Elephant Robotics

Service Robots in China

The State of Play 2022

CONTENTS

Elephant Robotics

REPORT SUMMARY

The service robot industry market value is growing with advances in AI technology and favorable government policies.

Unlike industrial robots, service robots can address human labor shortages and increase productivity. Based on robot manufacturing technology iteration and artificial intelligence technology innovation such as SLAM and human-robot interaction, service robots have been applied to many contexts. Simultaneously, the Chinese government has provided a growth-friendly environment by introducing favorable policies to support the service robot

As the service robot intelligence level progresses, their use in diversified application scenarios expand.

With the advances in artificial intelligence technology, service robots have progressed in deep learning, machine vision, semantic understanding, and cognitive reasoning fields. Driven by disruptive technology, service robots can perform tasks such as floor mopping, food delivery, party construction, government affairs, retailing, logistics, medical care, education, and emotional care (Cheng, 2019). Public transportation sites, government departments, and retail automobile industries have become new sectors for service robots.

The service robot industry will grow gradually to meet demand upgrading,demand substitution and demand exploration.

Service robots are driven by satisfying and serving human needs. It is believed that the low cost of education in the demand upgrading and replacement market will be the first direction to be launched and verified. Demand exploration products will meet the needs of rich selection and personalized, which requires a lot of market cultivation in the early stage, with high barriers and excellent development potential (Cheng, 2019).

Elephant Robotics

INDUSTRY OVERVIEW

1.1 Definition & Classification

A robot is a group of machines that perform tasks automatically. There is much debate over the classification of robots, so the International Federation of Robotics (IFR) classifies robots into industrial and service robots according to their applications. Industrial robots are applied to the production process and the environment of robots, including human-machine collaboration robots and industrial mobile robots. Service robots are robots that satisfy humans' needs including personal/household service robots and professional service robots (Pineda & Meza, 2015).

Considering robots often perform tasks in high altitudes, underwater, in natural disasters, and in other unique scenes in China, the Chinese classify robots into industrial, service, and specialized robots. Among those, the service robot is the youngest member of the robot family. Service robots are widely applied in daily life for service tasks. They have various applications in leisure and entertainment, commercial services, medical care, agriculture, education, and other fields (CSTC, 2019).

1.2 Development history

The robot has developed over three stages: program-controlled, adaptive and intelligent.

In the 1860s, Joseph Engelberger, known as the "father of robotics," founded Unimation and developed the world's first industrial robot. The modern robot industry started from this and kept advancing with technological progress and market demand changes. As a commercial service, the development of robots roughly followed three stages

Program-controlled robot (stage 1): Robots in this early stage functioned according to a pre-written program written by the staff according to the workflow, or by "teaching-reproduction", that is, the robot completes the corresponding work under human guidance, then stores and records every working step. Subsequently, the robot completes its tasks using the same process and method under the same environmental conditions. The program-controlled robot can simulate the human movement function using the preset process of picking, placing, flipping, unmounting, assembling, and shaking. Therefore, it is widely used in machine tools and industrial production, such

However, the robot in this stage has a notable limitation. It can only complete the work goal according to the established process and cannot flexibly adapt to the changing situation. In addition, due to the lack of ability to perceive the environment, it is unable to identify abnormal conditions in a timely way and make adjustments in the workflow, which can lead to uncertain and even dangerous events.

Adaptive robot (stage 2): The adaptive robot can sense the environment through a sensor device controlled by a computer. This robot obtains simple information about the operating environment and the operating object through the sensor. Then the computer analyzes and processes the obtained information and controls the robot's movement.

Adaptive robots already have some rudimentary intelligence and can cope with various environmental changes, but they are not yet fully autonomous and require the coordination of technicians.

Hod Lipson, Head of Cornell University's Creative Machines Lab, presented his lab's self-aware adaptive Robot at The Big Talk in Silicon Valley in February 2015. By making the robot self-learn in a specific environment and giving it the corresponding evaluation and feedback, the robot has improved imitation ability and intuitive judgment to enhance the analysis and processing of information and its adaptability.

Flexiv, Inc. introduced Rizon in 2019 as an adaptive robot designed to perform complex tasks in manufacturing, healthcare, retail, and other applications with extremely high error tolerance, strong anti-interference, and complete job mobility. Flexiv has developed new shaft joints, joint torque controllers, unique force-sensing technology, and hierarchical robot intelligence systems to ensure safe control and operation in human-robot interaction and uncertain environments.

Elephant Robotics launched myCobot in 2020, as an educational robot with a series of small but versatile collaborative robotic arms. It helps users achieve industrial and medical applications. The myCobot series of robotic arms provide usability, security, and low noise. It offers a highly competitive choice for many automation applications as it allows quick deployment and enables human-robot collaboration. It is safe and cost-effective, and increases business efficiency.

Intelligent Robot (stage 3): The robot industry has currently entered the initial stage of intellectualization. Robots at this stage have more human-like features mainly manifested in three aspects:

1. Diverse perception and interaction capabilities: Intelligent robots are equipped with various sensory systems such as vision, hearing, and touch, which can acquire external environmental information from multiple dimensions and process this information independently to further influence and control their behavior and interact with the

2. Flexible and independent decision-making ability: Intelligent robots mostly use algorithms to make decisions. According to different input values of the external environment, they can automatically calculate and generate corresponding decisions and instructions to control their behavior. Compared with adaptive robots, intelligent robots

3. Self-learning ability: The application of artificial intelligence technologies such as deep learning and reinforcement learning enables intelligent robots to learn and optimize. Through repeated training and learning, they can truly master working skills.

