading use cases for AI in 2022



# AI growth is fueled by innovation, with China leading the way

AI growth

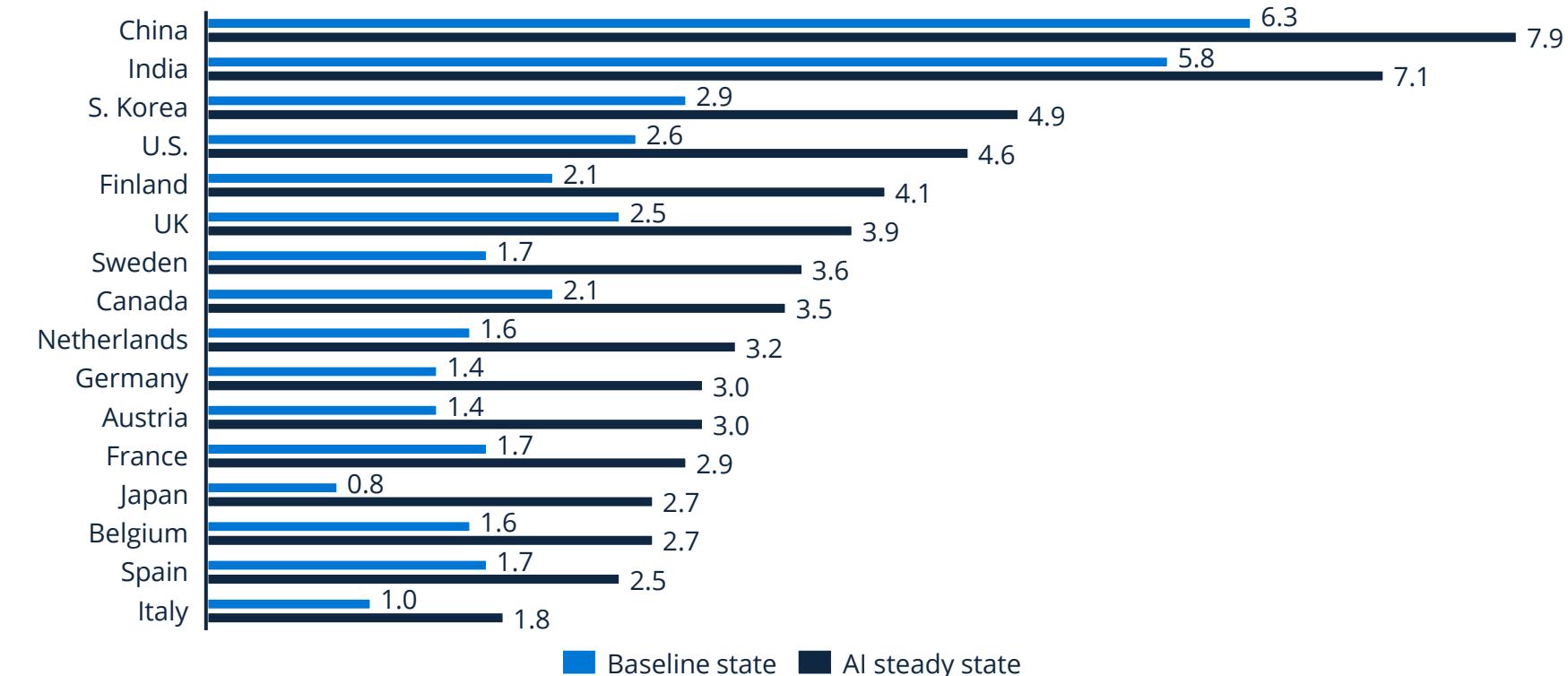
**Expert estimation in the field of most impactful countries in AI innovation between 2022-2025<sup>(1)</sup>**



# AI is expected to have a big impact on GVA growth rates

Impact of AI (1/7)

Potential annual GVA<sup>(1)</sup> growth rates in 2035 in %



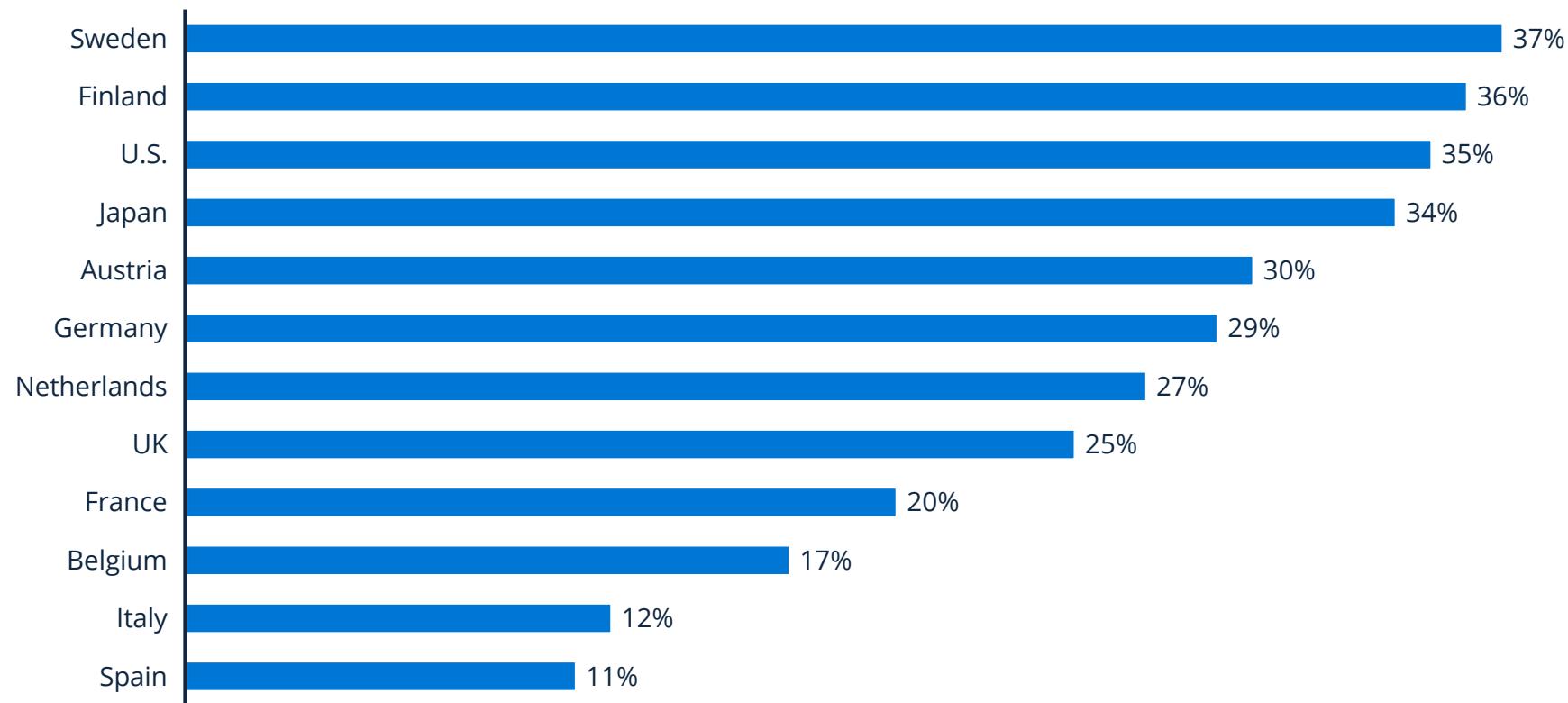
A study by Accenture and Frontier Economics expects AI to have a big impact on a country's gross value added (GVA). It estimates the annual GVA growth rates in 2035 for a baseline state, based on current assumptions regarding economic growth, and for an AI steady state, assuming artificial intelligence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

# AI has the potential to increase labor productivity

## Impact of AI (2/7)

**Impact of AI on labor productivity in developed countries in 2035**



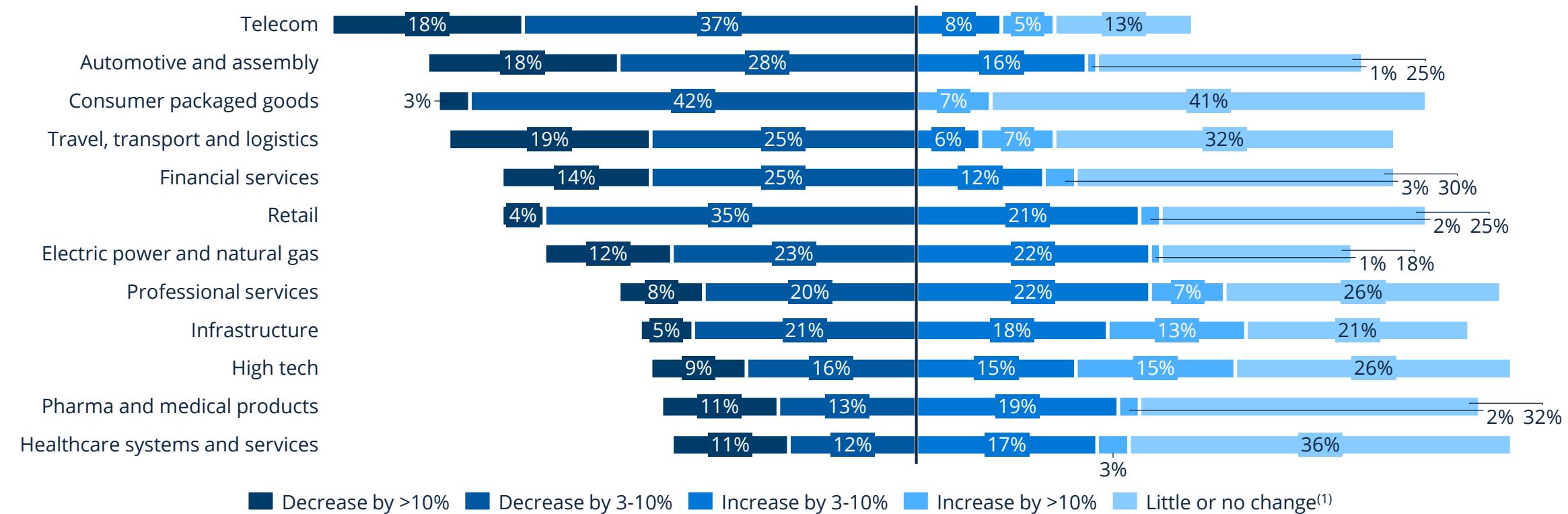
The study by Accenture and Frontier Economics also estimates that AI has the potential to increase labor productivity in countries.

The impact ranges from an 11 percentage points increase in Spain to 37 percentage points in Sweden.

# Telecom industry is predicted to undergo biggest workforce cuts

Impact of AI (3/7)

## Impact of AI on workforces in organizations worldwide in 2020-2023

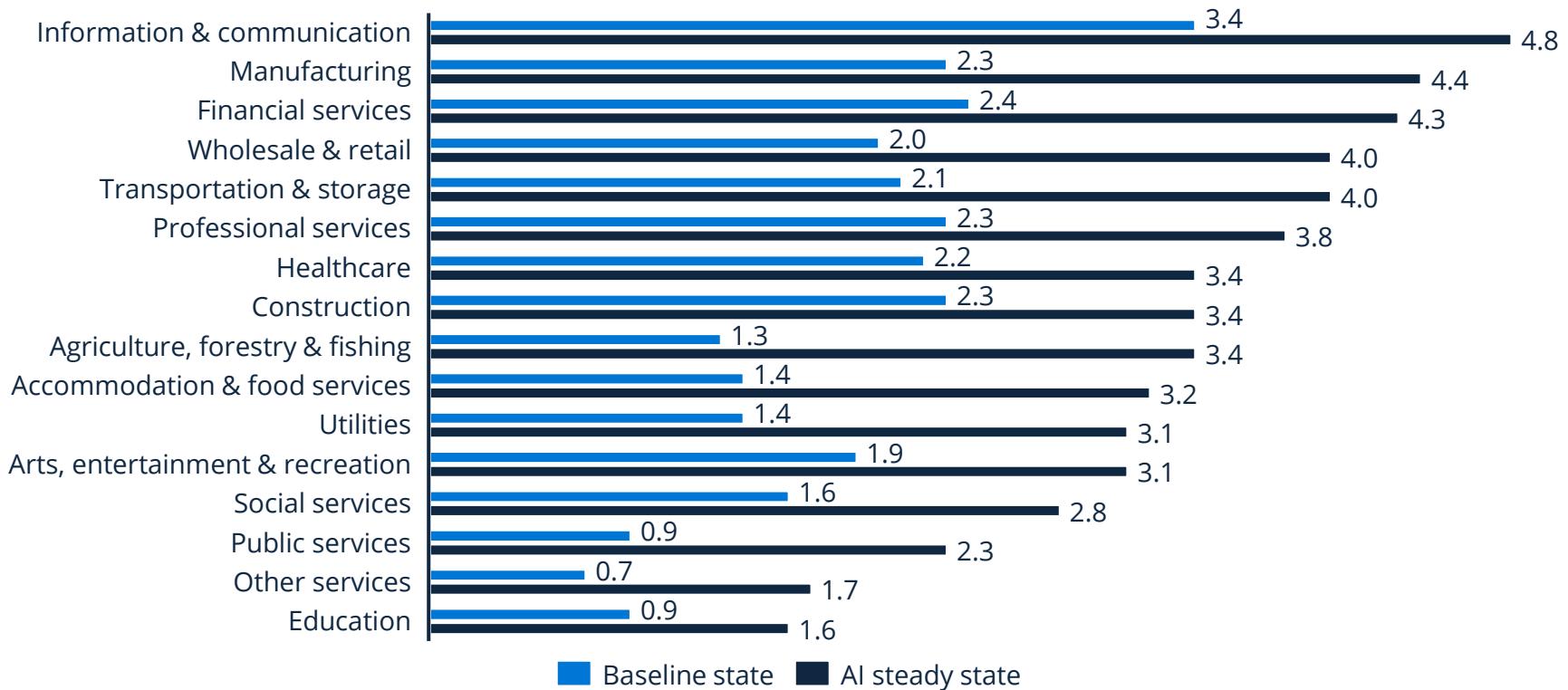


# AI has the potential to increase the growth rate of industries

## Impact of AI (4/7)

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. Moreover, companies that successfully implement AI strategies face the prospect of increasing their profitability by an average of 38% by 2035. Information and communications, manufacturing and financial services are expected to be the top gainers in terms of annual GVA growth rates, with 4.8%, 4.4% and 4.3%, respectively.

### Impact of AI on industry growth in 2035 in %

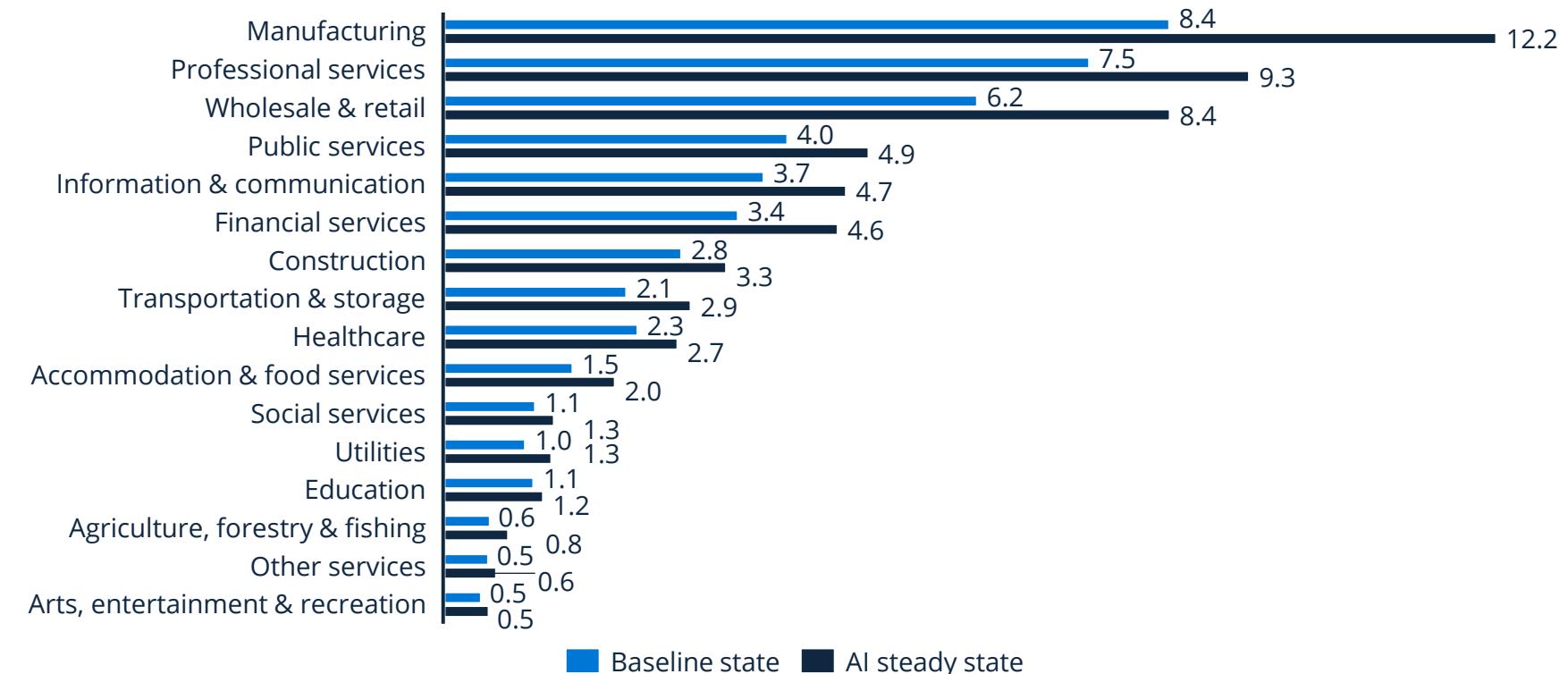


# AI can boost manufacturing output by almost US\$4 trillion

## Impact of AI (5/7)

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<sup>(1)</sup> by almost US\$4 trillion in 2035, followed by wholesale and retail (US\$2.2 trillion), professional services (US\$1.5 trillion), financial services (US\$1.2 trillion), information and communication (US\$1 trillion), transportation and storage (US\$0.8 trillion) and construction (US\$0.5 trillion).

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

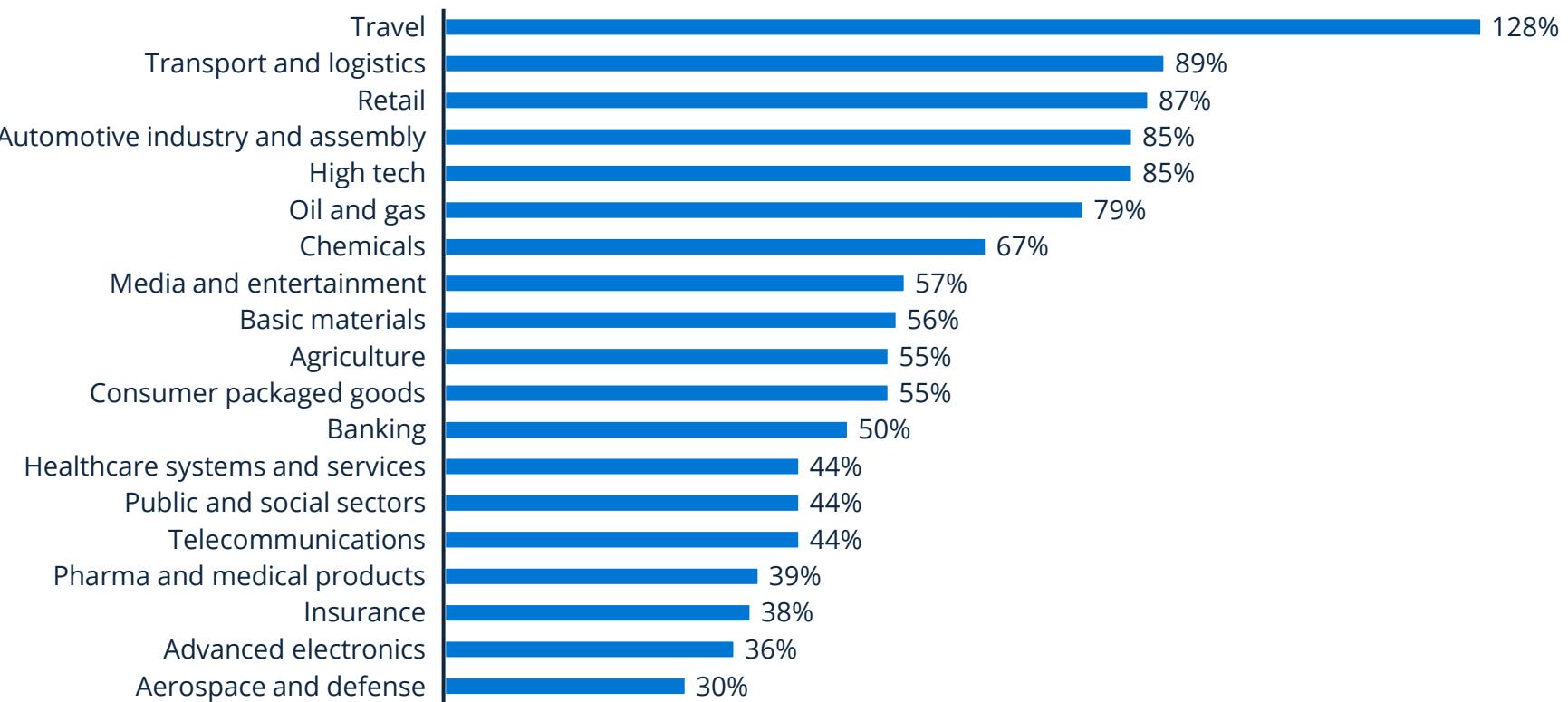


# AI has potential incremental value

## Impact of AI (6/7)

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. The travel industry has the highest potential incremental value of 128%, followed by transport and logistics (89%), retail (87%), automotive industry and assembly (85%), high technology (85%), oil and gas (79%), chemicals (67%) and media and entertainment (57%).

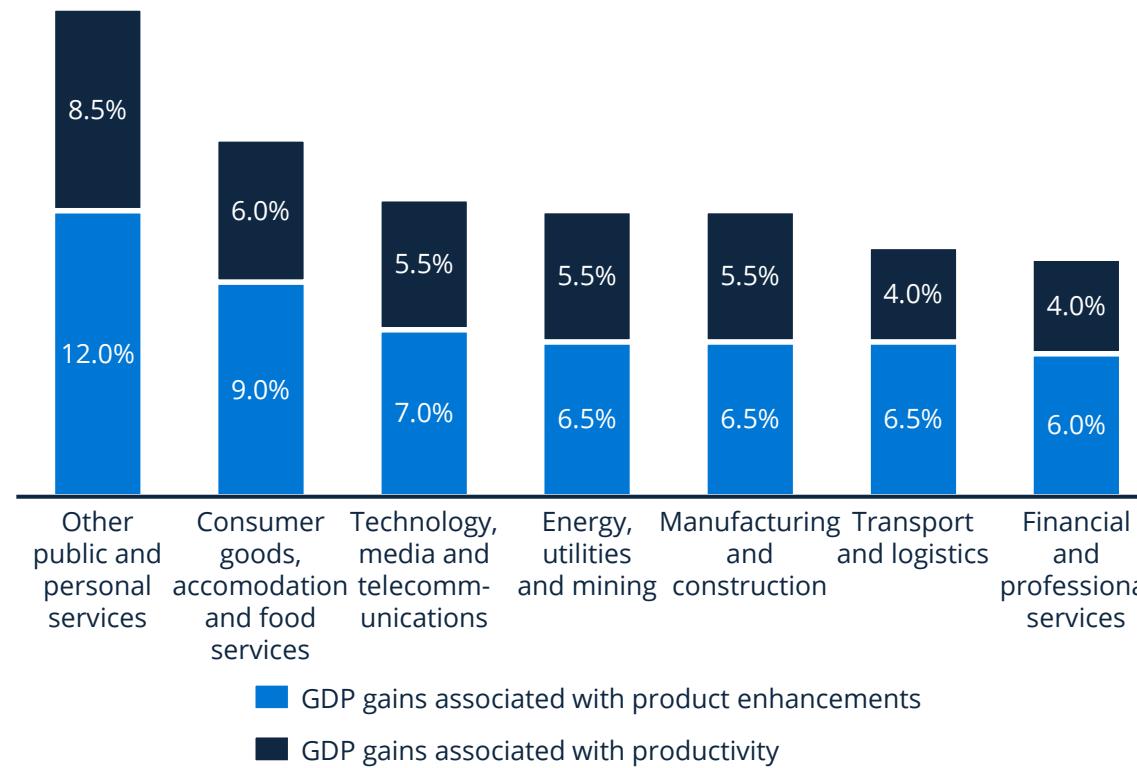
**Potential incremental value of AI as compared to other analytics techniques**



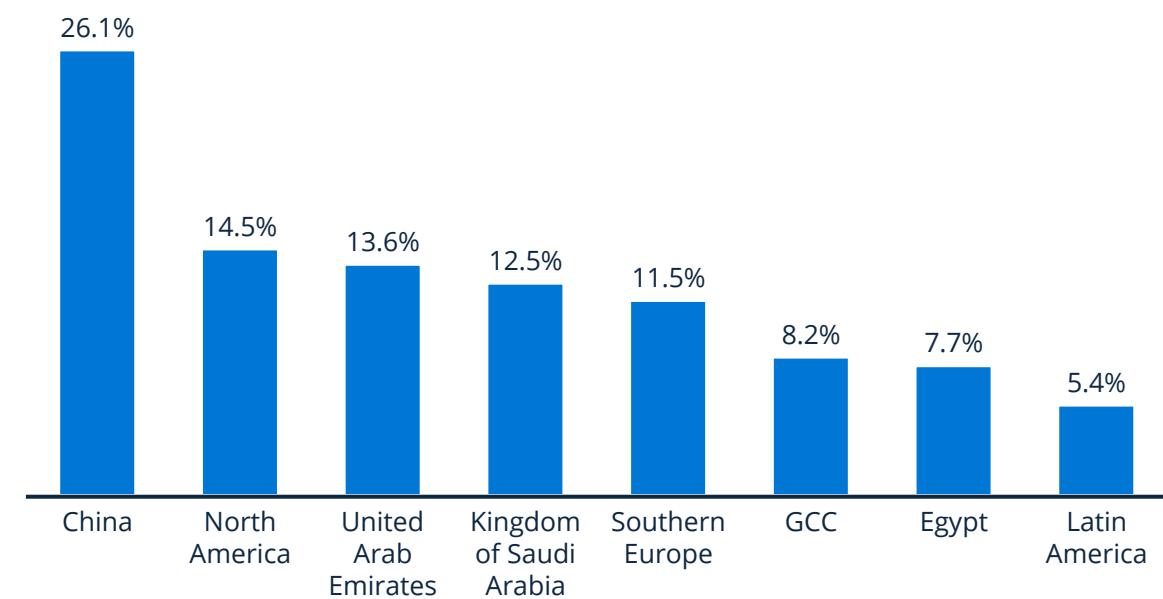
# AI is projected to contribute 26% to China's GDP by 2030

Impact of AI (7/7)

Projected increase of GDP due to AI by industry sector in 2030



Share of projected worldwide AI contribution to GDP in 2030, by region



## CHAPTER 2

# Technologies

The current AI ecosystem consists of machine learning, robotics, artificial neural networks and natural language processing (NLP). 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 act with a certain degree of self-awareness.

Artificial neural networks (ANNs) are built to mimic the working of a human brain. NLP deals with the interpretation and manipulation of human language by computers.



