A Robotics & Automation Roadmap for India

IEEE-SA Industry Connections Full-day Invitational Workshop
Tuesday June 27, 2017 @ IIT New Delhi, India

Workshop Organizers
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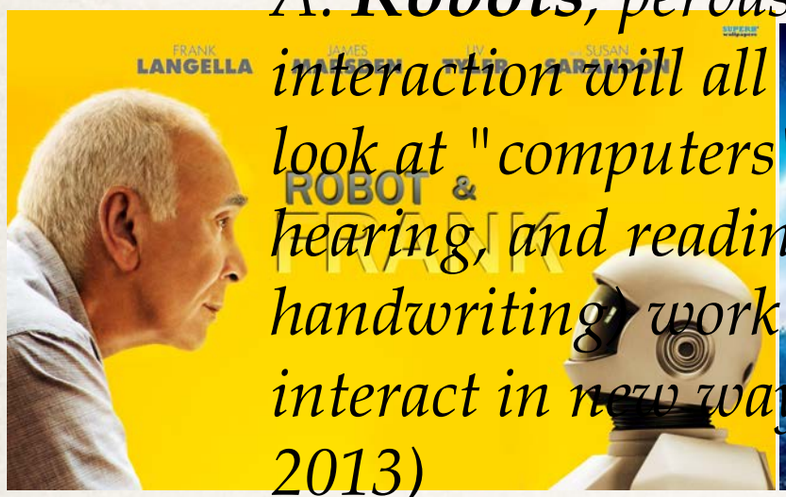
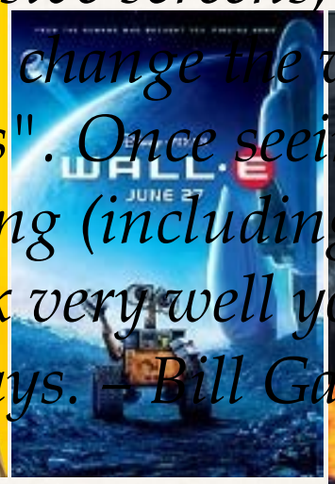
IEEE STANDARDS ASSOCIATION

Reality of Robotics & Automation

Q: "What emerging technology today do you think will cause another big stir for the average consumer in the same way that the home computer did years ago?

*A: **Robots**, pervasive screens, speech interaction will all change the way we look at "computers". Once seeing, hearing, and reading (including handwriting) work very well you'll interact in new ways. –Bill Gates (Feb. 2013)*





A

ROBOT

IN EVERY HOME

The leader of the PC revolution predicts that the next hot field will be robotics

By Bill Gates

Imagine being present at the birth of a new industry. It is an industry based on groundbreaking new technologies, wherein a handful of well-established corporations sell highly specialized devices for business use and a fast-growing number of start-up companies produce innovative toys, gadgets for hobbyists and other interesting niche products. But it is also a highly fragmented industry with few common standards or platforms. Projects are complex, progress is slow, and practical applications are relatively rare. In fact, for all the excitement and promise, no one can say with any certainty when—or even if—this industry will achieve critical mass. If it does, though, it may well change the world.

Of course, the paragraph above could be a description of the computer industry during the mid-1970s, around the time that Paul Allen and I launched Microsoft. Back then, big, expensive mainframe computers ran the back-office operations for major companies, governmental departments and other institutions. Researchers at leading universities and industrial laboratories were creating the basic building blocks that would make the information age possible. Intel had just introduced the 8080 microprocessor, and Atari was selling the popular electronic game Pong. At homegrown computer clubs, enthusiasts struggled to figure out exactly what this new technology was good for.

But what I really have in mind is something much more contemporary: the emergence of the robotics industry, which is developing

AMERICAN ROBOTIC: Although a few of the domestic robots of tomorrow may resemble the anthropomorphic machines of science fiction, a greater number are likely to be mobile peripheral devices that perform specific household tasks.

Robotics and Automation Activities in South Africa

By Simukai Utete, Jeremy Green, Ashley Liddiard, and Chris R. Burger

Second in the series of articles focusing on the state of robotics and automation in the BRICS countries: Brazil, Russia, India, China, and South Africa, this article provides an overview on South Africa written by researchers from the Council for Scientific and Industrial Research. The objective of this series is to inform the readers of the unique challenges that these countries have faced and the solutions they have adopted to solve their problems and to facilitate discussions with the interested members of the community. Please send your comments and feedback to the IEEE Robotics & Automation Society (RAS) Vice President of the Industrial Activities Board Raj Madhavan at raj.madhavan@ieee.org.

South Africa sits at the southern tip of Africa. The country has a population of 52.98 million, according to 2013 statistical estimates [1]. South Africa comprises nine provinces, with major cities including Johannesburg, Cape Town, Pretoria, and Durban. Sectors such as mining and agriculture have traditionally been large, but the government is working to move more from a resource-based economy to a knowledge-based economy. The country is involved in major science projects, such as the Square Kilometre Array, and there is a significant research taking place in a range of areas including biology and medical sciences. Robotics is also gaining importance in South Africa's science and technology landscape in industry as well as in academic institutions and science councils. This introduction to robotics and automation in South Africa seeks to give a flavor of some of the developments in the country. It is by no means exhaustive.