With the progress of AI technology, the autonomy of intelligent robots is constantly improved, and their application is expanded from personal and household sweeping and food delivery, to professional companion robots, education

For example, Da Vinci from Intuitive Surgical Companies (ISGR) in the United States is currently the world's most successful and widely used surgical robot. The surgeon does not need to touch the patient during the operation. The robot and surgical instruments simulate the surgeon's technical movements and surgical procedures through the

Ali Damo's AI Labs also launched two service robots for business series products. Their operation process is connected to Tmall Elves voice system, and Alipay. In this way, the demand of voice pay could be satisfied in specific scenario, and the value of these service robot has been improved by integrating with the ecosystem of Alibaba.

Foreign Internet companies are also accelerating their entry in the service robot market. Amazon launched a home robot in 2021. In addition, Google claims to have developed intelligent service conversation bots that can help customers order food. Boston Dynamics, which Google previously sold, launched its service robots for commercial

Elephant Robotics launched the MarsCat and Metacat, companion robots that can meet the needs of various service applications. MarsCat is the world’ s first bionic cat, aimed for home use. As a robotic pet its role is to bring surprise, joy and comfort to people. Just like a real cat, MarsCat is fully autonomous. No complicated instructions are needed to control its movements. It is fully responsive and has sensitive interactions. It can register touch, respond to voice, recognise faces and play with toys. Every MarsCat is unique from its eyes, body, and personality. Its personality will change according to the way people handle it. With a powerful quad-core Raspberry Pi, people can also program it quickly, giving it endless possibilities.

MetaCat has high simulation fur and smooth and friendly skin as a lifelike companion robotic pet cat. With AI support, MetaCat can interact with people like a real animal. Elephant Robotics launched the MetaCat to allow people a companion pet and feel less lonely. MetaCat is especially targeted to the elderly and children who may be unable to look after a real pet.

1.3 Driving forces

Driven by value, technology and policy, the service robot industry is in rapid growth.

1. Value: Robots have excellent application value which drives demand and promotes the development of the industry (Kuo, 2017).

To liberate productivity: Industrial societies use machines to increase productivity and free humans from back-breaking manual labor. In the era of Industry 4.0, intelligent manufacturing has become the core of the global manufacturing industry's development. The robot industry plays a significant role in promoting the upgrading of traditional industries and further increasing human productivity.

To improve productivity: With the labor costs increasing every year accompanied by the aging population trend, China's economic development is faced with the problem of insufficient labor and high costs. The wide application of service robots can alleviate many social problems caused by the imbalance of China's population.

To meet people's demand for consumption: The younger generation of consumers' demand for intelligent products is constantly upgrading. From smartphones to intelligent wearing, intelligent homes, and intelligent vehicles, from simple tool applications to emotional communication and daily companionship, robots are increasingly integrated in human work and life.

2. Technological advances: The iterative development of robot manufacturing technology and multi-party innovation of artificial intelligence technology has dramatically improved the degree of robot intelligence, thus promoting the wide application of service robots.

SLAM, servo motors, sensors, and advanced composite materials have enabled robots to have more acute senses and motion systems than humans. Robots are lighter, more precise, more flexible, and safer. Table 1 shows the related techonology that improves the robot's adaptability to a complex environment.

The gradual maturity of artificial intelligence interaction technology enables robots to have basic language and image recognition ability, emotional communication and strong logical computing ability. Robots have entered the intellectualization stage of independent "thinking" and gradually approach or even surpass human beings in many aspects to help them complete their work in a wide range of applications.

Perception & sensing	Motion control	Human-machine interaction
SLAM	Fluid/Motor control	AIT
Sensors	Arm	ASR
LIDAR	Control sensor	Semantics understanding
Millimeter-wave radar	Servo	Semantic synthesis
Optical camera	Reducer	Image recognition
GPS	AI chip	Deep learning
Ultrasonic sensor		Basic calculation
Gyroscope		

Table 1: Robotics related technology

For example, MyAGV, a mobile composite robot from Elephant Robotics, has validated the use of these technologies in many applications. The robot uses a Mecanum wheel, lidar, and a high-precision camera to significantly improve its ability to adapt to complex environments. MyAGV uses the eye-in-hand design, which can be paired with different accessories for identification and grasping. It can also achieve real-time movement and mapping through the SLAM lidar navigation.

3. Government policy: The world has entered a golden age of robot development. The Chinese government has proposed to speed up the building a strong manufacturing country.

On May 8, 2015, The State Council issued "Manufacturing in China 2025", a strategy designed to build China into a manufacturing power leading the world's manufacturing development through three decades of effort.

In 2016, the Robot Industry Development Plan (2016-2020), jointly issued by the Ministry of Industry and Information Technology, the National Development and Reform Commission, and the Ministry of Finance, called for five years of investment to form a relatively complete robot industry system in China.

The report to the 19th National Congress of the Communist Party of China (CPC) in 2017 pointed out that China should speed up its efforts to build China into a manufacturing powerhouse and develop advanced manufacturing. The government then released an action plan (2018-2020) of three years to foster a new generation of artificial intelligence "Intelligence+". The plan aims to promote robot use in elderly care, rehabilitation, assistive, children's education and public services such fire rescues.

1.4 Market size

The global robotics industry is growing rapidly, especially in China.

As an important part of the robot industry, service robots have been developing rapidly in the global market with the continuous improvement of intellectualization and application value.

