Lecture 9. Industrial Challenges and Opportunities

Fabio Bonsignorio
The BioRobotics Institute, SSSA, Pisa, Italy and Heron Robots

Older and newer attempts

Juanelo Torriano alias Gianello della Torre, (XVI century) a craftsman from Cremona, built for Emperor Charles V a mechanical young lady who was able to walk and play music by picking the strings of a real lute.

Hiroshi Ishiguro, early XXI century

Director of the Intelligent Robotics Laboratory, part of the Department of Adaptive Machine Systems at Osaka University, Japan

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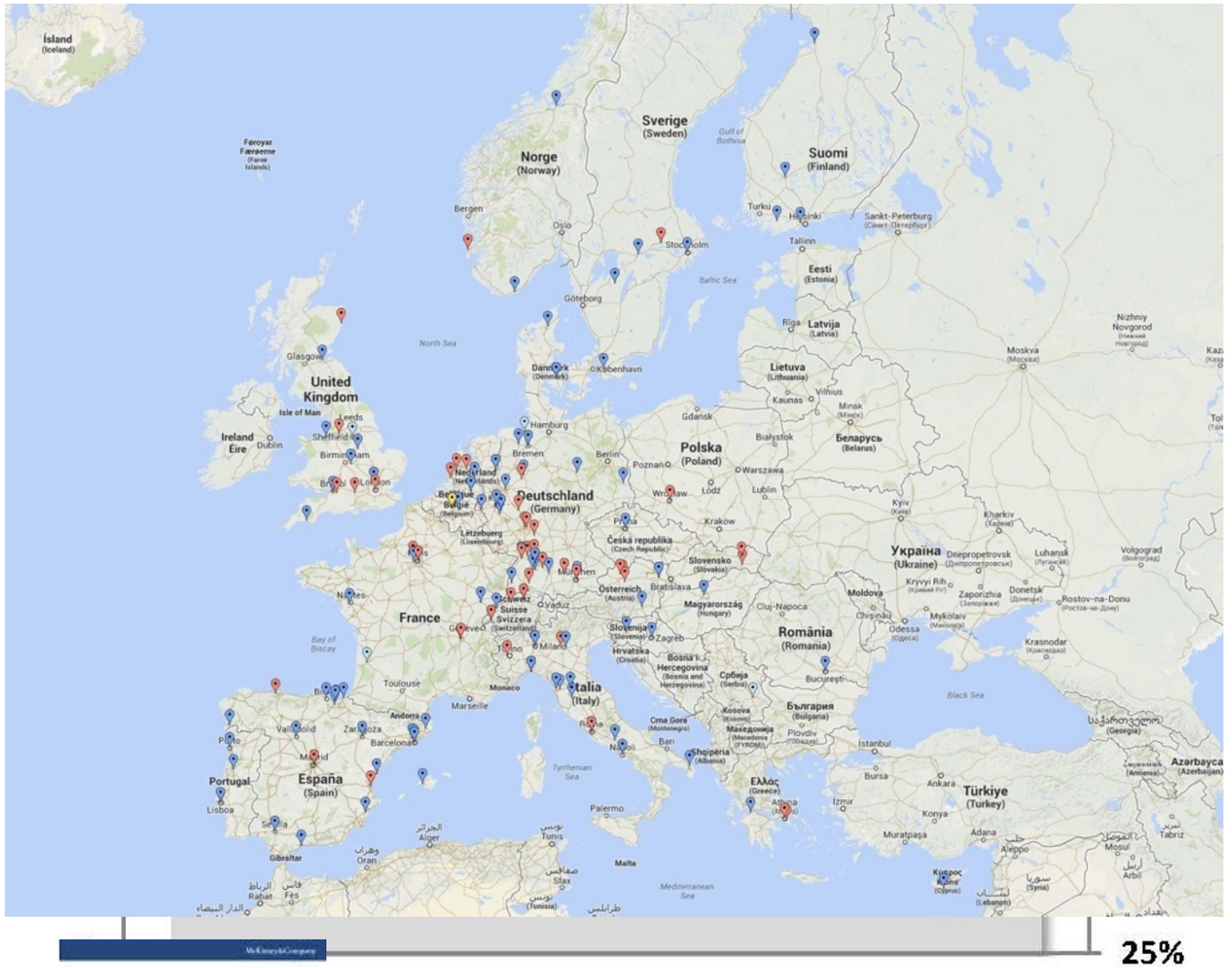
Data are very important, but they are not all in a digital economy. ACTIONS, MOBILI and STRENGTH are also needed! **Robotics**: a great opportunity to **innovate, connect** and **transform. Robotics is technology and business, but it is also creativity and fun!**

"[...] The size of the robotics market is projected to grow substantially to 2020s. This is a global market and Europe's traditional competitors are fully engaged in exploiting it. Europe has a 32% share of the industrial market. Growth in this market alone is estimated at 8%-9% per annum. Predictions of up to 25% annual growth are made for the service sector where Europe holds a 63% share of the non-military market. […]"

"[…] From today's €22bn worldwide revenues, robotics industries are set to achieve annual sales of between €50bn and €62bn by 2020. […]"

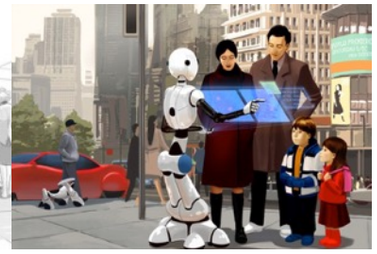


Robotics is one of the 12 disruptive technologies identified by McKinsey

http://sparc-robotics.eu/about/
SPARC Strategic Research Agenda

The Waves of Robotics Innovation





Third wave

Second wave

First wave

Society

Cognitive Science

& Bioinspiratio

Multif. Nanomat.

MC, Simpl., Self-org.