The importance and potential of robotics are recognized by South Africa's Department of Science and Technology (DST). The DST, which has previously supported strategies for nanotechnology and photonics, is now considering stakeholder submissions toward the formulation of a national robotics strategy. A strategy development process involving interactions of potential stakeholders has been running for more than two years and has identified areas where robotics could be important for preserving jobs and creating new ones, as well as improving productivity and competitiveness [2].

Given South Africa's history and the need for development to widen the scope of opportunity, the human angle is key. Human capital development would be a thrust of any strategy. This would encompass tertiary study as well as the training of technicians and artisans who could maintain robotics infrastructure, allowing for a larger share of demand for maintenance activity to be met from within South Africa.

In general, a discussion of robotics in many contexts raises the issue of employment, the question of whether robots will reduce jobs. There are specific jobs in certain industries where this might be an issue, but robotics can also be a driver for the creation of new jobs, and new types of industry, as well as a force to improve certain types of jobs. Stakeholder engagements around the robotics strategy brought out many advantages, which a robotics focus could confer, including improved competitiveness in certain industries and the provision of better working environments for certain types of activity. One example of the latter is the potential for the use of robotics to enhance safety. The strategy discussion to date has identified the initial focus areas for potential impact in South Africa as mining, flexible manufacturing, and medicine and health care [2].

Mining Robotics

Mining robotics is one of South Africa's biggest opportunities for robotics research and development to promote greater safety, extend the life of mines, and improve competitiveness. One reason is that there are large reserves of gold in underground deposits, which might become feasible to mine through new technologies, including robotics. Unexploited deposits are located in stability pillars, in areas that are unsafe for people, or found to be nonprofitable for extraction because of low grade or narrow deposit using existing mining technologies [3].

South African gold and platinum deposits share characteristics in that they are narrow (5 cm to 1.5 m) bands of ore hundreds of kilometers wide, dipping into the earth at between 12° and 30° from the surface to as yet uncharted depths. Challenges in mining at extreme depths of more than 5 km underground are such that the use of people to mine, as in the traditional narrow stoping, is not feasible. At this depth, the rock stresses make it unsafe for people to be near the rock face because of the high risk of a rock

Digital Object Identifier 10.1109/MRA.2013.2272204
Date of publication: 11 September 2013

Robotics and Automation Activities in Brazil

By Edson Prestes, Vitor Jorge, Mario Campos, and Roseli A.F. Romero

We are starting a series focusing on robotics and automation activities in the BRICS countries: Brazil, Russia, India, China, and South Africa. The objective of this series, in addition to providing an assessment of the state of the art, is to inform the readers of the unique challenges and solutions that these countries have adapted to their problems and to facilitate a discussion with the IEEE Robotics and Automation Society and other members of the community. This article, the first in the series, focuses on Brazil. Please send your comments and feedback to the Vice President of the Industrial Activities Board Raj Madhavan at raj.madhavan@ieee.org.

Covering an area of 8.5 million km^2 and with a population of around 200 million people, Brazil emerged in the international scene as a country with a solid economy and stable currency, being able to cope with the disastrous effects of the current global economic crisis. It recently received the investment grade from prominent risk-assessment agencies, which means the country is more likely to meet payment obligations, attracting more investments. In addition, Brazil, Russia, India, China, and South Africa formed a group known as *Brazil, Russia, India, China, and South Africa (BRICS)* to discuss and implement ways to improve the global economic scenario. Brazil is also a full member of the Mercosur and actively participated in numerous United Nations missions.

Regarding robotics and automation, Brazil has a small number of factory-installed robots, 20/10,000 employees, when compared with developed countries. According to the International Federation of Robotics, robot sales in Brazil reached 1,440 units in 2011, 125% more than in 2010 [1]. This number is gradually increasing in different industry segments such as automotive, consumer electronics, and beverages. Large companies such as EMBRAER, FIAT, Ford, GM, Phillips, Tramontina, Nestlé, and Chocolates Garoto S.A. installed robotics work cells in the past few years. In these cases, robots are used in applications such as tightening screws, welding, painting, molding, forging, and soldering in the automotive industry and pick and place tasks in the consumer electronics industry. Small- and medium-sized companies are also beginning to adopt robots to increase the production volume and improve the quality of their products while reducing operational costs. There are mostly international players in industrial robot manufacturing, e.g., Asea Brown Boveri, Siemens, FANUC, and KUKA. Regarding other segments, Brazil has few enterprises that build and deploy robots, for instance, X-Bot, Instor, AEL Sistemas, Modelix Robotics, and ARMTEC.

The robotics and automation research in Brazil is mainly conducted at public universities and a couple of government labs. However, there exist some public–private initiatives, e.g., EMBRAER and Aeronautics Technological Institute (ITA). They develop robots that are used, in the aviation industry, as part of the structural assembly line and in the process of joining metal parts of the aircraft. Petrobras Research Center developed a four-wheel remote-controlled robot capable of traveling and monitoring different regions, including land, water, and swamps [2]. It also conducts research on autonomous underwater vehicles (AUVs) to monitor deep-sea waters [3]. The number of robotics and automation papers in the main national conferences sponsored by professional and academic societies such as the Brazilian Automation Society, Brazilian Computing Society, and the Brazilian Society of Mechanical Sciences has significantly increased in the last decade. Currently, several Brazilian authors publish papers in the best international journals and conferences.