# Machine learning applies insights from existing data to new data

## Machine learning (1/2)

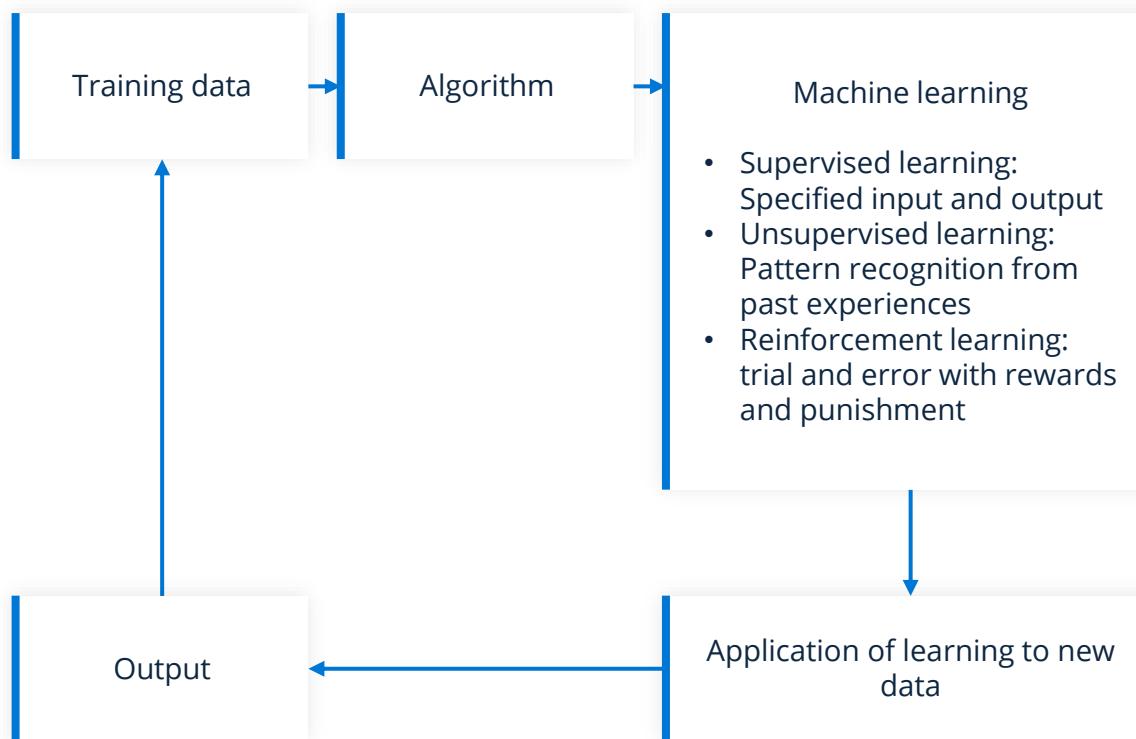
In machine learning, programs learn from existing data and apply this knowledge to new data or use it to predict data. Machine learning involves designing new learning algorithms and improving existing ones to enable computers to act without explicit programming. These algorithms allow computers to analyze 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. Common algorithms used during supervised learning include neural networks, decision trees, linear regression, and support vector machines. This technique is used effectively across various business purposes including predicting real estate prices, bank fraud, health risks, loan risks, and industrial maintenance. According to the business consulting firm Gartner, supervised learning will remain the most popular branch of machine learning over the short to medium term.
- 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, group inventory according to sales, and/or determine associations in customer data. The commonly used algorithms in unsupervised learning include Hidden Markov models, k-means, hierarchical clustering, and Gaussian mixture models.
- 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. Some of the use cases include autonomous driving, training robots, and teaching cars to park themselves.

# There are three types of machine learning applications

Machine learning (2/2)

## Illustration of the machine learning process



# 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:

- 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. The objective is to control a large number of simple robots to solve complex tasks.
- 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. Other use cases include assisting people with limited mobility, picking up soft objects such as fruit, and handling hazardous material.
- 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. According to BBC's Science Focus magazine, Honda Motor Corporation's Asimo is currently the most advanced robot in the world.
- Serpentine robots: Robots that are designed to mimic the movement of snakes in order to navigate through tightly packed spaces.

“We’ve gotten used to having machine intelligence that we can carry around with us. Now we’re going to have to get used to intelligence that has a body and moves around without us.”



Manuela Veloso, AI roboticist  
Carnegie Mellon University, 2020

# Artificial Neural Networks mimic the working of a human 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.

# Natural language processing deals with the interpretation of language

## Natural language processing

Natural language processing (NLP) is a branch of AI that deals with the interpretation and manipulation of human language by computers. The technology, albeit in a more primitive form, started gaining widespread recognition as early as the 1950s, when linguistic experts began developing machines to automate language translations. Today, the major advances in NLP are driven by various deep learning methods that are designed to mimic the functioning of neurons in the human brain. Interestingly, deep learning NLP can now continuously learn from examples or their experiences, thereby finding multiple applications in virtually every sector including healthcare, consumer goods and defense.

A few NLP driven common applications used by people in their daily lives include language translation products such as Google Translate, spell check features on products such as Microsoft Word and Grammarly, Interactive Voice Response (IVR) applications used in banks and call centers, and personal assistants such as Alexa, Siri, and Cortana. The key applications of NLP include:

- Speech to text: Popularly known as speech recognition, this technique involves the conversion of spoken language into text, which can be processed by other applications.
- Text-to-speech: Also known as speech synthesis, this involves the conversion of any text to related speech.
- Text processing: This technique involves making sense of the text and extracting bits of information that can be used to derive meaningful insights.
- Natural language generation (NLG): This technique differs from text processing in that it doesn't need much human intervention. In this, insights are directly inferred from the large dataset.
- Chatbots: Bots driven by NLP have the capabilities to understand a lot of human communication. Even though they cannot grasp the subtleties or nuances of human language, they can be programmed to respond to specific questions.
- Machine translation: This includes the automatic translation of text from one language to another. This technique has advanced from being solely reliant on predefined rules, to using complex statistical models, and most recently, using neural networks to mimic human-like thinking.

## CHAPTER 3

# 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 (1/5)

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".

“Today’s AI systems are typically trained to carry out a single task, one that they might get very good at, yet they can’t transfer their painstakingly acquired skills to any other domain. But human beings use their emotions to help navigate new situations every day; that’s what people mean when they talk about using their gut instincts. We want to give AI systems similar abilities.”

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Mary Czerwinski, Research Manager

Microsoft’s Human Understanding and Empathy Group, 2021

# Emotionally intelligent AI systems have various applications

Artificial emotional intelligence (2/5)



## 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 developed technology that is better than polygraph

Artificial emotional intelligence (3/5)



## 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.

# Huawei aims to build an emotionally intelligent voice assistance software

Artificial emotional intelligence (4/5)



## Huawei

The company 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 AI-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's new tech gathers insights of a person from handwriting

Artificial emotional intelligence (5/5)

## Receptiviti.ai

### 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

## BRAIQ

### 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.

# 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.

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 Naisense, SwiftKey/Microsoft Research, and Facebook AI Research.

“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  
DeepMind, 2017

# Algorithms can now transcend beyond pattern recognition

## Reinforcement learning (1/4)

Until recently, AI algorithms mainly operated on their ability to recognize patterns from large datasets to generate predictions. However, AI scientists have been working on a novel technology called reinforcement learning that not only enables pattern recognition but also helps the AI algorithms discover new and most optimal ways of finishing a task, simply by learning from their mistakes or inefficiencies. In a nutshell, reinforcement learning allows AI-powered algorithms to produce not predictions but actions that are most likely to finish a particular task faster or more efficiently than before.

A good example of this technology in action is Google owned Deepmind's AlphaGo computer program that has beaten many world champions in the game Go. In fact, one of the main reasons for its phenomenal success has been its use of reinforcement learning techniques. Instead of feeding the algorithm with past examples of Go champions playing games, the developers got it to play millions of matches against itself. Because of this, AlphaGo has had a chance to learn new moves and strategically evaluate if they improved performance or not.

Despite its obvious usefulness, the technology didn't find many takers for long with its use limited to industries such as education, video games, and robotics. Yet of late, other industries such as advanced electronics and semiconductors, agriculture, aerospace & defense, automotive, financial services, mining, oil and gas, pharmaceuticals, retail, telecom, and transport and logistics have started using the technology to solve complex business problems.

# Industries using Reinforcement learning in various applications (1/2)

## Reinforcement learning (2/4)

Industry	Application
Advanced electronics and semiconductors	<ul style="list-style-type: none"><li>● Optimize silicon and chip design to increase performance and reduce manufacturing costs.</li><li>● Optimize fabrication manufacturing process for improved yield and throughput</li></ul>
Agriculture	<ul style="list-style-type: none"><li>● Solve scheduling and production allocation challenges to increase yield</li><li>● Optimize network and warehouse logistics for reduced waste and costs</li><li>● Apply advanced pricing and promotion to improve product margins</li></ul>
Aerospace and defense	<ul style="list-style-type: none"><li>● Optimize engineering design processes to reduce time to market for new systems and improve quality</li></ul>
Automotive	<ul style="list-style-type: none"><li>● Optimize design processes to shorten development cycle for new cars and features and improve quality</li><li>● Deploy advanced predictive maintenance to prevent rare failures and unplanned outages</li><li>● Deliver real-time production monitoring and controls to increase manufacturing yield</li></ul>
Financial services	<ul style="list-style-type: none"><li>● Apply real-time trading and pricing strategies for greater agility and revenue</li><li>● Optimize ATM replenishment and allocation strategies to reduce costs and improve the customer experience</li><li>● Deliver advanced personalization capabilities that adapt promotions, offer, and recommendations daily for increased customer satisfaction and sales</li></ul>
Mining	<ul style="list-style-type: none"><li>● Optimize design process so teams can explore a greater range of mine designs for improving mine yield</li><li>● Use intelligent process controls for managing power generation and bore milling to increase yield and reduce costs</li><li>● Apply holistic logistics scheduling to optimize mine-to-shipping operations and reduce costs</li></ul>

- Optimizing product development cycles (AI-assisted design)
- Optimizing complex operations
- Informing next best action for each customer

# Industries using Reinforcement learning in various applications (2/2)

## Reinforcement learning (3/4)

Industry	Application
Oil and gas	<ul style="list-style-type: none"><li>Enable real-time well monitoring and precision drilling for increased yield</li><li>Optimize tanker routing to reduce costs and ensure on time delivery</li><li>Enable advanced predictive maintenance to prevent rare equipment failures and unplanned outages</li></ul>
Pharmaceuticals	<ul style="list-style-type: none"><li>Optimize drug discovery, identifying molecules of interest faster to reduce the time and cost of research and bring new therapies to market faster</li><li>Automate chemistry, manufacturing, and controls (CMC) to maximize batch yield and quality</li><li>Optimize biological methods to reach peak production output</li></ul>
Retail	<ul style="list-style-type: none"><li>Optimize routing, logistics network planning, and warehouse operations to reduce costs and keep shelves stocked</li><li>Implement advanced inventory modeling and digitize supply chain planning to prevent out-of-stocks and waste</li><li>Deliver advanced personalization capabilities that adapt promotions, offers, and recommendations daily for increased customer satisfaction and sales</li></ul>
Telecom	<ul style="list-style-type: none"><li>Optimize network layout to maximize coverage and minimize power consumption</li><li>Manage networks in real-time to optimize service quality and reduce downtime</li><li>Apply advanced personalization to increase cross-sell and upsell revenue</li></ul>
Transport and logistics	<ul style="list-style-type: none"><li>Optimize routing, logistics network planning, and warehouse operations to reduce costs and improve customer satisfaction</li><li>Optimize inbound and outbound delivery networks to minimize shipping delays and associated costs</li></ul>

- Optimizing product development cycles (AI-assisted design)
- Optimizing complex operations
- Informing next best action for each customer

# Companies using Reinforcement learning to solve problems

Reinforcement learning (4/4)

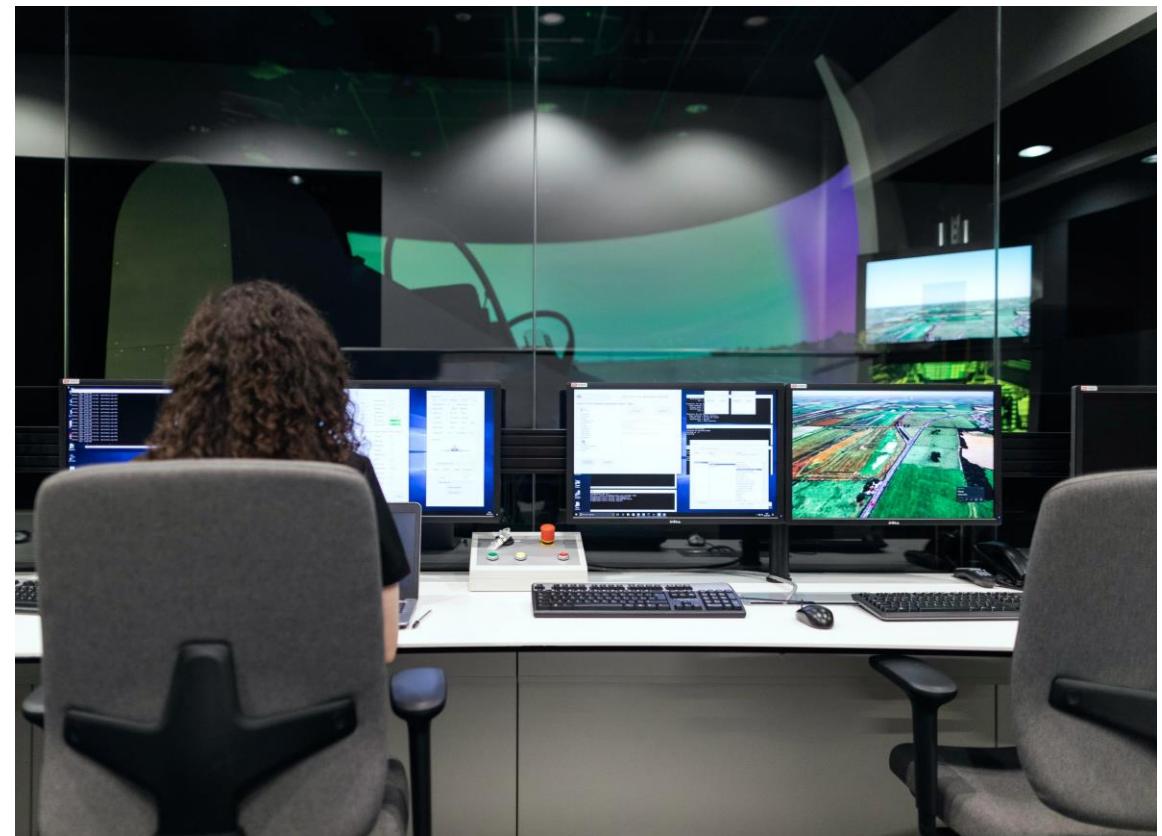
Company	Application	Sector	Inputs	Actions	Objective
 RBC	Trade execution platform for multiple strategies	Financial services	200 plus market related data inputs	Sell, buy, hold stocks	To trade as close as possible to VWAP, a common price metric
 NETFLIX	Test schedules for business partner devices	Technology	Historical test and device performance information	Which test to do next	Minimize device failure
 Spotify	Recommendation engine	Entertainment	Previous songs liked/disliked/not played	Which songs to put in your playlist	Maximize user listening time
J.P.Morgan	Financial derivatives risk and pricing calculations	Financial services	Historical market data	Price and sell a financial product	Maximize future cash flows of an investment portfolio
 Google	Data center cooling	Technology	Temperature/air pressure	Turn on fan; add water to air unit	Control temperature and reduce energy usage
 DiDi	Order dispatching	Ride-hailing	Number of idle vehicles, number of orders, location destinations	Match driver to passenger	Minimize pick up time and maximize revenue

# Deep learning is used across industries for various tasks

## Deep learning (1/4)

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 expected to play a pivotal role in developing autonomous cars

Deep learning (2/4)



## 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.

# One application of deep learning is to detect fraud

Deep learning (3/4)



## 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.



## 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.

# Deep learning is used to detect malware

Deep learning (4/4)



## 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 Alturos 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.



## Entertainment

Deep learning is having a profound impact on the entertainment industry, from the way movies are made to how they are marketed and distributed. On the production side, deep learning is being used to create more realistic and believable visual effects. It is also being used to create more lifelike and believable characters, both in animation and in live-action films. On the marketing and distribution side, deep learning is being used to target potential audiences with more precision and to track and analyze their behavior after they watch a film or TV show.

# China is the global leader in AI research

## Rise of China: Overview (1/2)

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 released by Stanford University in 2021 found that China surpassed the U.S. in terms of AI journal citations in the world, in 2020. Interestingly, it is not the first time this has happened with China having briefly taken the lead in 2004 and then again in 2017. Also, 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, the U.S. leads the world with a share of 54% in Q4'22, followed by China. China also developed its first 'national laboratory for deep learning' in 2017. The National Development and Reform Commission (NDRC) commissioned Baidu to create the lab in partnership with Tsinghua and Beihang universities and other research institutes. The lab's area of focus includes machine-learning-based visual recognition, voice recognition, new types of human-machine interaction, and deep learning intellectual property.

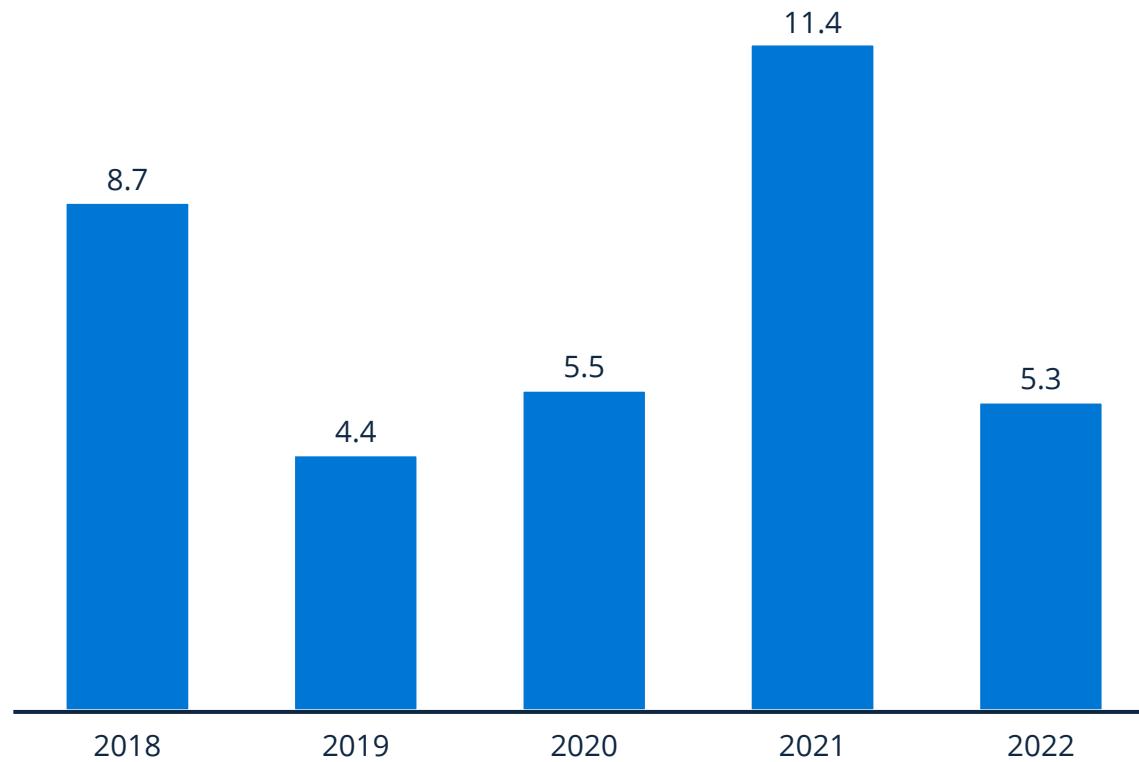
Another visible indication of Chinese dominance in the not-so-distant past is its strong investment in American companies. In fact, according to a 2022 study by the U.S. Treasury Department, Chinese interest in U.S. companies almost doubled in 2021 as compared to the previous year. In May 2019, Nikkei, a stock market index for the Tokyo Stock Exchange, published a study confirming that Chinese companies had surged ahead of their U.S. counterparts, on a ranking of the top 50 patent filers for AI over the period 2016-2018.

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, a 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.

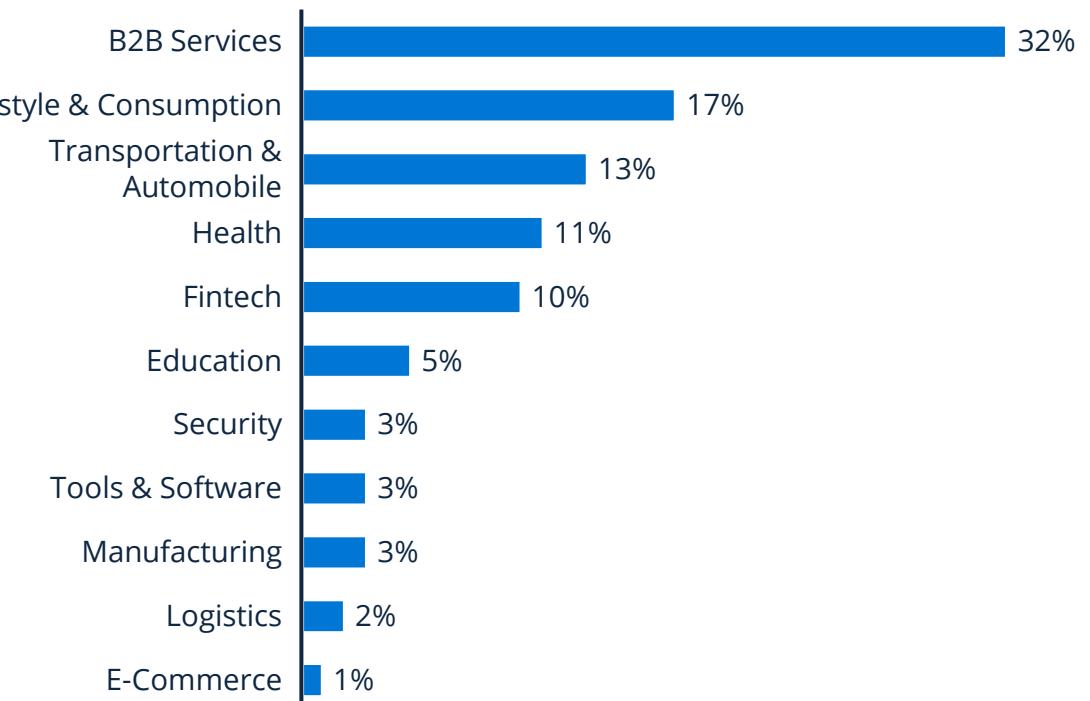
# Majority of China's AI related investment is in B2B services

Rise of China: Overview (2/2)

**AI fundings in China in billion US\$**



**China's AI investment by sector in 2019**



# 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 spent as much as 15% of its entire revenue on AI-related research in 2015, 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. In 2020, this expenditure increased to over 21% of Baidu's revenues. One of the biggest wins coming out of this investment is the PaddlePaddle deep learning framework that is now the biggest in China with 4.77 million developers and 180,000 enterprises globally. Unsurprisingly, the company's AI cloud revenue increased by as much as 64% in 2021.

## 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 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<sup>(1)</sup>.

## Divestments and spin-outs of non-core businesses

To direct more of its resources towards AI, Baidu sold its food delivery business Baidu Waimai in August 2017 and expanded its utility apps and its mobile ad business in May 2018. The company has now set up a new global business unit around its AI-powered services, such as the recommendation engine PopIn and keyboard app Simeji. In June 2022, the company announced that it was also looking to sell its 53% stake in the OTT platform iQIYI to develop its capital-intensive AI and autonomous driving businesses.

# Baidu has established research center to expand its reach in AI

Rise of China: Baidu

## **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: In June 2021, Baidu launched its fifth-generation robotaxi, Apollo Moon, with a production cost of RMB 480,000 per unit, at only one-third the cost of average L4 autonomous vehicles. This is part of 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.

Also, in 2021, Baidu launched JIDU, its autonomous car brand in partnership with Geely. JIDU, which started out with US\$300 million in start-up capital, raised another US\$400 million in early 2022.

Digital Human: Baidu's subsidiaries such as DuXiaoxiao, Xijiajia, and Xiling are part of its digital human platform, with AI applications in industries such as customer service, finance, entertainment, tourism, and government. According to company sources, Xiling has 98% accuracy in natural language processing and 98.5% accuracy in mouth shape synthesis.

Kaiwu 2.0: An advanced version of Baidu's cloud-based industrial internet platform, Kaiwu 2.0 offers 200 industrial solutions and 38,000 industrial models across areas such as quality control, safety production, energy saving and emission reduction, production, and manufacturing.

# Most of Tencent's AI investments are health-related

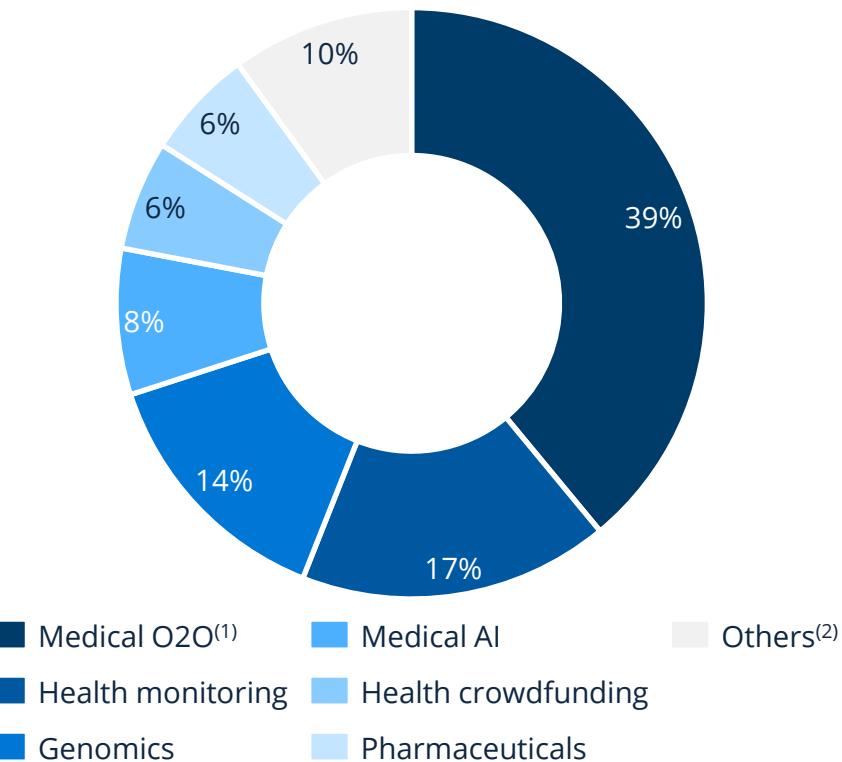
## Rise of China: Tencent (1/3)

With the slogan of 'Make AI Everywhere', Tencent is among the largest AI investors in China. In fact, in May 2020, the company announced an investment plan of around US\$70 billion over the next five years in cloud computing and AI. Among its major AI investments include computer vision company Qtong Vision, smart transportation provider Sinoits Tech and AI semiconductor chips manufacturer Enflame Technology, it's current 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 October 2020, the company also announced the launch of two new AI-powered medical imaging and data management devices; the AIMIS Medical Image Cloud and the AIMIS Open Lab which will aid in the management of medical data and speed the development of medical AI applications. In September 2022, it launched an AI-powered hearing aid with the Shenzhen Eartech Company.

Share of Tencent's AI investments in 2014-2017



Notes: (1) Medical Online to Offline service category (2) "Others" includes investment in resuscitation training, veterinarian social network, clinic and food safety

Sources: China Daily; Computer Business Review; Technode; The Drum

# Tencent invested in robotics start-up UBTech

Rise of China: Tencent (2/3)

## 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 focuses 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 since then, has collaborated with the company, aiming to launch robots that can communicate and interact more naturally and intuitively. At the 2021 Consumer Electronics Show, the company demonstrated its new line of humanoid robots, including the UV-C Robots, which have been developed especially to help businesses and schools function safely amid the pandemic. Tencent's latest invention in the field of robotics is a multimode quadruped robotic dog called Max which is equipped with advanced technologies such as terrain recognition and robot visual positioning.

## 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,

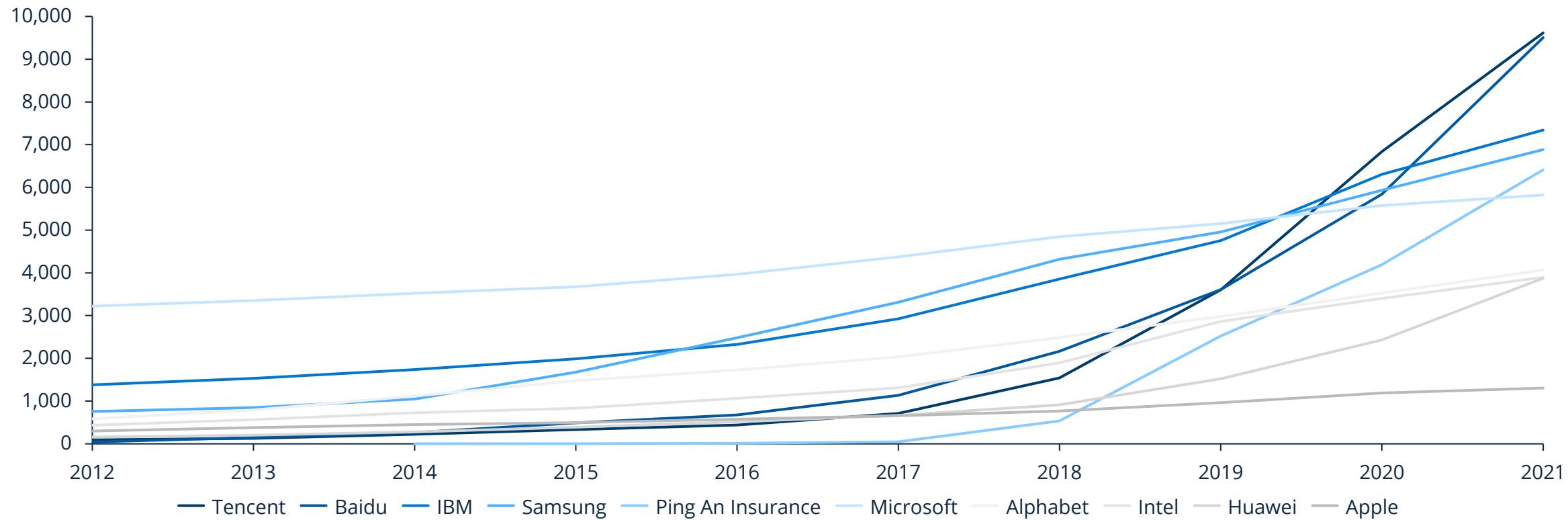
Dongfeng Liuzhou Motor, GAC Group, Geely, FAW China and the BMW group. In October 2017, the company launched an AI system that facilitates the manufacture of cars capable of calculating the best route, ordering food, and searching for parking lots with minimum human intervention.