IoT

ML

AI

Mech Eng

Ctrl Eng

Comp Sci

SEVENTH FRAMEWORK PROGRAMME

FIFTH FRAMEWORK PROGRAMME

SIXTH FRAMEWORK PROGRAMME

1st crest

2st crest

1st crest

2st crest

1st crest

2st crest

New wave of use-centered science-based radical innovations

Sustainable industrial leadership and ubiquitous societal impact

Advanced, Future and Emerging Robotics & Cognitive Systems

Industrial leadership and societal impact

Methodologies and Technologies for Robotics and Mechatronics

Industrial robotics

Robot Companions for Citizens

Coordination Action for the preparation and description of the FET flagship candidate

HORIZON 2020

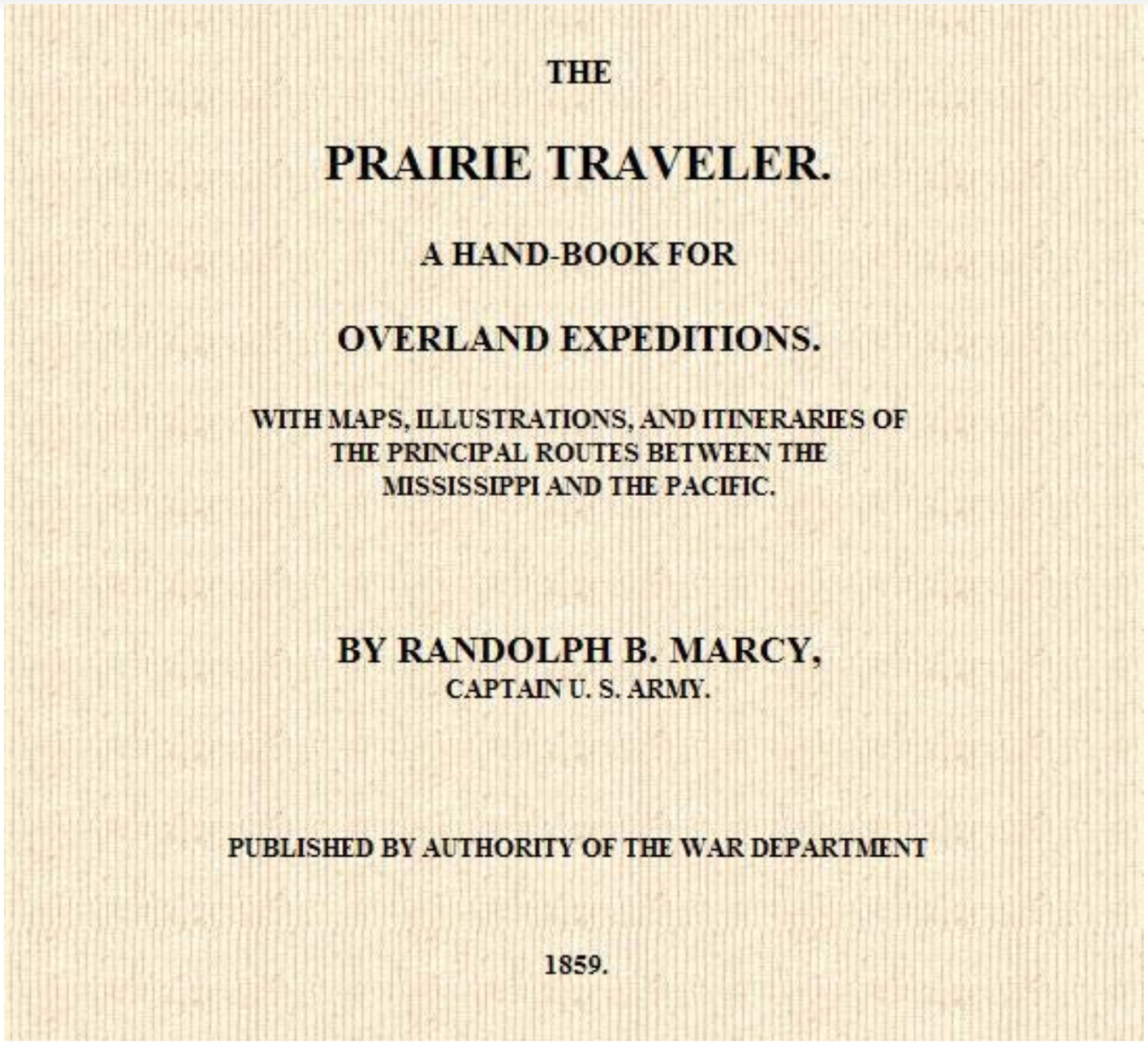
SPARC

Robotics body of knowledge

Future of Robotics

1990 2000 2015 2020 2025 2030

‘Caveat’



THE

PRAIRIE TRAVELER.

A HAND-BOOK FOR

OVERLAND EXPEDITIONS.

WITH MAPS, ILLUSTRATIONS, AND ITINERARIES OF
THE PRINCIPAL ROUTES BETWEEN THE
MISSISSIPPI AND THE PACIFIC.

BY RANDOLPH B. MARCY,
CAPTAIN U. S. ARMY.

PUBLISHED BY AUTHORITY OF THE WAR DEPARTMENT

1859.

Old ideas

“If every tool, when ordered, or even of its own accord, could do the work that befits it, just as the creations of Daedalus moved of themselves . . . If the weavers' shuttles were to weave of themselves, then there would be no need either of apprentices for the master workers or of slaves for the lords.”

Aristotle

(from Politics, Book 1, 1253b, 322 BC)

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Old ideas

The part of the quote "or even of its own accord" is elsewhere translated as "or by seeing what to do in advance" etc. (you may find many translations).