The potential of robotics application in Brazil is vast and not yet explored. Brazil has large gas and oil fields both inland and in the presalt region of the Atlantic Ocean. There are several challenges in oil production, ranging from underwater inspection, monitoring, assembly, and repair to remote operation of production platforms. Petrobras leads the use of robotics in pipe inspection, environment control, and mining initiatives. Smaller companies also have a share in this market, often in cooperation with larger companies, providing specialized robots for duct/pipe and oil tank inspection to maintain the integrity and safety of facilities' infrastructure.

The Brazilian defense ministry is investing on several projects related to robotics. One of them involves the use of unmanned aerial vehicles for border control, vigilance, target tracking, and recognition. Brazilian Federal Police (PF) have acquired the Hermes 450 developed by AEL Sistemas S/A, which

Digital Object Identifier 10.1109/MRA.2013.2255471
Date of publication: 6 June 2013

Overview of Robotics Activities in India (2013)

By Madusudanan Sathianarayanan, Manish Chauhan, Subir Kumar Saha, Suren Kumar, and Venkat Krovi

Third in the series of articles focusing on the state of robotics and automation (R&A) in the BRICS countries, Brazil, Russia, India, China, and South Africa, this article provides an overview of India. The objective of this series is to inform the readers of the unique challenges of these countries and the solutions they have adopted to solve their problems, and to facilitate discussions with the interested members of the community. Please send your comments and feedback to Vice President of the Industrial Activities Board Raj Madhavan at raj.madhavan@ieee.org.

Traditionally robotics and automation (R&A) technologies have not enjoyed success in the Indian milieu, partly due to the prohibitive technological costs and partly due to the in-parallel availability of an inexpensive labor force. However, it is noteworthy that this has not been due to a shortage of scientific temper to address challenging problems or the willingness to apply the most appropriate solution. As a nation, India is witnessing rapid industrialization, with a growth rate hovering between 7 and 10% over the past decade and an eye toward the global export marketplace. Within this context, the robotics industry in the country is worth approximately US$750 million (compared with a global estimate of US$17.6 billion) but is expected to grow at two to two-and-half times the average global growth rate [1].

In the past decade, R&A technologies have hastened the coming-of-age in India by helping speed up, simplify, and enhance the quality of various heavy-industry processes. Defense industrial applications remain another growing area for R&A and allied control-system technologies. Additionally, the rising affluence is also creating a consumer-focused marketplace for R&A technologies, including the health-care marketplace. Thus, from an overall perspective, the R&A picture in the Indian subcontinent mirrors the diversity and rapidly changing face of robotics worldwide (albeit on a smaller scale).

While presenting this overview of seemingly scant robotics activities within the Indian subcontinent, one needs to place this in the broader context of the technological capabilities of a nation that has successfully developed an indigenous space and nuclear program. In particular, the technological capabilities (in robotics, automation, and control systems) remain captive within the specific defense/governmental agencies and institutions and not particularly well publicized. More generally, in the pervasive one-company-for-life employment paradigm and lack of significant mobility within the labor-markets, R&A activities have traditionally remained siloed within institutional and organizational boundaries. Hence, this overview of robotics activities quite naturally coalesces around different organizations/agencies from educational institutions to research and development laboratories to actual specific industry sector deployments.

The broad categorization follows along from the source of the technological manpower with academic research organizations and educational support laboratories, and then leads into governmental and industrial research, and development laboratories, educational and hobby robotics organizations, and more recently, budding robotics-oriented professional societies. Yet, one needs to remain cognizant that this is a mere snapshot of activity at this instance in time.

As in the rest of the world, various literary and celluloid renditions of robotics play a critical role in capturing the imagination of young Indians. Additionally, interest in R&A (and embedded systems technologies at the lower end) has proven to be a natural evolution and extension of the programming paradigm and a natural target for numerous science, engineering, and technology career-oriented students each year.

Academic institutions, working in close collaboration with governmental and industrial research and development labs, are spearheading the growth of robotics in India. Much of the early efforts were led by the robotics labs within the Indian Institute of Science, Bangalore, and the Indian Institutes of Technology (IITs) in Delhi, Bombay, Madras, Kharagpur, and Kanpur. In more recent years, these have been joined by the nascent robotics labs in the next generation of IITs in addition to the National Institutes of Technology (NITs) and the Indian Institute of Information Technology (IIITs)—all institutions operating under the auspices of the Ministry of Human Resource Development. The diversity of research topics closely parallels the contemporary international research

Digital Object Identifier 10.1109/MRA.2013.2283182
Date of publication: 6 December 2013

RARI-WS Kickoff, June 27, 2017

Raj Madhavan

Worldwide R&A National Roadmaps (US)