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. In July 2020, the company launched TAD Sim 2.0, the latest generation of its autonomous driving simulation platform, designed to improve the development and testing of autonomous driving systems. Tencent's latest partnership is with Daimler Greater China Ltd., a subsidiary of Mercedes-Benz Group, to develop AI-based, self-driving technologies in China.

As of December 2021, Tencent was the largest owner of active machine learning and AI patent families

Rise of China: Tencent (3/3)

**Global largest patent owners in ML and AI from 2012 to 2021 by number of active patent**



# AI hardware is growing at a faster pace as compared 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. The revenues for AI software and hardware are expected to grow at a faster pace over the next three years at a CAGR of 33% and 17.2%, respectively.

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.

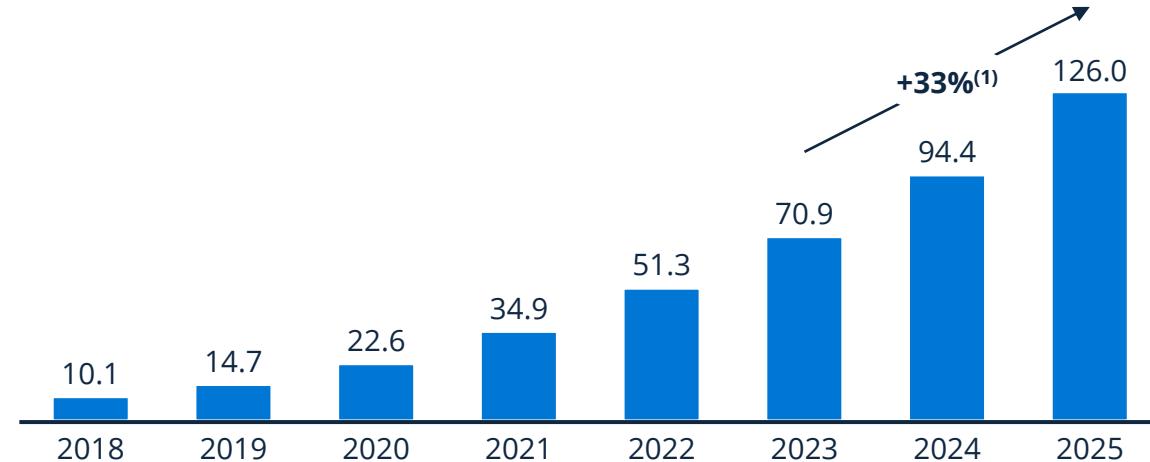
GPUs, which have begun to play a significant role in training large deep neural networks, are expected to be a major catalyst for AI progress. This is because GPUs offer a huge parallel architecture that has the ability to handle multiple tasks simultaneously. Since neural networks are required to process 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.

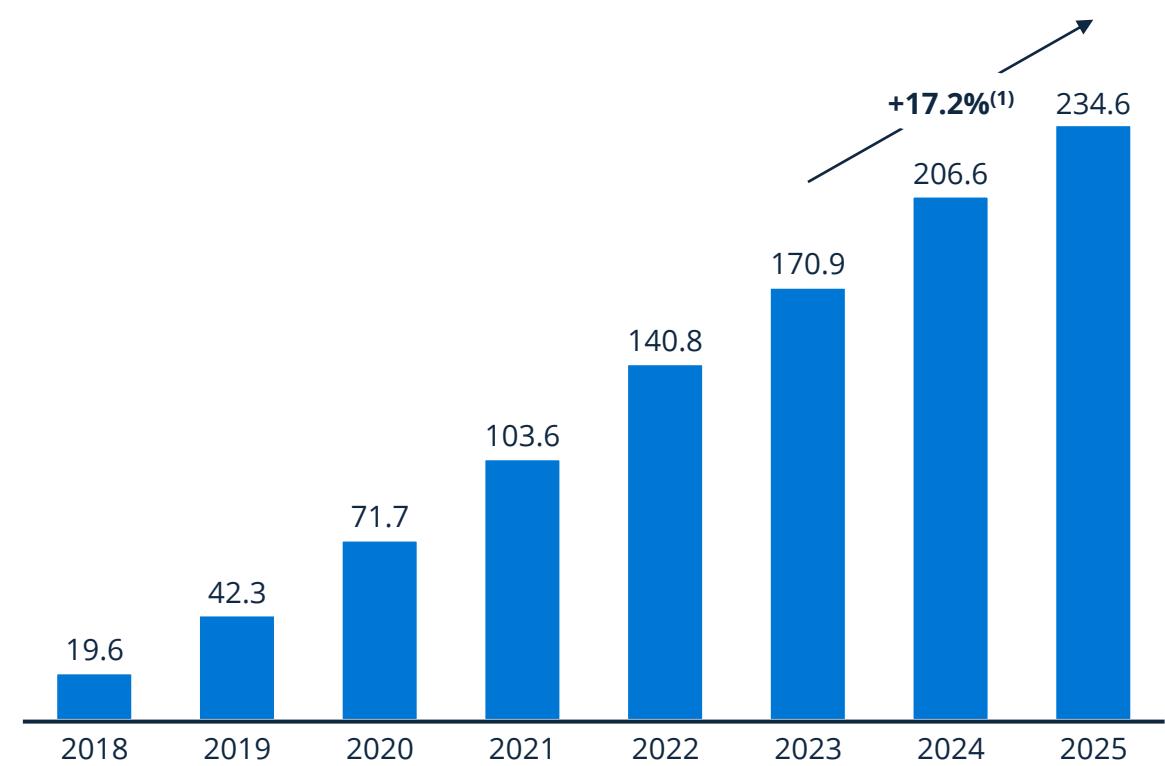
# AI-driven hardware market to cross US\$200 billion by 2024

Growth in hardware and software (2/2)

**Global AI software revenue projection in billion US\$**



**AI-driven hardware market revenue in billion US\$**



# 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, XProp 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.
- Datature: A Singapore-based start-up that has developed a no-code, end-to-end machine learning operations (MLOps) platform, that enables businesses to build advanced AI capabilities, including transfer learning, and deploy AI models quickly.

## CHAPTER 4

# Drivers

One of the major factors driving the current wave of AI growth is the strong interest of Venture Capital (VC) 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 163 trillion gigabytes by 2025. This growth in big data is driving the improvement of AI algorithms.



# VCs remained as the most active AI investors in 2022

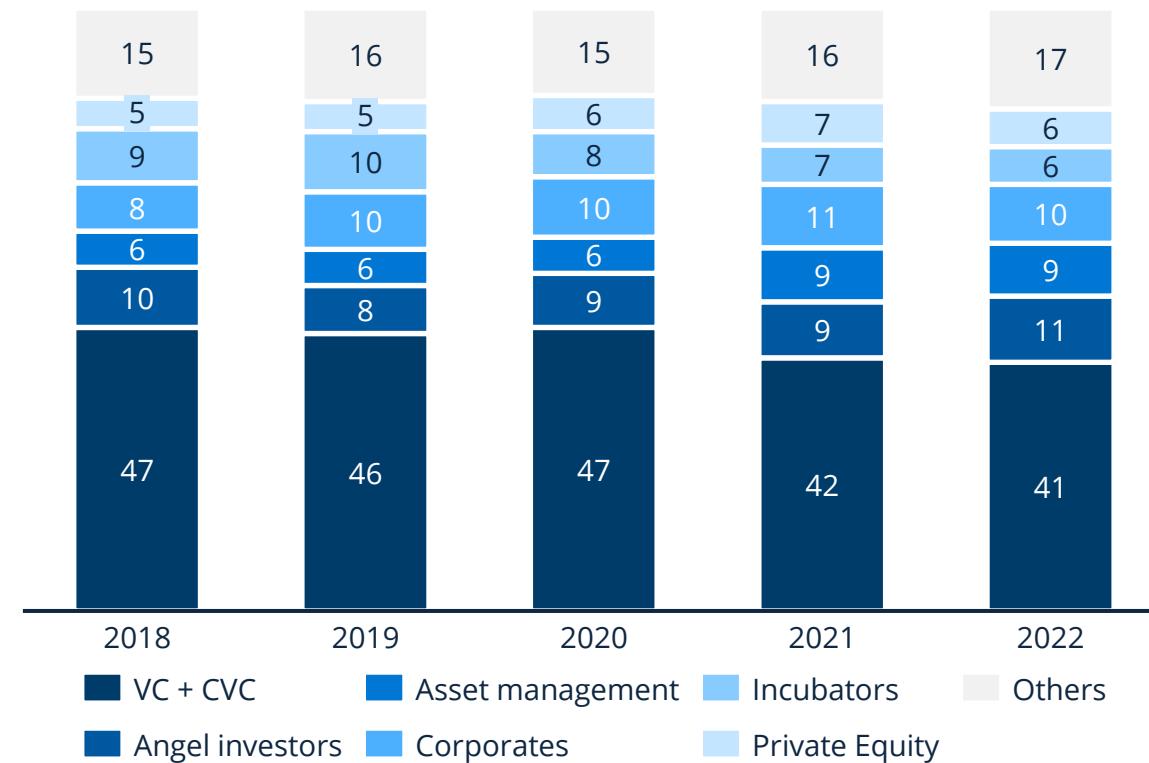
## Investors' confidence

One of the major factors driving the current wave of AI growth is the strong interest of Venture Capital (VC) investment<sup>(1)</sup> in AI start-ups. According to CB Insights, the annual global AI funding increased at a CAGR<sup>(2)</sup> of over 32.8% from US\$6.3 billion in 2015 to US\$45.8 billion in 2022.

The other key insights related to global AI investments in 2022 are:

- The U.S. with 236 deals worth US\$5.0 billion and Asia with 191 deals worth US\$2.4 billion maintain lead in AI-related deals and fundings in Q4'2022.
- AI deal share remained consistent in 2022 in major global markets.
- 2 out of every 5 AI related deals were for US-based companies.
- Average deal size reached US\$20.7 million in 2022.
- Funding for mega-rounds accounted for nearly 48% of total AI fundings in 2022. The U.S and Asia led the mega-round funding in Q4'2022.

Share of active AI investors in %



66 | Notes: (1) Includes investment by Corporate Venture Capital (CVC) investment (2) CAGR: Compound Annual Growth Rate / average growth rate per year

Sources: CB Insights; GCV Analytics; Singularity Hub; Company information

# Alphabet and Apple continued their AI acquisitions in 2022

Corporate VC investment (1/3)



## 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 in 2014. The most recent acquisition was in September 2022, when Google acquired the Israeli start-up BreezoMeter, which uses AI and machine learnings to monitor air pollutants. The company has made various AI investments over the last few years in companies such as Alter (AI avatar), BenchSci (health-tech), Calico (health-tech), DNNresearch (computer vision), Jetpac (computer vision), Iteratively (data analytics), Looker Data Sciences (data analytics), Moodstocks (computer vision), Kaggle (data analytics), Api.ai (natural language processing), and Granata (data analytics).



## 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), RealFace (facial recognition), Xnor.ai (edge-based AI), and Inductiv (data analytics). The latest acquisition was in February 2022, when the company acquired AI Music, which creates personalized soundtracks and music that adapts to user preferences.

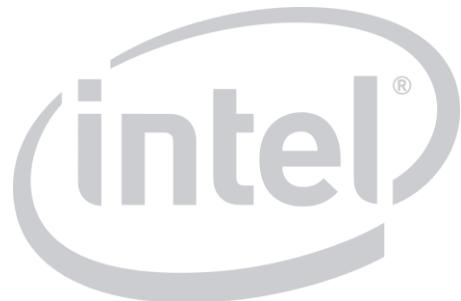
# Meta started investing in virtual fitting technology

Corporate VC investment (2/3)



## Meta (Facebook)

AI has become vital for Meta (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 Scape Technologies and Zurich Eye (computer vision). In April 2022, the company acquired Presize, a Munich-based start-up that specializes in *fit analytics* for customer shopping online.



## 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), Saffron (cognitive computing platform), Habana Labs (programmable AI), Moovit (mobility), Anotdot (autonomous business monitoring), Astera Labs (semiconductors) and Hypersonix (data analytics).

# SoftBank is focusing on AI investments with its Vision Fund 2

Corporate VC investment (3/3)



## Microsoft

Even though Microsoft has been making AI-related investments for over two decades, the launch of an AI fund by Microsoft Ventures in 2016, 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. The company's latest AI investments include TwoHat (content moderation), OpenAI (supercomputing), C3.ai (software), and Nuance Communications (healthcare).



## SoftBank

SoftBank is making significant investments in AI businesses through its Vision Fund 2. Even though the fund has not received much outside interest due to the perceived failure of the first Vision Fund, its key investments include a US\$640 million round in retail-focused computer vision company Trax and US\$150 million in Standard, another computer vision company. The company's 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.

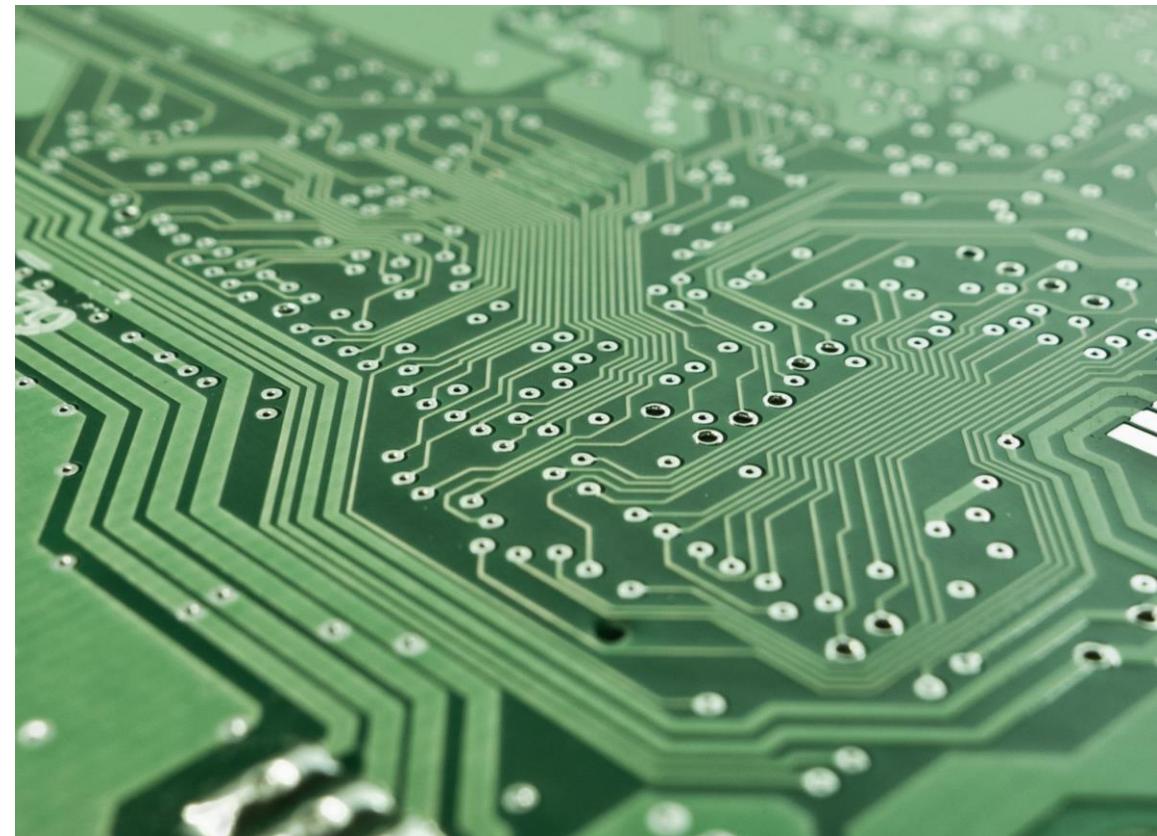
# Around 80% of the AI growth are due to advancements in computing power

## Computing power (1/4)

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.

In the next page, there are examples of what some of the key companies are doing in this area:



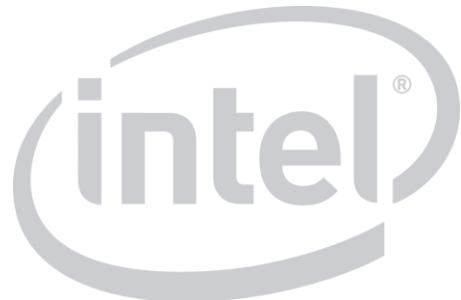
# Rapid advancements in computing power are driving the industry

## Computing power (2/4)



### Google

In 2020, the company launched its fourth generation of TPUs<sup>(1)</sup>, which are almost three times faster than the previous generation. These chips offer more than double the matrix multiplication TFLOPs of a third-generation chip. The Chip was first made available in February 2018 for other companies to use.



### Intel

In November 2019, Intel launched its next-generation AI chip with the codename Keem Bay. The chip, which has the capacity to handle trillions of operations per second, was initially supposed to go to market in 2020, but is now expected to start selling in the later part of 2022.

# Microsoft is building the world's first AI supercomputer

Computing power (3/4)



## IBM

In November 2021, IBM launched its new 127-quantum bit (qubit) 'Eagle' processor with over 100 operational and connected qubits. In fact, the number of classical bits necessary to represent a state on the processor is more than the number of atoms in the over 7.5 billion people alive today.

IBM's new hardware suite, called PowerAI, contains the Power8 server run by the Nvidia Tesla GPUs. In August 2021, the company launched the IBM Telum Processor that allows clients to use deep learning inference at scale.



## Microsoft

In March 2022, Microsoft announced that it demonstrated the underlying physics required to create a new kind of qubit. In May 2020, the company announced that it had made a supercomputer, specifically to train AI models. 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.

# Nvidia is introducing an AI-based supercomputer

Computing power (4/4)



## NVIDIA

In March 2022, NVIDIA launched the H100 chip, a new processor chip called the Grace CPU Superchip and announced its new AI-based supercomputer, Eos. Previously, in May 2020, it launched its A100 AI chip with 54 billion transistors and capacity to execute five petaflops of performance.

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.

NVIDIA is by far the leader in the AI computing industry, accounting for almost 100% of the market for training AI algorithms. In fact, over 70% of the top 500 supercomputers use its GPUs. Therefore, it is no surprise that almost all-important AI milestones, including DeepMind's board game champion AlphaGo and OpenAI's language prediction model GPT-3, have all run on NVIDIA hardware.

# 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.

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.

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.

In September 2022, Siemens unveiled Xcelerator, its open digital business platform as a way to accelerate digital transformation for industries, buildings, grids, and mobility. Software, IoT-enabled hardware, and digital services round out its portfolio.

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.

**“The ongoing success, stability, and even security, of any software solution requires a concerted effort from organizations to support the open-source they ingest.”**



**Stefano Maffulli, Executive Director  
Open-Source Initiative (OSI), February 2022**

# 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.
- 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.

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

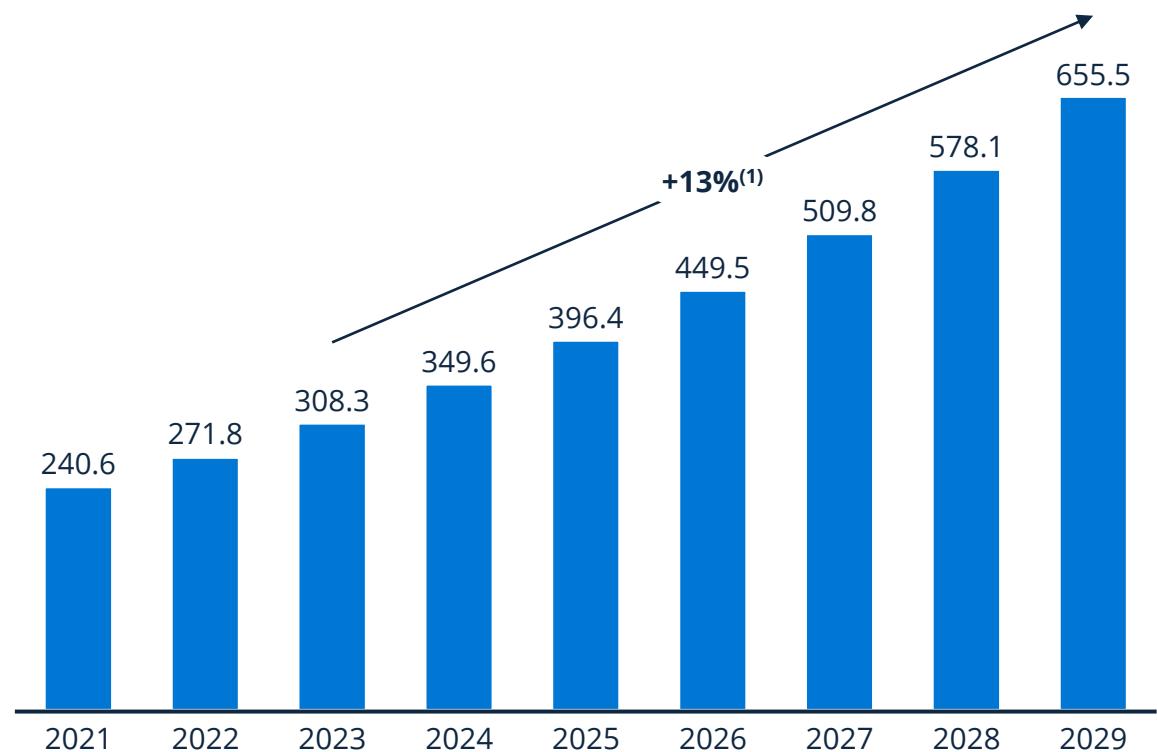
## Big data

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 163 trillion gigabytes by 2025.

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 analytics market in billion US\$**



## CHAPTER 5

# 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

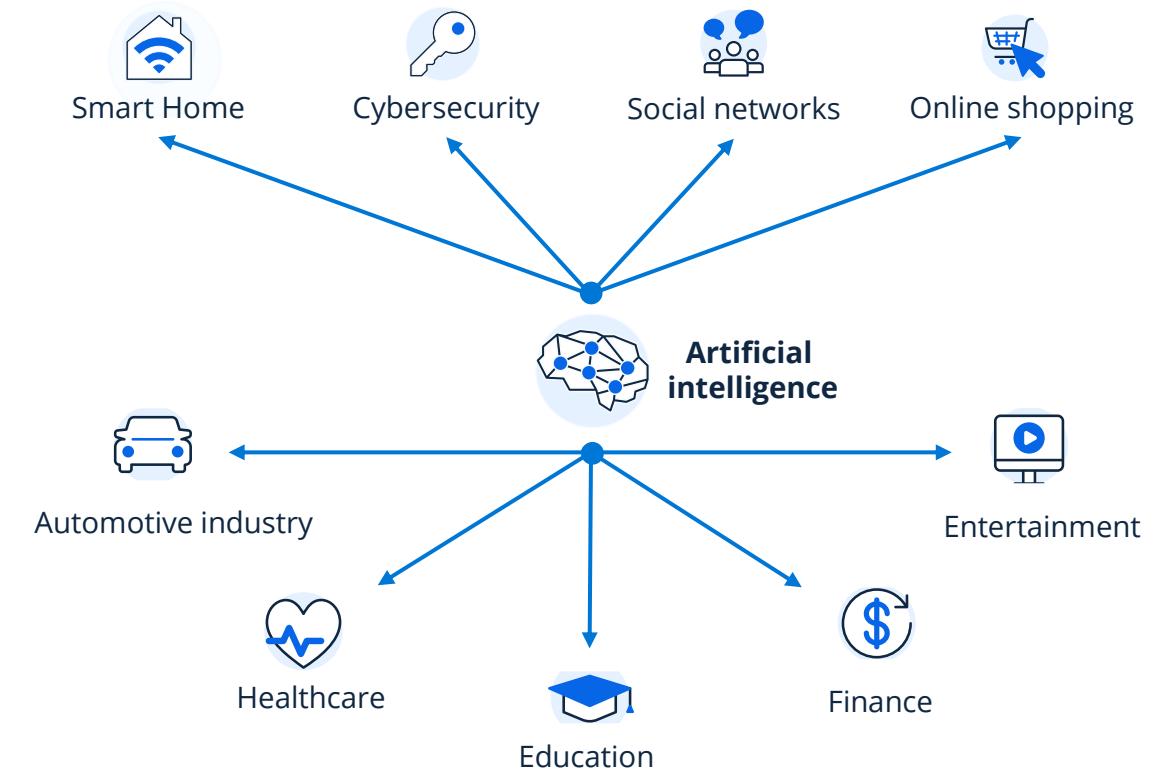
AI solutions are increasingly being customized to serve the needs across the automotive, healthcare, education, finance, entertainment, and other industries.

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.

Another key sector for the use of AI applications is in education, including the development of educational software that can provide personalized learning experiences for students. AI can also be used to create digital tutors that can provide real-time feedback and support to students as they go through their coursework. Additionally, AI can be used to develop assessment tools that can help educators to identify areas where students need additional support.

## Focus in this report



# 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.

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.

In January 2022, Microsoft along with institutional investment firm Baillie Gifford and Sir Richard Branson's Virgin Group invested US\$200 million in the self-driving start-up Wayve to solve challenges faced by self-driving cars.

In 2017, Ford had earmarked a US\$1 billion investment till 2022 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.

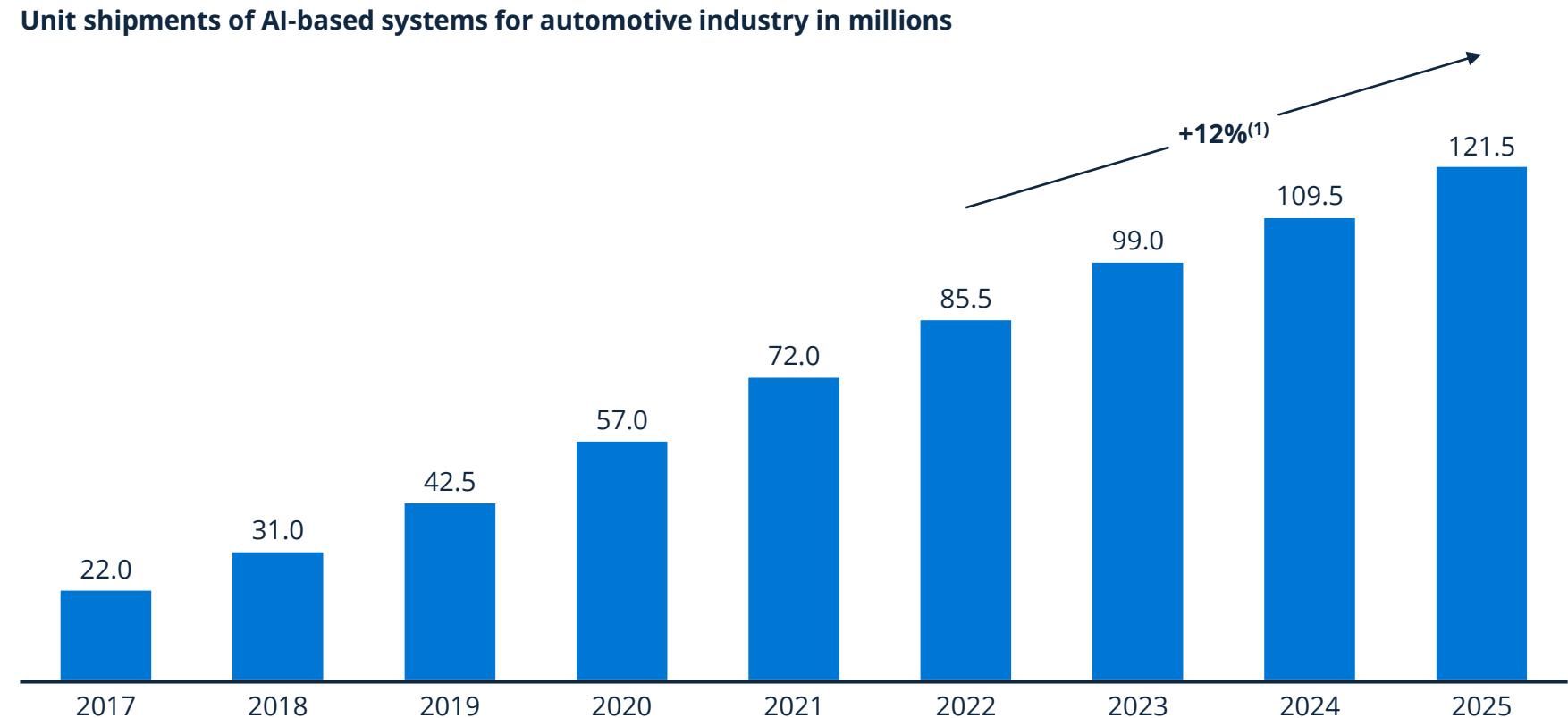
“AI is helping us to streamline our manufacturing even further and ensure premium quality for every customer. It also saves our employees from having to do monotonous, repetitive tasks.”

