

Towards Theory Problem of Advanced Robot and Its Development Strategy in China

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Compared with industrial robots, advanced robots present unique characteristics on theory basis, techniques and application fields, which is listed in high technology development programs of many developed countries. Attention of many scientists all over the world has been focused on advanced robot-related research that has become one of most important research topics in automation. In this article, after an overview of development and trends in advanced robots investigation, design and applications, the common technologies and fundamental science problems of advanced robots are discussed, and an advice on advanced robot development strategy in China is given.

Key words advanced robots, development strategy, automation

1 The Practical and Theoretical Significance of Research on Advanced Robots

As the typical representation of automatic devices, industrial robots have achieved great success in the manufacturing industries. Since 1980's, with the support of rapid development of information technology, control theory, artificial intelligence and sensor technology, robotic technologies have been widely applied in non-manufacturing industries. Throughout the world, the application of robots in non-manufacturing industries has become an important trend of automatic technologies, and the research on robots applied in this field has been paid more and more attention to. Advanced robots are indispensable to take the place of people in dangerous or execrable environments. They can conduct jobs that people cannot, such as jobs in space, deep sea and pipes, and they can also conduct precise operation.

Compared with industrial robots, advanced robots usually work automatically in unstructured environment, so they are more dependent on the abilities to acquire environmental information and to make intelligent decisions. Advanced robots should possess greater abilities of sensing, thinking and complex action abilities^[1]. They need much higher flexibility and maneuverability than industrial robot. What is more, advanced robots look quite different from conventional robots. From stated above, it can be concluded that the research on advanced robots embraces interdisciplinary knowledge, including mechanics, control technologies, computer science, artificial intelligence, microelectronics, optics, sensor technologies, material science and bionics. Therefore, research on advanced robots can promote the development of both robotics and other fields. Research on advanced robots emphasizes on intelligence and adaptability to make robots more widely applicable. Advanced robots are promising to be applied in the fields of space and deep sea exploration, agriculture, food industry, excavation, architecture, medicine, service, transportation, military and entertainment^[2]. Aiming at the respective feature of deferent field, researchers are developing deferent kinds of advanced robots, such as space robot, under-water robot, service robot, micro-operation robot, human-like robot, medical robot and military robot. These robots will fit the particular requirements of each field. The characteristics of advanced robots' high intelligence and far-ranging functions reach beyond the industry robot, which enables robots to be applied in more fields and get more intensive and extensive research^[3].

With land resources depleting, deep-sea exploitation has become an important strategy target for many countries. Exploration and exploitation of mineral resources in deep sea is the focus of competition nowadays. As an advanced instrument, under-water robot plays an important role in petroleum exploitation in the

seas, ocean scientific investigation, undersea resources exploration and undersea life saving. In the 21st century, the exploitation of undersea multi-mental nodule will come into the period of pilot scale test. Besides ocean reconnoitering, the installation, operation, maintenance and recondition of mining equipments for pilot scale test also need urgently various kinds of underwater robot. AUV can be used to measuring, monitoring, laying and retrieving devices for ocean experiments, and can be applied to defending and lives saving in the field of military as well cooperating with other diving devices.

China is experiencing the economic reform now while high-speed urbanization will promote the growth of both traditional and new-emerging industries. In the future, underground spaces will be utilized extensively, and city facilities will be constructed underground. So the development of shield robot, which can help lay all kinds of underground pipes and construct three-dimensional transportation, will come into a new-emerging industry.

With the update of people's living condition, medical robot and service robot are in great need in China. Research on medical robot will bring out not only technical innovation to traditional medical treatment, but also far-reaching effect to clinical or family rehabilitation.

Biotechnology is the most promising field in the 21st century, which will influence the industries of medicine, agriculture and manufacturing, and with which intelligent micro-operation robot is to be put into use with the development of biotechnology.

Based on the success of the experiment of unmanned spacecraft, China will accomplish more achievements in aerospace technology and engineering. We will realize space flight with astronauts; we will make explorations of the moon; and we will take part in exploration of the Mars. The development of space technology needs the support of robotics to provide equipment and service. Furthermore, technique revolution in military is carrying through, so new intelligent weapons on the basis of the advanced robotic and automatic technologies are required to adapt to high-tech wars.