November 7, 2016

A Roadmap for US Robotics

From Internet to Robotics

2016 Edition

Organized By

University of California San Diego
Carnegie Mellon University
Clemson University
Cornell University
Georgia Institute of Technology
Northeastern University
Northwestern University
Oregon State University
SRI Inc.
Texas A&M University
The University of Utah
University of California Berkeley
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Yale University

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University of California San Diego
Oregon State University
Georgia Institute of Technology

National Robotics Initiative 2.0: Ubiquitous Collaborative Robots (NRI-2.0)

PROGRAM SOLICITATION
NSF 17-518

REPLACES DOCUMENT(S):
NSF 16-517

National Science Foundation

Directorate for Computer & Information Science & Engineering
Division of Information & Intelligent Systems

Directorate for Engineering

Directorate for Education & Human Resources

Directorate for Social, Behavioral & Economic Sciences

U.S. Dept. of Agriculture

National Institute of Food and Agriculture

U.S. Dept. of Energy

U.S. Department of Energy - Office of Environmental Management (EM)

Department of Defense

Defense Advanced Research Projects Agency

Air Force Office of Scientific Research

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

February 02, 2017

January 11, 2018

Second Thursday in January, Annually Thereafter

IMPORTANT INFORMATION AND REVISION NOTES

Worldwide R&A National Roadmaps (EU)

Robotics 2020
Multi-Annual Roadmap

For Robotics in Europe

Horizon 2020 Call ICT-2017 (ICT-25, ICT-27 & ICT-28)

Release B 02/12/2016

Rev A: Initial release for Comment.

Rev B: Final release.

Worldwide R&A National Investments (China)

The New York Times | https://nyti.ms/2r7agZp

BUSINESS DAY

A Robot Revolution, This Time in China

点击查看本文中文版

By KEITH BRADSHER MAY 12, 2017

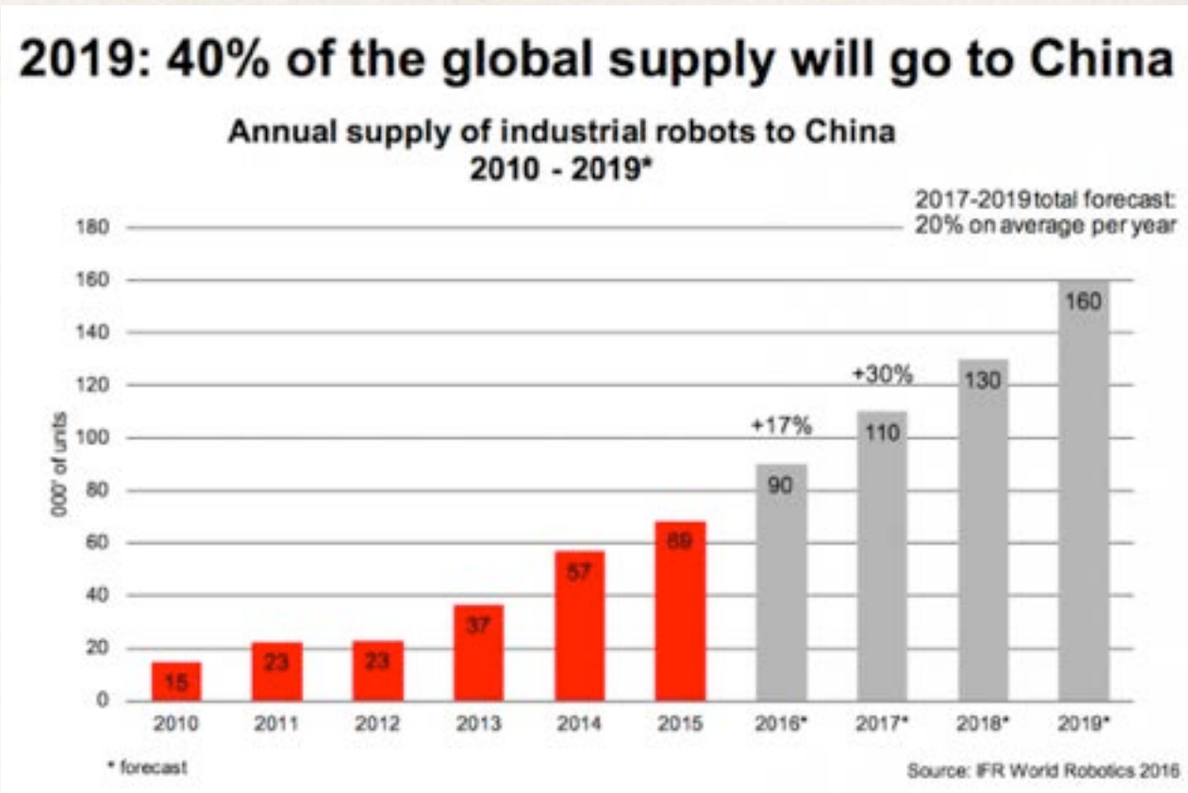
HANGZHOU, China — Even a decade ago, car manufacturing in China was still a fairly low-tech, labor-intensive endeavor. Thousands of workers in a factory, earning little more than $1 an hour, performed highly repetitive tasks, while just a handful of industrial robots dotted factory floors.

No longer.

