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Analysis on UK Robotics and Autonomous Systems Research Development

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***Abstract*—The development of robot technology change rapidly, computer systems, machine learning, artificial intelligence system, automation technology, automatic car, health and technology resources, networking will quickly change the human social and economic life. Robotics is not only the key support equipment of advanced manufacturing industry, but also an important entry point to improve human lifeway. Whether industrial robots application in manufacturing environment, or service-oriented robots applied in non-manufacturing environment, the research, development and industrialization is an important indicator of national science and technology innovation and high-end manufacturing level. The paper briefly introduces research and development architecture, development strategy, and key application fields in the UK. The article summarizes future development trend and the main research results of UK RAS, and it is discussed existing issues and future development direction. On this basis, the paper analyzes issues in robotics development in China and put forward some corresponding suggestions.**

Keywords—Robotics and autonomous systems (RAS); UK; Research and development; Strategic distribution

I. INTRODUCTION

In March 2016, the Price Waterhouse Coopers（PWC） released a research report “Redefining Business Success in a Changing World the 19th Annual Global CEO Survey” [1]. The report pointed out 8 decisions emerging core technology in the futurewhich included robotics, unmanned aerial vehicle (UAV) technology. Robotics and autonomous systems (RAS) technology, information technology and digital technique are known as manufacturing cutting-edge technology. It is the inevitable trend and future direction of advanced manufacturing industry development. Moreover, McKinsey Global Institute predicts that half of today’s work activities could be automated by 2055. It follows that robotics industry will serve as an important symbol of a country's science and technology innovation and high-end manufacturing level. RAS is one of eight core technologies identified by UK’s government as a national developing strategy. It is also the most important industry strategy potential field to promote economic growth [2].

A. Robotics and autonomous systems (RAS) development strategy

In July 2016, the UK government announced the first official robotics strategy “RAS2020”, which was collaborated on the planning and execution of the Robotics and Autonomous Systems (RAS) strategy by academia and government. Moreover, it provided financial support to ensure UK robotics industry to leading global competition race.

The government’s Technology Strategy Board has been granted $685 million for the next year's technology development funds, and $257M million of which has been allocated for jumpstarting UK RAS development plan. The UK government hoped through the RAS 2020 strategy, it would be able to garner a 10% share of global robotics market by 2025, which would be estimated $120 billion [7].

The strategy recommendations are following:

- Invest further in the five RAS strategy strands: coordination, assets, challenges, clusters and skills to build the UK’s RAS capability.
- Establish the means for funding agencies to formally work together in execution, so that ideas, people and activity flow readily from basic investigation through early stage demonstration to fully trialed commercial product.
- Establish a RAS Leadership Council to engage with senior leaders across a range of sectors in industry, academia and Government, providing independent advisory oversight of planning and execution of the strategy.
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- Continue to consult widely on potential Assets and cross sector Grand Challenges.
- Continue to develop dialogue with those involved in standards and regulation to develop more detailed thinking.

Price Waterhouse Coopers（PWC）:“Redefining Business Success in a Changing World the 19th Annual Global CEO Survey”: http://www.pwc.com.au/publications/ceo-survey-2016.html.

- Extend outreach and public engagement activities to continue changing public perceptions and improve understanding of public concerns.
- Articulate to businesses and investors internationally (e.g. through UKTI) that the UK aims to be the best place to invest in taking RAS technologies to market.

II. UK-RAS NETWORK DEVELOPMENT STRATEGIC LAYOUT

The Engineering and Physical Sciences Research Council (EPSRC) is a non-government funded agency which is under the British Research Council (RCUK), and it was created in 1994 by Department for Business, Innovation and Skills and Research Councils UK. The purposes of this British research council are: (1) Promote and support high quality basic, strategic and applied research in engineering and natural sciences and related education. (2) Improve knowledge and technology development and provide scientists and engineers training. (3) Responsible for knowledge popularization and public consultation in engineering fields (Mathematics, Robotics and Computer Science). (4) Improve research, training and innovation of engineering and physical science.