Since 2016, the annual average growth rate of the worldwide service robot market has reached 23.8%. According to IFR and the Chinese Society of Electronics, the average growth rate is 11.5 percent from 2016 to 2021. In 2021, the international service robot market reached $11.1 billion and was expected to grow to $12 billion in 2022. The global robot market was more than $25 billion in 2020. This was broken down to $14.49 billion for industrial robots, $12.52 billion for service robots, and $6.57 billion for specialized robots. (Chinese Institute of Electronics, 2021)
As one of the largest robot markets in the world, China is developing rapidly under the multiple stimulation of Chinese policies, technology, and market demand (IFR, 2020).

1.5 Capital analysis

Investing in robotics is becoming more rational, with investors favoring core technology manufacturers.

The number of projects in the robot industry is increasing. According to the Jingdata.com on July 26, 2019 there was a total of 1,589 robot-related projects (excluding UAVs) made up of 524 industrial robot projects, 465 service robots, 67 specialized robots, and other hardware and software providers such as robot parts, algorithms, and system integrator.

In 2019, as the capital market cooled down, investment in the robot industry became more rational. Investors are more inclined to be core technology manufacturers in the industrial chain, including core components, AI chips, and artificial intelligence interaction technology. Significant financing focuses on complete robot manufacture with explicit application or core technologies. In 2019, a total of 98 enterprises in the robotics sector received financing of about 43.8 billion yuan, most were toward service robots as shown in Table 2.

Firm	Financing rounds	Financing amount	ıcing time	Area
ROBOSEA	B	Tens of millions of RMB	May 2019	Underwater robot
Horizon Robotics	B	600 million US dollars	February 2019	AI solution provider
Geek	C	Undisclosed	July 2019	Logistics robot
Elephant Robotics	B	Undisclosed	December 2019	Collaborative robot

Table 2: Large financing events in the field of service robots

INDUSTRY CHAIN

2.1 Robot service ecosystem

The service robot service ecosystem comprises of core hardware suppliers (chips, controllers, servo, and sensor), software or program integrator (SLAM, robot version, language interaction, and cloud platform), and robot manufacturers. Robots are typically sold in the market through the sales channel, including self-management and agencies as shown in Figure 1 below.

Sales Channels

Robot Manufacturers

Core Hardware

Core Hardware

Figure 1: Robot ecosystem

2.2 Industry chain analysis

The industrial chain of service robots is complex, technology is the core, and the applications are diverse.

Overall, the supply chain of China's service robot industry is relatively mature. Driven by the demand for the commercialization of technologies, more and more enterprises have joined the service robot industry and become important technology and solution providers (Karabegović, 2017). With the development of industry refinement, the division of labor becomes increasingly sophisticated, and the supply chain becomes more complex (Cheng, 2019).

The core hardware of a service robot includes a servo motor, chip, controller, reducer, all kinds of sensors, and other parts responsible for motion control, basic computing, environmental perception, battery, power supply, memory, and other standard parts. ABB, NVIDIA, Elephant Robotics, and Panasonic are the leading hardware suppliers in robotics.

Software or program solution integrator provide software, algorithms, and technology solutions for the service robotics industry, such as SLAM and robot vision, language interaction technology, robot operating systems and software applications, and cloud services. Software or solution provider is the main link to develop and further improve the function of service robots, which involves the perception of the external environment, human-robot interaction, decision-making, and practical problem-solving.

Robot manufacturers mainly consist of SoftBank, Elephant Robotics, Baidu, and Google. At present, robot manufacturers are the leading force in promoting the commercialization of service robots and explore their value-in-use in diversified applications to support human life.

2.2.1 Core hardware

China's independent research and development capacity of servo is improving, and Chinese brands are rising.

Servo, also known as servo motor, is an electromechanical integrated component and the core component of robot motion control, including an integrated motor, controller, sensor, reducer, and other units. According to the actual environment control instructions of the robot, the servo drives the motor and reducer through the controller, enlarges, changes, and adjusts the torque and speed to flexibly control the robot's moving direction, motion state and position accuracy. Servo is generally likened to the joint "muscle" of a robot, which drives and controls the joint movement of the robot. The more joints there are, the better the movement performance of the robot. The more Servo is used, the higher the torque requirement.

In the past, foreign enterprises occupied the main control in the Servo field contributing to the bottleneck in the development of China's robot industry. Presently, the penetration rate of Chinese brands in China's Servo market is only 20%, and most of the market share is occupied by foreign brands. Among them, Siemens and Bosch Rexroth are the major players. Panasonic, Yaskawa and Mitsubishi, and other Japanese brands occupy a vital position in the small and medium-sized Servo market. Among Chinese brands, Huichuan and Eston are the leaders, with a combined market share of about 6%.

With Chinese brand-independent research and development of technological breakthroughs, this foreign dominance of the Servo market is eroding. First, "Manufacturing in China 2025" strategy has provided policy support and financial subsidies to develop the Servo system. Second, the explosive development of the industrial and service robot industries has expanded the downstream application and thus demand for Servo. Compared with foreign brands, Chinese Servo products have an obvious price advantage. Chinese brands have an average 15% price advantage compared with Japanese brands and 30% compared with European and American brands. Their economy and universality of application can be explored. Finally, the technology gap between Chinese and foreign brands is gradually narrowing. Presently, Chinese brands have been able to meet the needs of 70%-80% of everyday usage, and Chinese product brands are furthering their research and development efforts to seek technological breakthroughs.

The technological breakthroughs not only enable the relevant enterprises to obtain a first-mover advantage in the competition of the robot industry but also further accelerates the process of the market application of Chinese service robots (Zheng, 2016).

Chips are used for basic computing and command control of robots, and are in the early stages of development.

Chips are the other main hardware of the service robot, responsible for data calculation and command delivery. From the scope of application, the visible machine chip on the market can be divided into the universal chip and the dedicated chip. The universal chip can be used in computers, robots, intelligent devices, and other fields, such as CPU, GPU, and FPGA. Dedicated chips are chips designed for AI computing, also known as AI chips, such as Cambrian 1(Cho, 2020).