At Ford's newest car assembly plant in Hangzhou in east-central China, at least 650 robots, resembling huge, white-necked vultures, bob and weave to assemble the steel structures of utility vehicles and midsize sedans. Workers in blue uniforms and helmets still do some of the welding, but much of the process has been automated.

The state-of-the-art factory exemplifies the vast transformation that has taken place across manufacturing in China. General Motors opened a similarly ultra-modern Cadillac factory in the eastern suburbs of Shanghai, as well as one in Wuhan. Other automakers are also pouring billions of dollars into China, now the world's largest auto market.

Robots are critical to China's economic ambitions, as Chinese companies look to move up the manufacturing chain. The Ford assembly plant is across the street



- **5 yr. plan** to transform robotics industry
- **'Made in China 2025'**
- Ministries of Finance & Industry
- Natl. Development & Reform Commission
- Automating key sectors of economy
  - ➡ car manufacturing, electronics
  - ➡ logistics, appliances, food production

Raj Madhavan

Worldwide R&A National Investments (South Korea)

Rijksdienst voor Ondernemend Nederland

South Korea to Boost its Robot Industry with a New Development Initiative

Jiyoon Hong, Officer for Innovation, Technology & Science, February 2017

Introduction

Starting 2017, robots can readily be seen in South Korea at shipping centres or at hospitals for the benefit of patients' rehabilitation. During the Pyeongchang Winter Olympics of 2018, robots will act as receptionists or security guards. On November 15 2016, the Ministry of Trade, Industry and Energy (MOTIE) held a policy meeting with relevant government sectors to discuss the robot industry and to announce the Joint Robot Industry Development Initiative. This is a more detailed version of what was discussed in last October 2016 during the Robot Industry Development Roundtable. During the roundtable, the government announced that it will invest 400 million euros in the next five years and promote 80 public projects within the top 4 promising industries by the year 2020. After receiving feedback from experts and consulting with other government sectors, MOTIE came up with the Joint Robot Industry Development Initiative. This programme reflects the fervent wish on the part of the South Korean government to grow the robot industry as one of the new export industries. In order to do so, five to ten robots will be placed in the National Rehabilitation Centers to assist in patients' rehabilitation, and another ten to fifteen robots in general hospitals to assist in the transfer of patients. By 2018, a further five to ten social robots with AI will be placed in local post offices, while three to five surgical robots will be distributed among national hospitals.

MOTIE will focus on expanding the demand base for robots through market creation and system maintenance. It also intends to enhance robot service and platform distribution capability by promoting specialised companies, securing core technologies, building the workforce and creating proper infrastructure. Efforts will be made to grow the demand for advanced manufacturing robots by providing and expanding smartphone factories, as well as by creating public demand for service robots. In order to secure distribution capabilities, MOTIE will select ten to fifteen research institutes to be affiliated with robot companies as Advanced Robot Commercialization Centers to promote companies specialised in robots, creating a total investment of 80 million euros.

Creating demand for service robots

Medical and rehabilitation use, unmanned transport, social works and security are the four promising sectors in which the government sectors attempt to initiate 90 public projects and promote them by the year 2020. In the case rehabilitation robots, for which market vitalisation is urgently required, MOTIE and the Ministry of Health and Welfare will jointly host a Rehabilitation Robot Symposium (30 November 2016) to implement system modification.

- **'Intelligent Robot'**
  - ➡ one of ten National Economic Growth Engines
  - ➡ personal service, professional service, industrial robotics, defense, health/welfare, ocean/ underwater, construction, transport
- Current rate of investment is ~500 M$/year

Worldwide R&A National Investments (Japan)

