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The rise of the robot industry in China

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China has had the largest market for industrial robots in the world since 2013. With market needs and governmental support, the Chinese robot industry is expanding at an unprecedented rate in order to meet the challenges and opportunities of the rapidly developing Chinese economy. In this paper, the current state of the Chinese robot market and industry is summarised. Strategies for developing the Chinese robot industry are further discussed. It has been widely realised that the major obstacle in developing Chinese industrial robots has been the lack of capability to produce high-quality robot components such as motor drives, gearboxes, and controllers. Over the past 30 years, significant investments from the government and private sectors have been made in order to tackle this problem. However, the Chinese robot industry still faces major difficulties today. In the design and manufacturing of these components, "know-how" plays an important role. It is essential to obtain such know-how in order to overcome this obstacle and bring the Chinese robot industry to the next level.

Keywords: Chinese robot industry; industrial robot; robot components; robot market; robot applications; robotics research and development

Introduction

The Chinese economy is growing rapidly. As a result, so are the labour costs in factories. This has forced Chinese factories to switch from labour-intensive manufacturing to automated manufacturing. This transition has dramatically increased the need for industrial robots in China and created the largest industrial robot market in the world. In addition, manufacturing paradigms are shifting from energy- and material-intensive to innovation-oriented, in which automation plays an important role. These have presented the Chinese robot industry with great challenges and opportunities. In 2014, the President of China, Xi Jinping, stressed the importance of the robot industry for the nation's economy, and urged the Chinese robot industry to advance its technological competency and to expand its market.[1] Facing such challenges and opportunities, it is important for the Chinese robot industry to develop new strategies for the rapidly-changing market and manufacturing paradigms.

Background of the Chinese robot industry

The development of the Chinese robot industry began in the early 1970s, during the cultural revolution when the nation was in chaos.[2,3] Industrial robots and key robot technologies, such as motors and sensors, were developed by far-seeing pioneers, who created the first generation of Chinese industrial robots and applied them to manufacturing automation.[3,4] Their pioneering work made the central government recognise the importance of robot industry for Chinese economic development. In the seventh state five-year plan (1986–1990), the Chinese government supported the efforts to develop robotic technologies, including key robot components and industrial robots.[4] Furthermore, the national high-tech research and development (R&D) programme (863 programme) was initiated in 1986, and robotic technology received a major portion of focus and funding. With strong governmental support and efforts of the pioneers, several robotic research laboratories and institutes were established (Table 1). In the seventh state five-year plan, the first welding robots, painting robots, micromanipulation robots, and autonomous underwater vehicles (AUVs) were developed in China. In addition, more than 20 robot industrial parks were established by the mid-1990s. Besides industrial robots, robots for hazardous environments were also developed. Engineers at the Shenyang Institute of Automation, Chinese Academy of Sciences (SIA, CAS) developed the Explorer 1000 metres AUV, and the CR-01 and CR-02 6000 metres AUVs.[5] These AUVs laid the foundation for the development of the manned submersible vessel, Jiaolong, in 2012.[6] This

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Table 1. The pioneering robot laboratories in China.

Institutes	Founded	Representative robots
SIA, CAS	1972	AUVs
RIAMB	1970s*	Painting robots
Shanghai Jiaotong University	1979	Welding robots
Beihang University	1985	7 degree-of-freedom (DOF) robots
Nankai University	1985	Micro manipulator robots
Harbin Institute of Technology	1986	Welding robots, precise sensing

Note: RIAMB = Beijing Research Institute of Automation for Machinery Industry; SIA, CAS = Shenyang Institute of Automation, Chinese Academy of Sciences; AUV = autonomous underwater vehicle.
*The industrial robot research in RIAMB was founded in the early 1970s, but the specific year cannot be confirmed.

achievement has made China one of the leading countries in this field. In the 21st century, the Chinese robot industry expanded to incorporate intelligent robots, security robots, and robots for polar regions. Due to technological advances, robots are increasingly being used to automate industries. The first product lines equipped with painting robots were established in the automotive industry in the early 1990s.[7] Since then, the Chinese industrial robot market has emerged. To cater to this new market, several robot companies were established. With R&D support from the robotics laboratory at the Harbin Institute of Technology, BOSHI was established with a focus on system integration and high-precision sensing devices. In addition, the SIASUN Robot and Automation Company was launched in 2000.[8] These early developments in the Chinese robot industry and R&D efforts laid a strong foundation for the rapid development of robotic technology and applications in China today.