In general, advanced robotic technology will develop rapidly in the 21st century. Its application and commercial profit are promising and unpredictable. It will greatly improve people's life and social economy. Furthermore, advanced robots is the incarnation of au-

tomation science and technique of the 21st century, is the most typical representation of automation, and is an important trend of automation research all over the world. Advanced robot-related research will undoubtedly promote the development of automation^[4-6].

2 Review of Research on Advanced Robots

Advanced robotic technology takes advantage of the achievements of other fields, shows the development of high technology, and influences people's life more widely. So it has been emphasized all over the world. Lots of countries take advanced robotic technology as part of national high-technology development plan, such as America, Germany, Japan, as well as many developing countries, such as Singapore, Korea and Brazil^[3,7].

Now, advanced robot-related research is conducted in the listed fields:

(1) Underwater robot, including UAV and ROV. Developing UAV is the trend in the future^[8,9].

(2) Space robot, including robots accomplishing intra vehicular activities and extra vehicular activities, planet exploration robot, free-floating robot, etc. With the development of space exploration and exploitation, undoubtedly new types of space robots will come into being.

(3) Robots in engineering and construction. This kind of robot is mostly used in mineral exploration, and also used to inspect and maintain underground pipes transferring oil, gas, and water, to dig tunnels, decorate the house, burnish the ground, and clean the glass. Medical robot.

(4) Medical robot is gaining more and more attention. Medical robot can be used to conduct surgical operation, ophthalmic operation, operation in thorax, urinary system, and extra brain. Micro medical robot is also used in human body or other organism. Now, researchers concentrate on robot aiding surgical operation and virtual operation systems^[10].

(5) Micro-robot. Nowadays the advanced countries have achieved inspiring success in micro machine-electrical system. Specialists predict that the sale of micro-robot will be up to 20 billions in 2010^[11].

(6) Agricultural robot, including geponic robot, spray robot, transport robot, sheep-shearing robot, milking robot, and lawn-shearing robot.

(7) Military robot. They are mainly used to detect,

fight, guard and mine clearing.

(8)Service robot. They are mainly used in family and public service, such as caring the old, and the disabled, inducting the blind, serving as the shopping and tourist guide^[12].

(9)Nuclear industry robot is mainly used for maintaining and monitoring facilities of nuclear plant.

(10)Entertainment robot. Production of entertainment and toy robot will become a huge industry this century^[13].

With the support of "863" Project (China High Technology Program), China have conducted researches on underwater robot, micro-operation robot, military robot, humanoid robot and intelligent robot. Great success has been made in this field. In some areas, we have ranked among the first-class level, but generally, we lag behind the developed countries greatly. Advanced robots in China are far from mature production. Knowledge and technology on it is mainly learned abroad, with not many creations on advanced robots.

3 Characteristic Technology and Basic Scientific Problems of Advanced Robots

3.1 Characteristic technology of advanced robots

Advanced robots usually works in the unstructured environment. In the near future, its main control mode will be remote control, supplemented with local self-control. The operator and robot may either be at the same or at different places. When they are at different places, for example, the robot is in the deep sea or in the space; the communication time will be minutes. And the environment is usually unknown. So, sensing, planning, moving and communicating are characteristic technology.

(1)Remote control and monitor technology^[14]

It includes high-level self-control, concord and control of multi robot, remote control of robots in wide range through internets, ways to overcome the delay problem and local self-control.

(2)Interface^[15]

In resent years, a lot of work about interface is carried out. Many kinds of input and output devices are developed, such as data glove, 3-D mouse, shutter glasses, and helmets.

(3)Multi-sensor system^[16]

The acquiring, interfusing, understanding, processing and controlling of multi-sensor information is the key to make robots highly flexible and robust under

unknown environment.

(4)Navigation and localization

Navigation and localization are very important to autonomous mobile robots. In spite of great efforts many theory and technology problems can't be solved through^[17].