I think this is an important part of the quote, so it's good to go back to the original text:

Aristotle uses the word "προαισθανόμενον" – proaisthanomenon this means literaly: pro = before, aisthanomenon = perceiving, apprehending, understanding, learning (any of these meanings in this order of frequency) in my view it is clearly a word that is attributed to intelligent, living agents....i.e. ones with cognitive abilities (!)

personal communication, Dr. Katerina Pastra
Research Fellow
Language Technology Group
Institute for Language and Speech Processing
Athens, Greece

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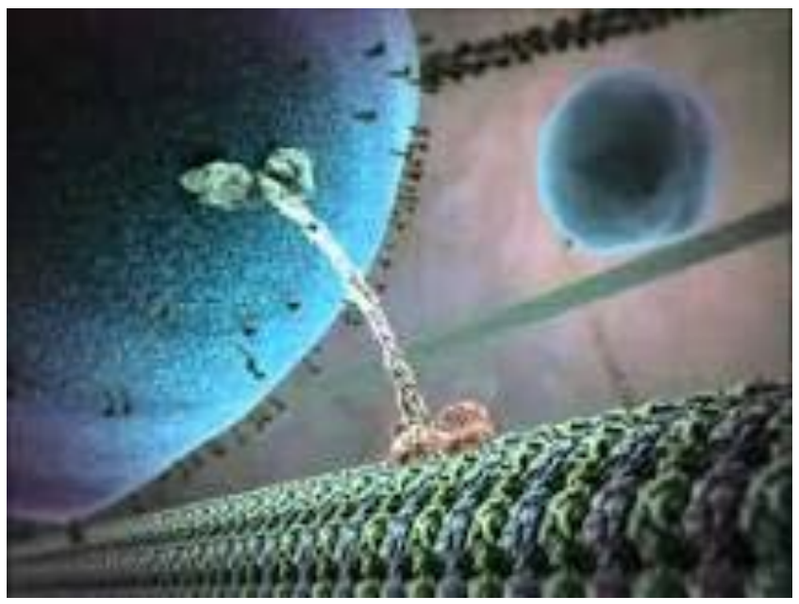
Old attempts

Karakuri Dolls
Chahakobi Ningyo (Tea Serving Doll) by SHOBEI Tamaya IX, and plan from 'Karakuri Zuii' ('Karakuri - An Illustrated Anthology') published in 1796.

Is It Alive?



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The real world is surprising

Columbus discovering America while looking for a short route to Asia (wikipedia)

There are unexpected events that change the F-O-R (at many levels)

Traders looking at screens during the global market crash of 2008 (seekingalpha.com)

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Two views of intelligence

classical:
cognition as computation

embodiment:
cognition emergent from sensory-motor and interaction processes

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Robots, artificial intelligence in the media

HAL, the "Hybrid Assistive Limb ®" Cyberdyne Inc.

Engkey, the Korean English language Teacher

Sex and marriage with robots? "It could happen" (David Levy)

Beer-serving robot

Engkey: the English language teacher

Korea to offer commercially viable English-speaking robots in 2013 한글

By Kim Tae-gyu

A total of 29 English-language education robots will be placed in 21 elementary schools in Daegu next week for a four-month feasibility study to check the commercial viability of robotic teachers, to go on sale in 2013.

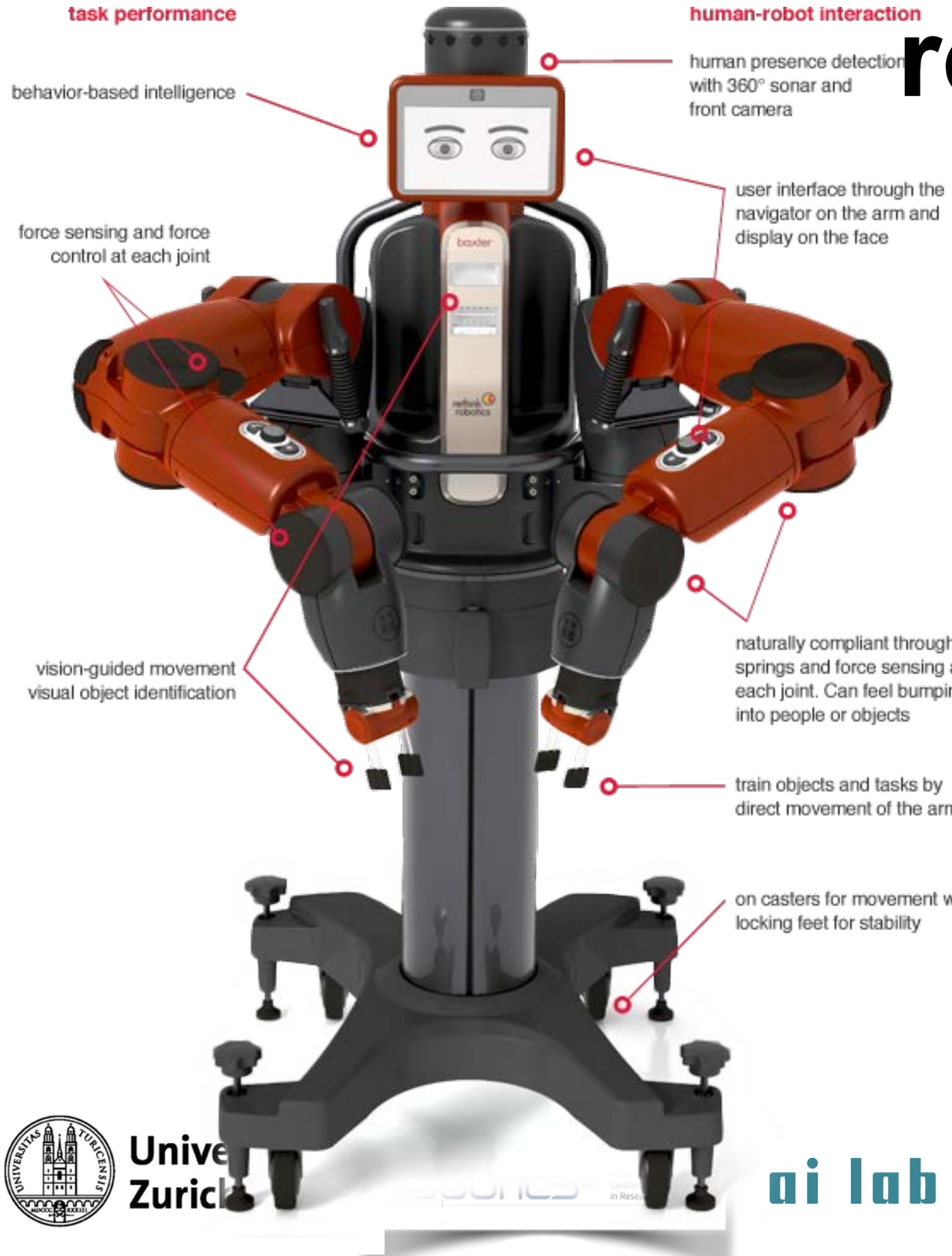
The state-run Korea Institute of Science and Technology (KIST) said Friday that the robotic assistants, dubbed "Engkey" combining "English" and "disc jockey," will help teachers during English classes.