The universal chip is complex for deep neural network computation of service robots because of its low efficiency and high power consumption, but its portability and flexibility are good. The special chip has high efficiency and low power consumption, but its portability and flexibility are poor.

Regarding the function, the AI chip is mainly used to support training and reasoning. Training uses a large amount of data to train the algorithm so that it has a specific function. Reasoning is the use of trained models under the conditions of new data through calculations derived from various conclusions. Training and reasoning are relatively separate processes in most AI systems and require different chips (Cho, 2020).

The amount of data processed by the training is large, and the situation is complex, which requires high computability and precision of the chip. Currently, the training is mainly concentrated on the cloud server. In addition, the training process may involve a variety of complex applications, so certain general functions are required to support it. Comparatively, reasoning has low requirements on computing performance, precision, and generality, and needs to complete tasks in specific applications, generally at terminals. Hence, it pays more attention to the optimization of the user experience.

Regarding technical framework, AI chips are divided into application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), central processing units (CPUs), and brain-like chips. Table 3 shows the related information of these three AI chips. In artificial intelligence applications, deep learning algorithms have three requirements for chip performance: high-speed communication of massive data, dedicated computing capability, and unstructured data processing. With their advantages, AI chips such as GPU, FPGA, and ASIC have excellent performance in the cloud or edge end and are widely applied. From the perspective of technology trends, GPU will still be the dominant AI chip in the short term, while GPU, FPGA, and ASIC will show a parallel trend in the long term. Brain-like chip is the final development mode of artificial intelligence, but it is still far from industrialization. In terms of the market trend, the global demand for AI chips will maintain rapid growth, and the market growth rate is expected to be close to 50% in the next five years. Although there is a big gap in chip technology in China, the demand for AI chips will likely grow more rapidly as AI applications are quickly implemented.

The global AI industry is growing rapidly, and the demand for AI chips is increasing. According to the latest statistics from Gartner, the global AI chip market reached $4.27 billion in 2018 and is expected to reach $32.3 billion by 2023 (Zheng, 2016).

Types	GPU	FPGA	ASIC	Brain-like chip
Description	Single instruction, multi-data processing, the use of many computing units and ultra-long pipeline, mainly used in the image field of computing acceleration	Suitable for multi-instruction, singular data flow analysis	Specialized AI chips that are customized for specific functions	Simulate human brain function to perceive, act and think
Characteristics	versatile, high computing performance, high power consumption	Programmable, power consumption and versatility are ordinary	Customizable, stable performance, average power consumption	Low power consumption, fast response speed, in the early stage
Examples	AMD, Intel, NVIDIA	Shenjian Tech	BITMAIN, Google, Horizon	IBM, Westwell

Table 3: Chips information

Chips from giant companies provide basic support for robots and other intelligent manufacturing industries.

In recent years, Chinese and foreign technology companies have competed in the chip field layout, including traditional chip manufacturers, Internet giants, and intelligent manufacturers. Regarding overall competition, Europe, America, South Korea, and Japan continue to lead the market and monopolize the middle and high-end cloud chips. Chinese enterprises have made progress but mainly focus on the periphery, and the cloud gap is noticeable. However, most Chinese chip research and development is still in the early stage and has taken an important first step, which lays a good foundation for the development of the robot industry. Table 4 shows the product news and launch dates of several chips and firms.

Types	Firm	Products News
Traditional chip manufacturers	Intel	August 2017: Launched Movidius aMyriad X VPU September 2017: Launched auto-nomic neuron chip
	NVIDIA	May 2017: Launched GPU Votta January 2018: Launched Jetson Xavier
Communications Technology Corporation	HUAWEI	August 2018: Launched "Kirin 980"
	Apple	September 2018: Launched new product with A12 Bionic
Internet giant	Baidu	July 2018: Launched AI chip "Kunlun"
	Google	May 2018: Launched TPU3.0
Startup	BITMAIN	October 2018: Launched AI chip BM1682 and producer BM1880
	Horizon Robotics	April 2018: Launched "Journey2.0"
	Cambricon	May 2018: Launched AI chip "MLU100"

Table 4: Launch date of chips

Robot chips need robust computing, judgment, and execution capabilities. Foreign manufacturers like Qualcomm, Intel, and NVIDIA are actively deploying robot chips. At the same time, Chinese enterprises such as Rockchip, ALLWINNER, and ACTS are working hard to keep pace with them. The RK3399 and RV1108 chips from Rockchip are used in service robots (Zheng, 2016).

2.2.2 Software or program solution integrator

SLAM solves the problems of robot navigation and positioning. Multi-sensor fusion is the industry trend.

SLAM: Simultaneous localization and mapping. SLAM solves the problems of robot localization and motion navigation in the virtual environment. It allows the robot to be placed in an unknown location in a foreign environment where it can draw a complete map of the environment whilst moving, avoiding obstacles and planning the movement route according to the actual situation.

The sensors of SLAM are mainly laser and camera, so the industry divides SLAM into laser SLAM and visual SLAM. Laser SLAM is currently more mature and stable and is the mainstream industry application. Visual SLAM has been the focus of industry research and development in recent years, but there are some deficiencies in both applications. Some industry enterprises have begun to research and develop MULTI-sensor fusion SLAM technology from the perspective of complementary advantages. Multi-sensor fusion is gradually becoming the industry development trend. Table 5 displays more information about their relative advantages and disadvantage.