(5)Machine intelligence^{[18][19]}

The features of most advanced robots depend on its intellectualized degree, which can ensure robot autonomously work in environments which are unknown or partly unknown. Advanced robots show intelligence in many aspects, such as perception of unknown environment, information processing, decision-making, harmony between human and robots, abilities of self-learning. Traditional symbol reasoning system, fuzzy logic, artificial neural networks and inheritance arithmetic are all embodiments of the great efforts of researchers in realizing artificial intelligence. Achievements in these aspects are far from people's expectation.

(6)Virtual technology

Remote control is a predominant way to use advanced robots that work in space, underwater, underground, rescuing action, fire control and entertainment. Virtual remote control based on multi-sensor systems, multi-media and virtual reality technology is expected to investigate intensively.

(7)Web robot technology

The development of communication and web technology make it possible to connect kinds of robots on internet and control them through web. The technology refers to web interface equipment, compression and decompression method of grouped information and the research of the transmission method.

(8)Multi agent coordinated-control technology

It involves colony behavior control technology that consists of multi agents and used to realize decision and self-decided operation. Micro and miniature robot technology involves micro machine, micro sensor and integration technology of micro-system. Soft robot technology investigates how to protect people in the environment where lots of people and robots coexist.

3.2 Key scientific problems of research on advanced robots

It's no wonder that technology introduced can help to make progress of China, but learning, copy and amelioration are hard to lead the scientific progress in

the world. We can only carry through the basic research with innovative energy for gestating the great technology revolution, and transform the scientific innovation to great economic benefit to increase the overall power of our homeland. Aiming at the tactic demand of developing our advanced robots technology in the 21st century and considering the advanced research of international robots and automatic progress, the following basic scientific problems should be given more attention to build strong basis for developing advanced robots that are of self-owned intellectual property right.

- (1) New type mechanism for advanced robots.
- (2) New type sensors for advanced robots.
- (3) Impersonate intelligence in advanced robotics.
- (4) New theory and strategy of information perception, understanding and control in unknown environments.
- (5) New method and theory for robots to autonomously work in environments cluttered with complex obstacles.
- (6) New means and technology for robots localization.
- (7) Ecological robotics research which study on how to apply ecology to developments of advanced robots.
- (8) New theory for the control of kinematics and dynamics of humanoid robot.
- (9) Interface between people and advanced robots.

4 Strategic Advice on the Development of Advanced Robots of China

4.1 Making use of the developing history of industry robots for reference, making use of the demand for principle to realize spanning development

Industry robots spring up and develop with the manufacturing's impulse for increasing the production quality, shorting manufacturing periods of productions and enhancing the productivity. Recalling the history of the development of manufacturing from the 1950's of last century, the development of industrial robots rises from the demand of automation in manufacturing, and industrial robots have become the key equipments on the production line. The development of industrial robots impulses the progress of ideas on manufacturing, and industrial robotic technology and industrial robotic systems develop quickly at the mean time. So the development of advanced robots and the research domain and

key technology of advanced robots should be decided according to the practical demand of the automation of our non-manufacturing industry. We should develop advanced robotic technology that owns Chinese characteristics.

On one side, research on advanced robots has to be faced with the key technical problems which constraints our country's economic construction and the development of industrialization; on the other side it has to hold the strategic key technology and the core technology which will make economic increasing in the future. So it should not only satisfies the demand of the development of the national economic presently, but also forecast the development in the future. Research on the forecast ability is the precondition of controlling the initiative in the market for enterprises, it is also the source power of national competition, and so it is the real meaning of high technology research. In the research process, we need not only learn advanced technology and experiences from western developed countries but also put importance on originality. We must grasp the strategic key technology and do research on basic and key technology extensively and intensively to realize the spanning development of our own advanced robots.

4.2 Research on advanced robots should aim at increasing the national economic power, ensuring the security of our country and enhancing the national competition in the world

(1) Serving for the automation development of non-manufacturing Advanced robots are used widely thanks to their many types and high automaticity, so they have a wider prospective than traditional industrial robots. In the next decade, developing intelligent machines applicable in building roads, pipeline task and other aspects fits the rapid development of the national basic facilities. Advanced robots will do lots of things in the 21st century in service. Medical robots, entertainment robots, healing robots, guiding robots and family robots are all worthy of attention and research.