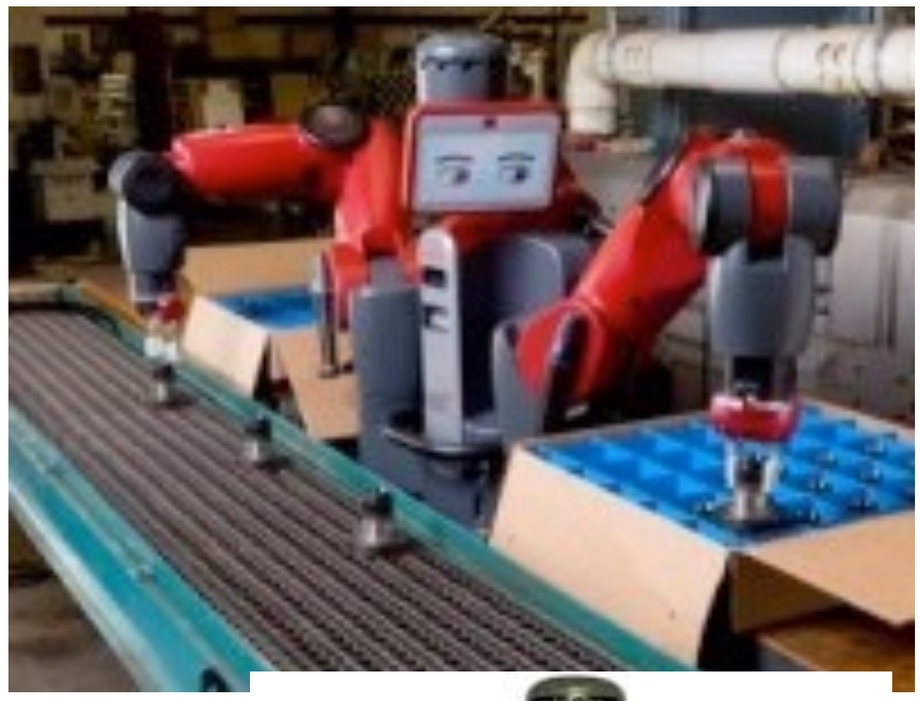
``We will carry out the second-phase pilot program with Engkey until next March after wrapping up the first project over the past year in Masan, South Gyeongsang Province," KIST spokesman Park Young-ho said.

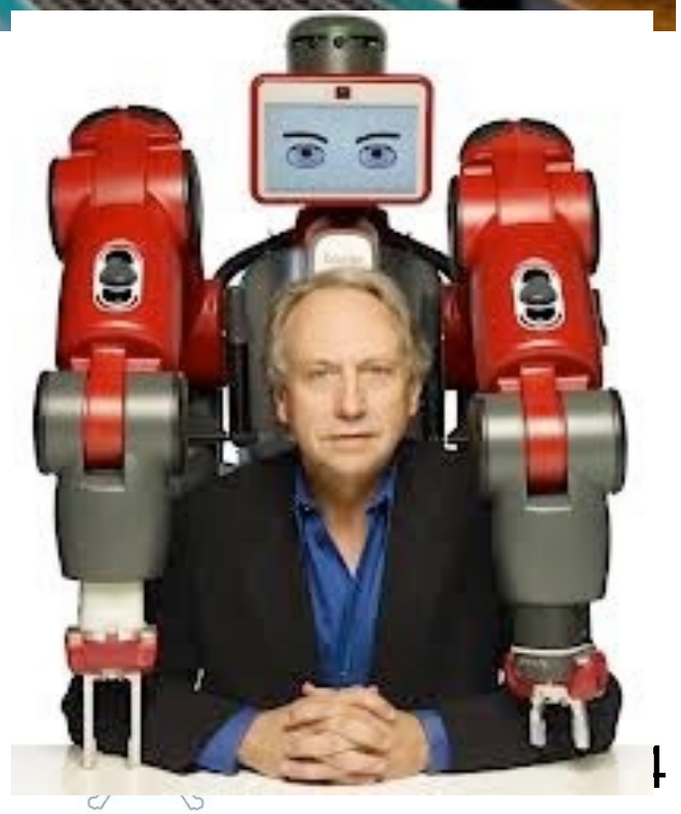
An English-language education robot named Engkey

rethink robotics

The factory “humanoid” robot “Baxter”