New Robot Strategy

Japan's Robot Strategy

- Vision, Strategy, Action Plan -

The Headquarters for Japan's Economic Revitalization

10/2/2015

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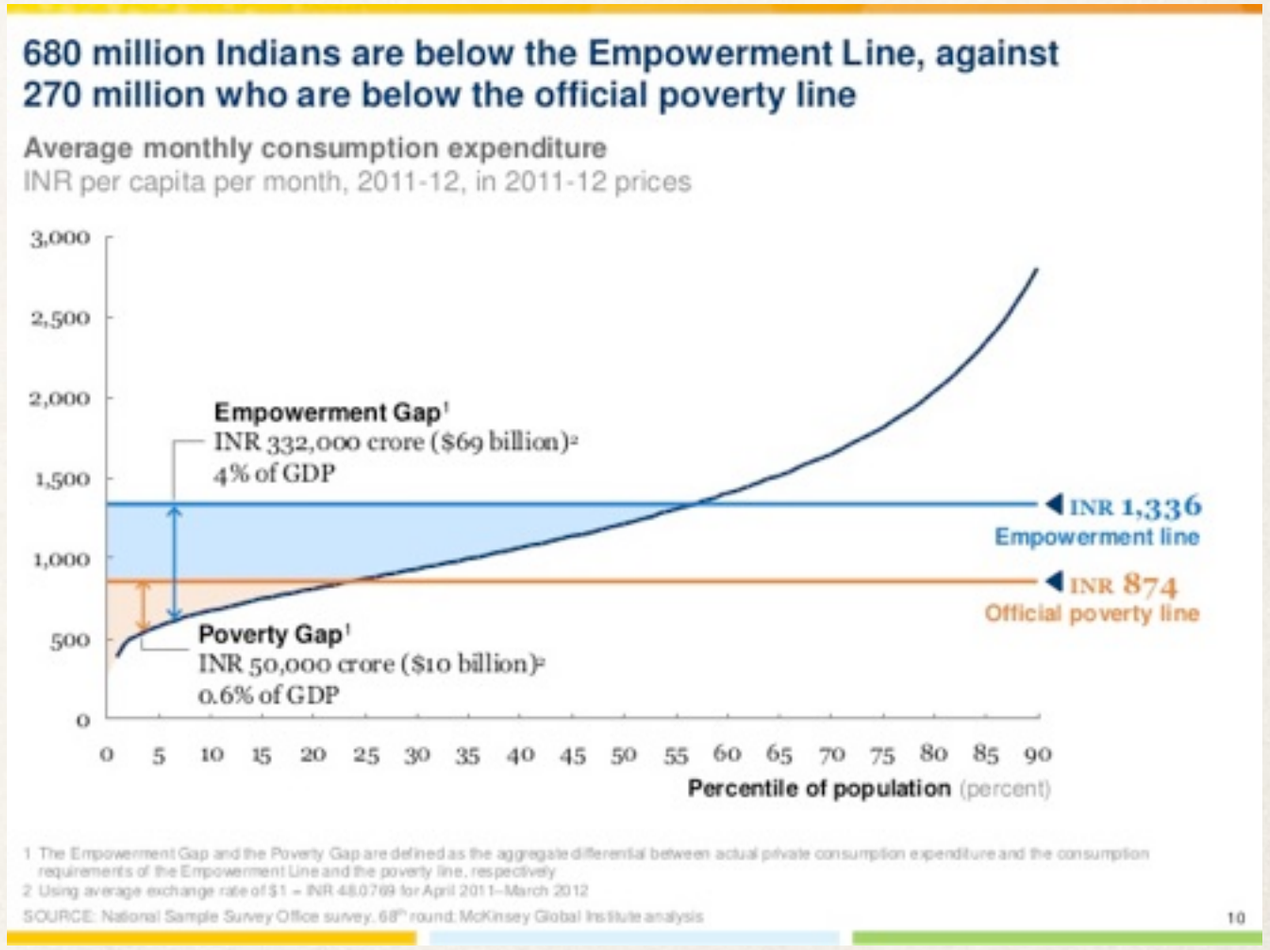
- Council for S&T **'Next generation Robotics'**
- **'Robot Revolution Initiative (RRI)'**
- 350 M$/year
- Humanoid & service robotics, intelligent environments
- Emphasis on transfer of results to the industry

Why do we need a roadmap for India?!
From Poverty to Empowerment

- GDP Growth 7.4% for 2016-17 (IMF)
- Poverty Rate decline 45% (1994) -> 22% (2012)
- 56% lack minimum acceptable living standards (2012)

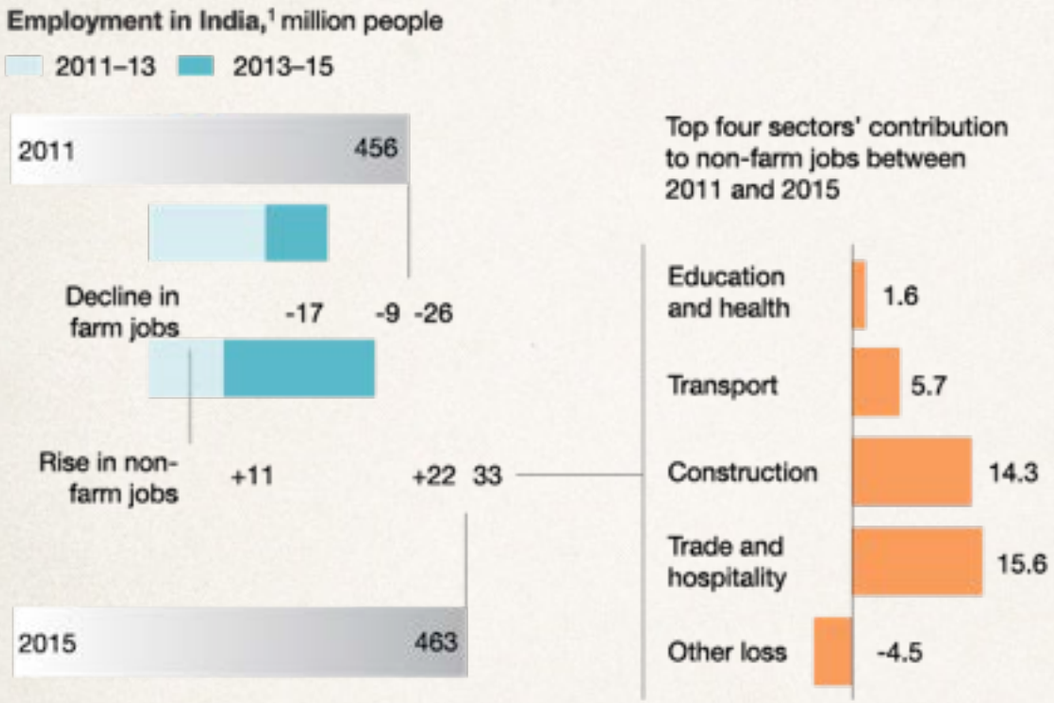


Raj Madhavan

Why do we need a roadmap for India?!
Risk Being Left Behind

The rise in non-farm jobs between 2011 and 2015 has more than compensated for the decline in farm jobs.