Since the UK government released RAS2020 strategic plan in 2016, the government will vigorously support EPSRC's UK-RAS Network 10 research centers and laboratories in government financial term(As shown in Table 1)

TABLE 1. UK-RAS NETWORK 10 RESEARCH CENTERS AND LABORATORIES

Administration Unit	**Organization Name**	**OrganizationType**	**Subject Field**	**Region**
EPSRC UK-RAS Network	The Centre for Advanced Robotics @ Queen Mary (ARQ), **Queen Mary University of London**	University Research Center /Lab	Conducting robotics research of the highest level and at generating disruptive innovations in all areas related to robotics.	London
	Centre for Intelligent Autonomous Manufacturing Systems, **Queen's University Belfast**	University Research Center /Lab	Multi-disciplinary research of Electrical/Electronic/Mechanical/Aerospace Engineering, Computer Science, Applied Mathematics, Statistics, and Psychology.	Northern Ireland
	Edinburgh Centre for Robotics, **University of Edinburgh and Heriot-Watt University**	University Research Center /Lab	Environment Interactions,Multi-Robot Interactions, People Interactions, Self Interactions, Enablers.	Edinburgh
	The Hamlyn Centre, **Imperial College London**	University Research Center /Lab	Medical robotics, Micro-machining and fabrication equipment, Multi-material, Precision 3D rapid prototyping,Fibre-optics and ablation laser.	Imperial College London (South Kensington Campus)
	National Facility for Innovative Robotic Systems,**University of Leeds**	University Research Center /Lab	Innovative robotics systems,Medical surgical technique,Prosthetic fitting and rehabilitation.	West Yorkshire, Leeds
	Oxford Robotics Institute，Department of Engineering Science，**University of Oxford**	University Research Center /Lab	Mobile autonomy.	Oxford
	Centre for Autonomous Systems Technology（CAST）, **Sheffield Robotics and The University of Liverpool**	University Research Center /Lab	Unmanned ground and air vehicles, Biologically inspired robotics, Service robotics, Societal research, Human-robot interaction, Systems verification and safety, Field robotics for outdoor and hazardous environments.	Liverpool
	Autonomy USRG, **University of Southampton**	University Research Center /Lab	Big data,humanfactors,underwater or high-altitude unmanned aerial vehicle.	Southampton
	UCL Engineering,THE FACULTY OF ENGINEERING, **University College London**	University Research Center /Lab	Large scale robotic manufacturing, remote inspection and making; Virtual Reality and haptic interaction and tactile sensing; Human scale tele-manipulation and robotic surgery; Micro-nano robotic manipulation; Robotic telepresence.	London
	International Manufacturing Centre **University of Warwick**	University Research Center /Lab	Hardware-in-the-loop, infotainment and communication simulation, a multi-sensory virtual environment, realworld environment and modular autonomous systems workbench.	Coventry

Training the next generation of world-class researchers in RAS is key to enhance the economic competitiveness of the UK. As part of the investment in robotics technologies from the UK government through the EPSRC, four Centers for Doctoral Training (CDTs) were established in Bristol, Edinburgh, Loughborough and Oxford (Table 2).

TABLE 2. UK-RAS NETWORK 4 CENTERS FOR DOCTORAL TRAINING (CDTS)