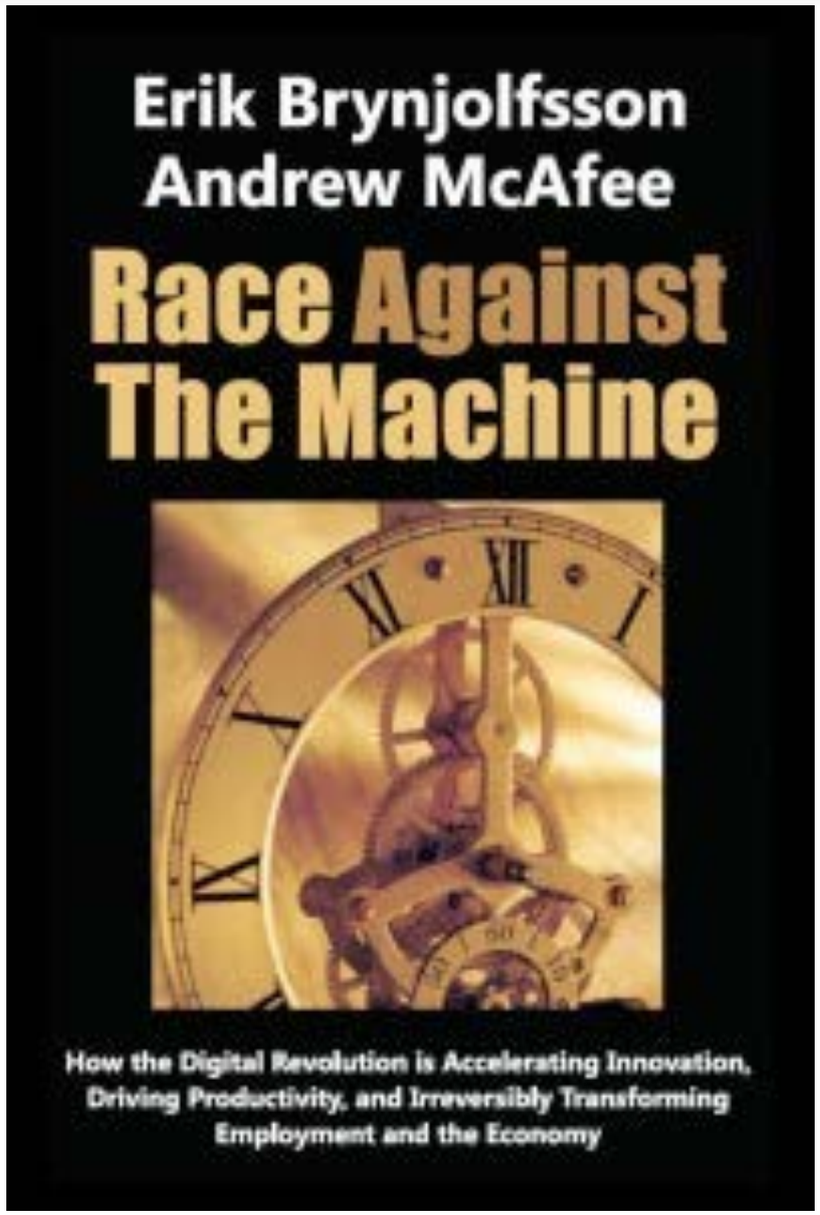




Univ
Zuric

ai lab

Someone is worried....



But maybe we should not be....

Erik Brynjolfsson (first author of the book above):

“The key to growth?

Race _with_ the machines”

