Recommendations for the Development of the AI Industry in China

The dramatic advancement of artificial intelligence (AI) technology in recent years has captured the attention of governments in various countries, many interested in its prospects for industrialization. With the support of the CAS Academic Divisions (CASAD), a task force headed by Prof. ZHANG Bo, a CAS Member from Tsinghua University, carried out studies on the development strategy of the academic discipline of AI and its industrialization with a focus on subjects such as state-of-the-art advances of AI, its industrial possibilities, and ways to develop the AI industry in China.

I. The Current Development of AI Technology and Its Industrialization

1. The Status Quo of AI Technology

The term "artificial intelligence" was coined by John McCarthy during the Dartmouth Meeting in the summer of 1956. At the conference AI was defined as the study and design of an intelligent agent, a system that could perceive its environment and take actions accordingly to maximize its chance of success in achieving certain goals. In the years that followed, AI became a field that places importance on research applications. During the period from the 1960s to the 1980s, the mainstream research direction of AI was the high-level thinking of human beings, which led to a reasoning and computing model based on knowledge and experience and to the development of the AI technology centering on heuristic searches. Such technology, however, could only address small scale/scope issues, such as an expert consultative system or a decision support system. Similarly, as early as the 1970s, artificial neural network technology was used as a computing model for human perception behavior, but it could only deal with issues of small-scale pattern recognition, for example in images or languages. After the 1990s, thanks to the wide application of probability and statistics in AI, its algorithm was rapidly improved both in search technology (such as the Monte Carlo tree search) and in deep learning centering on multi-layer neural networks. In the 21st century, especially since 2012 when the rapidly changing age of "Internet plus" was ushered in, the significant progress of big data and high-performance GPU-based computing has strongly promoted the intensive development of perception intelligence such as cognition intelligence, machine vision, speech recognition and natural language understanding. As a result, AI is entering an age of big data plus deep learning. These changes have enabled AI technology to become more practical, which greatly reduces the distance between scholarly studies and practical application, making it possible to industrialize AI technology.

2. The AI Industry

With the intensive integration of AI with technologies such as robotics, mobile Internet, the Internet of Things, big data and cloud platforms, AI technology and industry have started to play a critical role of fundamental, key and cutting-edge significance. Intelligent robots are being designed with more sensing and decision capacity and with stronger autonomy and environment adaptability. In addition, smart service in the age of "Internet plus" and life enhancements within a smart environment have begun to show a development trend featuring more natural human-computer interfaces, coordination and symbiosis. At the same time, the application range of intelligent machinery has been continuously extended from manufacturing to special service sectors such

as households, medicine, healthcare and recovery, entertainment, education, the military, space, aviation, ground, water surface, underwater, polar regions, nuclear energy, and macro-nano manipulation. To meet people's desire for smart service in the "Internet plus" age, AI has started to take a central role in the modern service industry, which has a significant bearing on people's daily life. In general, the distance between the scholarly studies of AI and its applications in industry is being reduced constantly, improving the link between AI and smart robotics. AI technology featuring environment adaptability embodies the main characteristics of a new industrial revolution. The smart robotics developed by AI technology may promote the "third industrial revolution" in the 21st century and bring about dramatic social changes.

II. Challenges and Opportunities in China's Development of the AI Industry

1. Formidable Challenges

In the wake of the global financial crisis, the key objective of industrial programs in certain advanced countries (such as the US re-industrialization program in 2011, Germany's Industry 4.0 in 2012 and Japan's new strategic program of robots in 2015) is to revive their national manufacturing industries and maximize their local high-tech advantages. To this end, there is an urgent need to advance production and service processes with information technology (digitalization and networking) and intelligent technology. In the manufacturing sector, although the technology for traditional machinery processing equipment such as articulated industrial robots is well developed, its global market is mainly held by four world giants: FANUC and YASKAWA in Japan, KUKA in Germany and ABB in Switzerland. These international monopolies have obvious competitive advantages in various links of the industrial chain, including core components, system integration and market share. China has been subject to an international monopoly in key components such as precision reducers (RV, harmonic and plenary gears), high precision servo motors, servo drives, and high-performance embedded controllers. In terms of cost-performance ratio and average fault free interval time, the products of articulated industrial robots made in China lag at least 5 to 10 years behind those in the advanced countries. The automated guided vehicles produced in China have long been at the mid- and low end of the value chain with low market share. Some key sensors (such as laser radar) have to be imported from Japan, Germany or the US. In addition, teaching programming-based traditional industrial robots can only replace simple and repetitive human activities in some workstations. In electronic manufacturing, industrial robots are now used at the front-end (such as high-precision SMT) and rear-end (such as assembly and transportation). In most mid-links, using machines to replace humans has not been realized yet. To implement China's "Made in China 2025" program, it is necessary to develop a new generation of smart robots with a certain environmental adaptability.

