ROBOTS AND SOCIETY

Forging global cooperation and collaboration

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As researchers create better robots, major robotics initiatives and government funding programs need better international cooperation and collaboration.

The year 2020 will witness a continuing increase in global robot installations. The five major markets for industrial robots—the United States, China, Japan, South Korea, and Germany—now account for nearly 75% of the total installations (Fig. 1), and the predicted per-year increase in average between 2020 and 2022 is likely to reach +12%. Whereas new manufacturing technologies such as industry 4.0 are driving the growing demand for robots, demographic shift associated with the aging population will see the use of robots for assistive and domestic applications jump significantly. The World Health Organization (WHO) predicts that by 2050, the proportion of the world's population over 60 years will reach 22%, which, in absolute number, will hit 2 billion (*1*).

In 2011, the U.S. government announced a new initiative called the National Robotics Initiative with investments for major advances in next-generation robotics. A new solicitation for fiscal year 2020, the National Robotics Initiative 2.0: Ubiquitous Collaborative Robots (NRI-2.0), has been announced as a joint effort of the National Science Foundation, the National Aeronautics and Space Administration, the National Institute for Occupational Safety and Health, and the U.S. Department of Agriculture National Institute of Food and Agriculture. The first NRI was established as the result of many years of effort, and the first U.S. National Robotics Roadmap was published in 2009 and updated in 2013 and 2016 (*2*). A further update is due in August 2020. It identified three major factors that drive the adoption of robots: economic growth, quality of life, and safety of first responders. For the first two, they are clearly interlinked—improved productivity in what is now a fiercely competitive international market and in the presence of an increasingly aging society. This pressure is clearly felt by many developed and developing countries.

With more than 800 robots per 10,000 employees, Singapore is now among the highest in the world in terms of industrial robot density (*3*). This high density reflects the city-state's reliance on technology, such as robotics, as a resource multiplier to mitigate the impact of its aging population due to consistently low birth rates. This complements its relatively open immigrant policy. With 45% of residents who are foreign born, Singapore is now one of the most cosmopolitan nations in the world. The National Robotics Programme (NRP) of Singapore has been established to encourage greater adoption of robotics and to ensure a more coordinated, coherent, and concerted effort in building Singapore's robotics capabilities. It is focused on technology and expertise development in robotics enablers, such as those related to end effectors, high-performance tactile sensors, indoor navigation in dense human environments, human-robotics interactions, soft robotics, and configurable robots. NRP is also working with relevant agencies to identify and close the gaps in standards, testing, and certification for robots and their supporting infrastructure especially for service robots. Given its resource constraints, particularly the demographic challenges, it is inevitable that Singapore will be a major robotics user. The NRP aims to make it a robotics innovator as well.

South Korea has also been ranked among the highest in robot density according to the International Federation of Robotics (IFR) (*3*). These rankings reflect the large investment in robotics by the government and emerging and well-established companies. The South Korean government has dedicated about $150 million to $200 million in its annual budget toward research and development (R&D) in robotics, and plans are in place to expand the robotics market size to $15 billion in 2023. The Ministry of Trade, Industry and Energy (MOTIE) spearheaded this R&D effort in robotics and established the Intelligent Robots Development and Distribution Promotion Act in 2008, which requires that a nationwide strategy on intelligent robots be presented every 5 years. The South Korean government has sponsored large R&D programs in robotics, such as the Underwater Construction Robotics R&D Center sponsored by the Ministry of Oceans and Fisheries (www.ucrc.re.kr/page_home_eng), Biomimetic Mechatronics (Bionic Arm) sponsored by the Ministry of Science and ICT (www.kist.re.kr/rmi), and Disaster Robotics R&D Center sponsored by MOTIE (http://drc.re.kr/). The South Korean government also offers various funding programs for international collaboration.

Europe is, in statistics, often presented as separate countries but it is more meaningful to treat it as a single entity for comparisons with, for example, the United States, considering that the largest research programs are coordinated at the European level. Already in 1998, the various scientific robotic stakeholders coordinated to form the EURON network. In the years after, the industrial network EUROP was formed; during the Seventh Research Framework of the European Commission (FP7), the two initiatives were joined into the euRobotics association (www.eu-robotics.net).

euRobotics has functioned as the private side in the public-private partnerships (PPPs) called SPARC (www.eu-robotics.net/sparc), which runs in the eighth framework called Horizon 2020 that ends in 2020. The European Commission is working to define the new framework program. The new program will have a part called Horizon Europe, which will be targeting research, and a second part called Digital Europe, which will be addressing industry and deployment of new technologies