(check his nice TED talk here:

http://www.youtube.com/watch?v=sod-eJBf9Y0)

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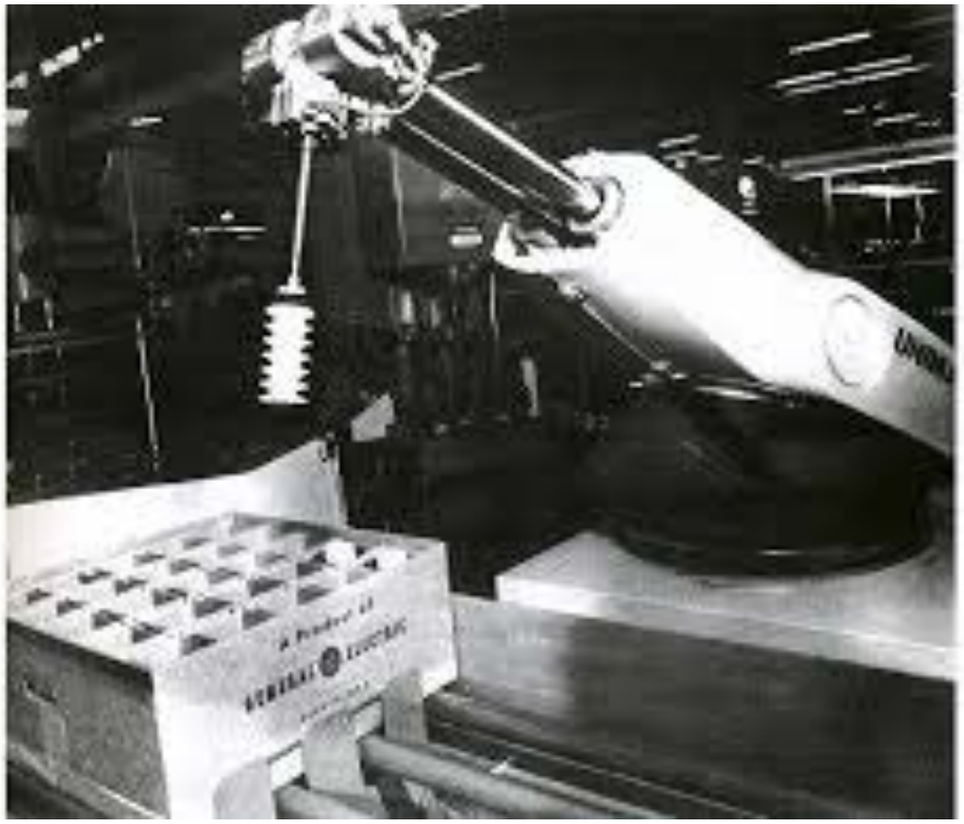
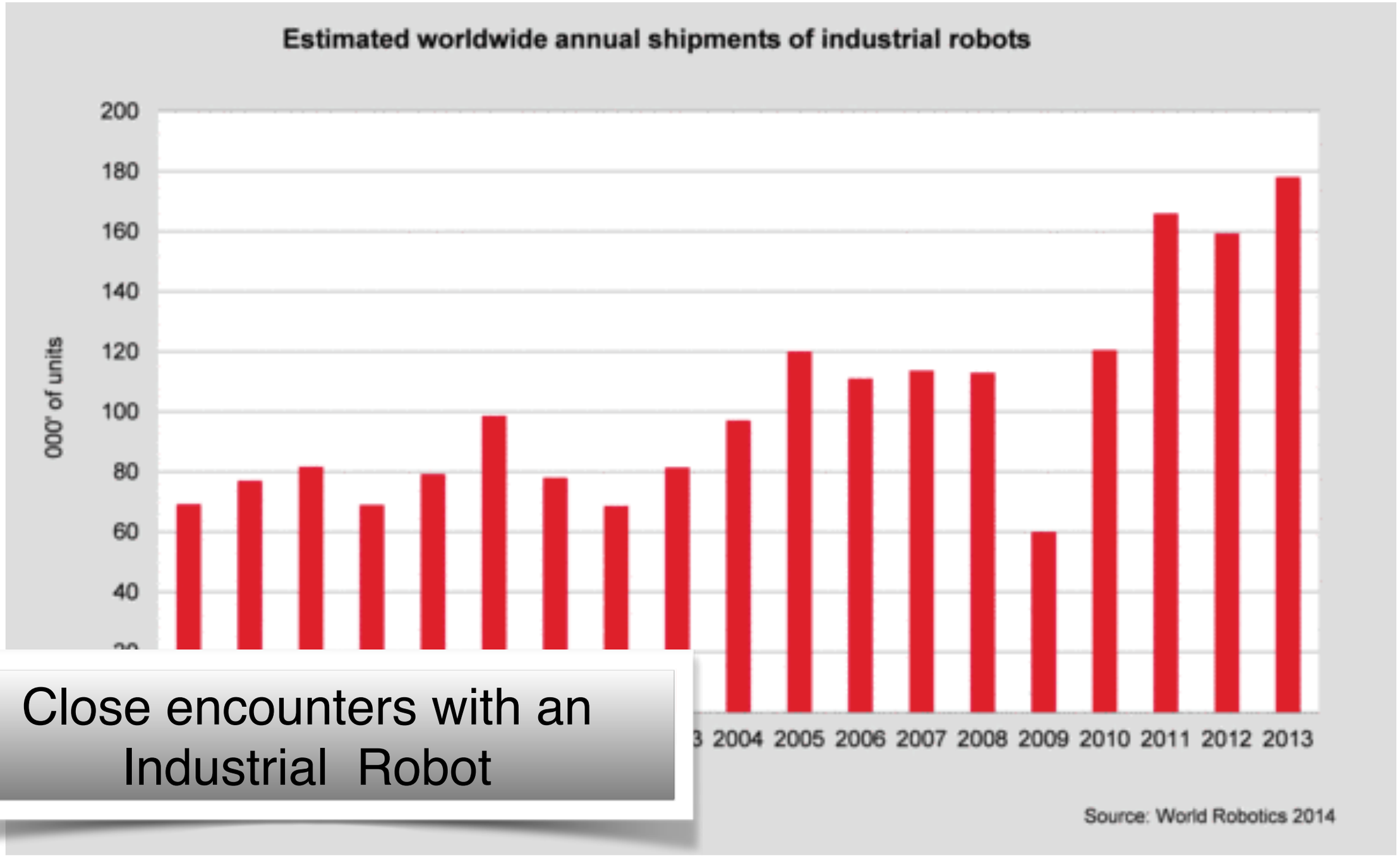
The First Wave