Advantages/ Disadvantages	Laser SLAM	Visual SLAM
Advantages	High reliability & Mature technology	Simple structure, diversified installation methods
	The drawing is intuitive, with high precision and no accumulated error	No sensor detection limitation, low cost
	Maps can be used for path planning	Semantic information can be extracted
Disadvantages	Restricted by radar detection range	Highly affected by ambient light, and cannot work in dark (no textured area) environment
	Installation has structural requirements	Due to the heavy computing load, the constructed map itself is difficult to be directly used in path planning and navigation
	Maps lack semantic information	The dynamic of sensor needs to be improved, and there will be accumulative error in map construction

Table5: The relative advantages and disadvantages of Laser & Visual SLAM

SLAM develops continuously with the change in market demand, but the whole industry is not mature enough.

The gradual maturity of SLAM technology is the basis for the improvement of the application value of service robots. With the continuous improvement of market requirements for service robot products, SLAM technology must constantly adapt and upgrade. Ease of use, high precision, and stable performance are SLAM industry's goals.

Within the robotics industry chain, two main types of companies provide SLAM technology. One is a company that provides navigation and positioning modules, and the other is a robot manufacturer developing self-used SLAM. Overall, SLAM technology in the Chinese robot industry is not mature enough and needs further development in accuracy and performance stability. In the Table 6, the basic information and technical features of some Chinese firms in robotic areas have been displayed.

Firm	Laser SLAM	Technical feature
Boocax	Founded in 2014, the company specializes in robotics, sensors and positioning and navigation solutions	It mainly uses lidar, combines UWB (ultra-wide-band technology), ultrasonic and infrared to achieve positioning, and uses multi-sensor information fusion technology to achieve
Sugan Tech	Founded in 2014, robot vision solutions	VSLAM algorithm can integrate a variety of sensors (lidar, inertial measurement unit, odometer, ultrasonic, etc.) to obtain stable and accurate position and attitude information, and help intelligent devices such as robots to obtain three-dimensional space environment information, so that they have the ability of autonomous movement, path planning, scene understanding and so on
Gaoxian Robotics	Founded in 2013, a robot navigation and positioning system developer	The company integrates laser and visual SLAM technology, and its service robots include home service robots, cleaning robots, security patrol robots, etc
Linkmiao	Founded in 2015, it provides modular laser SLAM autonomous positioning and navigation system solutions for indoor and outdoor use	The main product, NavI-Box (autonomous navigation BOX), is mainly used in the field of mobile robots

Firm	Laser SLAM	Technical feature
SLAMTEC	Founded in 2013, the main business is laser radar, namely, modular self-active positioning and navigation solutions	SLAMWARE is a single modular autonomous positioning and navigation system for robots that integrates BASIC LIdar SLAM and associated path planning functions positioning, navigation and path planning.
Elephant Robotics	Founded in 2016, it provides artificial intelligence and robotics technology, products and solution services	Launched myAGV Kit which can achieve navigation and mapping with SLAM laser radar to do real-time movement and mapping; autonomous navigation

Table 6: Fundamental states and technical feature of some Chinese firms

Owning a complete SLAM database will greatly enhance the competitiveness of technology companies

Apple, Google, and Facebook are investing heavily in SLAM technology and giving robots visual input to make them more sensitive and accurate in understanding their surroundings. SLAM can be used in robotics, autonomous driving, VR/AR, and many other fields. In many application fields, the SLAM database needs to be used as the support so that technology and environment can be closely combined and constantly updated and iterated to give full play to the maximum efficiency. We believe that having a complete SLAM database will significantly enhance the competitiveness of technology companies. For example, Facebook can use its vast user data and community power to analyze images and flag where users' images were taken. By analyzing the location of the smart glasses' cameras, Google can accurately present ads to users.

Google is currently implementing SLAM through Project Tango and working with companies like Lenovo. Tango uses two cameras to sense depth and context, which is more valuable. Apple developed ARKit based on its acquisition of crucial SLAM technology from German AR company Metaio in 2015. Snap is filing a new patent for a technology that combines GPS data with SLAM mapping to project relevant AR content into the real world.

Watch SLAM (launched in 2015) is the first homegrown SLAM system in China and one of the few commercially available SLAM systems worldwide since Metaio and 13th Lab were successively acquired. In addition, Baidu has incorporated SLAM technology into the core of its AI research. Lenovo is also working with Wikitude on Augmented Human Cloud, a SLAM database (Shukla, 2020).

In 2021, Elephant Robotics launched the world's smallest 6-DOF composite robot myAGV, which applied SLAM, enabling the robot to carry out real-time movement and mapping, autonomous navigation, and precise positioning.

Robot vision endows robots with the ability to perceive and recognize the world

Robot vision allows robots to "see" the world and "recognize" objects. Robot vision includes a variety of non-artificial ways to perceive and identify information technology, such as parts detection, quality sorting, optical character recognition, picture recognition, face recognition, and three-dimensional space perception. In service robots, commonly used robot vision technologies can be roughly divided into environment perception, three-dimensional space reconstruction, and object and image recognition (Zhang, 2022)

Environment perception: Robot collects and processes the information of the surrounding environment and objects, including spatial location, shape, outline, size, color, and brightness. By using intelligent cameras combined with laser, radar, infrared, and other sensors information is converted it into data that can be stored and calculated by the machine to help the robot perceive the world.

Three-dimensional space reconstruction: The collected space environment and object data are processed and calculated in the computer to construct a three-dimensional model that can be recognized and read by the machine and be used to "guide" the robot for decision-making, instruction and action planning (Malik, 2019).