—  
Robert Engelhorn, Director  
BMW Group Plant Munich, 2020

# 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<sup>(1)</sup> of 12.1% from 85.5 million units in 2022.



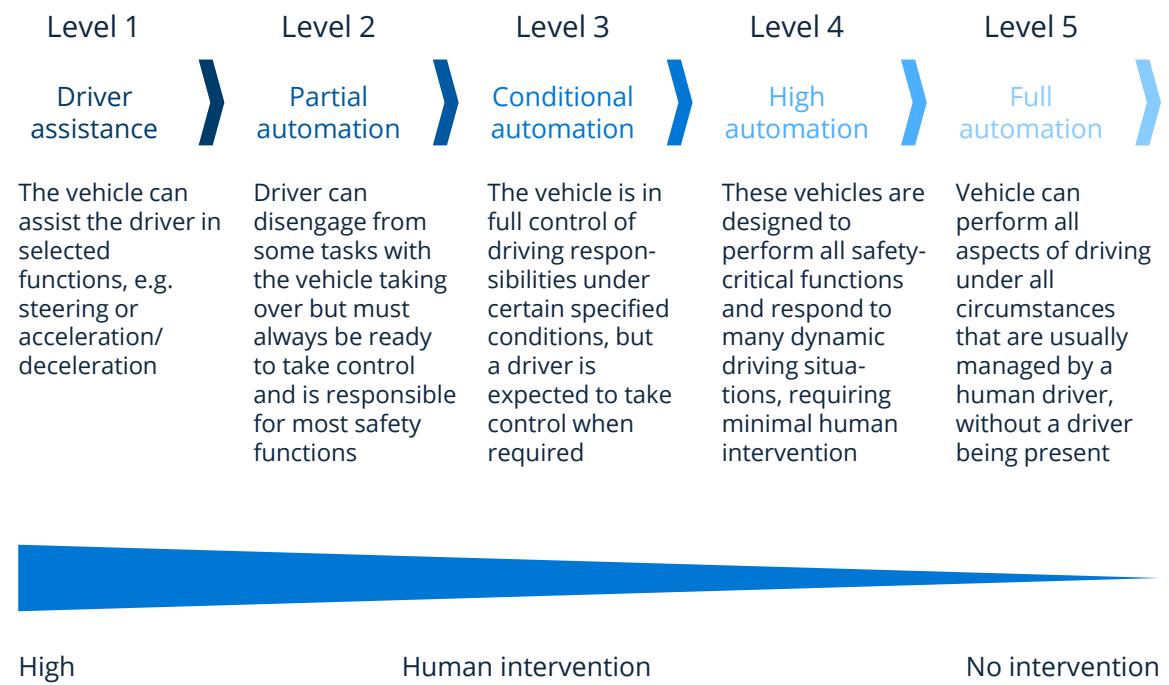
# Deep learning makes fully autonomous cars a reality

## Automotive industry: Autonomous driving (1/5)

According to a report by IHS estimates the annual sales of self-driving cars is expected to reach approximately 33 million units by 2040, with nearly 76 million vehicles with some level of autonomy sold by 2035. In value terms, the Boston Consulting Group estimates the market of autonomous vehicles to stand at US\$42 billion by 2025 and to increase to US\$77 billion by 2035. Another study by Bloomberg estimated the Americas region to witness the largest adoption of autonomous vehicles with a penetration rate of 5.4% by 2030, followed by Europe, Middle East and Africa (EMEA) with 3.9% and APAC with 3%. 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.

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.

### Impact of deep learning on autonomous driving



# 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	2024
	Q6 e-tron	Level 4	310	2022
	Elaine	Level 4	311	Concept
Baidu-BAIC Group	Apollo Moon	Level 4	N/A	2024
BMW	7 series	Level 3	435	2022
Byton (Previously Future Mobility Corp)	Byton	Level 4	250	Undecided
Faraday Future	FF-91	Level 4	300	2022
Fisker	Emotion	Level 4	400	Undecided
General Motors	Cruise Origin	Level 4	-	2023
Jaguar Land Rover / Waymo	Jaguar I-Pace	Level 5	298	Undecided

Company	Model	Autonomy level	Range in miles	Launch year
Kia	Niro EV	Level 2	239	2018
Mercedes-Benz	EQS	Level 3	480	2022
Navya	Autonom Cab	Level 4	N/A	2018
Porsche	Mission E	Level 4	310	Concept
Renault	SYMBIOZ	Level 4	N/A	Concept
	Easy Drive	Level 2	N/A	2019
	EZ-ULTIMO	Level 4	N/A	Concept
Toyota	Concept-i	Level 5	186	Concept

# 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, launched the testing phase of its self-driving car called Waymo in 2017, powered by over 2 million miles of real-world driving data. Since then, the company has not only launched its fleet of autonomous minivans in the U.S. but has also signed an exclusive agreement with Fiat Chrysler to develop self-driving commercial vehicles. Waymo's self-driving technology is currently being integrated into Ram ProMaster vans, which Fiat Chrysler sells globally.

Elon Musk, co-founder and CEO of Tesla, had initially 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. However, the launch date was then moved to the end of 2020 and there is still not much clarity on when the full-scale rollout might happen.

However, during Musk's visit to Brazil in May 2022, he announced that the company's fully autonomous technology would be ready by the middle of 2023. This seems unlikely given the current unfinished state of the company's proprietary Full Self-Driving suite.

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. What you need are the brains to make an autonomous car work safely and understand its environment.”

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Jeff Lemmer, VP and CIO  
Ford Motor Company, 2020

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

Automotive industry: Autonomous driving (4/5)

Company	Description	AI platform	Other partnerships
	Audi plans on spending close to US\$16 billion on self-driving and sustainable tech, by 2023	Nvidia – DRIVE PX 2	Partnered with Israel's autonomous vehicle simulation start-up Cognata to speed up the development of autonomous vehicles
	BMW has partnered with Qualcomm and Arriver since 2021 to launch Level 3 autonomous cars by the second half of 2025, with an eye on Level 4 autonomy in the years to follow.	Intel Nervana – incl. machine & deep learning training and simulation infrastructure	Mobileye <sup>(1)</sup> – EyeQ5 processor, 360° camera system, and a sensor fusion solution Intel – Intel GO automated driving solutions
	BYD established a US\$15.7 million joint venture fund with autonomous driving start-up Momenta to deploy autonomous driving capabilities across selected BYD car models	Nvidia – DRIVE Hyperion	Partnered with Nuro, a company that produces zero-occupant vehicles to produce electric autonomous delivery vehicles
	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 GM expects to begin production of its autonomous shuttle called the Origin, to begin in early 2023	IBM's Watson – OnStar Go	IBM – to develop OnStar's touch screen interfaces
	In May 2022 Hyundai announced it would invest US\$5 billion to support its initiatives in robotics, AI technologies, advanced air mobility, and autonomous driving capability	Nvidia – DRIVE	Partnered with Motional to develop IONIQ 5-based robotaxis with advanced autonomous driving capabilities

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

Automotive industry: Autonomous driving (5/5)

Company	Description	AI platform	Other partnerships
 Mercedes-Benz	In 2021, Mercedes-Benz announced it would invest more than US\$68 billion between 2022 and 2026 towards research on electric vehicles and autonomous driving	Nvidia	Microsoft – use of AI, digital twins, and data analytics to improve production efficiency, solve supply chain bottlenecks, and enhance resource allocations to prioritize EV and top-end vehicles
 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 Acquiring ride-hailing company Lyft's autonomous vehicle division called Level 5, for US\$550 million	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
	In 2019, announced plans to invest US\$2.6 billion in Argo AI, an autonomous vehicle start-up Its 2025 strategy focuses on developing robot taxis and cargo vans In September 2022, the company launched GEN.TRAVEL, a concept vehicle with Level 5 autonomy Volkswagen has also announced plans to set up a new division called 'New Mobility' which will develop its future electric and autonomous cars, based on the current ID range and the SSP electric car platform. The company has created its own software company called Cariad to develop a complete technology stack for autonomous driving up to Level 4.	Nvidia – Drive PX 2	Mobvoi – voice recognition and language processing technologies Mobileye <sup>(1)</sup> – to integrate its Road Experience Mgmt mapping service into VW cars Qualcomm – to provide its Snapdragon Ride Platform that will be used to run Cariad's software in all of Volkswagen's passenger car brands.
	Unveiled its production version of the XC90 self-driving car, in June 2019 The company expects self-driving cars to make up one-third of its sales, by 2025 In January 2022, the company launched its new Level 3 autonomous driving system called Ride Pilot.	Nvidia – DRIVE PX 2	Microsoft – to install Skype for Business on new Volvo 90 Series cars Waymo- for driverless electric cab service

# 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:

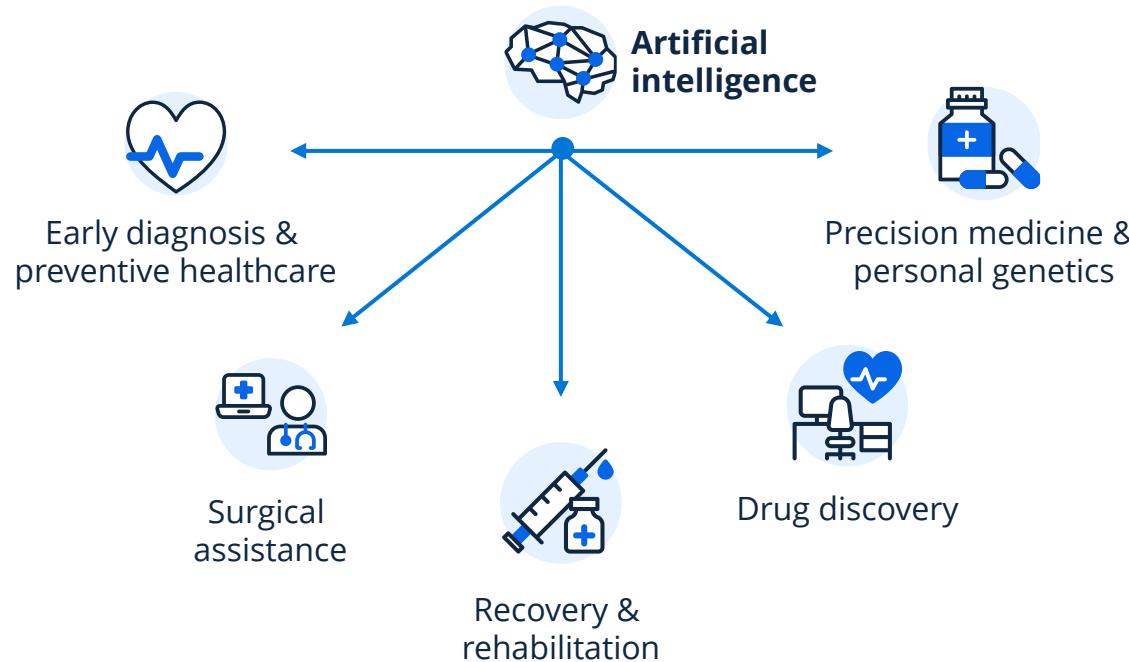
- GM and IBM have partnered to enable IBM's AI supercomputer Watson to power GM's upgraded onboard car system called OnStar Go. This platform now uses data from the cloud to offer recommendations to drivers on places to eat, shop, or fill gas. Moreover, when drivers are nearing a preferred location, 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.

# AI is changing the entire healthcare operating models

Healthcare: Overview (1/2)

## 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.

# AI impels transition from reactive to proactive healthcare

## Healthcare: Overview (2/2)

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.
- Google Cloud's Healthcare App: By using AI solutions, its programming interface allows physicians to make more informed clinical decisions based on data from users' electronic health records.



# 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 Babington. CEO  
PrescribeWellness, 2017

# AI applications facilitate early and accurate diagnosis

## Healthcare: Early diagnosis (1/3)

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. Until recently, the sample data used was of the general population and helped in the detection of common diseases. However, doctors have now started to analyze a patient's own medical record to find out if they are at risk of developing a rare disease. One of the pioneers of this technology is the Perelman School of Medicine at the University of Pennsylvania and the University of Florida College of Medicine. Researchers in these universities are developing a set of algorithms to identify which patients are at risk of five different types of vasculitis and two different types of spondyloarthritis.

Other examples of AI systems designed for early diagnosis are listed below:



# IBM Watson helps detect early signs of cancer

Healthcare: Early diagnosis (2/3)



## 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.

# AI platforms help doctors to design treatment plans

Healthcare: Early diagnosis (3/3)



## 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.



## 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%.



UNIVERSIDAD  
DE MÁLAGA



UNIVERSIDAD  
DE GRANADA

## University of Malaga and the University of Granada

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 compare it with that of a healthy person using deep learning.



## Oncora Medical

Developed a data analytics platform which enables doctors to design radiation treatment plans for patients.

“Predictive diagnostics, enhanced by data, present a significant near-term opportunity for the life sciences industry. It’s also likely to resonate with payors, since these trials can generate better outcomes. They can also deliver sizable cost savings by enabling earlier identification and treatment of higher-risk patients.”

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Tejas Savant, Executive Director, Life Science Tools and Diagnostics  
Morgan Stanley, 2022

# 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 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.

# 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

# AI systems reduce time and costs to develop novel drugs

## Healthcare: Drug discovery (1/2)

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

- COVID-19 vaccine: Researchers in Australia's Flinders University along with Oracle, have developed and are now testing a COVID-19 vaccine, that is expected to be available for public use in the short to medium term. AI and cloud computing technologies have been used to prevent the Spike protein from binding to the ACE2 receptors on human cells. Moreover, in the UK, the Medicines and Healthcare Regulatory Authority (MHRA) has awarded Genpact UK a US\$2 million contract to develop an AI-powered tool to process data relating to any vaccine side effects.
- 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.

# AI systems enables companies to conduct around 800,000 experiments a week

## Healthcare: Drug discovery (2/2)

- 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.
- Recursion Pharmaceuticals: Developed a platform that combines the best elements of high-throughput biology and automation with the latest advances in AI. With the help of computer vision, machine learning, and neural networks, the company conducts over 800,000 experiments every week.



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

## Healthcare: Precision medicine and personal genetics (1/2)

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<sup>(1)</sup>, 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<sup>(2)</sup>.
- Human Longevity: This was started by Craig Venter, the man credited with mapping the human genome. The company conducted a study which showed that clinicians were able to identify adults at risk for key health problems by combining whole-genome sequencing with advanced imaging and blood metabolites. The study was published in the Journal Proceedings of the National Academy of Sciences in early 2020.
- Deep Genomics: A Toronto-based start-up which applies GPU-based deep-learning to determine how strongly genetic variants affect RNA splicing<sup>(3)</sup>, 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.

# Editas Medicine is using AI for gene editing

Healthcare: Precision medicine and personal genetics (2/2)

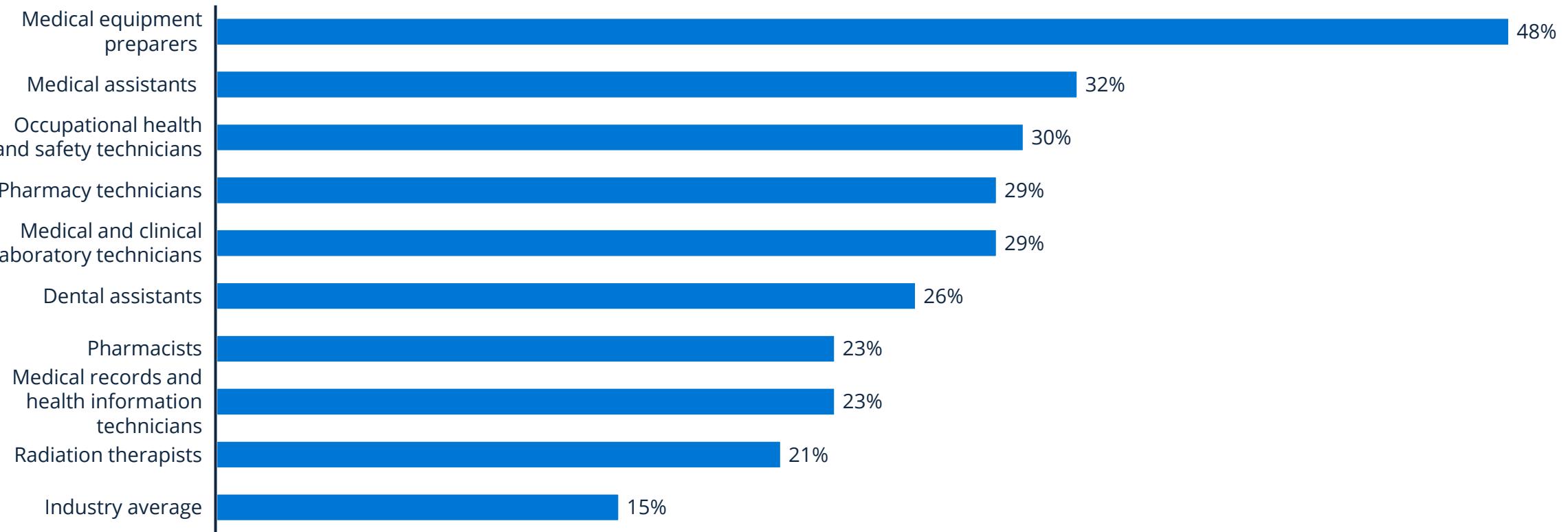
- AstraZeneca: The company is expected to analyze up to two million genome sequences by 2026 through its company-wide genomics initiative in an effort to discover rare genetic sequences that are associated with various diseases.
- Editas Medicine: Specializes in a process called gene editing using a 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.



# 15% of current work hours could be automated by 2030

Healthcare: Impact of AI on healthcare workforce

## Current hours worked in healthcare that could be freed up by automation by 2030<sup>(1)</sup>



# AI in healthcare includes Machine learning, NLP, and computer vision

## Technologies: Overview

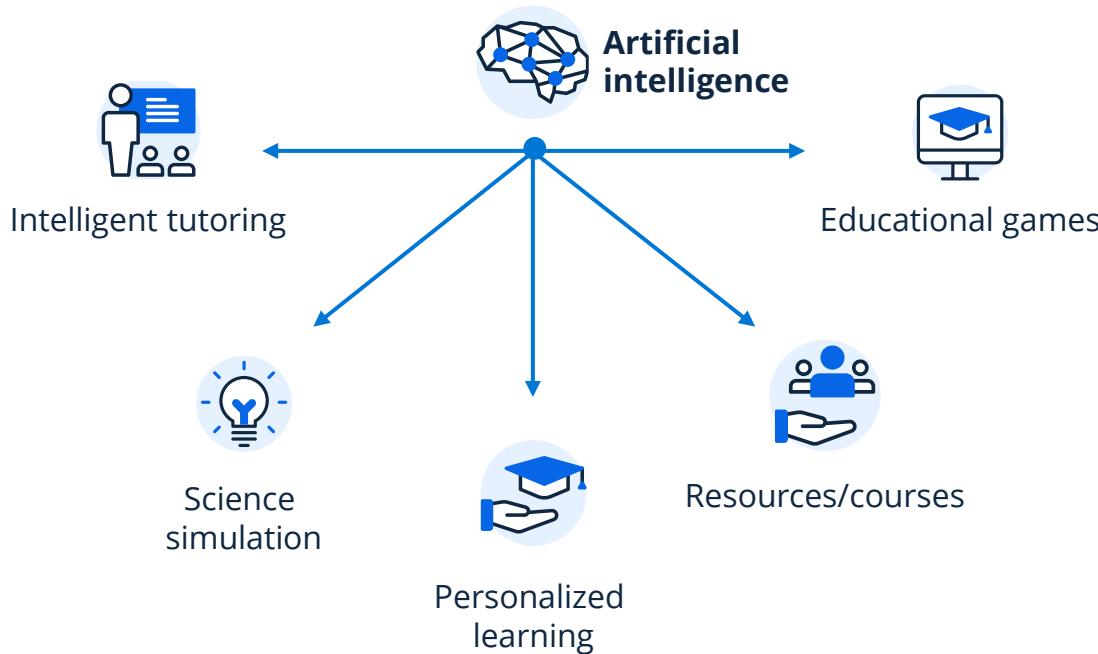
### Technologies involved in AI healthcare

Application scenarios	Underlying technologies	Representative companies	Constraints	Estimated maturity
Medical imaging	Computer vision	Infervision Yidu Cloud	Rule and specialty: High misdiagnosis rate, such as the average misdiagnosis rate due to imaging analysis reaching 27.8% Lack of training data	> 10 years
Electronic medical record (EMR)	Natural language processing Speech Recognition	Unisound CTME iFLYTEK	Low market acceptance	2-5 years
Assisted diagnosis and treatment	Robot	TINAVI SMAROBOT SIASUN Robot	Various specialties Limited by market regulation, such as about 97 months is required from molecule discovery to FDA approval	2-5 years
Disease risk prediction	Machine learning	Berry Genomics Precision Genomic BGI Genomics	-	In the near future
Health management	Computer vision	MORE HEALTH Airdoc iCarbonX	-	In the near future
Drug discovery	Machine learning	Cipher Gene 3D Medicines Ribo	Existing rules and specialties Limited by market regulation	10 years

# AI is driving the personalized learning industry

## Education: Overview

### 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.

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

## Education: Intelligent tutoring (1/2)

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.

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<sup>(1)</sup> 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.

“Adjusting learning based on an individual student’s particular needs has been a priority for educators for years, but AI will allow a level of differentiation that’s impossible for teachers who have to manage 30 students in each class”

—  
**Bernard Marr**

Author and Strategic Performance Consultant, 2020

# 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.



“A student might learn one way to do a problem and that would be sufficient. But a tutoring system needs to learn every kind of way to solve a problem. It needs to learn how to teach problem-solving, not just how to solve problems.”

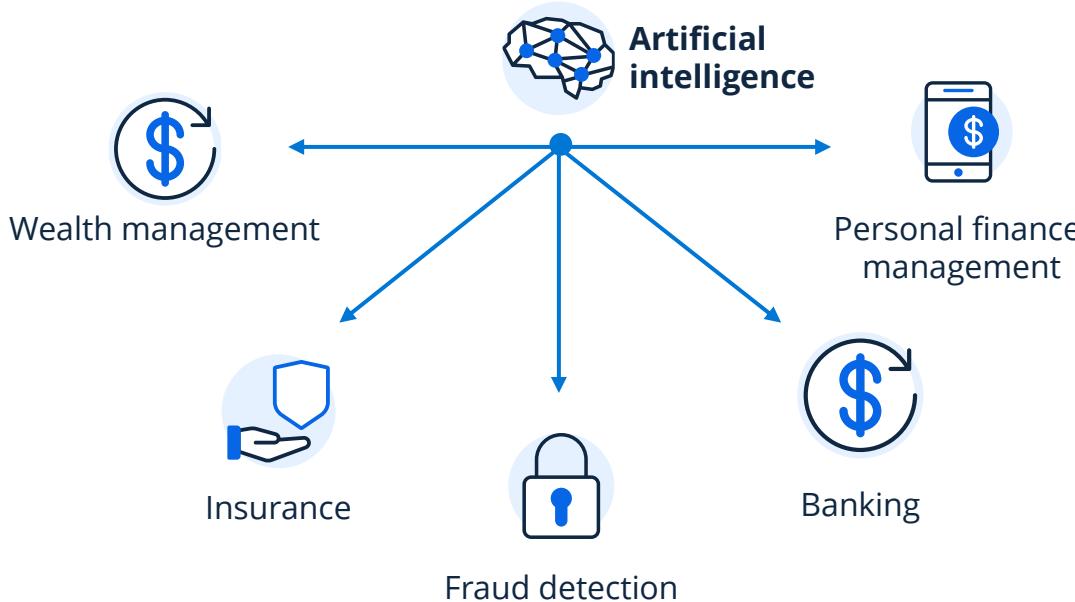


Daniel Weitekamp III, Ph.D. student  
CMU’s Human-Computer Interaction Institute (HCII), 2020

# Its wealth of data makes the finance industry perfect for the use of AI

## Finance: Overview

### 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. 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.

# AI wealth management solutions offer higher personalization

Finance: Wealth management (1/3)

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.



# BlackRock is using AI to analyze data to predict transactions that likely to fail

Finance: Wealth management (2/3)



## 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 uses machine learning to relate stock and currency prices

Finance: Wealth management (3/3)



## **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.

# Cybercrime costs the economy several hundred billions

Finance: Fraud detection (1/4)

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\$600 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.

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. The unicorn Darktrace is an example of a company offering AI-powered cybersecurity services. Its machine learning platform understands the normal patterns of behavior of each user and device connected to a corporate network.



# AI-based systems can identify potential targets for fraud before they occur

Finance: Fraud detection (2/4)



## 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.

Furthermore, COOPER, a data-driven platform for detecting and fighting fraud, has been introduced by the company. Through COOPER, the company will be able to analyze vast amounts of data and detect complex patterns rapidly, enabling the company to continuously improve the fight against fraud.



## Lloyd's Banking Group

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.

Also, a new AI-based fraud detection system known as "The Rat" has been introduced by the bank in order to identify people who may be targeted and stop their financial losses before they occur.

# Several finance institutions use AI to combat and prevent fraud

Finance: Fraud detection (3/4)



## 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.

Moreover, ThetaRay has introduced an AI-based Anti-Money-Laundering (AML) analytics that uses machine learning to monitor financial transactions, integrate data, and triage alerts. With its new cloud version, the company aims to increase the speed at which banks and fintech firms can detect potential attacks.

# VISA uses AI to determine legitimate transactions

Finance: Fraud detection (4/4)



## Westpac

The company 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.

Moreover, Westpac is developing AI applications to deal with customer complaints; these are six times more effective than human systems. With AI, nine times as many customers are protected from fraud, and accuracy has increased.



## VISA

Between 2017 and 2022, the company spent approximately \$9 billion on cybersecurity, including \$500 million on AI and data analytics. Using AI and machine learning techniques the Visa Advanced Authorization (VAA) can determine whether a transaction is legitimate or fraudulent within 300 milliseconds. A total of \$26 billion in fraud was prevented by VAA alone in 2021. Furthermore, Visa Account Intelligence detects fraud before it occurs using AI and machine learning.

# AI tools 'learn' patterns to deliver personalized financial advice

Finance: Banking, personal financial management (1/6)

**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.



# Fonetic offers speech recognition to automate customer service

Finance: Banking, personal financial management (2/6)



## Feedzai

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



## FinGenius

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



## Fonetic

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



Eva Money APK

## Eva Money

A personalized financial assistant mobile app that uses AI and conversational intelligence to answer questions related to personal finances.

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

Finance: Banking, personal financial management (3/6)

Personal Financial Management: Another area in financial services where AI is making a mark is personal financial management (PFM). Over the past few 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. Moreover, the pandemic made digital the main channel for clients to engage with their wealth managers and advisors. On the other hand, wealth management companies have accelerated their cloud migration journeys and have also started delivering more intuitive and personalized solutions.



# Alivia app uses AI to identify peoples' spending pattern

Finance: Banking, personal financial management (4/6)



## 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.



## 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.



## Simple

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



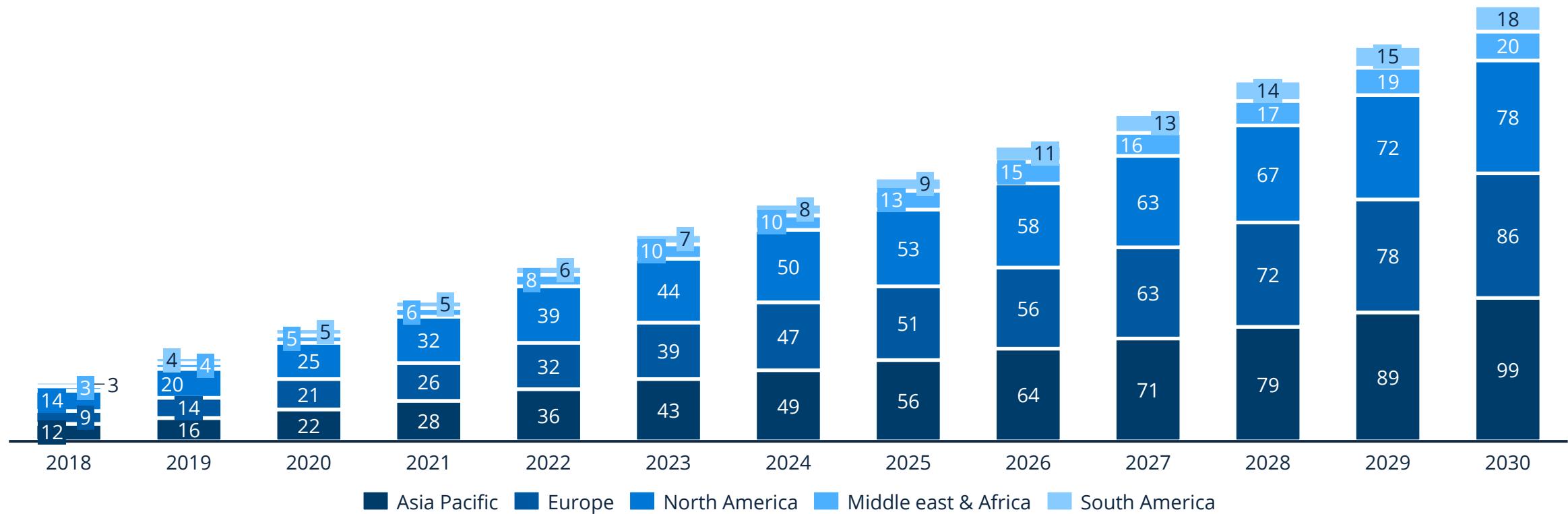
## Olivia

A free financial assistant app based on artificial intelligence and behavioral economics. This app essentially identifies patterns in how people spend money.