The global industrial robot market dramatically increased in 2013. The number of global industrial robot units sold in 2013 was 178,132. Furthermore, the market grew at a record-breaking rate of 12%, up to US$9.5 billion in 2013.[9] The automotive industry is the most important consumer of industrial robots, taking 39% of the total market share. In addition, metal, chemical and rubber, and food industries also took increasingly large shares of the market in 2013, accounting for 9%, 7%, and 4% of the global market, respectively. From a regional perspective, the largest regional market is the Asian (including Australia and New Zealand) market, with 98,807 industrial robots installed, 17% higher than the number in 2012. In Asia, the Chinese robot market became the biggest robot market globally in 2013 in terms of annual installation. More than 36,560 units were installed in 2013 in China.

With the rapid development of the Chinese economy, the labour costs of the Chinese manufacturing industry are also increasing dramatically.[10–12] Many international corporations have already started to move their plants out of China due to the increasing labour costs.[13–15] To face this challenge, it is essential for the Chinese manufacturing industry to change from labour-intensive manufacturing to automated manufacturing. Furthermore, the Chinese manufacturing industry has been undergoing a major transition in order to develop a high-value-added and sustainable industry. Both of these have provided golden opportunities for the development of the Chinese robot industry.

Besides the strong application pulling, the development of new technologies, such as cyber technology, communication, and intelligent sensing and control have pushed the development of robotic technology to a new level. Thus, an intelligent robot driven manufacturing paradigm emerges.[1,16] As the world centre of manufacturing, China can take this opportunity to transform its manufacturing industry to an innovation driven, sustainable, and global competitive industry.

The current status of the Chinese robot industry

The Chinese industrial robot market has expanded dramatically in the past several years. Industrial robot installations in China increased from 15,000 units in 2010 to 37,000 units in 2013. Currently, the Chinese industrial robot market accounts for 20% of the global market, and is the largest in the world. In the first six months of 2014, the Chinese robot industry installed 6400 industrial robot units, 66.8% of the total units installed by the Chinese robot industry in 2013. The Chinese Robot Industrial Alliance (CRIA) estimated that the total number of Chinese industrial robot installations would be more than 12,000 in 2014, 25% higher than in 2013.[17] Though it is increasing at such a high rate, the Chinese industrial robot market still has great potential and is expected to grow even faster in the coming years. The International Federation of Robotics (IFR) reported that the number of industrial robot units per 10,000 workers in China is only 14, less than a quarter of the world average of 62, and far less than that of developed countries. In South Korea, this number is more than 400. In major developed countries, this number is more than 100 (Figure 1).[18] According to a report from the IFR, the Chinese industrial robot

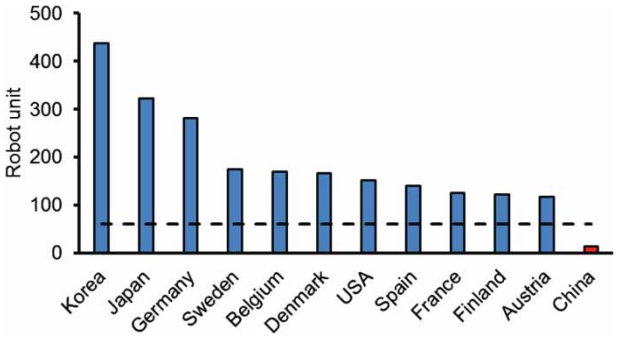

Figure 1. The number of industrial robots per 10,000 employees in manufacturing plants.
Note: The dashed line is the world average number. Please view the online version for the colour reference (http://dx.doi.org/10.1080/1023697X.2015.1043959).