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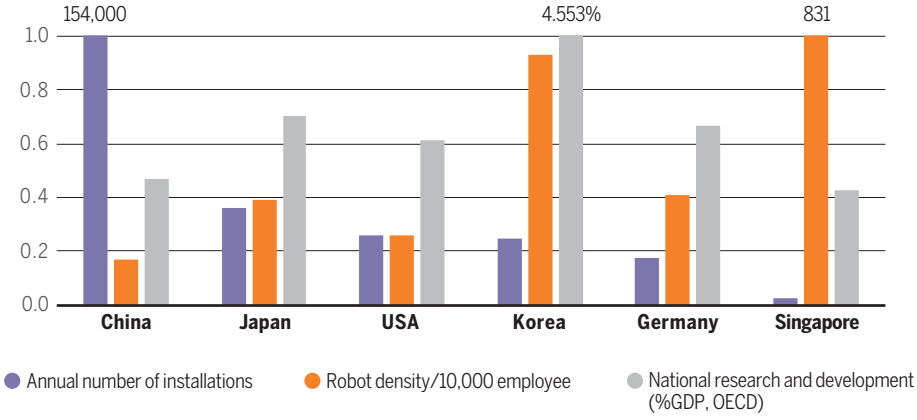

Fig. 1. Robotics and R&D investments by country. Annual installations of industrial robots (China, 154,000), robot density per 10,000 employees (Singapore, 831), and domestic spending on research and development (percentage of GDP; Korea, 4.553%), normalized to the maximum values in each category for the countries shown. Data sources: International Federation of Robotics (IFR) and Organisation for Economic Co-operation and Development (OECD).

for the digital economy and society. Horizon Europe will be divided further in three pillars: (i) Excellent Science, (ii) Global Challenges and European Industrial Competitiveness, and (iii) Innovative Europe. For pillar two, which addresses the cooperation between academia and industry to boost technologies and solutions underpinning EU policies and sustainable development goals, a budget of €52.7 billion has been proposed. New PPPs will be proposed, and euRobotics has taken the lead together with the Big Data Value Association to create a new partnership on artificial intelligence (AI) for which euRobotics will clearly cover the essential and most difficult physical part of AI. This new AI PPP will form the basis for the robotics investment until 2027. Furthermore, not related to PPP, other important initiatives are also forming to support the work of euRobotics as a private association from the content side, which include, for example, CENTRIS (www.centris-ai.eu), which gathers top scientists and researchers in Europe to create an even stronger knowledge base for European robotics.

We have seen, in recent years, increasing development of cooperative robots—robots that are able to cooperate with human operators, learn from demonstrations, interact intelligently with the environment, and collaborate seamlessly with their robot peers of similar or different architectures. To support this, the National Natural Science Foundation of China launched an 8-year, $200 million national research initiative called the Tri-Co (Coexisting-Cooperative-Cognitive) Robot in 2016. Coexistence will allow robots to ubiquitously and safely work alongside humans, whereas cooperation will enable robots to coordinate and collaborate effectively with other agents (either people or robots). Last, cognition will provide robots with the means to gather information, perceive, learn, and predict environmental changes and the behaviors of other agents. From deep sea to space exploration, from microrobotics to megascale infrastructure robots, the pace of development and government support for robotics in China is accelerating. There is also increasingly strong synergy among fundamental science, technology development, and applications of robots.

Research efforts are making robots more intelligent, cooperative, and interconnected with improved learning and adaptation, interoperability, autonomy, and human-robot interaction, and major robotics initiatives and government funding programs need better international cooperation and collaboration. This needs to be at both strategic and tactical levels because we are all faced with similar socioeconomic challenges and the need for developing new talents. From the research and development standpoint, future generations of robotics need to be supported by a wide range of science and engineering disciplines as identified in (*4*). It is only through such cooperation and collaboration that we can make a true difference in the societal value of robotics.

REFERENCES AND NOTES

1. Ageing and Life Course, WHO; www.who.int/ageing/en/.
2. A Roadmap for UK Robotics (2016); https://cra.org/ccc/wp-content/uploads/sites/2/2016/11/roadmap3-final-rs-1.pdf.
3. World Robotics 2019 Edition, IFR; https://ifr.org.
4. G.-Z. Yang, J. Bellingham, P. E. Dupont, P. Fischer, L. Floridi, R. Full, N. Jacobstein, V. Kumar, M. McNutt, R. Merrifield, B. J. Nelson, B. Scassellati, M. Taddeo, R. Taylor, M. Veloso, Z. L. Wang, R. Wood, The grand challenges of *Science Robotics*. *Sci. Robot.* **3**, eaar7650 (2018).

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