Employment in India,[1] million people



Top four sectors' contribution to non-farm jobs between 2011 and 2015

[1] Years are financial years from April to March. Thus 2011 is from April 2010 to March 2011.

Source: Labour Bureau; UN Population Division (Medium variant); McKinsey Global Institute analysis

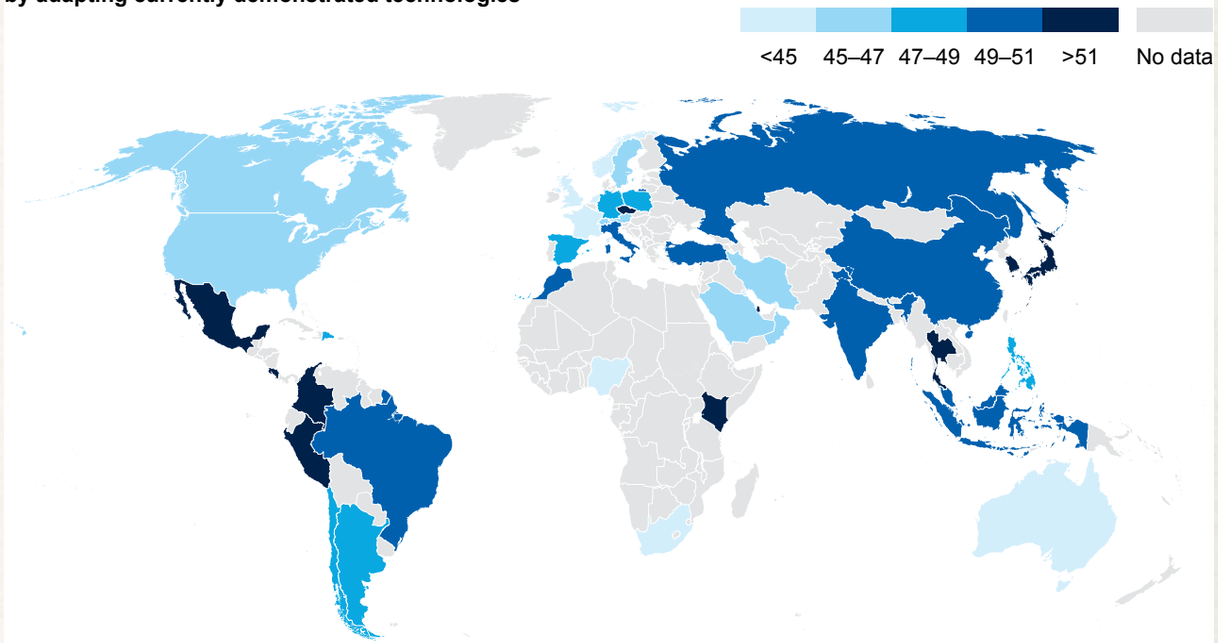
McKinsey&Company

RARI-WS Kickoff, June 27, 2017

Exhibit E5

The technical automation potential of the global economy is significant, although there is some variation among countries

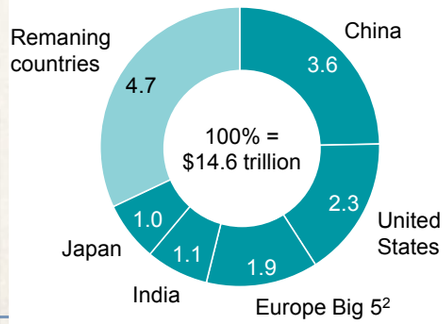
Employee weighted overall % of activities that can be automated by adapting currently demonstrated technologies[1]



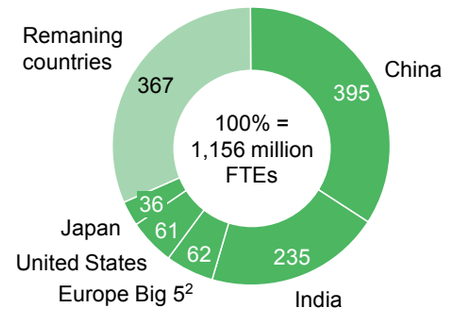
Technical automation potential is concentrated in countries with the largest populations and/or high wages

Potential impact due to automation, adapting currently demonstrated technology (46 countries)

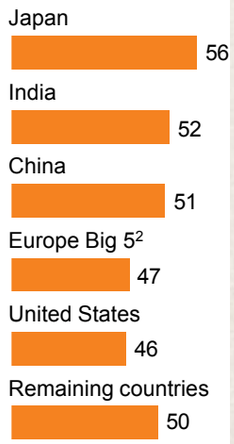
Wages associated with technically automatable activities
$ trillion



Labor associated with technically automatable activities
Million FTE



Automation potential
%



1 Pakistan, Bangladesh, Vietnam, and Iran are largest countries by population not included.
2 France, Germany, Italy, Spain, and the United Kingdom.
NOTE: Numbers may not sum due to rounding.