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Face/object recognition is the ability of robots to distinguish individual differences through face/object features. For example, a greeting robot can identify customers' basic information, such as gender, age, gait, posture, and clothing characteristics, and provide a personalized greeting.

Robot vision market is broad, the competition is uncertain, and Chinese and international enterprises are accelerating the layout.

Robot vision is a comprehensive application technology involving artificial intelligence, image processing, signal, and sensing technology. In recent years, with the increase of the artificial intelligence industry, robot vision-related technologies have been rapidly developed, especially in the face/object recognition field. The basic technology is relatively mature, and the market has entered the peak stage of commercial exploration.

Presently, China is becoming one of the most active players in the field of robot vision, with a wide range of applications, covering semiconductor and consumer electronics, automobile manufacturing, photovoltaic semiconductor, robotics, and other areas of the national economy. According to the China Robot Vision Industry Alliance statistics, the robot vision industry proliferated from 2015 to 2018, with a compound annual growth rate of more than 35%.

There are more than 200 international and local robot vision enterprises in China, 300 product agents, and over 70 professional robot vision system integrators. The number is still growing at a rate of 20% per year. Although the upward trend is clear, Chinese enterprises are mainly system integrators from the point of competition. At the same time, foreign companies with independent research and development of the core components have a technical advantage. Almost all the high-end value market is dominated by international companies like COGNEX, KEYENCE, and HEXAGON. There is no leading enterprise with a dominant position in China yet. According to research from China Robot Vision Industry Alliance, the average sales volume of Chinese robot vision enterprises in 2017 was about 72.69 million yuan, and the annual sales volume of enterprises over 100 million only accounts for 16.5%.

Global Internet and semiconductor companies are racing to develop vision technology and compete in intelligent image processing. Intel acquired Itseez and Movidius to strengthen its electronic perception and image understanding capabilities. Google acquired industrial perception to complement industrial robots' 3D visual recognition technology. Facebook and Google have teamed up with VisionLabs, a Russian computer vision company, to develop a common open-source computer vision development platform.

Robot interaction technology based on language interaction has been widely used, but needs to be improved.

Interaction technology is one of the core technologies to improve robot affinity and application value and make the robot close in human characteristics. In addition to the visual interaction, language interaction (in the form of voice or text) is another widely used robot interaction technology. Most service robots on the market are capable of language interaction. In addition, haptic interaction is gradually expanding from touch screens to the broader electronic skin (Sheridan, 2016).

Language interaction: The robot can understand human language and perform simple language communication through natural languages processing technologies such as speech recognition, semantic understanding, and speech generation. Language interaction technology has developed rapidly in recent years and is generally promoted in the industry. According to the announcement by iFlytek in June 2018, the speech recognition accuracy rate is close to 98 percent, which provides the foundation for robots to understand human language. In addition, using semantic understanding, language synthesis, and personalized corpus to build a professional question-answering system is also a key area of artificial intelligence research. In recent years, language interaction in intelligent customer service has gradually improved. The development of language interaction technology in China has been on the right track, but there are still many shortcomings. For example, continuous communication, noise influence, far-field identification, and other problems widely concerning the industry have yet to be resolved. Chinese language interaction technology still needs to be improved.

Haptic interaction: This interaction can be divided into two kinds. One is to interact with the robot through the touch screen, which is more in line with the user's actual usage habits and is also a supplement to the language and visual interaction. The other is the robot's electronic skin and all kinds of sensors so that the robot can sense the surrounding environment and respond.

In the field of language interaction, Google, Apple, Microsoft, and Amazon are the four international market leader giants. In 2011, Google acquired SayNow, a voice-communication technology company, and Phonetic Arts, a voice-synthesis technology company. In 2014, it acquired several speech recognition-related patents from SR Tech Group. In addition, Google has opened up its speech recognition API for real-time speech recognition and translation applications in more than 80 languages. By acquiring voice technology companies such as Siri, Novauris, and VocalIQ, Apple is beefing up its speech recognition capabilities based on neural network algorithms as it builds a larger ecosystem on Siri, its voice assistant. Microsoft added to Cortana's machine-reading and writing capabilities by acquiring Maluuba, a Canadian AI company, and further expanding its market share based on Windows 10. Amazon has opened up its artificial intelligence voice assistant Alexa to allow third-party developers to improve voice-based technology on the platform, adding features that have led to widespread adoption of Amazon's Echo smart speaker.

Chinese companies have also made breakthroughs in the field of language interaction. iFlytek has released a new interface of intelligent human-robot interaction service, AIUI, which can provide interactive services of different contents and scenarios for users through the combination of dialect recognition, microphone array far-field sound pickup, voice wake-up, multi-round dialogue, and other technologies, and various intelligent hardware based on unified interface interaction.

Service robot operating systems are developing towards multiple trends. Chinese brands are gradually entering the market.

The robot operating system is an integrated software platform for managing robot hardware and resources, enabling robot programmers to use the platform to develop robot software. Currently, most mainstream robot operating systems are based on Linux kernel development, such as ROS, Android, ROSA, and Turin Robot operating system Turning OS. In addition, Microsoft also launched the Windows OS robot operating system, mainly used in medical robotics.

ROS: ROS is an open-source operating system designed specifically for robots. A prototype of ROS was developed in 2007 by Stanford University's AI Lab and robotics company Willow Garage for their robotics project. After several years of development, ROS has grown from a niche operating system to one of the international mainstream robot operating systems (Joseph, 2018).

Android: Android is the most commonly used operating system for mobile phones and one of the mainstream operating systems for robots. Most current consumer robots, such as SoftBank's Pepper robot, use the Android system. The Android market has become more mature due to its widespread smartphone use, so several robot manufacturers have adopted the Android system.