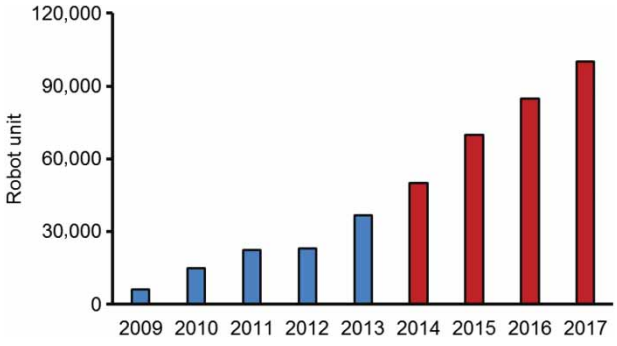

Figure 2. The annual industrial robots shipment in China.
Note: The red bars from 2014 to 2017 are estimated values. Please view the online version for the colour reference (http://dx.doi.org/10.1080/1023697X.2015.1043959).

installation will grow dramatically over the next several years (Figure 2), and the number of operating industrial robots in China will overtake that of the European Union (EU) and North America.[19]

The growth of the Chinese robot industry is also driven by strong governmental support. In 2012, the Ministry of Science and Technology of China announced major development plans for intelligent manufacturing and service robots.[20] According to these plans, the Chinese government will make major investments in the development of industrial robots, service robots, and advanced manufacturing automation equipment. With governmental support, China has established more than 30 industrial parks dedicated to the manufacturing of robots. By September 2014, China had established 428 robot companies. More than 40 of them have gone public, including SIASUN, the first public industrial robot company in China. SIASUN was started by scientists and engineers in SIA, CAS in 2000. With 15 years of development, SIASUN has established its leadership in the Chinese robot industry. Currently, SIASUN has a market value of RMB 23 billion. Its products include industrial robots, cleaning robots, automated guided vehicle (AGV) robots and service robots. These products have

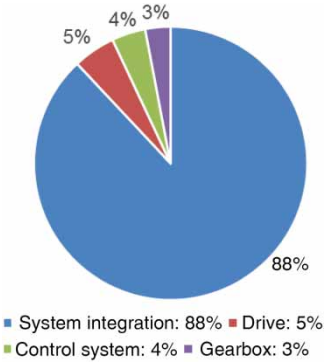

Figure 3. The major types of Chinese robot companies: system integration, drive, control system and gearbox. Please view the online version for the colour reference (http://dx.doi.org/10.1080/1023697X.2015.1043959).

been exported to 13 countries and territories throughout the world.

The Chinese robot industry also invests heavily in R&D. By September 2014, the Chinese robot industry had filed 23,877 patents related to robotic technology, 56% of which are invention patents. Though the Chinese robot industry is developing very rapidly, it still cannot meet the increasing market needs in China. According to a report from the IFR,[3] in spite of the 65.5% increase of domestic robot installations in 2013, Chinese robot companies only account for a quarter of the Chinese industrial robot market, mainly at the low end.[9] The automotive, electrical/electronics, and metal industries are the top three sections in the industrial robot market. Among them, the automotive industry takes 50% of the Chinese industrial robot market. However, Chinese robot companies only have around 10%, 45%, and 25% of shares in these three industries, respectively. In 2013, Cartesian robots and transferring robots are the main robot types made by the Chinese robot industry. However, the markets for articulated arm robots and welding robots are mainly dominated by foreign robot companies; in 2013, the Chinese robot industry only accounted for 20% and 10% of the two markets, respectively. In addition, the Chinese robot industry depends heavily on foreign companies for key robot components. According to a report from the Gaogong Robot Industry Institute (GRII),[7] 88% of Chinese robot companies are system-integration providers. The companies that make drives, control systems, and gearboxes only account for 5%, 4%, and 3%, respectively (Figure 3).[21]

Opportunities and challenges facing by the Chinese robot industry

With rapidly growing market needs and strong governmental support, the Chinese robot industry is developing at an unprecedented rate. However, despite its rapid growth, technological gaps between Chinese and foreign

robot companies still exist. The key robot technologies are sensing, driving, and intelligence. The sensing and driving technologies have been the major obstacles in the development of the Chinese robot industry.[22] Currently, major components of industrial robots such as drives, gearboxes and controllers still heavily depend on foreign supplies. It is essential for the Chinese robot industry to develop the capabilities and competencies required for the production of these key components. With decades of development, the technology and marketing accumulations will enable the Chinese robot industry to reduce the technical disparities with foreign companies and play a more important role in the Chinese robot market.