SOURCE: Oxford Economic Forecasts; Emsi database; US Bureau of Labor Statistics; McKinsey Global Institute analysis

Harnessing the Potential of R&A for India
Some Thoughts … (My Wishlist)

- Manufacturing for India, in India, by India
- Skilled-labor training & new job creation
- Fostering entrepreneurship

- Education centered on learning instead of jobs
- Next-generation workforce (w/ emphasis on women)
- Bridging the R&D gap between Industry-Academia-Government

- Funding for Innovation & Commercialization of emerging technologies
- Regulation & Governance
- Ethical, Legal, and Societal Considerations

R&A Roadmapping for India
Goals & Deliverables

- **Understand and Identify**

  (with particular attention to socio-economic, cultural, environmental, and sustainability factors)

  - ➡ What existing R&A solutions exist across public and private sectors
  - ➡ Requirements of stakeholders
  - ➡ How existing roadblocks and impeding processes can be minimized

- **Anticipated Outcomes**
  - ➡ industries adopting best practices and benefitting from technology adoption
  - ➡ academia/industry preparing the next generation workforce and researchers
  - ➡ informing government of existing gaps and how these can be bridged

- **Expected Deliverables**

  A roadmap document describing
  - ➡ identified needs to accelerate development focusing on the Indian market
  - ➡ prioritization of recommendations to address the identified needs
  - ➡ standards development activities for the R&A industry in India

Where do we go from here?

- **Identify 8-10 top priorities**
  - ➡ Circulate WS summary & Publicize roadmapping effort
  - ➡ Collect Feedback/Suggestions before identifying top 10 themes
- **Form Working Groups centered on prioritized themes**
  - ➡ WG Chairs needed
  - ➡ Continue discussion and develop draft docs. via telecon and Google Docs.
- **Organize Second F2F RARI WS (1Q 2018)**
  - ➡ WGs report
  - ➡ Interactive workshop with key stakeholders to build consensus on the roadmap
  - ➡ Refine ideas
- **Release v1.0 of the Roadmap (July 2018)**

AGENDA

Session I 09:30 – 13:00 (By Invitation-only) Venue: ME Seminar Room (II-422)

9:30	9:35	Welcome from Workshop Organizers
9:40	10:00	A Robotics and Automation Roadmap for India – Why now? (Raj Madhavan)
10:00	11:30	**Industry Presentations** • Munir Mohammed (IEEE-SA, Bangalore) • Jagannath Raju (Systemantics, Bangalore) • Swagat Kumar (TCS, Mumbai) • Awanish Tiwari (ABB, Bangalore) • Rejin Narayanan (Ingen Robotics, Trivandrum) • Achu Wilson (Sastra Robotics, Cochin) • Anant Malewar (Nex Robotics, Mumbai) • Parvez Alam (UCAL Fuel Systems, Chennai) • Anup Wadhwa (AIA, New Delhi)
11:40	*11:55*	*Coffee Break*
11:55	12:55	**Academia Presentations** • T. Asokan (IIT Madras) • C.S. Kumar (IIT Kharagpur) • Vineet Vashista (IIT Gandhinagar) • Sudipto Mukherjee (IIT Delhi) • P.M. Pathak (IIT Roorkee) • K. Madhava Krishna (IIIT Hyderabad)
13:00	*14:00*	*Lunch*

Session II 14:00 – 15:45 (By Invitation-only) Venue: ME Seminar Room (II-422)

14:00	15:45	**Government & Funding Agencies Presentations** • Bani Hazra (RDE, Pune) • D.N. Badodkar (BARC, Mumbai) • Sambhunath Nandy (CSIR-CMERI, Durgapur) • S.S. Kohli (DST) • Santanu Chaudhury (CEERI, Pilani) • Suprotim Ganguli (GITA, New Delhi) • *Discussions and Q & A (45 min.)*
15:45	*16:30*	*Coffee Break (Move to Lecture Hall Complex from ME Seminar Room)*
16:30	17:30	**Panel Discussion (Public) Venue: Lecture Hall Complex (LHC) 111** • *Q & A from attendees and Discussion among panelists* • *Moderator (Raj Madhavan)*
17:30	17:45	Closing Remarks

* In your technical domain areas (e.g. representative R&A technologies) and sectors (e.g. academia, industry, government), **what is your opinion on where India stands with respect to state-of-the-art** in comparison to countries where R&A can be considered to be advanced (Japan, EU, and the US, for instance)?
* What are the major **roadblocks that preclude progress and pose an impediment to wide acceptance in the above technical domains and sectors**? What are your suggestions on how these can be overcome?
* **How can industry, academia, and government work together** in areas that you think where collaboration and cooperation are needed the most?
* In terms of social acceptance and non-technical factors, **how can the proposed roadmap be of assistance in conveying and crystallizing the benefits of R&A**? For instance, in Education of next-generation workforce, Research funding for innovation and commercialization, Fostering entrepreneurship?

Thank you for your participation!

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Raj Madhavan