# Use of AI in the banking industry will generate US\$301 billion by 2030

Finance: Banking, personal financial management (5/6)

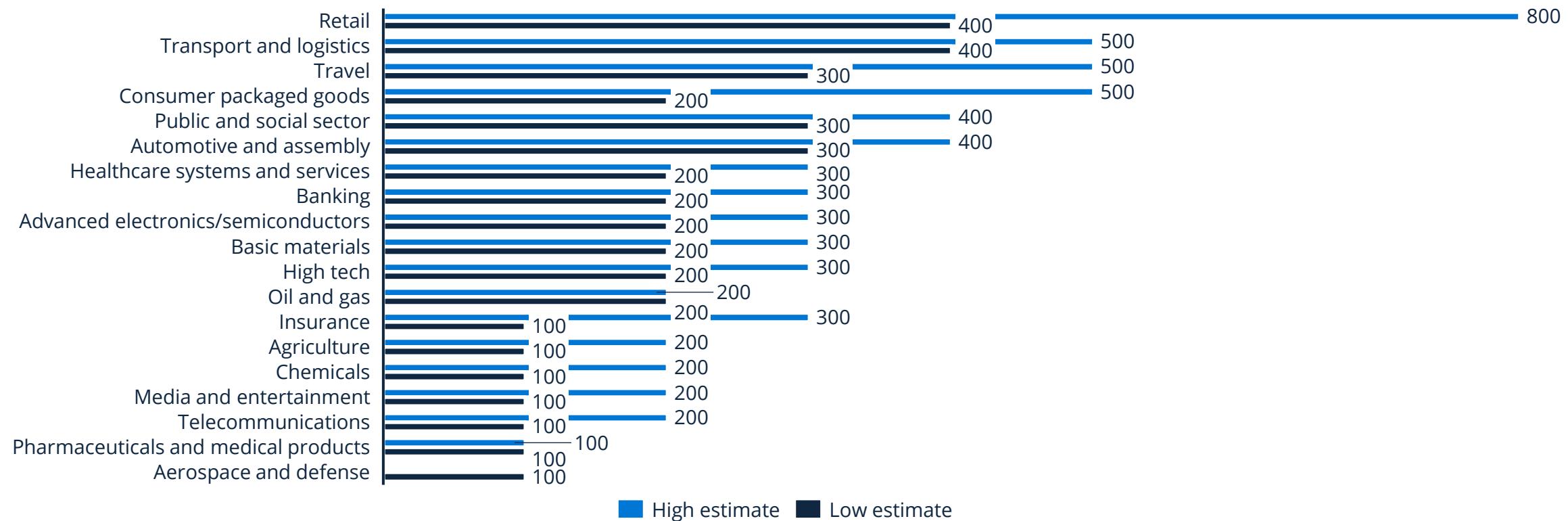
**Business value derived from AI in banking industry worldwide from 2018 to 2030 in billion US\$**



# The impact of AI on retail industry is estimated at 0.4 to 0.8 trillion US\$

Finance: Banking, personal financial management (6/6)

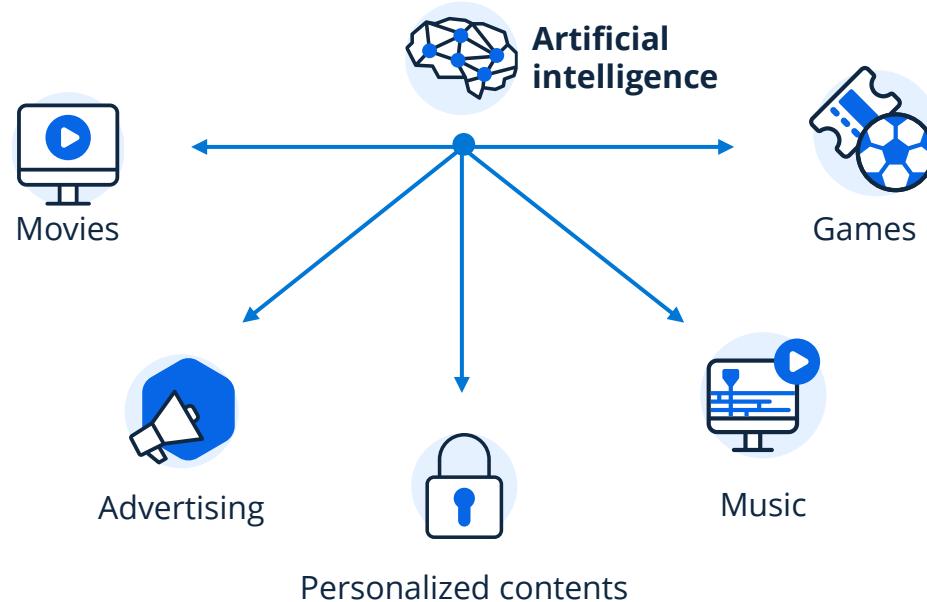
## Potential aggregate economic impact of AI worldwide in the future in billion US\$



# AI can be used to provide personalized contents in the entertainment industry

## Entertainment: Overview (1/3)

### Overview



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.

Three examples are:

- IBM Research and 20th Century Fox: 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.

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

## Entertainment: Overview (2/3)

- 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 at the Sci-Fi London contest in 2016.
- Cinelytic: The use of artificial intelligence can also be applied to analyzing a film's script to predict its potential revenues. The Warner Bros. studio utilized Cinelytic, an AI-based platform, to predict box office success.
- Netflix: uses various AI solutions to predict which images best engage which viewers. It also uses these technologies to create relevant thumbnail images to drive viewer engagement. For example, in the series *Stranger Things*, Netflix used AVA's AI-powered virtual assistant lead management platform to analyze over two million static video frames.



# AI enables gaming characters to develop their own personalities

## Entertainment: Overview (3/3)

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 pre-determined 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.

## CHAPTER 6

# 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 applications, followed by natural language processing. Heading into 2020, there were over 2,600 AI start-ups across 13 categories. The AI companies have cumulatively raised around US\$239.2 billion in funding during 2015-2022.

Over the years, the number of AI acquisitions have grown steadily, only to dip for the first time in 2020, as the COVID-19 outbreak prompted many businesses to prioritize core operations over new acquisitions. However, the acquisitions gained momentum and the around 312 M&A deals signed in 2021. The number of M&A deals declined in 2022 compared to the previous year and around 259 deals registered during the year.



# Highest number of AI start-ups in machine learning applications

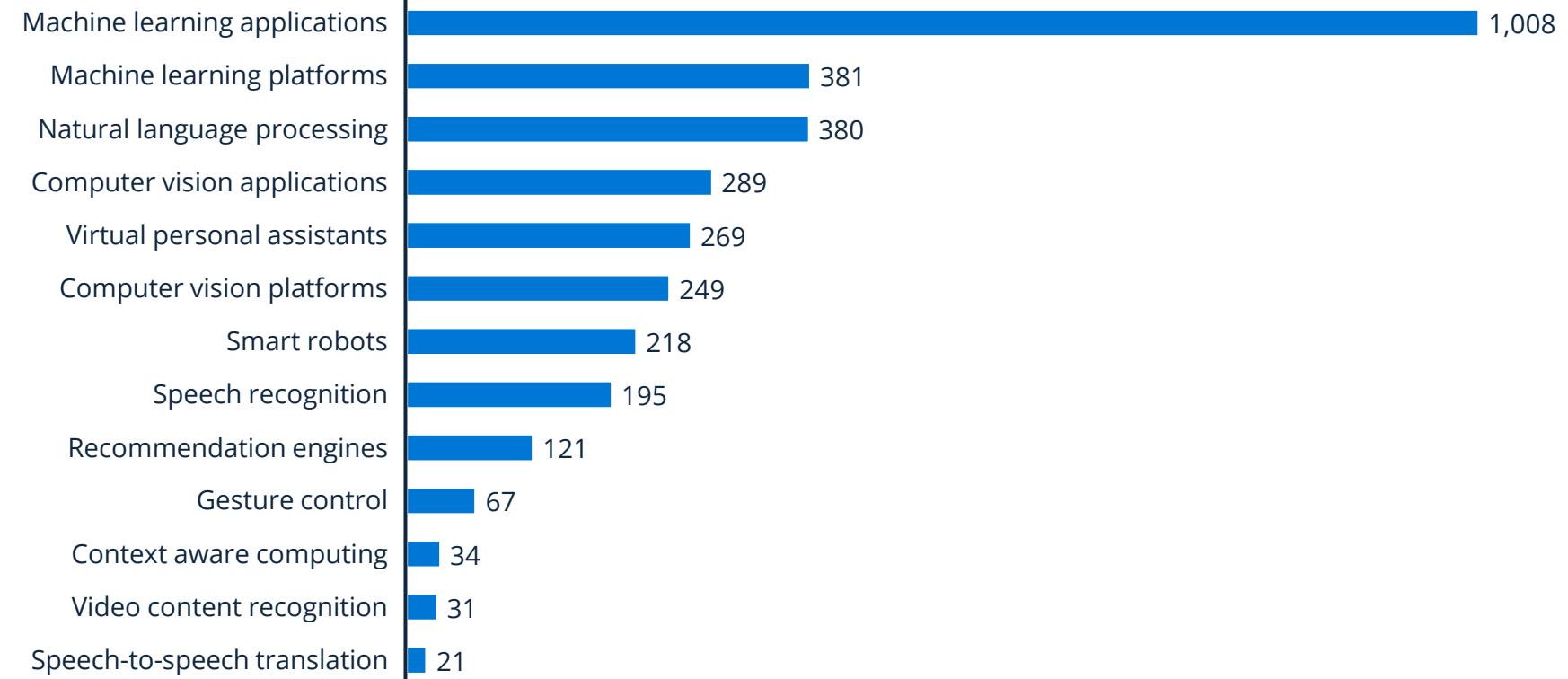
Overview (1/4)

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. Heading into 2020, there were over 2,600 AI start-ups across 13 categories.

The AI companies have cumulatively raised around US\$239.2 billion in funding during 2015-2022.

The annual global funding of AI start-ups increased at a CAGR<sup>(1)</sup> of over 32.8% from US\$6.3 billion in 2015 to US\$45.8 billion in 2022.

## Number of AI start-ups



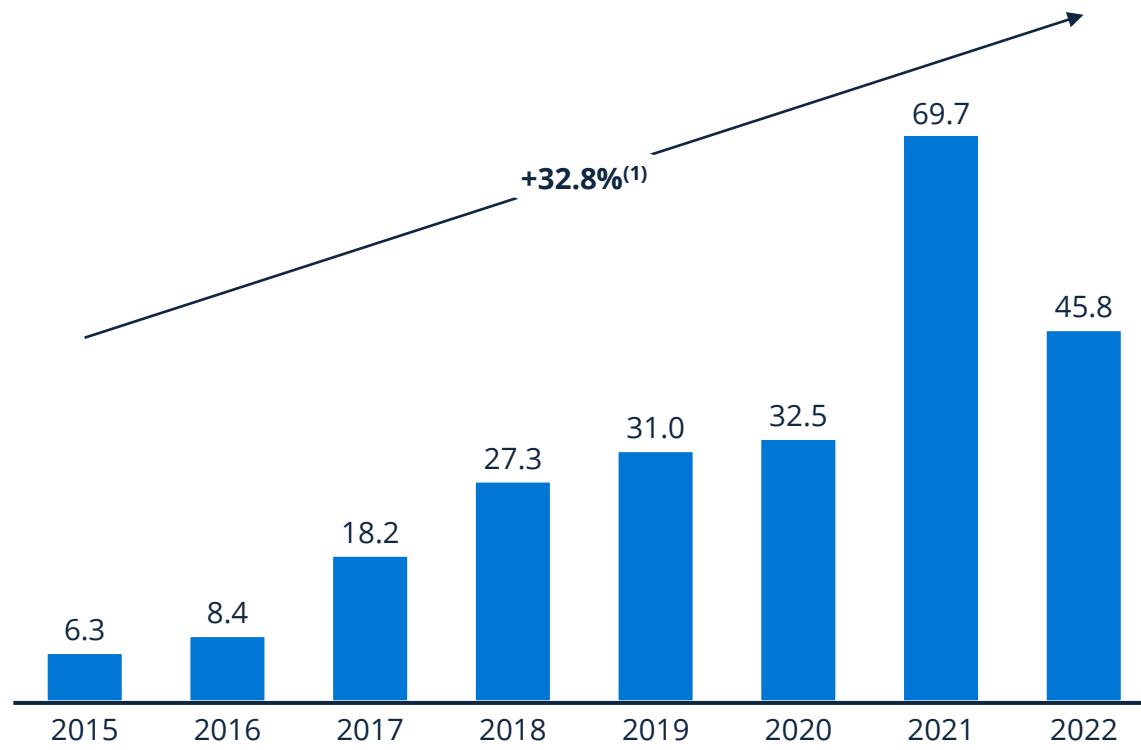
129 | Notes: (1) CAGR: Compound Annual Growth Rate / average growth rate per year

Sources: CB Insights; Venture Scanner, as of September 2019

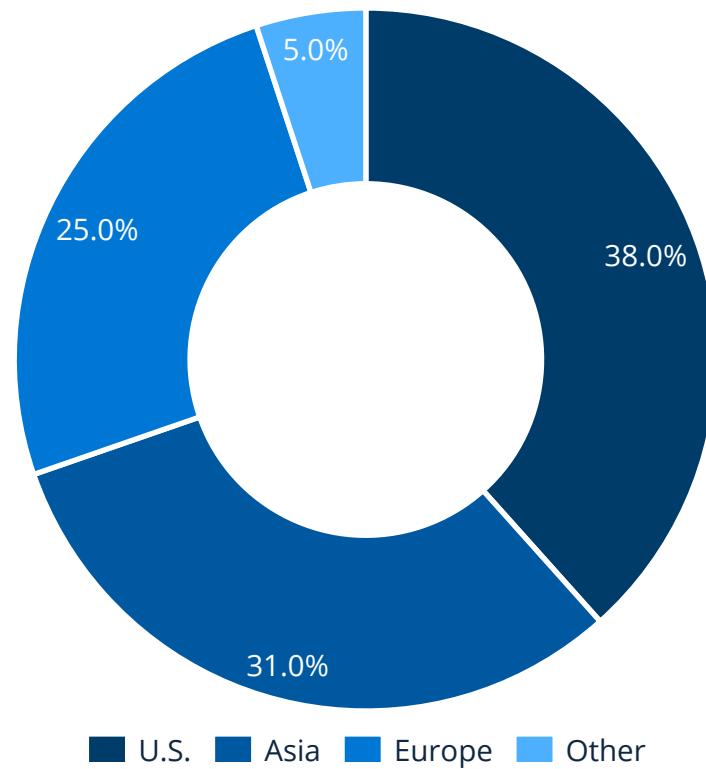
# Funding of AI start-ups grew at a CAGR of over 33% between 2015 and 2022

Overview (2/4)

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



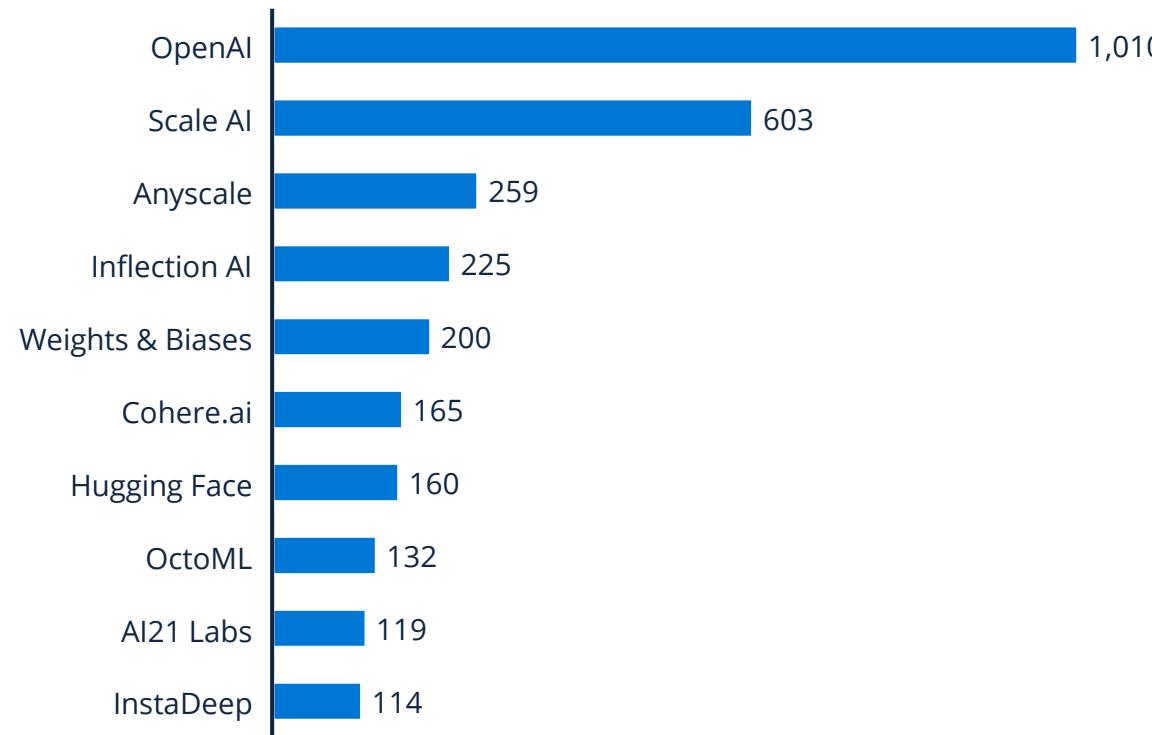
**AI start-ups: global deal share by region in Q4 '22**



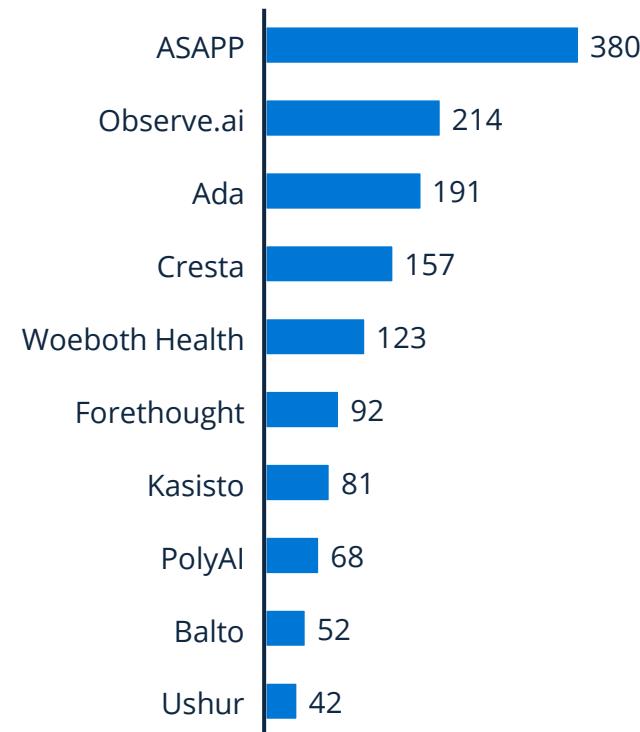
# ASAPP is the most funded chatbot/conversational AI worldwide

Overview (3/4)

**Global Leading ML Operations/Platform startups in 2023, by funding in million US\$**



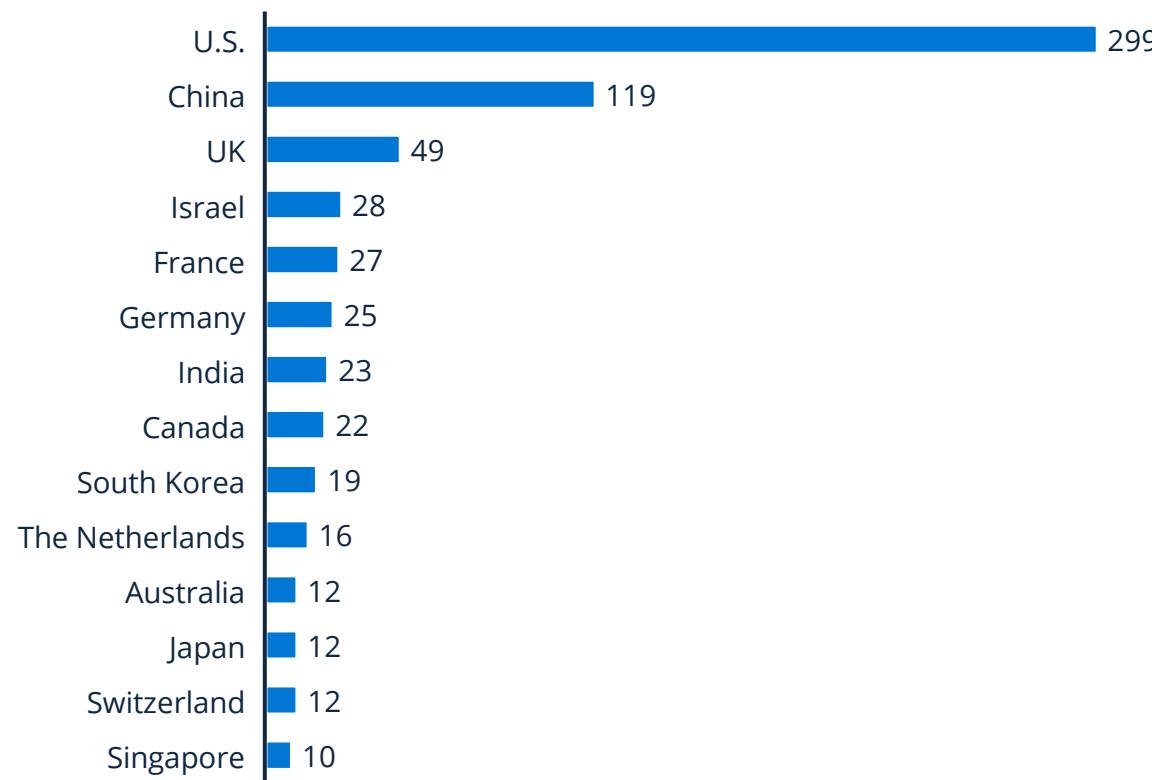
**Global Leading chatbot/conversational AI startups in 2023, by funding in million US\$**



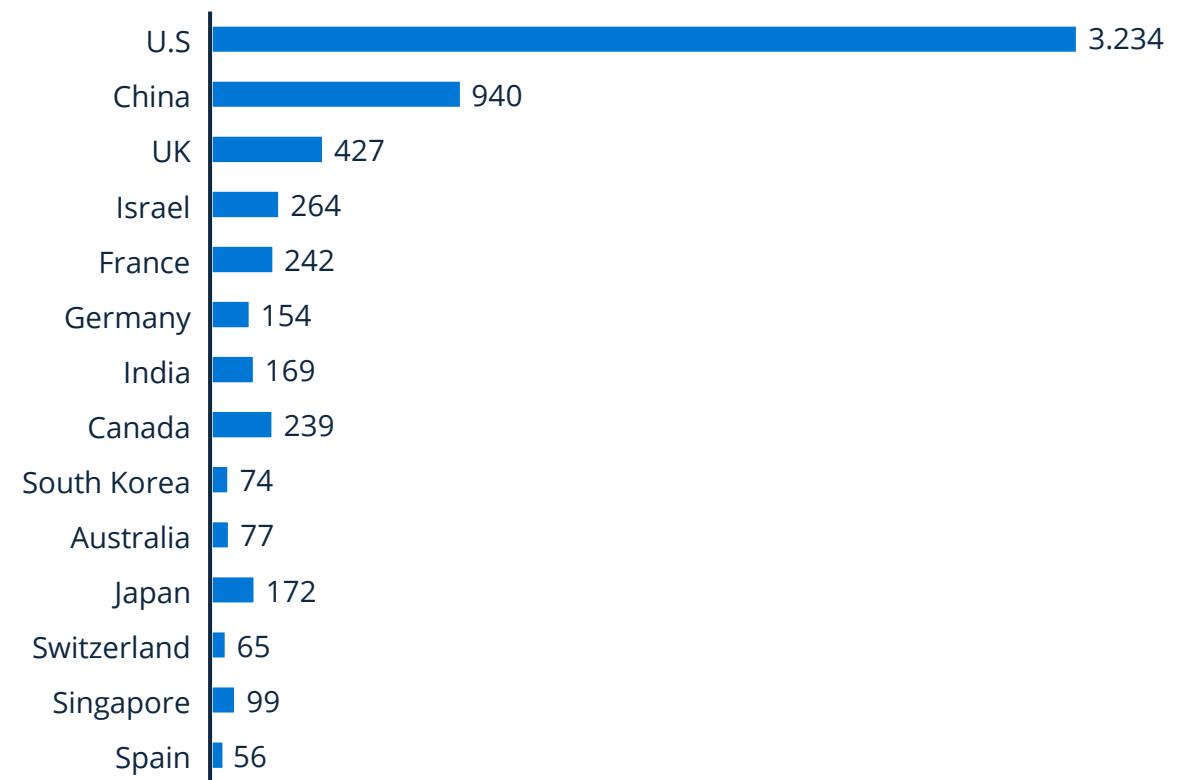
# The U.S. had nearly 300 newly funded AI companies in 2021

Overview (4/4)

**Number of newly funded AI companies by countries in 2021**



**Number of newly funded AI companies by countries in 2013–2021**



# Major fields of investment by leading AI enterprises (1/2)

Investment by AI enterprises<sup>(1)</sup> (1/2)

<b>Finance</b>	<b>Healthcare</b>	<b>Education</b>	<b>Autonomous driving</b>	<b>Enterprise service</b>	<b>Basic components</b>
<b>Alibaba</b> Zhongan Insurance Ant Financial	<b>Tencent</b> iCarbonX Xtalpi	<b>Alibaba</b> Xiaobao Online Knowbox	<b>Tencent</b> NIO	<b>Alibaba</b> SenseTime MEGVII IrisKing Moreidian Technology	<b>Tencent</b> Hesai Technology SoundAI
<b>Tencent</b> Zhongan Insurance	<b>JD.com</b> RIMAG Zhizhen Internet Technology	<b>Tencent</b> Afanti Yuantiku Yangcong345	<b>Alibaba</b> Xpeng Motors AISpeech DeepMap	<b>SIG</b> Bytedance	<b>Alibaba</b> Cambricon DeePhi Tech Orbbec Kneron C-SKY Video++
<b>JD.com</b> Taicang Technology ChinaScope Juxinli.com	<b>CASH Capital</b> Yunhu Healthcare W&R Technology TMIRob Raysight Medical Linking Med	<b>Baidu</b> Knowbox Zike Zuoyebang	<b>Baidu</b> NIO Idriverplus Smartereye Hesaitech	<b>Baidu</b> MiningLamp Yonghong Tech	<b>CAS Investment</b> Bitmain Ickey Cambricon

# Major fields of investment by leading AI enterprises (2/2)

Investment by AI enterprises<sup>(1)</sup> (2/2)

<b>Finance</b>	<b>Healthcare</b>	<b>Education</b>	<b>Autonomous driving</b>	<b>Enterprise service</b>	<b>Basic components</b>
<b>Apple</b> FreightWaves	<b>IBM</b> Hafnium Labs Explorys (Acquired)	<b>CASH Capital</b> Squirrel AI Learning Simpleware	<b>JD.com</b> NIO IDRIVERPLUS Carrobot	<b>Alibaba</b> Xiao-i Robot Video++	<b>Microsoft</b> Datazen Software (Acquired) Open AI
<b>IBM</b> Accrue	<b>SIG</b> XtalPi	<b>Google</b> Edwin	<b>Apple</b> Drive AI (Acquired) VocallQ (Acquired)	<b>Tiantu Capital</b> ZMT Tongdun CICC DATA	<b>Apple</b> Silk Labs (Acquired)
<b>Microsoft</b> Voiceitt	<b>Apple</b> Volley Labs LearnSprout (Acquired)	<b>SIG</b> WELTMEISTER	<b>Google</b> Synetiq ABEJA Tecacent (Acquired) DeepMind (Acquired) Kaggle (Acquired)		
<b>SIG</b> Abc fintech	<b>IBM</b> Syngli				

# Global High-growth AI Enterprises (1/2)

AI enterprises growth (1/2)

Ranking	Company name	Country	Growth rate	Segment
1	Shape Security	US	~23,000%**	Business Services
2	BrainChip	US	~16,000%**	Chip
3	Razorpay Software	India	~11,000%**	Finance
4	BioCatch	Israel	~10,000%**	Finance
5	Signifyd	US	~6,000%**	Business Services
6	Yixue Education—Squirrel AI	China	~5,000%*	Education
7	UiPath	US	~4,000%**	Robotics
8	Remark Holdings, Inc	US	~3,700%**	Data Services
9	Domino Data Lab	US	~3,200%**	Finance
10	Voltari	US	~3,000%**	Advertisement
11	Mujin Inc	Japan	~1,200%*	Industrial
12	Vectra AI	US	~1,000%**	Security
13	DataRobot	US	~900%	Deep Learning
14	Bytedance	China	~700%*	Business Intelligent
15	Pinduoduo	China	~650%	Retail