To expand its current market share, besides traditional robot applications, it is important for the Chinese robot industry to develop competency in emerging robot applications. Foreign robot companies have dominated the current major industrial robot markets, especially in the automotive, metal, and electrical/electronic industries. With labour costs on the increase, the industrial robot market is expanding into many new industries, such as home appliances, printing, food, and energy. To expand the industrial robot applications in these fields, robotics engineers should understand the characteristics of the targeted industries and develop solutions to meet the specific requirements for these different industries. For example, industrial robots can automate the packaging processes in the food industry, which requires that the robots work in a sterilised environment, which is different from that of the industrial manufacturing plants. These emerging markets have great potential considering the scale of the manufacturing industry in China. In addition, the Chinese robot industry has advantages with respect to service robots. With the rising labour costs and increasing number of senior citizens in China, the potential market for service robots could be significant. As domestic companies, their better understanding of the Chinese culture gives them competitive advantages in this field. Furthermore, the Chinese robot industry can ease the technological gaps with foreign companies by taking the opportunities offered by the current transition in the manufacturing paradigms. Enabled by the development of information technologies and the increasing concerns about the environment, the manufacturing industry has been undergoing a transition from material- and energy-intensive to sustainable growth. Integrating with information technologies, such as cloud computing, big data, and the internet, robot technology plays an important role in this transition. The Chinese robot industry can grasp this opportunity to become a world leader in robot technology, as well as in the global market.

In spite of decades of strong movement support through initiatives such as the national 863 programme, the Chinese robot industry still has difficulties developing key robot components. The Chinese robot industry has a clear understanding of the problem ("know-what") and the technological principles ("know-why"); the difficulty is from developing so-called "know-how". Know-how is not simply a collection of knowledge, but the technical information accumulated through practical experience.[23] For example, the technical principles of manufacturing servo motors have been detailed in textbooks for decades, but the technical specifics about making high-precision, reliable servo motors – the *know-how* – still hinders the development of the Chinese robot industry. Know-how consists of technical experiences, methodologies, process protocols, etc., and is rooted deeply in working attitudes, quality control, and social values with regard to the design and manufacturing process. As the saying goes, "Rome wasn't built in a day"; a considerable amount of time and nurture are needed to develop truly valuable know-how. The status of Germany and Japan as leaders in the robot industry is rooted in their centuries of efforts to establish a rigorous industry ecosystem, including the attitudes of industrial workers, management, and quality assurance. The Chinese robot industry needs this kind of environment to obtain the missing know-how. To establish an environment that can generate know-how, it is essential for the Chinese robot companies to change from striving for short-term profits to aiming for long-term rewards. Through continuous and focused investments, the Chinese robot industry can develop its own know-how. For example, through four decades of focused development of underwater vehicles, the Chinese robot industry has obtained the key know-how for manufacturing in this field, enabling the development of Jiaolong manned submersible vessel. Finally, it is also important for the Chinese robot industry to invest in training its workforce and developing a positive company culture, since technological know-how exists in the workforce. To improve work attitudes and increase the standard of workplace conditions, long-term investment is required. For example, the Chinese robot industry and research laboratories can cooperate with universities and even middle schools to develop robotics-related courses for preparing future engineers and workers.

Conclusions

The Chinese robot industry is facing historical opportunities and challenges. The fast growing Chinese economy and industry and the changing of labour force provide vast potential growth opportunities for the Chinese robot industry. It has been accumulating technologies and talents for several decades. The market, technical maturity, and the strong governmental support enable the Chinese robot industry to meet the challenges of transforming manufacturing paradigms and new emerging robot applications. The combination of application and market

pulling with technology pushing has provided a huge thrust for the Chinese robot industry to grow and eventually become a world leader in robotic technologies as well as applications.

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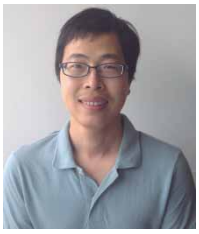

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