Furthermore, intelligent service robots are expected to become the fifth key intelligent machinery after televisions, personal computers, game consoles and smart phones. Service robots include personal/household service robots and professional (specialized) service robots. In recent years, major developed countries have made the development of service robots a national strategy and blueprinted their technology roadmaps. As a birthplace of service robots, the US has long placed importance on the research and development of robots for the military and medical services and also for domestic tasks such as cleaning, and its technology in this regard is leading the world. A Roadmap for US Robotics from Internet to Robotics, published in 2013, considered that the importance of robotics is comparable to the Internet in the 20th century. As an important technological approach to addressing an aging society and labor shortage in Japan, the Japanese government recently shifted the priority of robot research, development and production to the area of domestic robots that could take care of patients, perform household chores and assist the elderly. Similarly, the Republic of Korea (ROK) has made service robot technology one of its ten engine industries. It is striving to make rapid progress through integration of the service industry with information technology, focusing on robots for rescue operations, health rehabilitation and medical services. At the same time, the EU has launched the world's largest robot research and development program, SPARC, seeking applications in such fields as agriculture, health, transportation, security and domestic service.

Currently, more than 400 companies globally are committed to the research and development of service

robots. The international competition in this field is intense. In the age of the Internet the traditional robotic enterprises are undergoing consolidation by IT giants using their huge capital and also through acquisition. Because of the diversified applications of service robots, there is an urgent need for the development of artificial intelligence. Multinational companies recognize that intelligent hardware and real economies are future development trends and therefore have a strong desire to make cross-industry advances. Service robots are at the industrial frontiers, and accordingly the sophistication and maturity of the technologies they depend on are critical for multinationals if they are to gain a niche in the intense market competition. A glance at the world's key players in advanced service robotics shows that all of them are equipped with first-class research teams and strong R&D capacity. Their founders are mostly experts or professors in the field, and consequently the companies possess key components and technologies, and majority market share. Although some innovation firms (such as Ecovacs, UBTECH, TURING and PARTNERX) have recently emerged in China, they do not have many key technologies and a large market share. They are confronted by severe challenges in different aspects of the robot industrial chain, ranging from upstream (key components or materials and key sensors), to mid-stream (system integration, operational systems and cloud platforms) and downstream (including household use, personal use, entertainment, education, medical, logistics and military sectors).

In general, as China is still in the mid- or later development stage of industrialization, it has not fully completed the historic tasks of atomization and informatization (digitalization and networking). With a fairly weak industrial foundation and capacity, China has to depend on others for key components such as advanced sensors and precision decelerators. At same time, the growing emphasis on intelligent industrial development makes clear the need to address some common key technologies. China's dream of building a strong manufacturing country and advancing "Internet plus" places demands on the development of next-generation smart service machinery. Indeed, we are confronted by a two-fold challenge in terms of vision and reality and catchup and leapfrog development.

2. Opportunities

With the constant advancement of the information revolution, the recent economic/social development based on "Internet plus," informatization (digitalization and networking) and intelligentization have become key directions for development. The increasingly huge demand on key AI technologies has improved connections between the science value of AI and its application value, reducing the distance between academic studies and industrial application. The novel breakthroughs of weak AI, which focuses on the in-depth neural network, are expected to help China's manufacturing sector address the grave challenges it is confronted by and make leapfrog progress.

It is a pity that China missed the opportunities of previous industrial revolutions and the information revolution in the 20th century, which together replaced about 5% of existing manpower, a freeing up of the productive forces. Nevertheless, intelligent manufacturing and its part in service and people's lives have just begun in today's world. The application scope of intelligent machinery has continued to expand and the development of new industrial directions based on the new applications is under way.

At present the average growth rate of China's industrial robotics is 35%, much higher than that of Germany (9%), ROK (8%) and Japan (6%). According to statistics, the manufacturing sectors that intensively use industrial robots in China include the automobile and auto parts industry (61%), the mechanical processing industry (8%), the electronic manufacturing industry (7%), the rubber and plastics industry (7%) and the food industry (2%).

The opportunities for development of intelligent machines in China are now jointly created by the rigid demands of industrial upgrading, the intelligent machine development under the national program of "Made in China 2025" and people's desire for intelligent service in the new normal of "Internet plus." This may lead to more consumer digital products (such as consumer drones, smart balance wheels, and automatic vacuum cleaners), the development of new generation intelligent machinery products (machines with environmental adaptive capacity and a human power replacing rate up to 60%), and the networking of intelligent services (such as smart homes, intelligent transportation, care for the elderly and disabled, and healthcare).

Started in 1978, China's research into AI lags behind that in the US by two decades. It is worth noting, however, that the development of AI studies in

the world was slow in these years, and therefore the gap between China and the rest of the world was not large. In general, in terms of AI research and application, we are basically at the same starting point as other countries in the world.