Ranking	Company name	Country	Growth rate	Segment
16	Cloudwalk	China	~600%*	Facial Recognition
17	Welltok	US	~500%**	Healthcare
18	Tesla	US	~430%**	Autonomous Driving
19	SenseTime	China	~400%	Computer Vision
20	BounceX	US	~400%*	Marketing
21	CrowdStrike	US	~374%*	Network Security
22	Alteryx	US	~370%**	Data Mining
23	SequoiaDB	China	~363%*	Finance
24	Avant	US	~360%**	Finance
25	Cloudera, Inc.	US	~350%**	Data Services
26	JiaHe Info	China	~330%*	Agriculture
27	GumGum	US	~310%**	Computer Vision
28	Blue Prism	UK	~304%*	Robotics
29	Unisound	China	~300%	Speech Recognition
30	SparkCognition	US	~260%**	Network Security

# Global High-growth AI Enterprises (2/2)

AI enterprises growth (2/2)

<b>Ranking</b>	<b>Company name</b>	<b>Country</b>	<b>Growth rate</b>	<b>Segment</b>
31	SmartDrive Systems	US	~250%**	Autonomous Driving
32	HireVue	US	~230%**	Business Services
33	Alibaba Group	China	~225%**	Comprehensive
34	Iflytek Co.Ltd	China	~223%**	Speech Recognition
35	Facebook	US	~210%**	Comprehensive
36	Uber	US	~193%*	Autonomous Driving
37	Splunk	US	~190%**	Business Analysis
38	MEGVII	China	~190%	Computer Vision
39	BYJU'S	India	~184%	Education
40	ZeMoSo Technologies Pvt Ltd	India	~170%*	Comprehensive
41	XiaoMi	China	~162%**	IoT
42	Conversica	US	~150%**	Marketing
43	9FGROUP	China	~140%*	Finance

<b>Ranking</b>	<b>Company name</b>	<b>Country</b>	<b>Growth rate</b>	<b>Segment</b>
44	Amazon	US	~110%**	Comprehensive
45	NVIDIA	US	~107%**	Chip
46	Globant	US	~106%**	Data Services
47	Salesforce	US	~90%**	Cloud computing
48	Alphabet	US	~80%**	Comprehensive
49	Ant Financial	China	~60%	Finance
50	Domo	US	~40%	Business Intelligent

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
1	OpenAI	11,000	Microsoft, Khosla Ventures, Reid Hoffman Foundation	California, U.S.
2	ByteDance	9,500	TCV, General Atlantic, SoftBank, KKR & Co., Primavera Capital Group, Sequoia Capital, Tiger Global Management, GGV Capital, Morgan Stanley, Goldman Sachs, Bank of China, Korea Investment Corp	Beijing, China
3	Databricks	3,500	Counterpoint Global, Franklin Templeton Investments, Andreessen Horowitz, New Enterprise Associates	California, U.S.
4	SenseTime	2,600	Alibaba Group, Fidelity International, HOPU Investment Management Company, Qualcomm Ventures, Temasek Holdings, Tiger Global Management, SBCVC, Silver Lake Partners, Suning.com	Beijing, China
5	Anduril	2,200	Valor Equity Partners, Andreessen Horowitz, General Catalyst, Lightspeed Venture Partners, 8VC	California, U.S.
6	Nuro	2,100	Tiger Global Management, T. Rowe Price, SoftBank Vision Fund, Gaorong Capital, Greylock	California, U.S.
7	UiPath	2,000	Accel, Alkeon Capital, Altimeter Capital, CapitalG, Credo Ventures, Dragoneer Investment Group, Earlybird Venture Capital, G Squared, Kleiner Perkins Caufield & Byers, Sequoia Capital	New York, U.S.
8	Lacework	1,900	Google Ventures, Altimeter Capital, D1 Capital Partners, Sutter Hill Ventures, Tiger Global Management, Liberty Global Ventures	California, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
9	Faire	1,700	D1 Capital Partners, Dragoneer Investment Group, Durable Capital Partners, Sequoia Capital, Lightspeed Venture Partners	California, U.S.
10	Affirm	1,500	Caffeinated Capital, Durable Capital Partners, Founders Fund, GIC, Khosla Ventures, Lightspeed Venture Partners, Morgan Stanley, Ribbit Capital, Wellington Management,	California, U.S.
11	Face++ (MEGVII)	1,400	Alibaba Group, Ant Financial, Boyu Capital, SK Group, China State-Owned Assets Venture Investment Fund, Foxconn Technology Group, Qiming Venture Partners	Beijing, China
12	Tempus	1,300	Baillie Gifford, Google, Franklin Templeton Investments, Novo Holdings, New Enterprise Associates, Revolution Growth, T. Rowe Price	Illinois, U.S.
13	Snyk	1,200	Qatar Investment Authority, BOLDstart Ventures, Sands Capital, Tiger Global Management, Evolution Equity Partners	London, UK
14	Dataminr	1,100	Andreas, BoxGroup, Credit Suisse, Deep Fork Capital, Eldridge, Fabrice Grinda, GSV Capital, Richmond Global Ventures, Lurra Capital, Moore Capital, MSD Partners, Valor Equity Partners	New York, U.S.
15	Babylon Health	1,100	Adam Balon, Demis Hassabis, Hoxton Ventures, Jon Wright, Kinnevik AB, Mustafa Suleyman, NNC Holdings, Richard Reed, Vostok New Ventures	London, UK
16	Freenome	1,100	Andreessen Horowitz, Anne Wojcicki, Asset Management Ventures (AMV), Data Collective DCVC, Founders Fund, GV, Innovation Endeavors, Polaris Partners, Section 32, Verily	California, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
17	Tanium	1,100	Salesforce Ventures, Wellington Management, TPG Growth	Washington, U.S.
18	Pony.ai	1,100	Ontario Teachers' Pension Plan, Toyota Motor, KUNLUN, ClearVue Partners, Eight Roads Ventures	California, U.S.
19	Zoox (Acquired by Amazon)	1,000	AID Partners Capital, Alium Capital, ARCHina Capital Partners, Blackbird Ventures (Australia), Composite Capital Management, Draper Fisher Jurvetson (DFJ), IDG Capital	California, U.S.
20	DataRobot	1,000	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.
21	Zymergen	974.1	5 Prime Ventures, AME Cloud Ventures, Data Collective, Draper Fisher Jurvetson, ICONIQ Capital, Innovation Endeavors, Obvious Ventures, Prelude Ventures, Sci-Fi VC, SoftBank Vision Fund	California, U.S.
22	UBTech Robotics	942.8	CDH Investments, CITIC Securities, CreditEase, Green Pine Capital, Haier Group, Telstra, Tencent Holdings, Qiming Venture Partners	Shenzhen, China
23	Dataiku	846.8	Wellington Management, Battery Ventures, Insight Partners, CapitalG, Dawn Capital	New York, U.S.
24	Cybereason	750.6	CRV, SoftBank, Spark Capital, Lockheed Martin	Massachusetts, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
25	Cerebras Systems	720	Benchmark	California, U.S.
26	Graphcore	682	Amadeus Capital Partners, Atomico, BMW i Ventures, C4 Ventures, Dell Technologies Capital, Microsoft, Samsung Catalyst Fund, Sequoia Capital	Bristol, UK
27	Recursion Pharmaceuticals	615.4	Bill & Melinda Gates Foundation, CRV, Data Collective DCVC, EPIC Ventures, Felicis Ventures, Lux Capital, Menlo Ventures, Mubadala Investment Company	Utah, U.S.
28	Scale AI	602.6	Dragoneer Investment Group, Greenoaks, Tiger Global Management	California, U.S.
29	Benson Hill	592.9	Alexandria Venture Investments, Collaborative Fund, GV, iSELECT FUND, Lewis & Clark Ventures, Mercury Fund, Mercury Fund, Prelude Ventures LLC, S2G Ventures	Missouri, U.S.
30	Shield AI	573.1	US Innovative Technology Fund	California, U.S.
31	Shift Technology	540	Accel, Avenir Growth Capital, Bessemer Venture Partners, Elaia Partners, General Catalyst, Iris Capital, Microsoft Accelerator Paris	Paris, France
32	AlphaSense, Inc.	520.1	First Fellow Partners, Quantum Strategic Partners, Tom Glocer, Triangle Peak Partners, Tribeca Venture Partners	California, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
33	CrowdStrike	485.6	Accel, CapitalG, Cloud Apps Capital Partners, General Atlantic, IVP (Institutional Venture Partners), Instant Scale Ventures, Telstra Ventures, Warburg Pincus	California, U.S.
34	CloudMinds	468.6	Foxconn Technology Group, Guosheng Group, Keytone Ventures, SoftBank, Walden International	California, U.S.
35	SingleStore	464.1	Goldman Sachs Asset Management, Insight Partners, Google Ventures, Hewlett Packard Enterprise, IBM Ventures	California, U.S.
36	Genuity Science (formerly 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.
37	BloomReach	452	Bain Capital Ventures, Battery Ventures, Chris Dixon, Lightspeed Venture Partners, New Enterprise Associates	California, U.S.
38	Rokid	438.3	Advantech Capital, CDIB Capital, Credit Suisse, IDG Capital Partners, Linear Venture, Temasek Holdings, Vision Plus Capital, Walden International	Hangzhou, China
39	Grammarly	400	Baillie Gifford, BlackRock, General Catalyst	California, U.S.
40	SoundHound	351	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.
41	WorkFusion	341.3	Alpha Intelligence Capital, Declaration Partners, Hawk Equity, iNovia Capital, Georgian Partners, Guardian, iNovia Capital, New York Presbyterian Ventures, NGP Capital	New York, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
42	Algolia	334.2	Accel, Aglaé Ventures, Alven Capital, Clark Valberg, Point Nine Capital, SaaStr Fund, Storm Ventures	California, U.S.
43	Flatiron Health (Acquired by Roche)	324.9	Allen & Company, Baillie Gifford, Casdin Capital, First Round Capital, GV, LabCorp, Roche, Stripes Group, SV Angel	New York, U.S.
44	Alation	315	Costanoa Ventures, Sanabil Investments, Thoma Bravo, Sapphire Ventures, Dell Technologies Capital	California, U.S.
45	Aeye	314.1	Airbus Ventures, All Blue Capital, Intel Capital, Kleiner Perkins, R7 Partners, Taiwania Capital, Tyche Partners, Vektor Partners,	California, U.S.
46	ZestAI	300	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.
47	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.
48	BenevolentAI	292	Lansdowne Partners, Lundbeck, Upsher Smith Laboratories, Woodford Investment Management	London, UK
49	Spark Cognition	286.6	Alameda Ventures, CME Ventures, The Entrepreneurs' Fund, US Department of Energy, Verizon Ventures	Texas, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
50	Anyscale	259	Addition, Intel Capital, Andreessen Horowitz, New Enterprise Associates	California, U.S.
51	Element AI	257.5	Business Development Bank of Canada, Canadian Government, Data Collective, Hanwha Investment Corp, Intel Capital, M12, National Bank of Canada, Nvidia, Real Ventures	Montréal, Canada
52	Mobvoi	252.8	Google, Sequoia Capital, SIG China, Volkswagen Group, ZhenFund	Beijing, China
53	XANT.ai	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.
54	H2O.ai	251.1	Capital One Growth Ventures, Nexus Venture Partners, Nvidia, Paxion Capital Partners, Transamerica, Transamerica Ventures, Wells Fargo & Co	California, U.S.
55	Anki	234.5	Andreessen Horowitz, C4 Ventures, Index Ventures, JP Morgan Chase & Co., Silicon Valley Ventures, Two Sigma Ventures	California, U.S.
56	Darktrace	230.5	Hoxton, Invoke Capital, Insight Venture Partners, KKR & Co., SoftBank, Summit Partners, Vitruvian Partners, Taliz Capital, Ten Eleven Ventures	Cambridge, UK
57	C3 AI	228.5	Breyer Capital, Sutter Hill Ventures, Pat House, Pat House, The Rise Fund, TPG Growth	California, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
58	Inflection AI	225	N/A	California, U.S.
59	Trifacta	224.3	Accel, Cathay Innovation, Columbia Pacific Advisors, Deutsche Börse, Ericsson, Google, Greylock Partners, Ignition Partners, New York Life Ventures, Ridge Ventures	California, U.S.
60	Invoca	201.5	Accel, Morgan Stanley Alternative Investment Partners, Rincon Venture Partners, Salesforce Ventures, StepStone Group, Upfront Ventures	California, U.S.
61	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
62	iCarbonX	200	China Bridge Capital, Tencent Holdings, Zhongyuan Union Cell & Gene Eng	Shenzhen, China
63	Afiniti	200	Daniel Klueger, Frederick Ryan, Global Asset Management, Ivan Seidenberg, TRG (The Resource Group), Zeke Capital Advisors	Washington D.C., U.S.
64	Weights & Biases	200	Bond, Felicis, Insight Partners, Coatue, Trinity Ventures	California, U.S.
65	Holidu	199.8	83North, Coparion, EQT Ventures, Lios Ventures, Prime Ventures	Munich, Germany

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
66	Shape Security	183	Baseline Ventures, EPIC Ventures, Focus Ventures, JetBlue Technology Ventures, Kleiner Perkins, Norwest Venture Partners, Singtel Innov8	California, U.S.
67	Onfido	182.1	Christian Faes, CreditEase Fintech Investment Fund, David Rowan, Jon Reynolds, Khaled Helioui, Plug and Play, Salesforce Ventures, Taavet Hinrikus	London, UK
68	Atomwise	176.6	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.
69	Sentient Technologies	174.4	Access Industries, BlackPine PE Partners, Horizon Ventures, NJF Capital, Tata Communications	California, U.S.
70	Nauto	173.9	Allianz Ventures, BMW i Ventures, Draper Nexus Ventures, General Motors Ventures, Greylock Partners, Index Ventures, Playground Global, SoftBank, Toyota AI Ventures	California, U.S.
71	Cohere.ai	164.9	Salesforce Ventures, Tiger Global Management, Index Ventures	Ontario, Canada
72	Mythic	164.7	AME Cloud Ventures, Andreas Bechtolsheim, Black Rock, Data Collective DCVC, DFJ, Future Ventures, Lam Research, Lockheed Martin Ventures, Lux Capital, SoftBank Ventures Korea	Texas, U.S.
73	Appier	164.5	EDBI, FirstFloor Capital, Media-Tek, Naver Corp, LINE Corp, Pavilion Capital, Qualgro VC, Sequoia Capital, Translink Capital, UOB Venture, WI Harper Group	Taipei, Taiwan

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
74	Brain corporation	161	ClearBridge Investments, Qualcomm Ventures, Satvik Ventures. SoftBank Vision Fund	California, U.S.
75	Hugging Face	160.2	Lux Capital, Addition, Ronny Conway	New York, U.S.
76	Preferred Networks	152	Chugai Pharma, FANUC, Hakuhodo, Hitachi, Mitsui & Co, Mizuho Corporate Bank, Nippon Telegraph and Telephone Corporation, Toyota Motor, JXTG Holdings,	Tokyo, Japan
77	Nexar	149.5	Aleph, Alibaba Innovation Ventures, Mosaic Ventures, Nationwide Ventures, Ibex Ventures, True Ventures, Expansion Venture Capital, Tusk Ventures	Tel Aviv, Israel
78	PerimeterX	148.5	Andreas Bechtolsheim, Canaan Partners, Data Collective DCVC, Vertex Ventures, Vertex Ventures US	California, U.S.
79	Upstart	144.1	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.
80	Digital Reasoning	134	Barclays, BNP Paribas, Credit Suisse, Goldman Sachs, HCA, In-Q-Tel, Lemhi Ventures, NASDAQ, Square Capital	Tennessee, U.S.
81	Conversica	132	Ben Brigham, CIBC, Green D Ventures, Kennet Partners, Providence Strategic Growth, Savano Capital, The Yard Ventures, Toba Capital	California, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
82	OctoML	131.9	Tiger Global Management, Addition, Amplify Partners, Madrona	Washington, U.S.
83	KONUX GmbH	130.6	Boundary Holding, Greenbay Ventures, FOUNDER.org, MIG, New Enterprise Associates, Unternehmertum Venture Capital Partners, Upbeat Ventures	Munich, Germany
84	Orbital Insight	130.2	Balyasny Asset Management, Clearvision Ventures, CME Ventures, Geodesic Capital, GV, Intellectus Partners LLC, Lux Capital, Sequoia Capital	California, U.S.
85	Liulishuo	128.9	Cherubic Ventures, China Media Capital (CMC), Hearst Ventures, GGV Capital, IDG Capital, RTA Capital, Trustbridge Partners	Shanghai, China
86	Vicarious	122	Felicis Ventures, Fenox Venture Capital, Iconical, Khosla Ventures, Morpheus Ventures, Samsung NEXT, Wipro Ventures	California, U.S.
87	Tractable	119.9	415, Acequia Capital (Acephat), Greg Gladwell, Ignition Partners, Insight Venture Partners, Plug and Play, Scott Roza, Zetta Venture Partners	London, UK
88	AI21 Labs	118.5	Ahren Innovation Capital, Walden Catalyst, Google for Startups, Pitango VC	Tel Aviv, Israel
89	Petuum	108	Advantech Capital, Northern Light Venture Capital, Oriza Ventures, SoftBank, Tencent Holdings	Pennsylvania, U.S.
90	Endgame (Acquired by Elastic)	107.2	Bessemer Venture Partners, Columbia Capital, Edgemore Capital, Kleiner Perkins, Paladin Capital Group, Tech Operators, Top Tier Capital Partners	Virginia, U.S.

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
91	InstaDeep	107	Alpha Intelligence Capital, CDIB Capital, AfricInvest, Endeavor Catalyst	London, UK
92	SymphonyAI Sensa (formerly Ayasdi)	106.3	Centerview Capital, Citi Ventures, Draper Nexus Ventures, FLOODGATE, GE Ventures, IVP, Khosla Ventures, Kleiner Perkins, Caufield & Byers	California, U.S.
93	Dynamic Yield	105.3	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.
94	Prophesee (formerly Chronocam)	105	360 Capital Partners, Bosch, CEA Investissement, iBionext Growth Fund, Intel Capital, Nissan-Renault, Robert Bosch Venture Capital	Paris, France
95	Chorus.ai	100.3	Emergence Capital Partners, Georgian Partners, Redpoint	California, U.S.
96	Clarifai	100	Corazon Capital, GV, LDV Capital, Lux Capital, Menlo Ventures, Union Square Ventures	New York, U.S.
97	MOOGsoft	92.9	Goldman Sachs, HCL Technologies, Northgate Capital, Redpoint, Singtel Innov8, ST Telemedia, Wing Venture Capital	California, U.S.
98	OrCam Technologies	86.4	Clal Insurance Enterprises Holdings, Intel Capital, Meitav Investment House, Moshe Gaon	Jerusalem, Israel

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

#	Company name	Funding in mUS\$	Key Investors	Headquarter
99	Kindred AI	79	11.2 Capital, Bold Capital Partners, Data Collective DCVC, Eclipse, First Round Capital, Tencent Holdings	California, U.S.
100	MAANA	77.2	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.

# The number of AI M&A deals declined by 17% in 2022

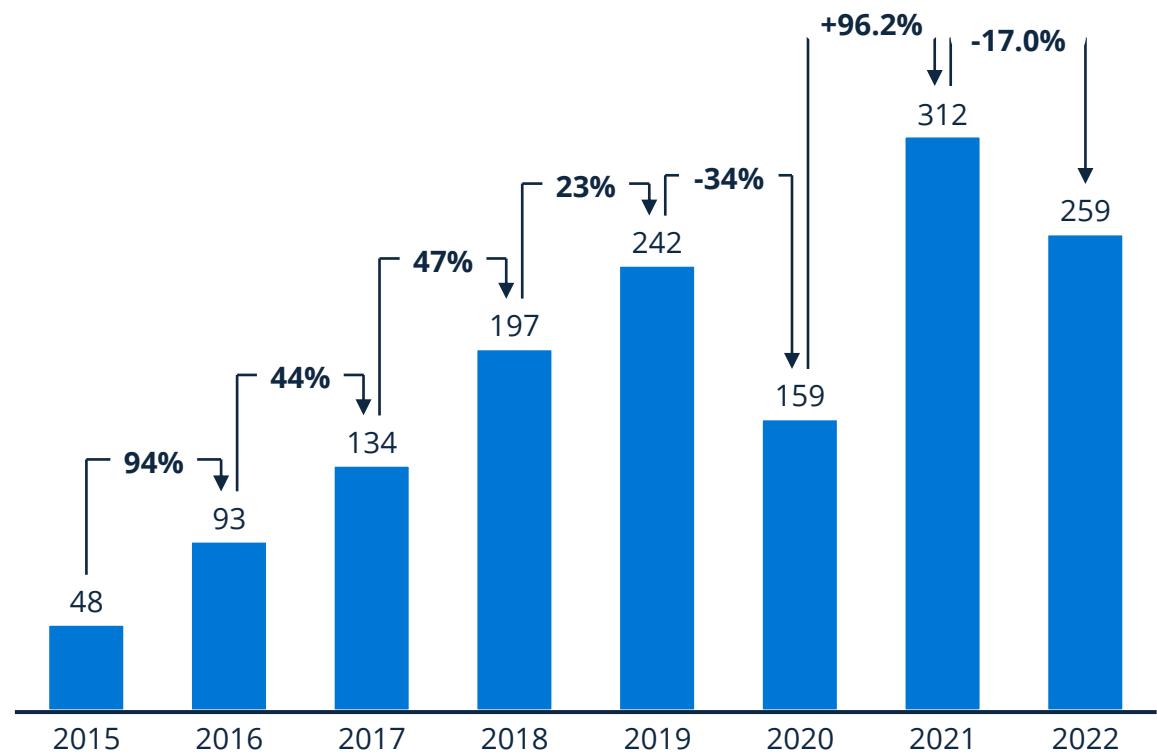
## Mergers & acquisitions

Over the years, the number of AI acquisitions have grown steadily, only to dip for the first time in 2020, as the COVID-19 outbreak prompted many businesses to prioritize core operations over new acquisitions. However, the acquisitions gained momentum and the around 312 M&A deals signed in 2021. The number of M&A deals declined in 2022 compared to the previous year and around 259 deals registered during the year.

One of the biggest deals of Q4'2022 (with announced deal size) was B3's acquisition of Neurotech, which develops solutions for the automation of the entire decision cycle for US\$107 million, in November. However, in 2022, the largest acquisition was by Shopify where it acquired Delivery for about US\$2.1 billion in July 2022.

U.S. tech giants are acquiring more AI companies than anyone else. In fact, in Q4'2022, two out of top five acquisitions in the space were from the U.S.

**Number of AI acquisitions**



# Between 2016-2022, Apple made 27 AI tech acquisitions

Top 5 global AI acquirers

Company	2016	2017	2018	2019	2020	2021	2022
	Emotient Tuplejump Software Turi Flyby Media Glimpse	Lattice Data Pop Up Archive RealFace, Shazam Entertainment DeskConnect SensoMotoric, Regaind	Asaii Silk Labs Spektral Aps	Drive.ai Laserlike PullString Spectral Edge Lighthouse AI <sup>(1)</sup>	Inductiv Subverse Voysis XNOR.AI <sup>(1)</sup> Vilynx	Curious AI	AI Music
	OpsRules Partners Tecnilogica	Clearhead Genfour Media Hive Search Technologies LabAnswer Government Endgame <sup>(2)</sup>	kogentix Real-Time Analytics Platform <sup>(3)</sup>	BRIDGE Energy Group Pragxis Technologies Sutter Mills	Clarity Solution Group ESR Labs N3 Salt Solutions	BRIDGEi2i Analytics	ALBERT Inc, Blackcomb Consultants, Tenbu, XtremeEDA, Ergo
	Eyefluence Moodstocks Speaktoit Anvato, Apigee	Hallii Labs Private Kaggle AI Matter	Terraform Labs Xively Socratic.org	Superpod	Looker Data Sciences SolveBot	BreezoMeter	Alter, Phiar Technologies, BreezoMeter
	Genee TouchType	Maluuba Hexadite	Bonsai AI, Lobe AI Semantic Machines XOXCO	Promotel IQ Jclarity	Cyberx Orions Systems	Suplari, Two Hat Security	Nuance Communications
	FacioMetrics	Ozlo Faytea	Bloomsbury AI Confirm.io	CTRL-labs GrokStyle Servicefriend	Scape Technologies	AI.Reverie	Armature Studio

# Recent M&A deals (1/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
Odin Vision	A company that develops cloud AI-enabled applications for endoscopic procedures.	80	Olympus	Dec 2022
HelpShift	A conversational customer service platform that leverages AI, bots, and messaging-based communication.	75	Keywords Studios	Dec 2022
Neurotech	A company that develops advanced solutions for the automation of the entire decision cycle.	107	B3	Nov 2022
UniteNots	A SaaS solution for AI-based targeted loyalty in retail.	40	Eagle Eye	Nov 2022
Alter	An open-source platform that consists of a 3D avatar system and motion capture for web3.	100	Google	Oct 2022
Kickertech	A business-to-business (B2B) sportsbook operation.	18	Betsson	Oct 2022
Supertone	An AI audio tech company that produces infinite combination of voices by mixing different elements of human voice.	32	HYBE	Sep 2022
42dot	A company that focused on software for autonomous driving using an in-house sensor	438	Hyundai Motor Company	Aug 2022

## Recent M&A deals (2/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
Deliverr	A company that uses predictive analytics and machine learning to provide shipping and logistics solutions to eCommerce providers	2,100	Shopify	Jul 2022
Seebo	Develops process-based artificial intelligence which helps manufacturing teams optimize processes	200	Augury	May 2022
PubPlus	An AdTech start-up that enables real-time analysis of content effectiveness and content optimization	60	ClearPier	May 2022
TABS	Provides diligence-as-a-service platform	21	PreIPO	May 2022
Area 1 Security	A security start-up that has developed a product that stops phishing attacks before they land in inbox	162	CloudFlare	Apr 2022
Nispera	Provides artificial intelligence (AI) and machine learning-enabled software-as-a-service (SaaS) targeting the renewable energy sector	30	Fluence	Apr 2022
Tera Biosystems	Cardiovascular disease biotechnology company	6	Valo Health	Apr 2022
PlaySight Interactive	A company that specializes in video technology, data capture, high performance analytics and automated video production for sports	82	Slinger Bag	Feb 2022

# Recent M&A deals (3/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
Digit	A neobanking platform that provides automated savings, investing, and banking tools	213	Oportun	Dec 2021
Exceed.ai	A Conversational AI Platform that helps augment marketing and sales capabilities through conversation automation	30	Genesys	Dec 2021
Flow Commerce	Provides cross-border and end-to-end platform for brands and retailers	500	Global-e	Nov 2021
Reonomy	An AI-powered data platform for the commercial real estate industry	202	Altus Group	Nov 2021
Agara Labs	an artificial intelligence-powered support platform for cryptocurrency trading	50	Coinbase	Nov 2021
Caper AI	A start-up that builds smart cart and cashier-less checkout technology that uses computer vision and other techniques to detect items and ring them up for shoppers	350	Instacart	Oct 2021
Neura	Provides advanced analytics powered by patented Artificial Intelligence (AI) and Machine Learning (ML) technologies	50	Otonomo	Oct 2021
Respond Software	Provider of cybersecurity investigation automation services.	186	FireEye	Nov 2020

## Recent M&A deals (4/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
Convrg.io	Provides a platform to build and run machine learning tools that can be used to train, run comparisons, and recommendations.	N/A	Intel	Nov 2020
Vilynx	An AI video start-up that provides software to analyze a video's visual, text, and audio content.	50	Apple	Oct 2020
Arm	Interconnects mega compute power in the data center to the machine learning processors for AI algorithms in the edge point devices such as wearables and sensors.	40,000	Nvidia	Sep 2020
Xilinx	Provider of flexible and adaptive processing platforms that enable innovation across various technologies such as cloud and edge computing.	35,000	AMD	Aug 2020
ThousandEyes	Provider of network intelligence services.	1,000	Cisco	Aug 2020
Cognetik	Provider of marketing analytics and customer experience optimization services. The Cognetik brand was retired in January 2021 and the company operates as Brillio.	N/A	Brillio	July 2020
Zoox	Autonomous driving.	1,300	Amazon	July 2020
CyberX	Provider of an IoT/OT cybersecurity platform.	180	Microsoft	June 2020

# Recent M&A deals (5/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
Byte Prophecy	Provider of AI-powered big data analytics services.	N/A	Accenture	May 2020
Softomotive	Provider of robotic process automation	111	Microsoft	May 2020
Softomotive	Provider of robotic process automation	111	Microsoft	May 2020
Moovit	A smart-transit start-up providing real-time updates to ride-sharing service users.	1,000	Intel	May 2020
Mellanox	Provider of AI enabled computer networking products.	7,000	Nvidia	Apr 2020
Nyansa	Deploys AIOps that uses artificial intelligence to automate the identification and resolution of IT issues in real-time	N/A	Vmware	Feb 2020
Zen3 Infosolutions	Provider of software product engineering, DevOps testing, machine learning, AI and analytics services.	64	Tech Mahindra	Feb 2020
Mudano	Provider of analytics, data and artificial intelligence capabilities.	N/A	Accenture	Feb 2020

# Recent M&A deals (6/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
AI Factory	Provider of image and voice recognition services through its proprietary deepfake-style technology.	166	Snap	Jan 2020
Xnor.ai	Uses machine learning and image recognition tools for delivering AI capabilities on low-resource edge devices.	200	Apple	Jan 2020
Loom Systems	Helps automate manual processes and mitigate operational issues in new environments.	N/A	ServiceNow	Jan 2020
Novayre Solutions	Provider of RPA software such as the Jidoka RPA platform.	N/A	Appian	Jan 2020
Looker	Provides a SaaS unified platform for data that delivers business insights to every employee at the point of decision	2,600	Google	June 2019
Express Logic	Develops real-time operating systems (RTOS) for internet of things (IoT) and edge devices powered by microcontroller units (MCUs)	N/A	Microsoft	Apr 2019
CANVAS Technology	Creates safe, autonomous technology that can power both indoor and outdoor driving	N/A	Microsoft	Apr 2019
Sonics	Developer of technologies and solutions for semiconductor design	N/A	Facebook	Mar 2019

# Recent M&A deals (7/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
Chainspace	Developer of a smart contract development platform that can facilitate payments and other services through blockchain technology	N/A	Facebook	Feb 2019
Citus Data	Offers solutions that empower real-time big data by scaling out PostgreSQL	N/A	Microsoft	Jan 2019
Superpod	Q&A app developer	N/A	Microsoft	Jan 2019
TSO Logic	Provides cost modelling software	N/A	Amazon	Jan 2019
GitHub	Provides a large code repository that is used by developers and companies for hosting projects, documentation, and code	7,500	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

# Recent M&A deals (8/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
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
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

# Recent M&A deals (9/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
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	Meltwater	Aug 2017
AI Matter	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
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

# Recent M&A deals (10/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
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

# Recent M&A deals (11/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
Maluuba	Natural language processing	N/A	Microsoft	Jan 2017
Harvest.ai	Provides cybersecurity solutions	20	Amazon	Jan 2017
Yodil	Develops enterprise data management software	N/A	Duck Creek Technologies	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

# Recent M&A deals (12/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
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
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

# Recent M&A deals (13/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
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
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

# Recent M&A deals (14/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
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

# Recent M&A deals (15/17)

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

# Recent M&A deals (16/17)

<b>Company</b>	<b>Description</b>	<b>Deal value in mUS\$</b>	<b>Acquirer</b>	<b>Date</b>
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
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

# Recent M&A deals (17/17)

Company	Description	Deal value in mUS\$	Acquirer	Date
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
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
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

## CHAPTER 7

# 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 ride-sharing company Uber is using AI for autonomous driving, food deliveries, and mapping research.