FCA Melfi Renegade Jeep Line

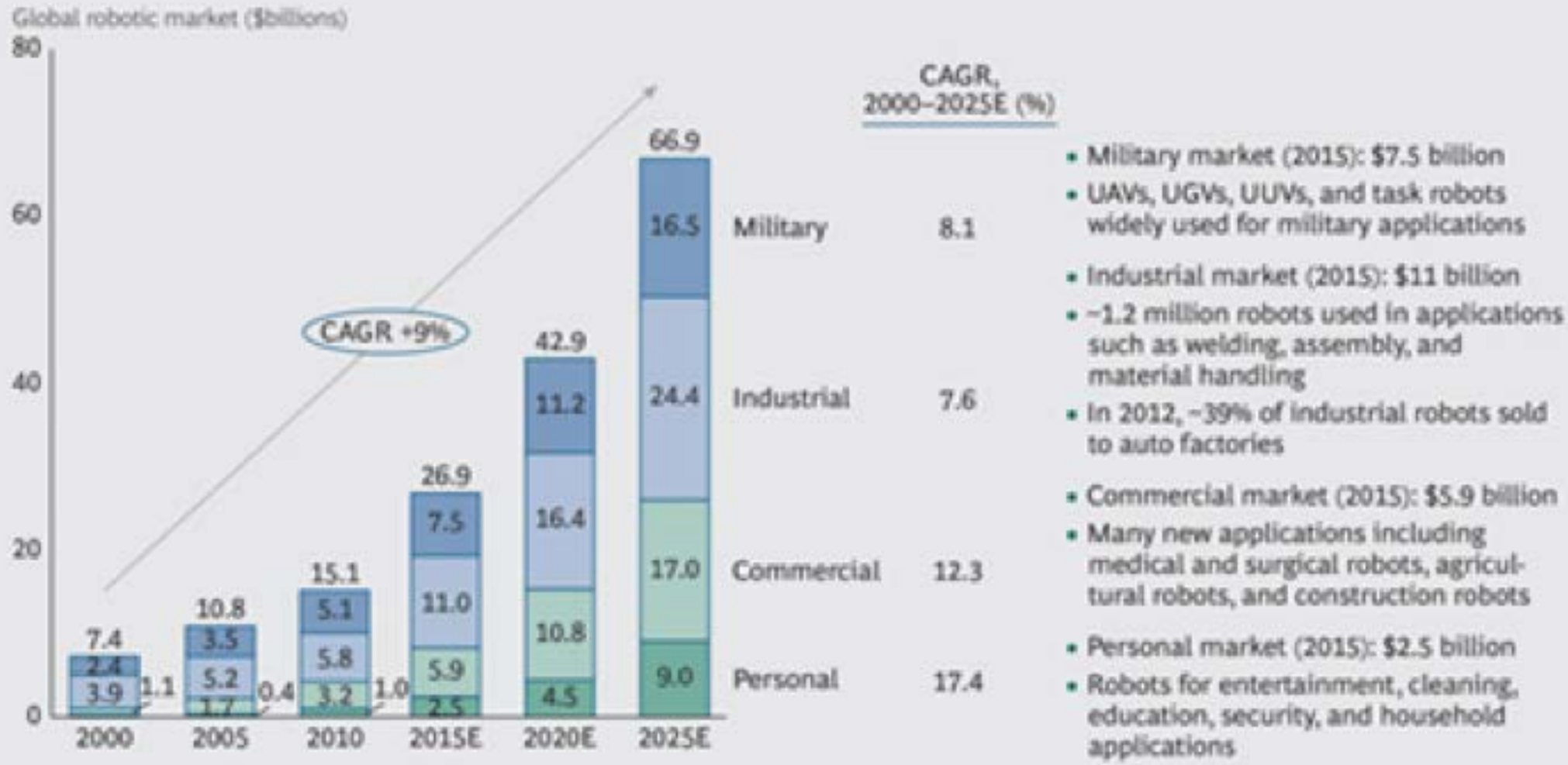
The First Wave



Close encounters with an Industrial Robot

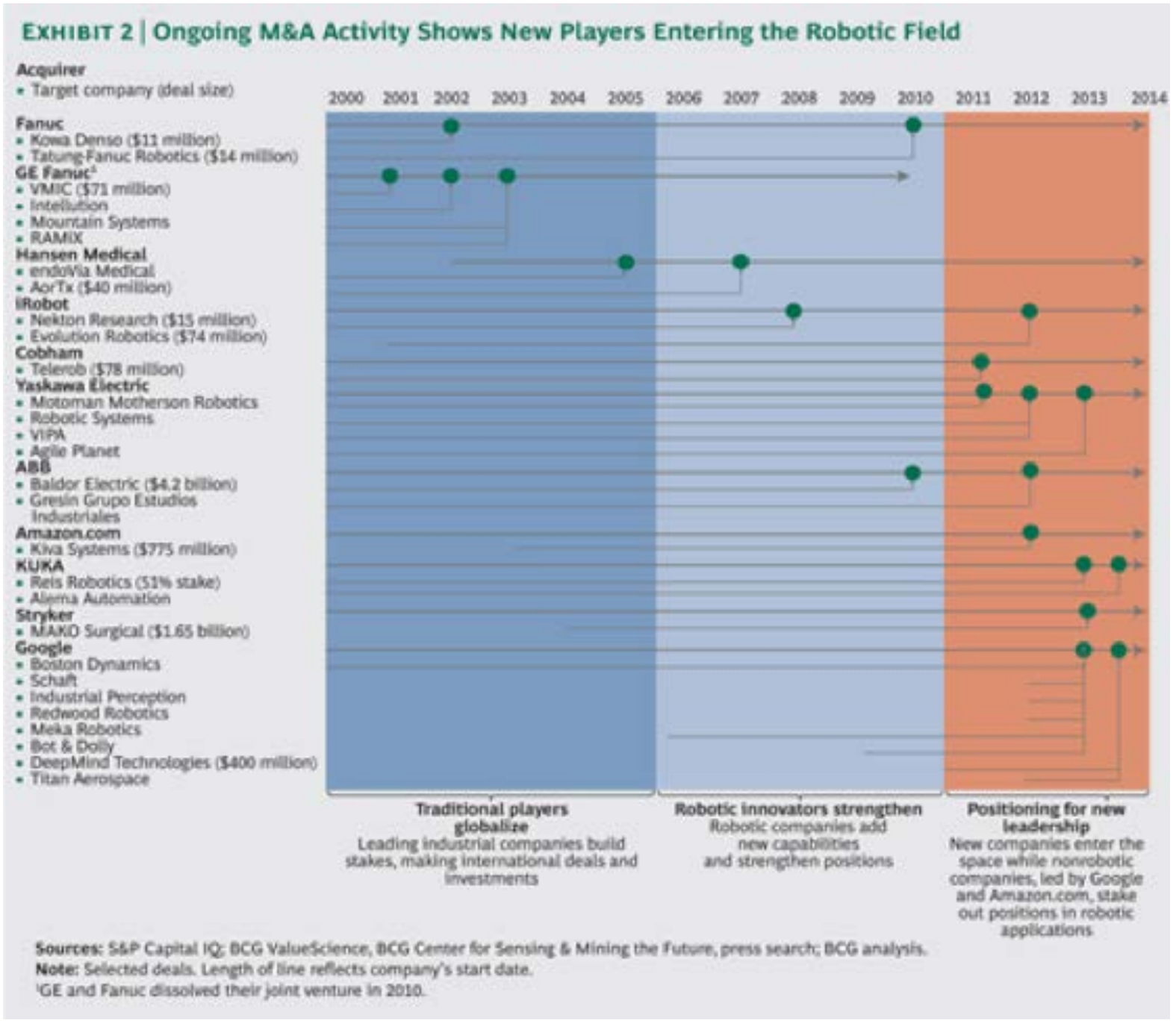
The Second Wave

EXHIBIT 1 | Worldwide Spending on Robotics Is Expected to Reach $67 Billion by 2025



Sources: International Federation of Robotics, Japan Robot Association; Japan Ministry of Economy, Trade & Industry; euRobotics; company filings; BCG analysis.
Note: UAV = unmanned aerial vehicle; UGV = unmanned ground vehicle; UUV = unmanned underwater vehicle. Estimates do not include the cost of engineering, maintenance, training, or peripherals.