Organization Name	**Subject Field**	**Region**	**Organization Information**
Bristol Robotics Laboratory, EPSRC Centre for Doctoral Training in Future Autonomous and Robotic Systems (FARSCOPE)	Embedded intelligence, autonomous robot systems, human-robot interaction, energy autonomy, collective locomotion, tactile sensors and haptic feedback systems, motion tracking/positioning systems, unmanned aerial vehicles, swarming behavior, dependability, wearable and pervasive systems, medical and rehabilitation robotics, machine vision, and bio-inspired architectures.	University of the West of England, Frenchay campus, Bristol	BRL's interdisciplinary research team focuses on key robotics features and applications. The FARSCOPE CDT is delivered jointly by the University of Bristol and the University of the West of England through their partnership, the Bristol Robotics Laboratory.
Edinburgh Centre for Robotics, (University of Edinburgh & Heriot-Watt University) EPSRC Centre for Doctoral Training - Edinburgh Centre for Robotics	The Edinburgh Centre for Robotics produces innovation ready postgraduates equipped through technical preparation, and cohort-wide training with scientific, creative, ethical and enterprise skills, in programmes supported by User partners operating in RAS crucial market sectors including oil and gas, defense, renewable energy, healthcare, assisted living, transport, space, automotive, manufacturing, nuclear, digital media and education.	Heriot-Watt University, University of Edinburgh, Edinburgh	The goal of the CDT is to train innovation-ready robotics researchers to be part of a multi-disciplinary enterprise, requiring sound knowledge of physics (kinematics, dynamics), engineering (control, signal processing, mechanical design), computer science (algorithms for perception, planning, decision making and intelligent behavior, software engineering), as well as allied areas ranging from biology and biomechanics to cognitive psychology.
Loughborough University, EPSRC Centre for Doctoral Training in Embedded Intelligence	Embedded Intelligence is the integration of intelligence into products, processes and services so that (1) they work better and (2) increase productivity, efficiency and connectivity. Our cores areas of expertise and interests are; autonomous products, functional materials with high performance connected systems, data-to-knowledge solutions, and engineering for industry, life and health.	Loughborough, Leicestershire	The uniqueness of the CDT-EI resides on the capability to innovatively address a myriad of Embedded Intelligence challenges posed by technical needs ranging from the EI supply chain: the design stage, through manufacturing of embedded or on-bedded devices, to the software behind data collection, as well as integrative technologies, to finally the requirements from end-users.
University of Oxford, EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines and Systems (AIMS)	(1) Robotics, Vision and Perception; (2) Machine Intelligence & Multi-Agent Systems; (3) Control & Verification; (4) M2M, Secure Sensing & Actuation.	Department of Engineering Science,University of Oxford, Oxford	The aim of the CDT is to train a world-class cohort of researchers in the theory and practice of a new generation of autonomous intelligent machines and systems. The training programmer of the CDT will provide a comprehensive, state-of-the-art view to autonomous intelligent systems; combining theoretical foundations, systems research, academic training and industry-initiated projects and covering a range of topics aligned to four key skills areas.

III. UK-RAS DEVELOPMENT FRAMEWORK

The UK government goal is to improve interactive, cognitive physical tools, automation and control of RAS. The priority research fields include perception and cognitive robotics, autonomous systems, healthcare and assistive robotics, service and vehicle robotics. The government will build on the UK's existing robotics and autonomous systems

research and industrial capability to ensure that future growth and success is enabled across a broad range of core industrial sectors, such as aerospace, nuclear and automotive; in addition to enabling new capabilities in emerging cross-sectorial issues like demanding environments(See Figure 1)

From the application point of view, UK advanced robotics technique has tremendous developing space in national defense, medical treatment, manufacturing industry, transportation, entertainment and education. UK's leading technology can expand potential market in remote operation, disabled organ substitution and medical instruments. Firstly, UK-RAS characteristics focus on variety advantage technologies of UK, including materials science, electronics, telecommunications, digital media, artificial intelligence and software engineering. Secondly, UK-RAS Industrial Cluster has formed regional innovation ecosystem, and it has powerful networking opportunities and a complete set innovation facilities. It is easy for the public to get knowledge of guidance, finance, business management and training. Finally, small and medium enterprises (SMEs) are the core of UK-RAS revolution, and they are successful key for acquiring robots and autonomous systems assets, responding to challenges and resources.