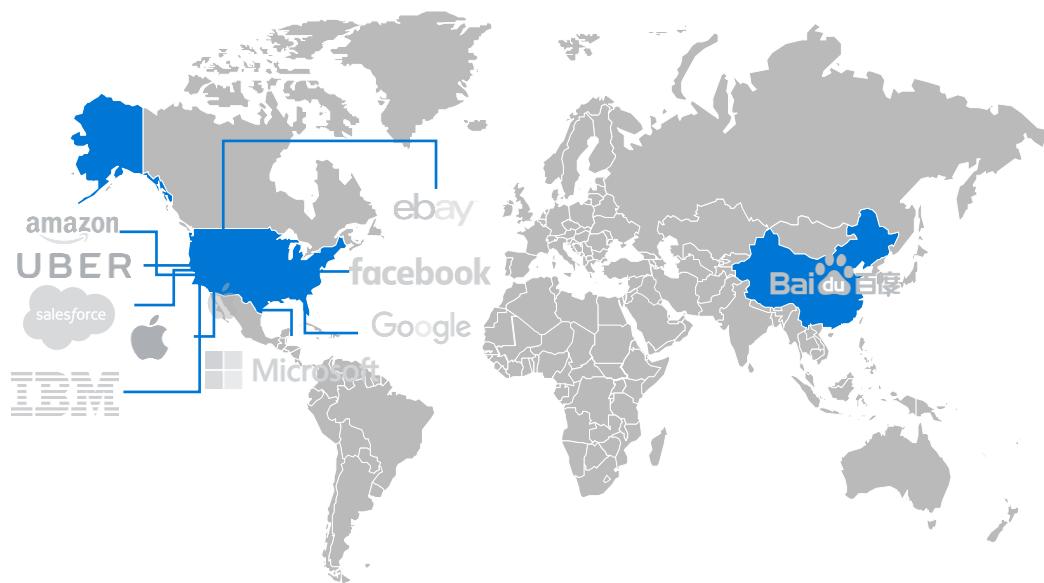
Collaborative development is on the rise, and leading companies such as Amazon, Apple, Facebook, Google/DeepMind, IBM, and Microsoft are currently working in partnership towards developing AI applications. The acquisition of small-scale AI companies in relevant fields by tech giants like Apple, IBM, 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\$ <sup>(1)</sup>	Key AI areas
Amazon	Washington, U.S.	514.0	Text-to-speech, computer vision, deep learning, NLP
Apple	California, U.S.	394.3 <sup>(2)</sup>	Machine learning
Baidu	Beijing, China	17.9	Machine learning, robotics
eBay	California, U.S.	9.8	Predictive analytics, cloud-based AI, big data
Facebook	California, U.S.	116.6	Language technology, machine learning, computer vision
Google	California, U.S.	282.8	Machine learning, deep learning, automotive industry
IBM	New York, U.S.	60.5	Machine learning, cognitive architectures
Microsoft	Washington, U.S.	198.3 <sup>(3)</sup>	Machine vision, machine learning, healthcare
Salesforce	California, U.S.	31.4 <sup>(4)</sup>	Machine learning, analytics
Uber	California, U.S.	31.9	Voice and image recognition, machine learning, automotive industry

170 | Notes: (1) As of Dec 2022 (2) As of Sep 2022 (3) As of Jun 2022 (4) As of Jan 2023

Sources: Annual reports; Corporate newsletters

# Amazon works in various areas to advance Alexa's capabilities

## Amazon: Overview

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's Alexa Fund which provides up to US\$200 million in venture capital funding to fuel voice technology innovation, has so far made 109 investments including 36 lead investments and 14 exits. 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.

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

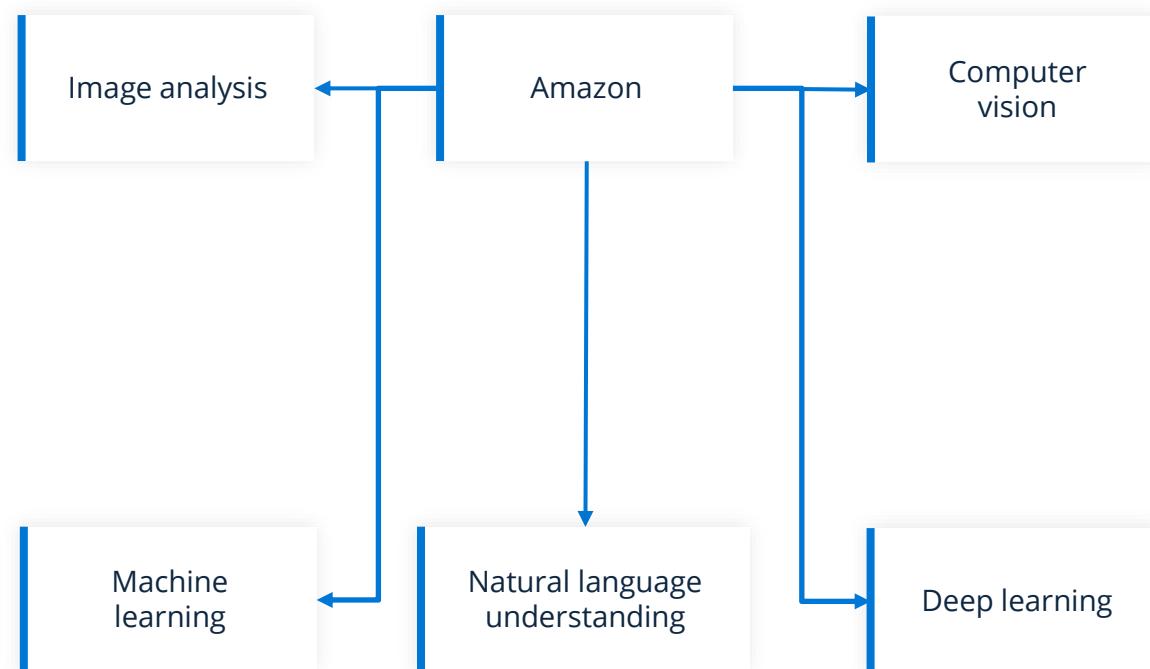
Year incorporated:	May 1996
Revenue:	US\$513,983 million (Dec 2022)
Loss before tax:	US\$5,936 million (Dec 2022)
Market capitalization:	US\$857 billion (Dec 2022)
Employees:	1,541,000 (Dec 2022)



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

Amazon: R&D areas

## R&D areas



# Amazon Rekognition provides facial analysis

Amazon: AI initiatives (1/3)



## Amazon Rekognition

Launched in November 2016, mainly for enterprises, the Amazon Rekognition service provides image recognition, categorization, and facial analysis with deep learning technology that doesn't require any machine learning expertise. 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. The service allows enterprises to create applications that talk and build entirely new categories of speech-enabled products.

# Amazon Go uses AI to expedite the shopping process

Amazon: AI initiatives (2/3)



## 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), a portable Bluetooth and Wi-Fi enabled speaker) and Amazon Fire TV. Recently, Amazon launched additional AI features for Alexa including Amazon Halo which provides AI-driven wellness insights for consumers and improvements to make conversation more natural.

# Amazon Comprehend uses machine learning to find patterns in text

Amazon: AI initiatives (3/3)



## 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.



## Amazon Comprehend

A natural language processing (NLP) service from Amazon that uses machine learning to find patterns and relationships within text. It helps enterprises to gain valuable insights from text in documents, product reviews, social media feeds, customer support feeds, and e-mails.

# Amazon launched SageMaker Data Wrangler in December 2020

Amazon: AI platform



## Amazon SageMaker

Launched in November 2017, it is an end-to-end AI platform that helps prepare data, and build, train and deploy machine learning models. Its various tools include labeling, data preparation, feature engineering, statistical bias detection, auto-machine learning, training, tuning, hosting, monitoring, and workflows. In December 2020, the company launched SageMaker Data Wrangler, a new and upgraded service to hasten the data prep process for machine learning and AI applications. Among its customers include Capital One, Siemens and T-Mobile.



## Amazon Connect Voice ID

Uses machine learning to provide real-time caller authentication to make voice interactions faster and more secure. This product is particularly useful for contact centers that have had to endure a time-consuming authentication process in the past. Notably, Amazon Connect is an open platform that can be integrated with other enterprise applications, such as Salesforce. It can also be integrated in other AWS services.

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

## Apple: Overview

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.

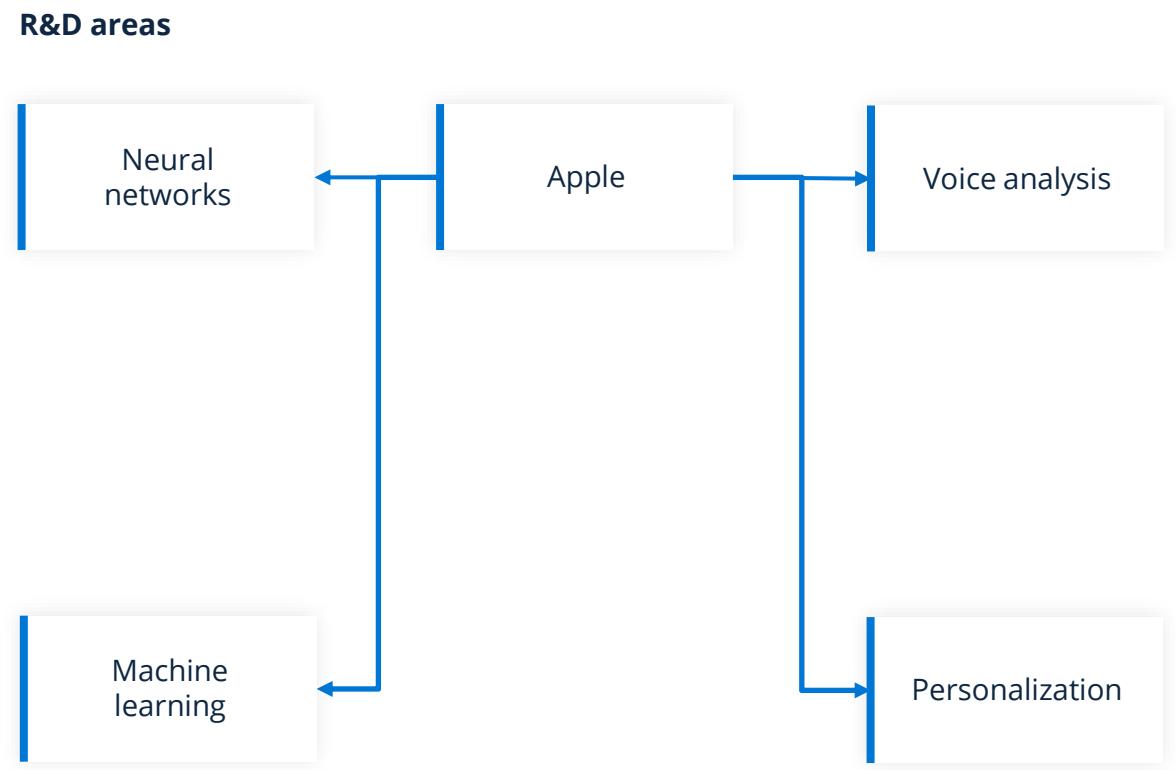
Over the years, Apple has kept its AI projects and research publications shrouded in secrecy. However, in December 2016, the company published its first AI paper, describing how image recognition training can be enhanced by using computer-generated images over real-world images. Since then, Apple has 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\$394.3 billion (Sep 2022)
Profit before tax:	US\$119.1 billion (Sep 2022)
Market capitalization:	US\$2,067.0 billion (Dec 2022)
Employees:	164,000 (Sep 2022)



# Apple's AI research is used in several services and features

Apple: R&D areas



# Baidu's Big Data Lab focuses on developing AI algorithms

## Baidu: Overview

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.

In 2021, the company ranked first globally for patent applications in the areas of deep learning and autonomous driving. In fact, it had filed 22,000 AI-related patent applications by April 2022, with 16,000 of them filed in China (4,600 of which have been granted). Baidu is also one of the largest investors in AI globally, allocating as much as 23% of its core revenue in related R&D in 2021. This was the highest among the top 500 Chinese companies. Interestingly, more than 90% of its patented technologies have been converted into related products and services.

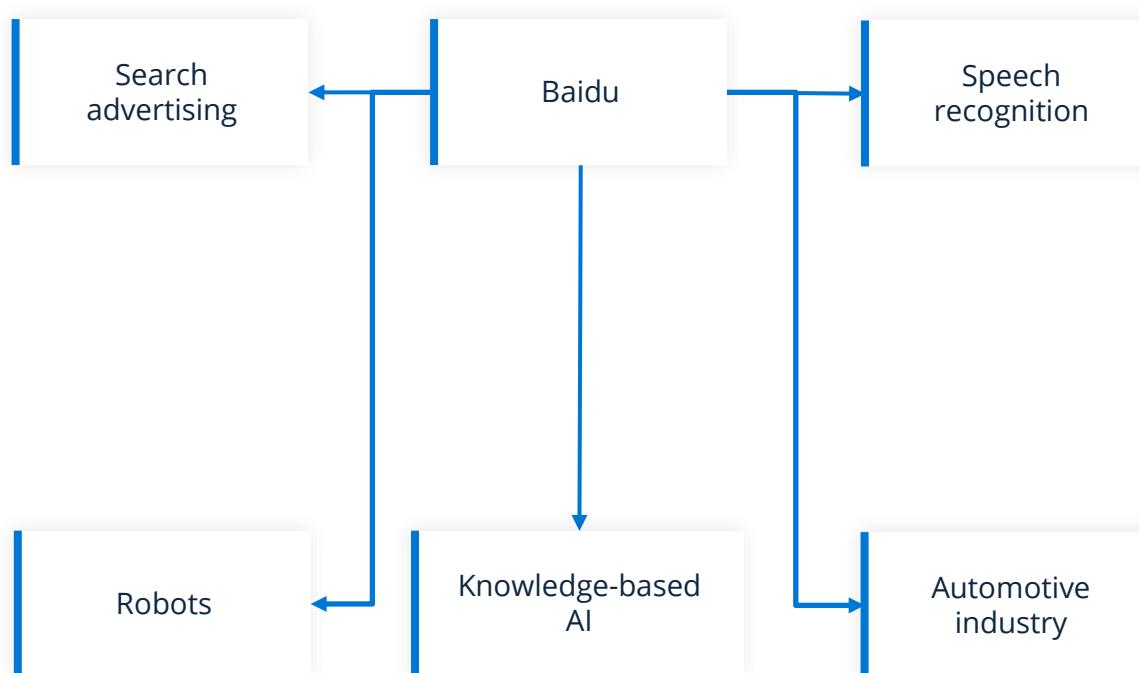
Year incorporated:	Jan 2000
Revenue:	US\$17.9 billion (Dec 2022)
Profit before tax:	US\$1.5 billion (Dec 2022)
Market capitalization:	US\$39.5 billion (Dec 2022)
Employees:	41,300 (Dec 2022)



# Baidu's Big Data Lab works in several AI areas

Baidu: R&D areas

## R&D areas



# One area of Baidu's AI research is robots

## Baidu: AI projects

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.

# eBay's AI efforts aim to improve communication in eCommerce

## eBay: Overview

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.

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

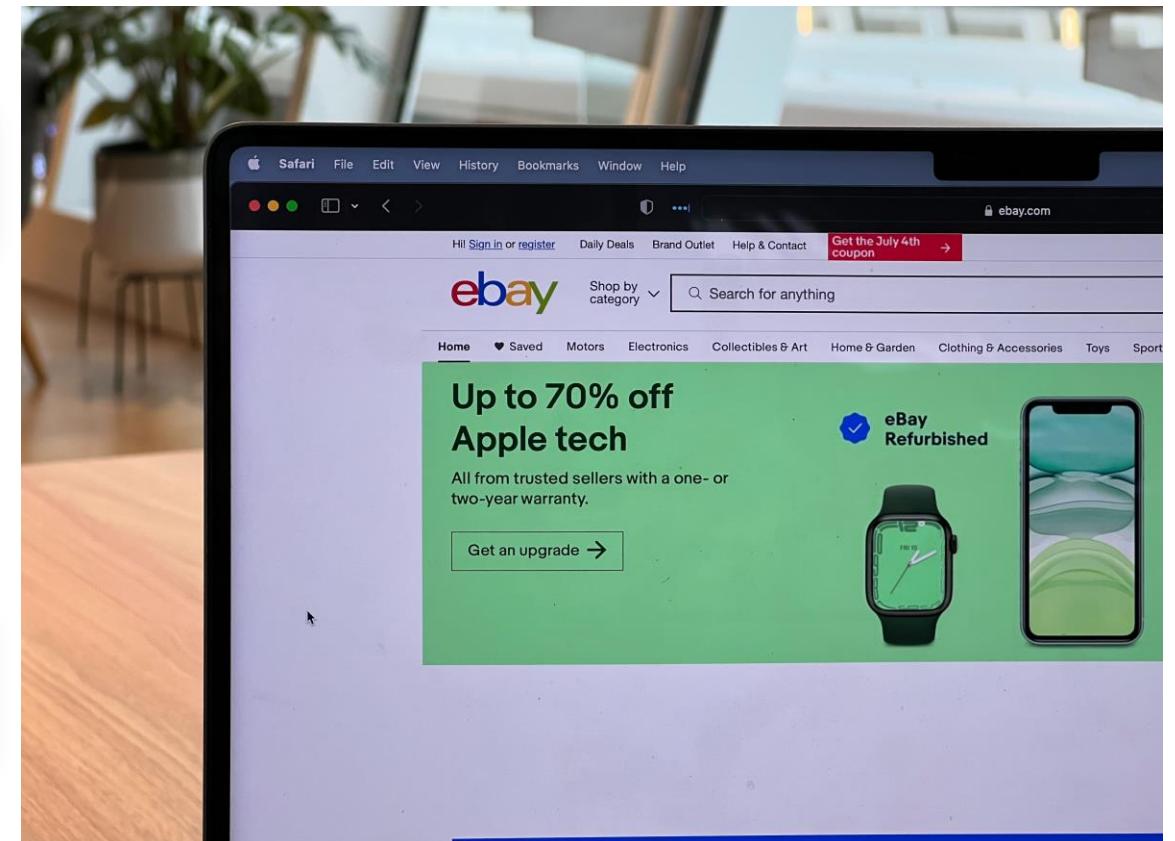
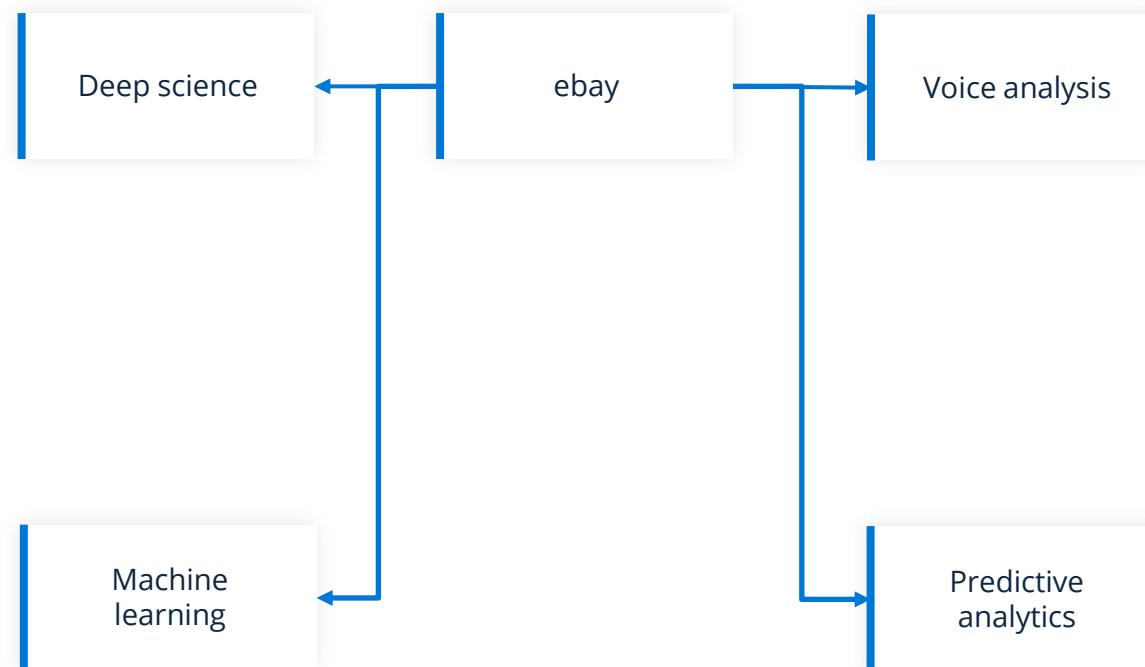
Year incorporated:	Sep 1995
Revenue:	US\$9.8 billion (Dec 2022)
Loss before tax:	US\$1.6 billion (Dec 2022)
Market capitalization:	US\$22.5 billion (Dec 2022)
Employees:	11,600 (Dec 2022)



# eBay's AI research is used in several services and features

eBay: R&D areas

## R&D areas



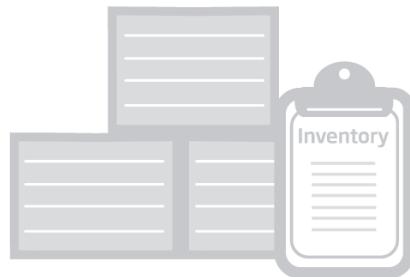
# eBay's AI initiatives focus on buyers and sellers

eBay: AI initiatives



## eBay ShopBot

Launched in October 2016, ShopBot is an AI-powered smart personal shopping assistant integrated with the Facebook messenger. It interacts with buyers to help them select the best deal for a particular product. These services can fulfill the needs of consumers when traditional search engines are unable to do so and can fill in the gaps when human expertise is not available.



## Inventory solutions

An AI-powered retail platform that helps sellers to identify inventory gaps for a particular product and sends alerts to stock up. It makes price recommendations based on-demand and also suggests stock and price adjustments when special events are trending.

# Facebook created its AI research group in 2013

## Facebook: Overview

Meta, formerly 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.

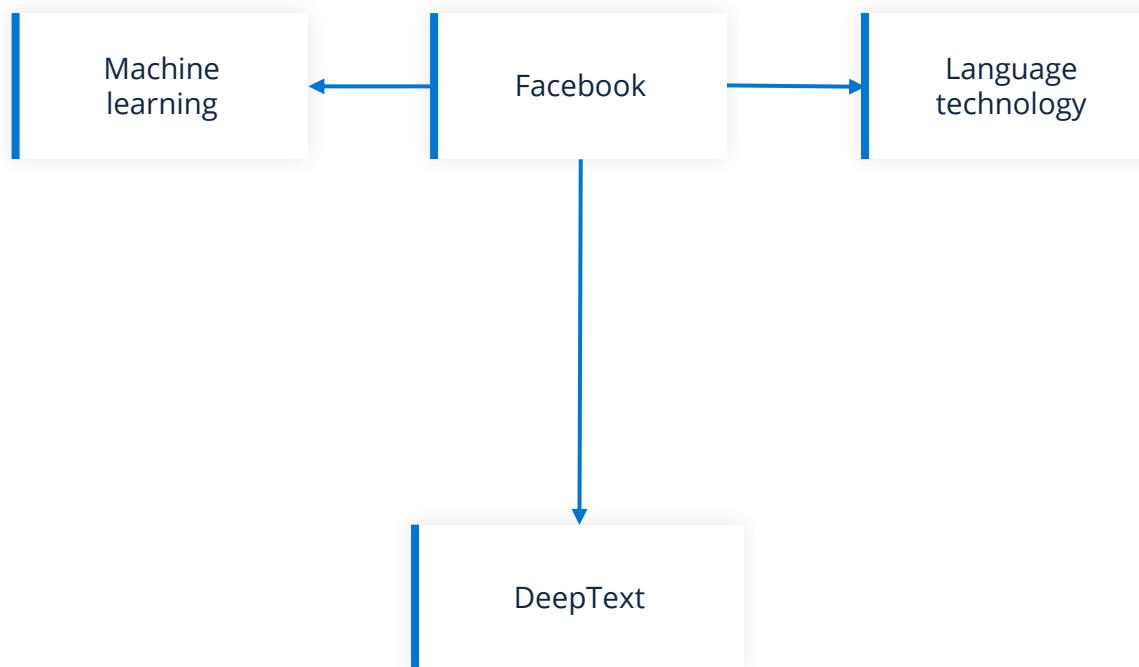
Year incorporated:	Feb 2004
Revenue:	US\$116.6 billion (Dec 2022)
Profit before tax:	US\$28.8 billion (Dec 2022)
Market capitalization:	US\$271.4 billion (Dec 2022)
Employees:	86,482 (Dec 2022)



# Facebook's AI research is used in several services and features

Facebook: R&D areas

## R&D areas



# Facebook's AI initiatives focus on enhanced text understanding

Facebook: AI initiatives (1/2)



## FB Learner Flow

This machine learning platform 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 areas 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.

# Facebook's new AI initiatives focus on understanding videos

Facebook: AI initiatives (2/2)



## DeepText

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.



## AI to understand videos

As part of a new project, Facebook is developing AI enabled systems that can comprehend video content as well as humans. The AI systems will become more accurate by learning videos from global streams from different countries and languages. As a result, they will be able to recognize the nuances in visual clues across cultures and regions.

# Google's DeepMind focuses on developing AI applications

## Google: Overview

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 healthcare 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.

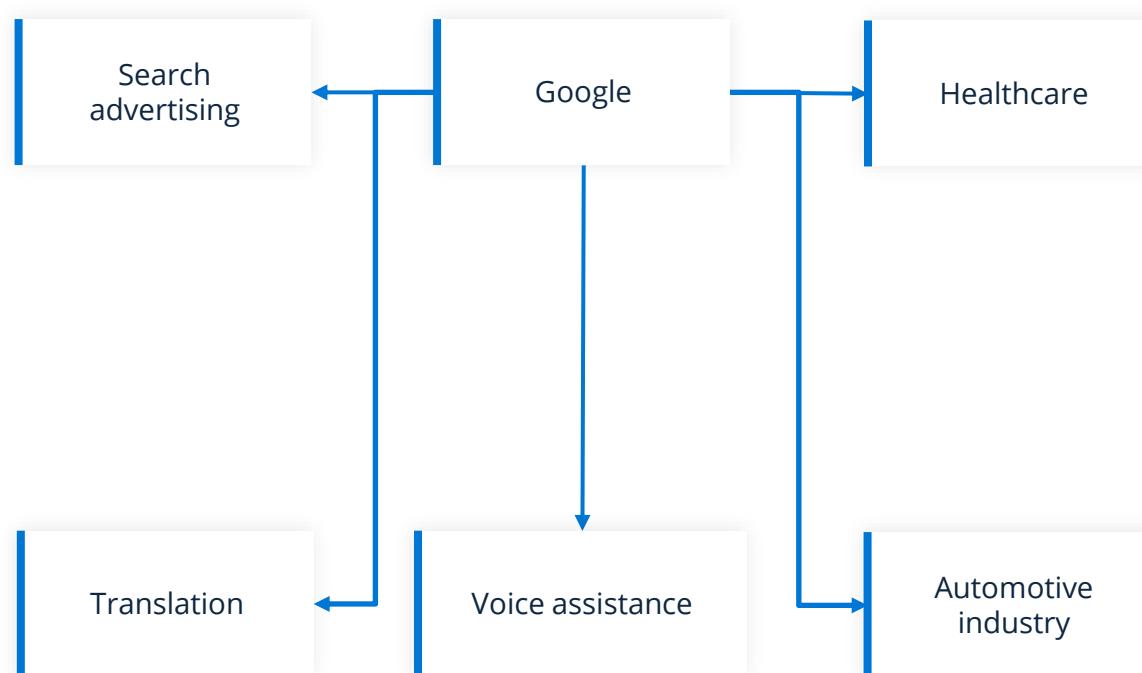
Year incorporated:	Sep 1998
Revenue:	US\$282.8 billion (Dec 2022)
Profit before tax:	US\$48.1 billion (Dec 2022)
Market capitalization:	US\$1,148.0 billion (Dec 2022)
Employees:	190,234 (Dec 2022)



# Google's AI efforts touch various industries and services

Google: R&D areas

## R&D areas



# Google is using AI to upgrade its traditional offerings

Google: AI initiatives (1/2)



## 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.

# Google Assistant aimed at providing human-like interactive experience

Google: AI initiatives (2/2)



## Voice assistant

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)

# Besides healthcare, Google's AI efforts also include automobiles

Google: Automobiles & healthcare AI initiatives



## 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<sup>(1)</sup> 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.