In conclusion, China's AI development is entering a critical stage, which requires a top-down design for its future direction. The close integration of AI with smart machines, smart manufacturing, (mobile) Internet and cloud service could trigger a new round of revolutionary technical changes. While it might be hard for China's firms to compete with the four key international players by making breakthroughs in key technology and components in the traditional industrial robot industry, we are at the same starting point as many advanced countries regarding intelligent machinery. Possibly we can stay abreast with them or even become a leader in the field if only we can seize the opportunity of this historic change.

III. Countermeasures and Suggestions

1. Strengthening Overall Design and Coordination

In today's China, people generally pay attention to the research and development of AI systems, especially the application of AI technology in various sectors, such as intelligent manufacturing, intelligent transportation, smart homes and Internet-based intelligent services. However, we fail to assign adequate importance to the research and development of key generic technologies of AI systems and their basic hardware, software and interfaces. Therefore, it is advisable to address and promote top-down design and coordination in this regard. Taking neuromorphic computing and AI as a fulcrum, efforts should be made to explore the working principles and systematic structures of AI and achieve breakthroughs in key technologies and components. Because neuromorphic computing is more suited to solving AI problems than traditional computers, success in its research and development will provide AI systems with generic basic hardware and software, and has the potential to create large companies similar to Intel (chips), IBM (overall units) and Microsoft (software) and avoid making the same mistakes that occur when key technology and components are controlled by others.

2. Accelerating the Development of the AI Industry in China

It is advisable to select some typical projects with strategic significance for national security and the development of key sectors to demonstrate technological industrialization in the field. By taking advantage of our social system, which is ready to pool resources to accomplish important goals, planning will be made across the industrial chain of those projects with a focus on their attributes such as being frontier, fundamental, key, generic, socially beneficial and high-tech with strategic importance. The industrial demonstration of AI technology should be promoted by integrating such sectors as industry, universities and research institutions. These projects might include intelligent manufacturing that could meet national strategic demand such as in the assembly lines of advanced air fighters and ships in the national defense and military industry, modern intelligent service for people's livelihoods such as in education, entertainment, healthcare and recovery, smart homes for the elderly and smart transport.

3. Strengthening the Industrial Foundation

China has a long-term demand for industrial robots in the manufacturing industry. We should seize the development opportunity for upgrading digital intelligence or environment-adaptively in the campaign to "replace people with machinery" by cultivating local firms for key components, overall units and application engineering. Preferential policies should be introduced to support firms featuring specialization, customization and uniqueness. Plans should be made for an overall industrial chain so as to encourage breakthroughs in bottleneck components (such as precision decelerators, high power density integrated hydraulic /electric driving control systems, precision servo motors, integrated compound joints, high cost-effective embedded microminiature general controller/voltage driving biped robotics bionic dexterous hands and feet, and low-cost radiation radar). Efforts should be made to make leapfrog progress in a new generation intelligent robotics industry. Comparatively, in the field of AI and intelligent service machinery, China and advanced countries are at a similar starting point. In terms of basic research and technological accumulation, we are not far behind. We even have some advantages in market demand and policy support. Indeed, we have a window

of opportunity for catchup or leapfrog development.

To strengthen the foundation and capacity of industry, there is a need to enforce policy supporting firms that feature professionalism, customization, and uniqueness. A spirit of draftsmanship should be fostered among workers, encouraging their dedication to develop the proficiency in intelligent machinery component or functional module production.

4. Embarking on the Road of Innovation-driven Development with Chinese Characteristics

It is advisable to establish new national collaborative innovation centers or state laboratories for AI and intelligent machinery, or to make good use of the existing ones by introducing novel innovation systems and mechanisms. The development of technological innovation and encouragement of entrepreneurship should be strengthened by making AI an engine with an international vision. It is advisable to promote the development of AI, the intelligent machinery industry and typical objective products by fostering chain-wide planning and its integrated implementation. At the same time, research should be simultaneously conducted in such interdisciplinary fields as brain science, recognition science, psychology/computer science and AI.

There is a need to achieve standardization, modularization and general utilization through the development of computers and focus on bottleneck components or modules and key and critical generic technologies with bearing on a new generation of intelligent machines. We should strengthen the standard acquisition and utilization of fundamental data and big data of intelligent machines. At the same time, we should pay attention to the integration of intelligent machines with new generation information technology, especially the mobile Internet, big data and cloud platforms.

5. Facilitating Training of Interdisciplinary Professionals

As AI is a typical interdisciplinary S&T field, it is advisable to cultivate a large number of interdisciplinary professionals for its research, development, and in particular, innovation and entrepreneurship. It is advisable to create industrial chain-wide planning and promote the integrated development of AI, the smart robotics industry, and R&D of typical targeted products. At the same time, there is a need to set up interdisciplinary research and training institutions and research teams in top-notch universities and the Chinese Academy of Sciences, so as to promote the integration of information science, brain science and other disciplines.