On the whole, traditional open-source system occupies the mainstream market regarding service robot operating system. Various manufacturers also invest in the research and development of operating systems according to the actual needs of their fields. There are multiple products in the market. However, product dispersion is not conducive to establishing an overall industry standard and therefore inconveniences users and developers. Whether there will be a standard operating system on the market in the future is likely to be controversial.

2.2.3 Robot application

The intelligence level of service robots has been significantly improved, and the application launching process has been accelerated.

With artificial intelligence technology's continuous development, service robots have made significant progress in deep learning, robot vision, semantic understanding, cognitive reasoning, and other aspects. Their intelligence level has been significantly improved. Driven by technology, the product types of service robots are also gradually enriched and infiltrated into multiple applications. The food delivery robots first launched in the market are expanding to other uses such as party construction, government affairs, education, retail, logistics, medical care, emotional care, etc.

Government robots briefly introduce the fundamental theories of communism, like the party's history, policies, and so on. Besides, the machine is designed in a humanoid shape and behaves and moves like an actual human; it can avoid obstacles on the way and conduct a normal conversation with humans, which means one positive side of it is its interactive features. It can be used to provide services in government halls, hospital halls, bank halls. However, its most important purpose is to promote the ideology of the Communist Party of China. These services include a party-building calendar, party building curriculum, party affairs consultation, oath of party membership, party history introduction, exhibition hall tour guide, party spirit education, and other functions.

Moreover, this kind of robot has AI helping its operation to make it capable of performing the above functions and can be connected to cloud service. 70% of these government robots are in a guidance role, which can simplify the work process, reduce the cost of the workforce, improve operation efficiency, and propel the development in robot intelligence (Jingdata, 2022).

The educational robot is the representative of robot application in the field of education and is the typical application of artificial intelligence, speech recognition, and bionic technology in education. Educational robots are small in size, light in weight, widely used, and cost-effective. They can play a positive role in cultivating and improving students' scientific literacy, as well as cultivating students' innovative consciousness and creative thinking.

Retail robots use the unique advantages of their interactive service system to provide new solutions for problems in retail such as variable performance of sales staff. At the same time, the novel sales form of robots also entertains consumers and provide self-service consumption applications for them.

With the rapid development of e-commerce, the logistics industry in China has shifted from labor-intensive to technology-intensive industry. This transformation in upgrading, handling, stacking, and sorting functions have proliferated. Logistics robots generally have automatic navigation functions, can move between shelves, identify products and remove them from the shelves according to the system instructions, transport the products and product shelves to the courier side, assist the courier in handling and sorting, and can significantly improve logistics efficiency, saving warehouse area.

The medical robot is dedicated to institutions for medical examination and treatment, with high barriers and high value-added characteristics. Currently, medical robots are mainly used in patient rescue, transport, surgery, and rehabilitation applications. Surgical robots mainly include laparoscopic, orthopedic and neurosurgery. Due to the advantages of accurate positioning, delicate movement, dexterous operation, small surgical wound, and lack of fatigue, medical robots are applied to surgical procedures of the heart, gallbladder, spine, and other organs.

Emotional companion robots generally have anthropomorphic properties and can actively identify family members, initiate active conversations, capture and transmit images, interact verbally or via audio, and provide emotional feedback. These robots can also provide emotional communication and companionship to the elderly and teenagers (Bogue, 2020).

Humanoid robots in logistics and storage develop rapidly.

A humanoid robot is a robot resembling the human body in shape. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes, such as the study of bipedal locomotion, or for other purposes. With the advancement of technology, humanoid robots' ability has improved, and it has been gradually recognized and accepted by the market, playing a role in more fields. In 2017, Toyota Motor Corporation released the humanoid robot "T-HR3", which is positioned as a companion robot that can provide safety support for life in various environments such as homes and medical institutions. It can complete more gentle and flexible movements and balance the whole body in different poses. Boston Dynamics' Atlas humanoid robot is already capable of falling to the ground to climb up and continuously bounce after the somersault function. With a more robust perception and decision-making system, the action ability of the robot is increasingly close to humans.

Elephant Robotics' myBuddy is a delicate and compact dual-arm robot, mainly used in family and education. This robot can be controlled in various ways and has a strong interaction ability (Stasse, 2019).

AGV and unmanned vehicle technology have been applied in intelligent warehousing and logistics. Jingdong, Meituan, and other e-commerce companies are deploying AGV uncrewed vehicles and using AI+ unmanned vehicle technology to solve the "last mile" problem in logistics, which will significantly change the status quo of logistics, express delivery, and takeout industries. AGC robots are developing rapidly at an annual growth rate of more than 40%. As an essential carrier of artificial intelligence, logistics robots are expected to in a period of rapid development opportunities (Cheng, 2019).

2.3 Case analysis

NVIDIA, the image-processing chip leader.

NVIDIA, founded in 1993, is headquartered in California, the United States, and is the world's well-known innovative chip manufacturer. NVIDIA focuses on image processing chips, covering five product technology families: GeForce, Quadro, Tegra processors, Data center acceleration tool Tesla, and data center tool GRID. Regarding terminal application types, NVIDIA's products mainly serve five needs: games, professional graphics, data center, automotive, and OEM & IP.

In terms of revenue structure, according to NVIDIA's 2018 annual report, gaming remains the largest core business segment, accounting for 53%, followed by data centers at 25%, professional visualization at 10%, OEM & IP at 7% and automotive at a minimum of 5%. NVIDIA's data centers serve the three major markets of high-performance computing, big data, and artificial intelligence. GPU-accelerated computing based on NVIDIA's Tesla acceleration tool can improve the computing performance of customer software by five times and reduce operating costs by 60 percent. Driven by advances in artificial intelligence and the need for accelerated computing power across industries, NVIDIA's data revenue continues to grow, with data center revenue of $2.932 billion in 2018, up 52% from a year earlier. Customers of NVIDIA data centers not only including universities such as Harvard and Stanford but also well-known energy, financial, and manufacturing companies, as well as online companies such as e-commerce, social media, and cloud service providers.