(2) Fitting the developing demand of information technology, biology medical technology and nano-technology. Research on advanced robots should supply automatic aided research equipment that is highly intelligent, highly flexible and highly precise, should develop micro-operation robots and the manufacturing equipments of micro-electronic mechanical parts oriented docking operation of optic fiber in optical engineering,

and should develop micro-operation robots oriented the biology medical engineering that are used in precise micro-operation system of the manufacturing of biochips.

(3) Taking account of the demand of the national defense and new resources exploitation

Research on advanced robots should aim at increasing our national defense and martial abilities, strengthening national security and national position and making full use of resources in the oceans and universe. We should develop martial robots, space robots, robots working in deep oceans and submarine carrying people, etc.

4.3 Strengthening the management of organizations and paying more attention to international cooperation

Research on advanced robots in our country starts so early that we have made some great achievements in this field. In some areas, we grasp advanced technologies throughout the world. We will attain self-owned intellectual property rights of research achievements in advanced robots and form robot industry as long as we decide appropriate goals, improve the management, adopt the method of recycling fund, organize research units with good condition and strong basis to cooperate on the key technology of advanced robots, accelerate the association of the scientific research units and enterprises, pay attention to the combination of key technologies and applied technologies, construct effective mechanism to implement the applied engineering of advanced robots. In addition, managers should work wisely to overcome the flippancy emotions and thought of success at once which exist in the present academic circle and in the management teams of science.

We should not only learn from abroad on advanced technologies and pay attention to the international cooperation, and insisting on making decisions by ourselves. The USA, Japan and the league of European have made rapid progress in robotic research and have accumulated lots of experiences. So we can speed up the research, enhance the research level and get advanced achievements by strengthening the international cooperation. In fact, western countries learn from each other on advanced robots research. For example, "the united robots plan" led by the department of defense of America united Canada, England, Japan, France, German and Israel to do research on autonomous robot system which can be used in martial environments such as supporting materi-

als transfer, operating armies and spying in complex environments. The international cooperation can be conducted by many kinds of ways such as joining international robotic organizations, academic communication, visiting each other, cooperation on projects in official or personal ways.

4.4 Paying attention to interdisciplinary intercross and infiltration

Owing to the complex and uncertain working environments of advanced robots and the high expectation on intelligence and autonomous ability, research on many other disciplines cannot be avoided. Besides computer technology, sensor technology, micro-electronic technology, control theory and signal process, we need knowledge of probability, bionics, perception theory, virtual augmented technology, micro-machine theory, medicine, optics, new materials and biological heredity, etc. So we have to utilize the advantage of multi-subject, pay attention to interdisciplinary intercross and infiltration, ally to tackle key problems and get new fruits on advanced robots research and apply them practically.

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NSFC and AF Strengthen Their Cooperation

Fresh headway has been made in the bilateral cooperation between NSFC and the Academy of Finland (AF). Four 3-year joint research projects are co-funded by both sides from the year 2002. This is an experiment both in supporting concrete joint research projects under the bilateral agreement and in the complete adoption of the international evaluation system in project review.

Bilateral agreement on scientific cooperation between NSFC and AF was signed in as early as 1990, ascertaining the 12-person/month exchange volume every year. In 2001, an attachment to the agreement, a detailed document on funding co-operation, was inked, in which both sides agreed to support joint research projects between Finnish Centers of Excellence and Chinese high-level research groups in the fields of natural sciences, such as physics, chemistry, earth sciences, life

sciences, information sciences, material and engineering sciences.

Following the document, an open call for applications was carried out during Dec. 2001 to Jan. 2002, which resulted in nine joint applications both to AF and to NSFC. Then came the international evaluation process from Feb. to March 2002. Each application was rated by two foreign, qualified reviewers chosen respectively by NSFC and AF. According to the evaluation outcomes, AF and NSFC created a priority list of its own and both lists were taken into account equally. Finally, four test applications were funded for June 2002 to December 2005. Altogether AF invests 718 860 Euros in the approved joint projects, approximately 60 000 Euro per project per year.

(Fan Yingjie, Lu Rongkai)