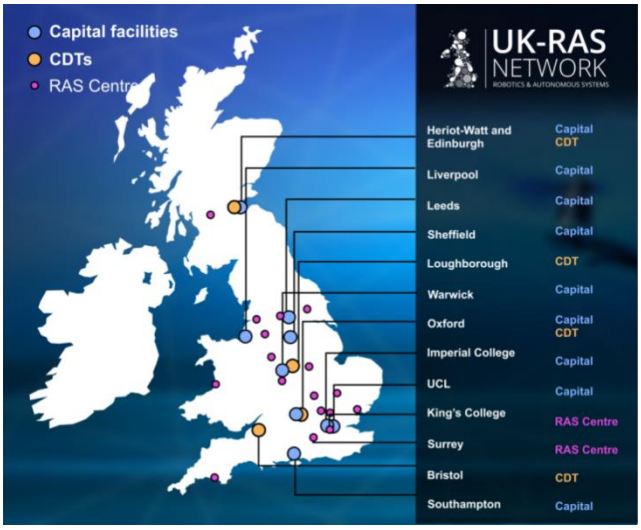

Fig 1. UK RAS R & D research strategic distribution

IV. Open issues and suggestions for UK-RAS future development

The industrial robot is irreplaceable important equipment in advanced manufacturing industry.In 2013, the Ministry of Industry and Information Technology of the People's Republic of China released "Several Opinions of China's State Council on Promoting the Reform and Development of the Tourism Industry".It was proposed that a relatively complete industrial system of industrial robots should be formed in 2020, and 3-5 international competitiveness leading enterprises and 8-10 supporting industrial clusters should be resulted.By May 2015, the State Council issued "Made in China 2025", and the Chinese Government cleared and definited 9 strategic tasks and priorities, including high-end CNC machine tools and robotics [3]. In April 2016, "Robotics Industry Development Plan (2016-2020)" has been issued by National Development and Reform Commission and Ministry of Finance [4].

In recent years, China has rapid growth in robotics industry and been recognized as world recognized manufacturing leading power. In 2015, China's industrial robotics market reached 66 thousand units, an increase of 16%, and about 1/4 of global sales.Under national science and technology program support, through long-term science and technology innovation, China has gradually mastered in advanced design and manufacturing methods of industrial robotics. Moreover, it completed scale application demonstration in automotive, electronics, logistics, transportation, sanitary products [5].

Although China's robotics industry was keeping in progressive, but there is a certain gap compared with international counterparts. There are some suggestions for China's RAS rapidly expanding:

- Lack of core key technologies and Independent innovation capability;
- Robotics industry has become increasingly homogeneous and low end of high-end industry phenomenon;
- The domestic market has been carved up by foreign enterprises; domestic robotics brand occupancy is relatively low;
- Strengthen research on robotics development strategy and create industrial development environment;
- Strengthen key technology research, attach importance to next technology generation and standards;
- Rapid development in service robotics industry;
- Enhance talent team construction in robot industry.

V. Conclusion

With rapidly development of robotics technology, robotics and autonomous system has been improved through increased automation and efficiency. Meanwhile, demand for robotics industrial applications and social services are becoming more important.The manufacturing industry requires a large number of industrial robots, intelligent machines and equipments to assist human beings engaged in complex and heavy labor; daily family life also requires a variety of intelligent robotics to help people engage in a wide variety services. With increasing maturity, RAS technology has entered a period of rapid development in 21 Century [6]. After 20 years of reforming and opening up, China's economy and technology has made considerable progress and development with grasping technology development conditions. For this purpose, RAS technology has been included in national medium and long-term science and technology development plan.

China's manufacturing capacity utilization in manufacturing cost advantages and high volume, encourage and support a number of large and medium-sized enterprises in the development of robotics industry. It will be possible to make China become a robotics R & D and manufacturing leading power, and promote social services, manufacturing

industry, education, and entertainment industry to have advancement of science and technology. It will also drive industry development in information, communication, automation, electrical engineering, and manufacturing industry.

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