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

## IBM: Overview

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.

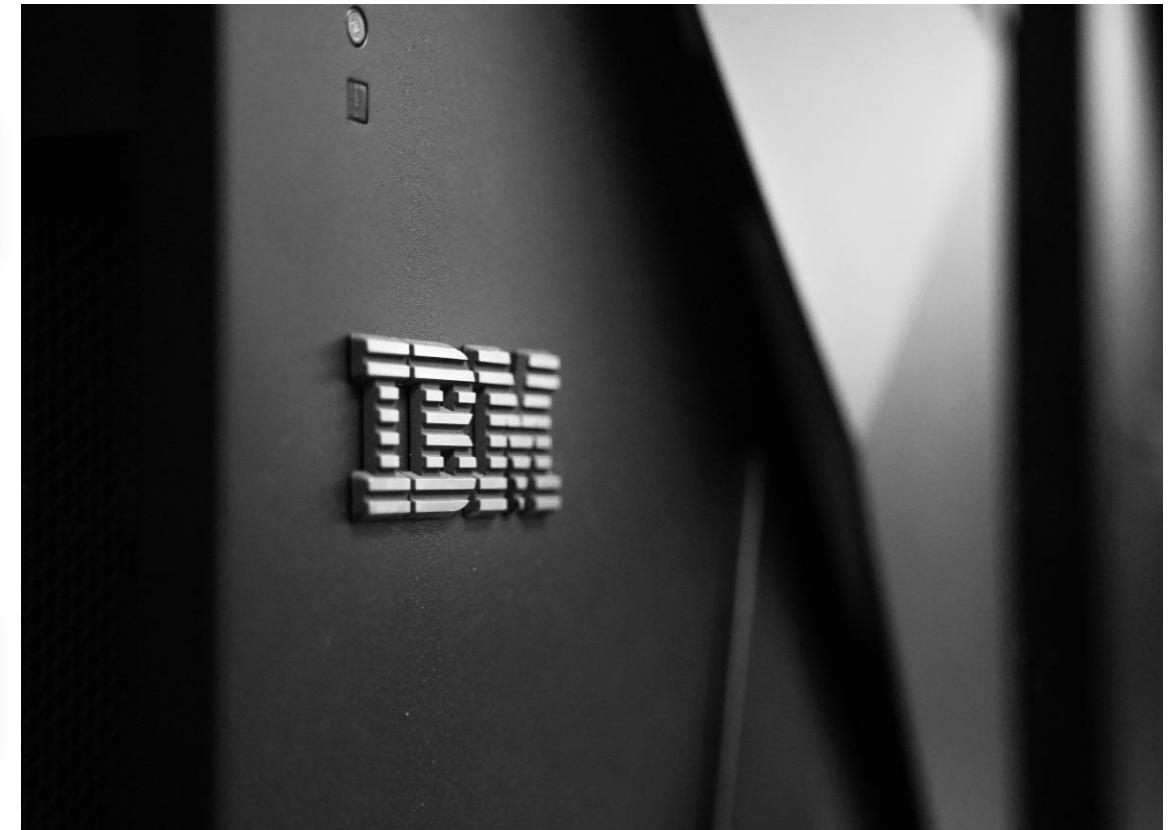
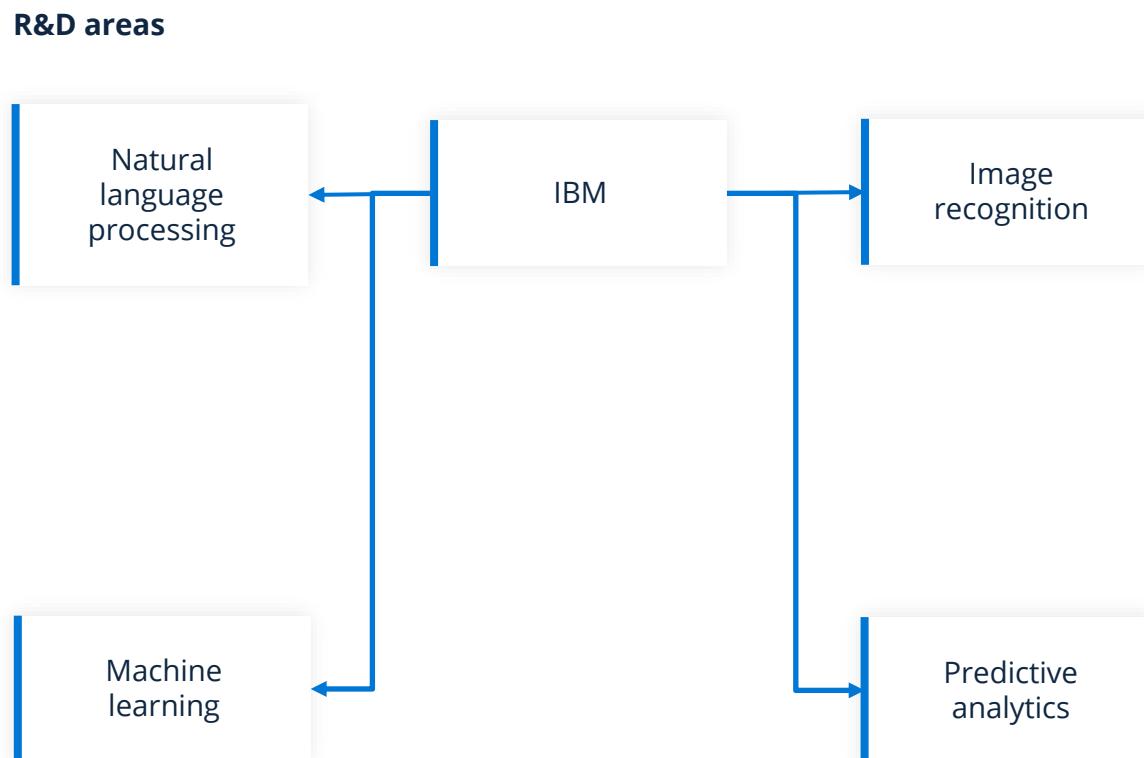
IBM's AI efforts date back to the 1950s, when it created a checkers player that learned from experience. The company's AI initiatives gained prominence with the development of the AI-powered Deep Blue computer platform, which defeated chess grand master Garry Kasparov in 1997. Currently, IBM's AI initiatives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

Year incorporated:	Jun 1911
Revenue:	US\$60.5 billion (Dec 2022)
Profit before tax:	US\$1.2 billion (Dec 2022)
Market capitalization:	US\$127.4 billion (Dec 2022)
Employees:	297,900 (Dec 2022)



# IBM's AI efforts include various industries and services

IBM: R&D areas



# Watson is one of IBM's main AI projects

IBM: AI initiatives



## Watson

A supercomputer that applies NLP, information retrieval, knowledge representation, automated reasoning, and machine learning technologies to answer questions. The Watson platform can now be used in retail, healthcare, hospitality, entertainment, aerospace, and other sectors. 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. In terms of cybersecurity applications, 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<sup>(1)</sup> 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.

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

## Microsoft: Overview

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.

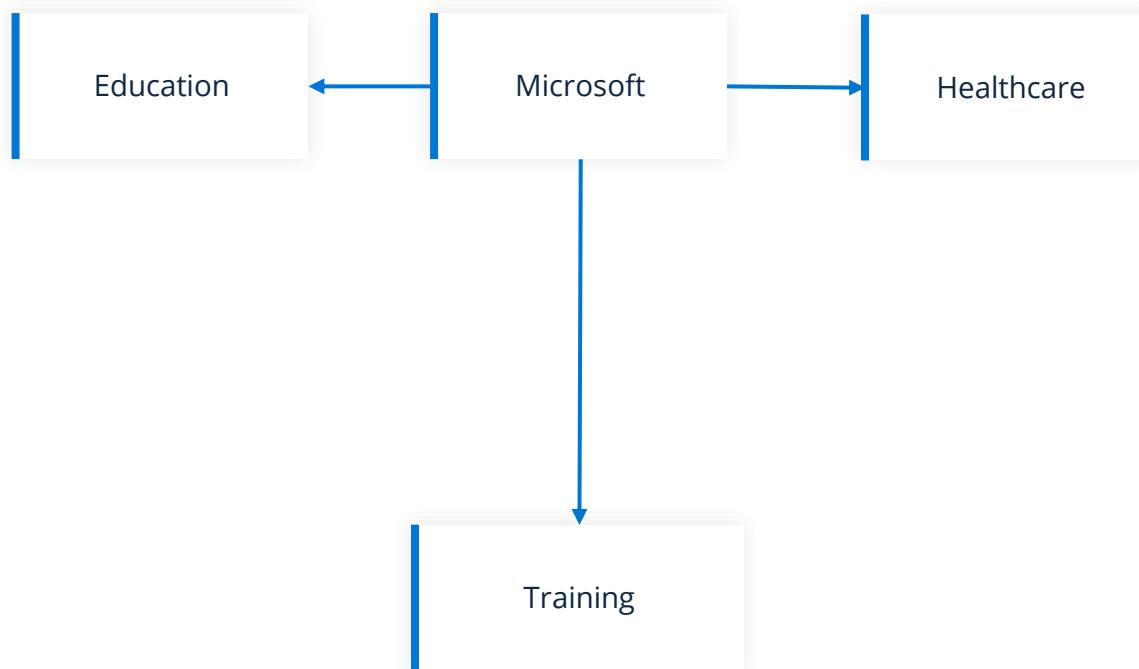
Year incorporated:	Apr 1975
Revenue:	US\$198.3 billion (Jun 2022)
Profit before tax:	US\$83.7 billion (Jun 2022)
Market capitalization:	US\$1,788.0 billion (Dec 2022)
Employees:	221,000 (Jun 2022)



# In healthcare, Microsoft aims at creating programmable biological cells

Microsoft: R&D areas

## R&D areas



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

# In 2016, Salesforce acquired several companies specialized on AI

## Salesforce: Overview

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.

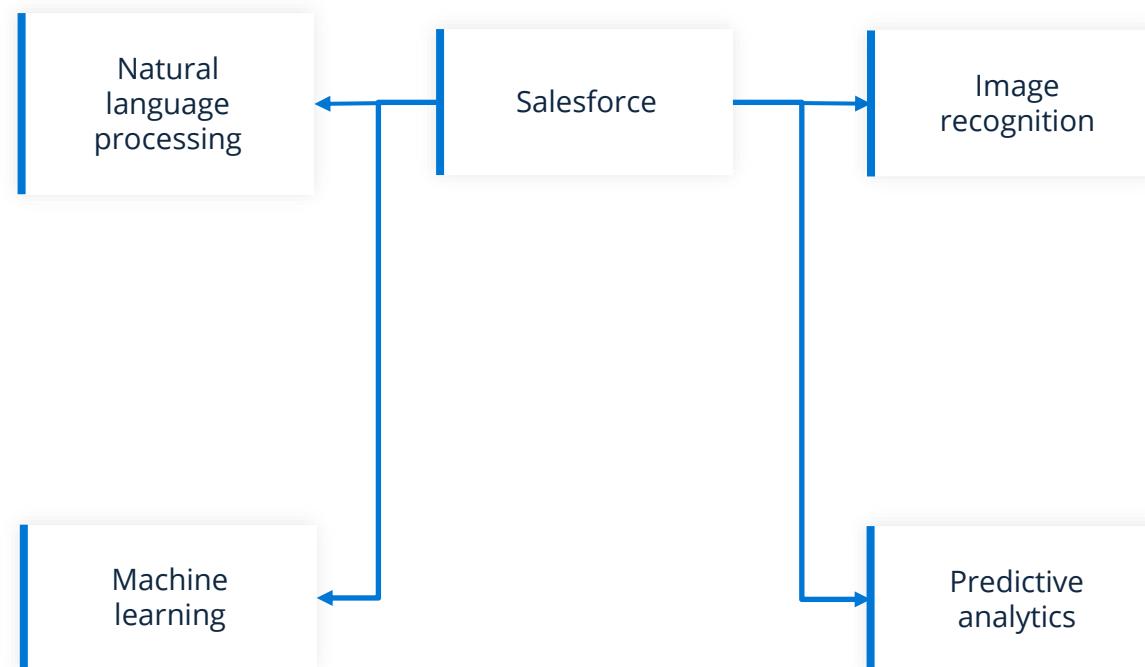
Year incorporated:	1999
Revenue:	US\$31.4 billion (Jan 2023)
Profit before tax:	US\$0.7 billion (Jan 2023)
Market capitalization:	US\$132.6 billion (Dec 2022)
Employees:	73,390 (Jan 2023)



# Salesforce's AI efforts include various industries and services

Salesforce: R&D areas

## R&D areas



# Uber seriously committed to develop its AI capabilities in 2016

## Uber: Overview

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.

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.

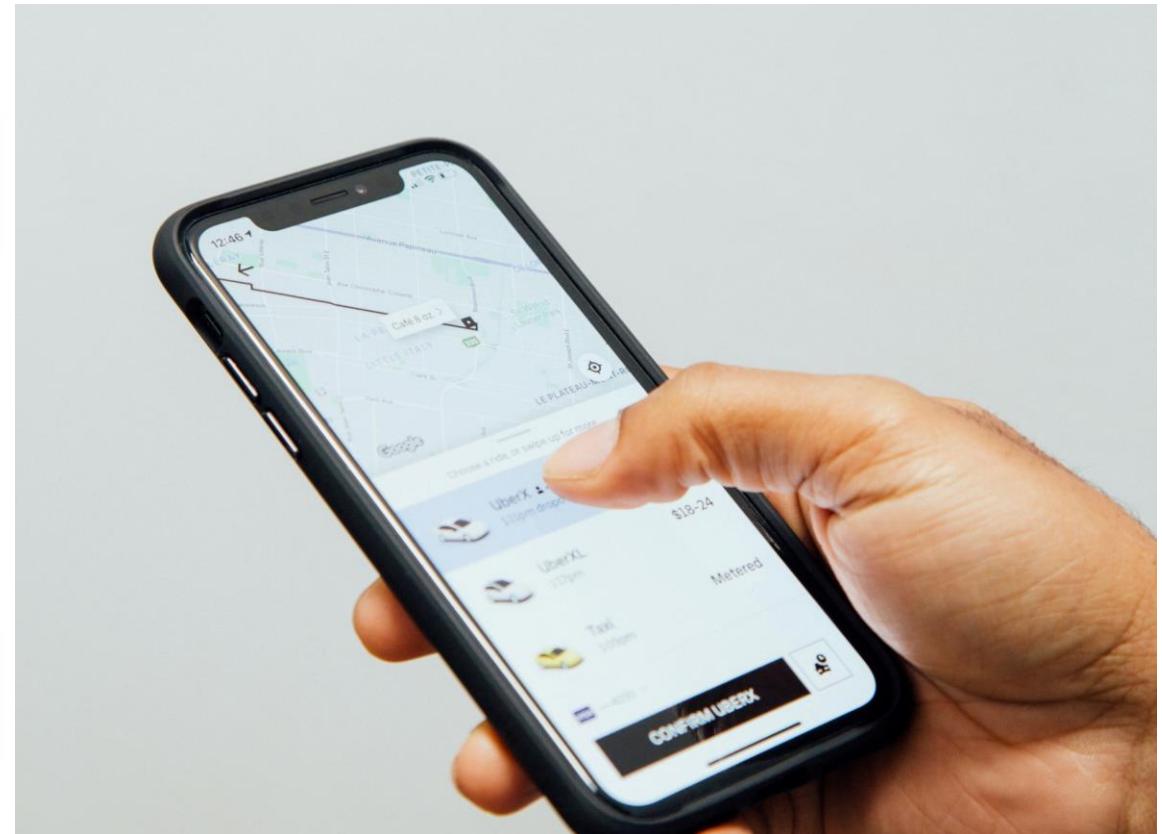
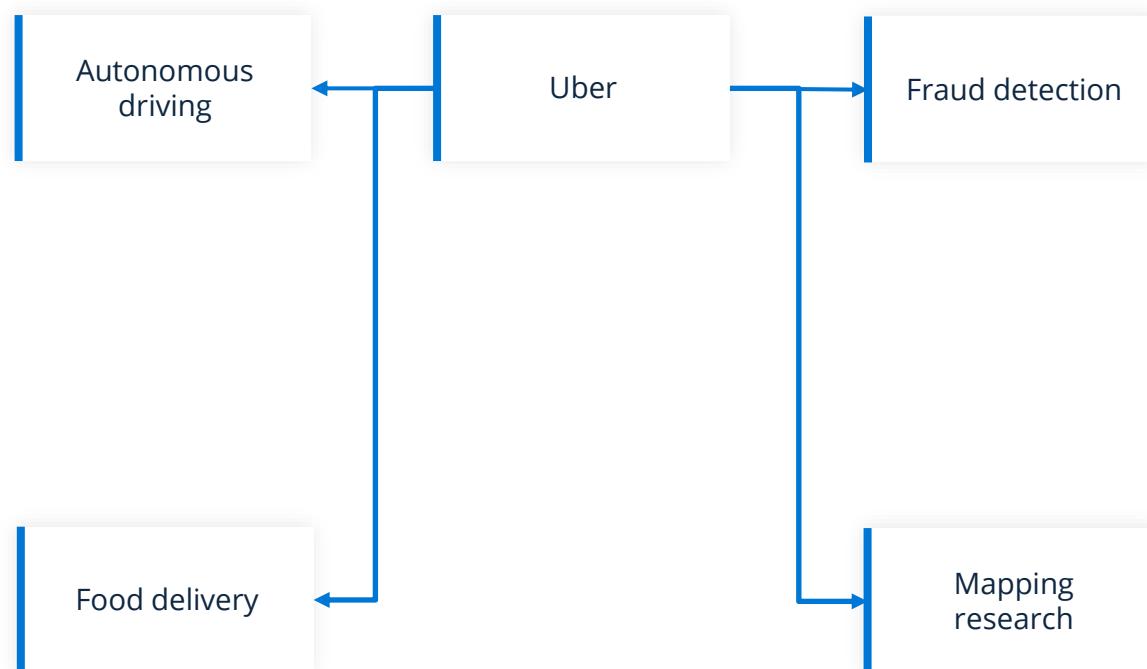
Year incorporated:	2009
Revenue:	US\$31.9 billion (Dec 2022)
Loss before tax:	US\$9.4 billion (Dec 2022)
Market cap:	US\$49.3 billion (Dec 2022)
Employees:	32,800 (Dec 2022)



# Uber's AI efforts include various industries and services

Uber: R&D areas

## R&D areas



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

Uber: AI initiatives (1/2)



## Autonomous driving

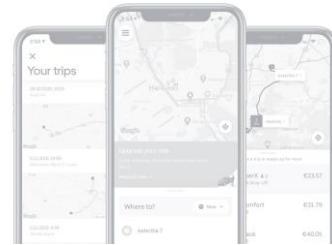
Uber's autonomous car development initiative, led by the company's Advanced Technologies Group (ATG), began testing its service in September 2016 by picking up passengers in Pittsburgh, Pennsylvania. During the trial period, selected Volvo SUVs were fitted with sensors (cameras, radars, and LIDARs) and 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.

## 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.

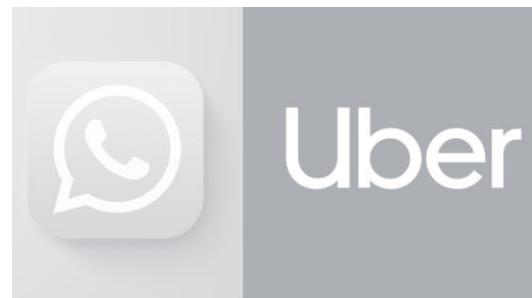
# Uber's AI-powered chatbot allows customers to book a ride via WhatsApp

Uber: AI initiatives (2/2)



## 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.



## WhatsApp to Ride (WA2R)

Uber has introduced an AI-powered chatbot, WhatsApp to Ride (WA2R), which enables customers to book rides via WhatsApp rather than installing an additional app for the bookings. The chatbot was piloted in Lucknow, a city in India and then introduced in the Delhi-NCR region, one of Uber's top cities globally by volume.

## CHAPTER 8

# Appendix



# Authors



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**Dev Mehta**

Founder and Director, AgileIntel Research

As Team Lead at Company Insights, Leonie specializes in Product Development. Additionally, she continues to carry out the tasks of her previous role at Statista as Senior Project Manager, leading department-wide projects. Before that, she worked as a consultant at EY for Transaction Advisory Services with a focus on large carve-out and integration projects.

Dev Mehta has over 12 years of experience working for market research, legal, and consulting companies. He has worked in various sectors such as defense, digital marketing, fintech, insurance, and consumer goods.

Dev Mehta completed his Postgraduate Diploma, majoring in Business Management at Massey University, New Zealand, and has a Master of Arts in Marketing Management from Middlesex University, London.

**Contact**

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EU: [eu.support@statista.com](mailto:eu.support@statista.com)

# 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.

## STATISTA CONSUMER INSIGHTS

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[statista.com/global-consumer-survey](http://statista.com/global-consumer-survey)

The screenshot shows the Statista Consumer Insights homepage. At the top, there's a navigation bar with links for 'Prices & Access', 'Statistics', 'Reports', 'Insights' (which is highlighted in blue), 'Infographics', 'Services', and a search bar. Below the header, a main banner features the text 'Understand what drives consumers' and a sub-section about survey items for female Millennials. It includes two buttons: 'Request access' and 'Request a webinar'. To the right of the banner is a data visualization showing 'Attitudes towards shopping' with a pie chart and some descriptive text. Below this are several icons and statistics: a speech bubble icon with '2,000,000+' interviews, a globe icon with '56 countries & territories', a person icon with '3.5bn+' consumers represented, a shopping bag icon with '15,000+' international brands, and a bar chart icon with '500+' topics & industries. The overall theme is global consumer data analysis.

## STATISTA MARKET INSIGHTS

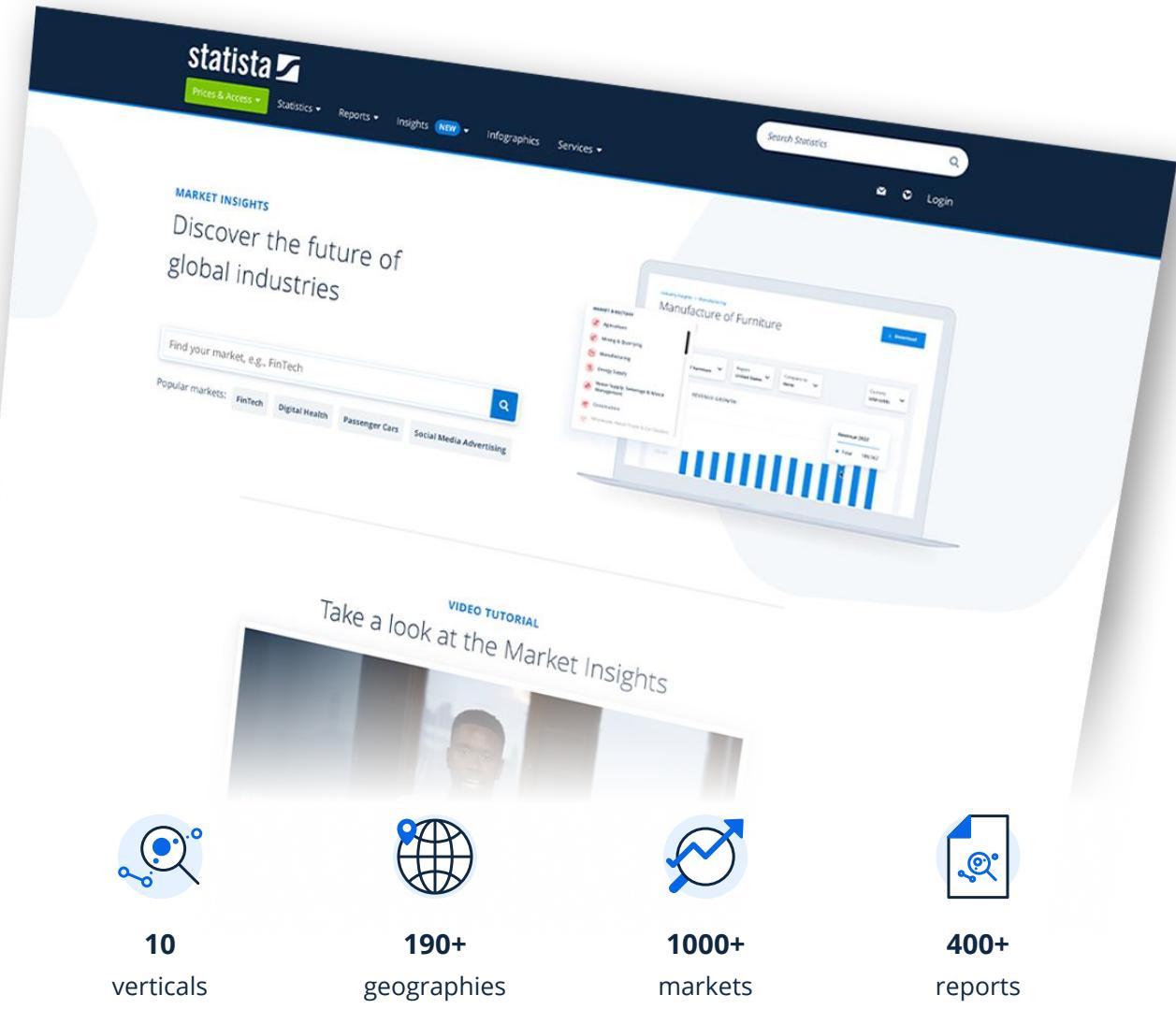
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The screenshot shows the Statista Market Insights homepage. At the top, there's a navigation bar with links for 'Prices & Access', 'Statistics', 'Reports', 'Insights' (which is highlighted in blue), 'Infographics', and 'Services'. Below the navigation is a search bar labeled 'Search Statistics' and a 'Login' button. The main heading 'MARKET INSIGHTS' is followed by the subtext 'Discover the future of global industries'. A search bar below this allows users to 'Find your market, e.g., FinTech'. There's also a list of 'Popular markets' including FinTech, Digital Health, Passenger Cars, and Social Media Advertising. To the right, there's a large image of a laptop displaying a bar chart titled 'Manufacture of Furniture'. Below this, a video thumbnail with the text 'VIDEO TUTORIAL Take a look at the Market Insights' is shown. At the bottom, there are four icons with corresponding statistics: a magnifying glass icon for '10 verticals', a globe icon for '190+ geographies', a chart icon for '1000+ markets', and a document icon for '400+ reports'.

10 verticals

190+ geographies

1000+ markets

400+ reports

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The screenshot shows the Statista Company Insights homepage. At the top, there's a navigation bar with links for 'Prices & Access', 'Statistics', 'Reports', 'Insights' (marked as 'NEW'), 'Infographics', 'Services', a search bar, and a 'Login' button. Below the navigation, a main banner features the text 'Gain insights into over 70 million companies' and a subtext explaining the service's purpose: 'We provide relevant information about businesses worldwide. Narrow down your research results using different indicators to find potential customers, get a grasp of your competitive landscape to assess the market, and identify emerging trends to continuously support your strategic decision-making.' A call-to-action button 'Explore our Company Insights tool' is visible. To the right of the banner, there's a video thumbnail titled 'STATISTA TUTORIALS How to use Company Insights' featuring a woman speaking. Below the banner, several data points are displayed with icons: '70m+' privately held companies, '50,000+' publicly listed companies, '100+' industries, '200+' countries & territories, and '20+' financial KPIs. A 'USE CASES' section below highlights 'Empowering people with company data' and lists five categories with icons: '70+ million privately held companies' (building icon), '50,000+ publicly listed companies' (globe icon), '200+ countries and territories' (location pin icon), '1,000+ reports focusing on key company data' (document icon), and '160+ data tables of top companies' (grid icon).

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# Pragmatic AI

## How to leverage the momentum

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Analytical powerhouse and AI implementation

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Digital strategy and Business building