NVIDIA has seized the opportunity, taking advantage of its lead-in GPU field to develop AI chips. NVIDIA launched the first Pascal GPU optimized for deep learning in 2016. In 2017, NVIDIA launched Volta, a new GPU architecture with performance five times better than Pascal, and TensorRT 3, a new neural network inference accelerator. TensorRT 3 can be programmed to accelerate existing and future network architectures.

Elephant Robotics, a technology company specializing in the production and application of robots.

Elephant Robotics, founded in 2016, is headquartered in Shenzhen, China. The company focuses on robot research and production, platform software development, and intelligent manufacturing services. Elephant Robotics has independently developed Collaborative Robots (Elephant Robotics®P/C/E Series) and Bionic Robots (MarsCat). Robots manufactured by Elephant Robotics have been sold in countries such as Korea, Japan, the United States, Germany, Italy, and Greece to name a few.

The myCobot-Pi six-axis collaborative robot is a multi-functional, lightweight, intelligent robotic arm. Users of the robot can personally customize the robotic arm, as it supports multi-platform secondary development and can effectively help users achieve multi-scene application development. The myCobot-Pi has a net weight of 850grams (i.e., under two pounds), a payload of 250g, and an operating range of 280mm. It is compact but powerful and has rich software and hardware interaction methods and diversified compatible extension interfaces.

In 2019 at CES, a bionic AI robot pet MarsCat caught the attention of journalists and cat lovers worldwide. Likewise, this robot pet can walk, run, sit, stretch, express meows, and other gestures independently. After two years of ongoing R&D, MarsCat has started mass production to meet the increasing demand from the community, especially those with cat allergies and who feel a sense of isolation. In addition to a bionic body, MarsCat has two OLED eyes that give

INDUSTRY SUMMARY & PROSPECT ANALYSIS

3.1 Industry summary

The party construction, government affairs and judicial fields are becoming the new areas for service robots. The core value of service robots is to replace or assist human life and labor with efficient and cost-effective robot operations that offer a high degree of environmental standardization. In the past year, party construction, justice, and government affairs are becoming new fields for service robots use.

Robots have also been used in the dissemination of party information. They respond to knowledge queries and publicity and explain the party' s history and provide guidance. They help make information dissemination more flexible and fun, and therefore more readily accepted by the audience.

The judicial field has specialization characteristics, and it is difficult to recruit staff. Based on its robust knowledge base and case storage function, the robot can inquire on the case law knowledge popularization and application value, reducing the need for labor personnel conducting repetitive tasks. It can improve the efficiency of information retrieval and case example search, provide convenient case comparison and analysis, classifying and summarizing the application of laws and judicial interpretations to improve information utilization efficiency.

The application of robots in government affairs mainly depends on the recognition degree and popularization maturity of local governments, which is a top-down promotion mode. At present, the regional organizations and institutions are implementing centralized handling of government affairs and simplifying the process by introducing a series of convenient policies such as synchronous handling of various businesses. Robots can play the role of guidance and interaction and improve the efficiency of handling affairs (Cheng, 2019).

Compared with the leading level of foreign countries, the Chinese robot industry is relatively underdeveloped, the technology of core components is weak, and many of the core components are highly dependent on imports, so the cost is high. However, in recent years, with the improvement of Chinese research and development investment, robot manufacturers have broken through the core technology, and significantly improved robot performance. Service robots can assist or independently help humans complete some simple tasks in practical applications. With the development of servo, the movement ability of robots is becoming stronger, and their actions are becoming more flexible, making enterprises begin to pay attention to the application direction of robots (Bogue, 2020).

Different from industrial robots, service robots have more robust consumption attributes. The core logic of industrial development is demand-driven, and user value is dominant. Enterprises that can give their full attention to robots' tools, entertainment, and educational value, cut into the rigid and high-frequency needs, provide efficient solutions will have industry competitiveness. In the business market with an apparent demand, due to the long span of the service industry and the development trend of satisfactory operation, customers' personalized demand is increasing.

3.2 Prospect analysis

The industry will meet the needs of upgrading, demand substitution and demand exploration.

Service robots owns the attributes of service and consumption, and take meeting and serving human needs as the fundamental driving force of development. It is believed that the service robot industry will develop step by step to meet demand upgrading and substitution.

From the point of view of demand, we divide the market demand into three levels: demand upgrade, demand replacement, and demand exploration. Demand upgrade is a deeper intelligent, automatic, and multi-functional upgrade of existing intelligent products in the current market, giving higher added value to the products. Demand substitution is a new way to replace the original demand. In practical applications, most robots are used to replace people. Demand exploration is a future-oriented demand that has not been verified yet and needs to be explored gradually.

Demand upgrading and demand substitution will be the first direction to be implemented and verified.

Such demand is confirmed to exist, and the risk of fake demand is significantly reduced. Upgrading the realization of existing requirements through technical iterations and solution optimization can effectively improve the processing efficiency, in line with product development and progress law. It will carry out natural iterations based on original cognition without substantial fragmentation. Market education and penetration cost are lower, which is more conducive to promotion.

Demand exploration products will meet the selective rich and personalized needs. The early-stage of exploration needs a lot of market cultivation because of the high barriers and excellent development potential.

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