The Second Wave



The Second Wave

Table 4.1

Estimated yearly shipments of multipurpose industrial robots in selected countries. Number of units

Country	2012	2013	2014*	2015*	2016*	2017*
America	**28.137**	**30.317**	**33.700**	**35.500**	**38.500**	**40.000**
Brazil	1.645	1.398	2.000	2.300	3.000	3.500
North America (Canada, Mexico, USA)	26.269	28.668	31.500	33.000	35.000	36.000
Other America	223	251	200	200	500	500
Asia/Australia	**84.645**	**98.807**	**120.000**	**144.500**	**165.000**	**186.000**
China	22.987	36.560	50.000	70.000	85.000	100.000
India	1.508	1.917	2.500	3.000	4.000	5.000
Japan	28.680	25.110	28.000	30.000	31.000	32.000
Republic of Korea	19.424	21.307	23.500	24.000	25.000	26.000
Taiwan	3.368	5.457	6.000	6.500	7.500	9.000
Thailand	4.028	3.221	4.200	5.000	6.000	7.000
other Asia/Australia	4.650	5.235	5.800	6.000	6.500	7.000
Europe	**41.218**	**43.284**	**46.000**	**47.000**	**49.000**	**55.000**
Czech Rep.	1.040	1.337	1.800	2.000	2.300	2.600
France	2.956	2.161	2.300	2.400	2.600	2.800
Germany	17.528	18.297	19.500	19.500	20.000	21.000
Italy	4.402	4.701	4.800	5.000	5.200	5.500
Spain	2.005	2.764	3.000	3.500	3.600	3.800
United Kingdom	2.943	2.486	2.500	3.000	3.200	3.500
other Europe	10.344	11.538	12.100	11.600	12.100	15.800
Africa	**393**	**733**	**800**	**850**	**900**	**1.000**
not specified by countries**	4.953	4.991	4.500	5.000	5.500	6.000
Total	**159.346**	**178.132**	**205.000**	**232.850**	**258.900**	**288.000**

Sources: IFR, national robot associations

*forecast

** reported and estimated sales which could not be specified by countries

The Second Wave

Table 4.2

Estimated operational stock of multipurpose industrial robots at year-end in selected countries. Number of units

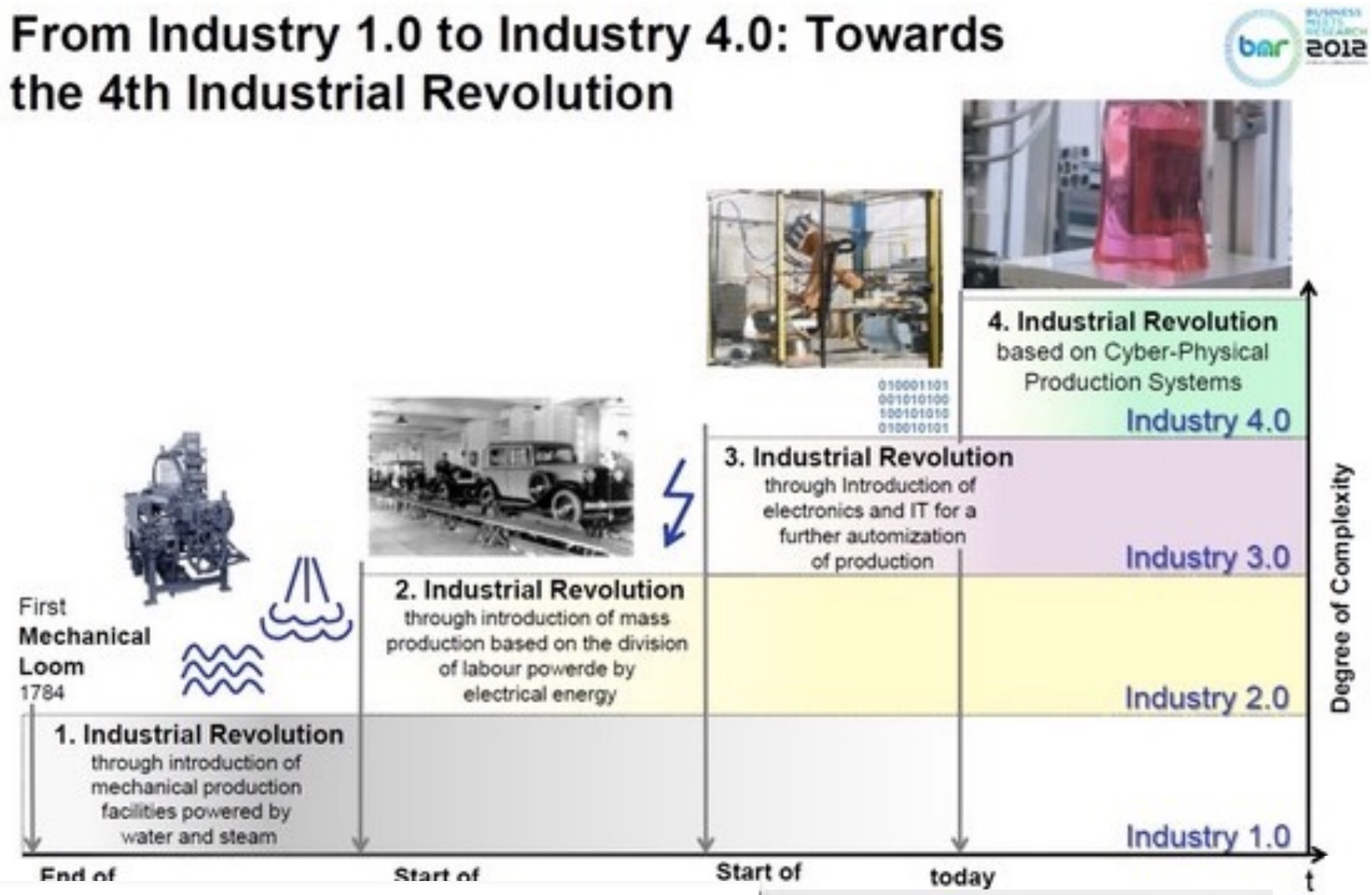
Country	2012	2013	2014*	2015*	2016*	2017*
America	**207.017**	**226.071**	**249.500**	**272.100**	**295.200**	**313.200**
Brazil	7.576	8.564	10.300	12.400	15.200	18.300
North America (Canada, Mexico, USA)	197.962	215.817	237.400	257.700	277.500	291.900
Other America	1.479	1.690	1.800	2.000	2.500	3.000
Asia/Australia	**628.889**	**689.349**	**777.100**	**880.000**	**991.600**	**1.107.600**
China	96.924	132.784	182.300	250.800	332.300	427.900
India	7.840	9.677	12.100	15.100	18.700	23.300
Japan	310.508	304.001	306.700	305.100	299.000	287.000
Republic of Korea	138.883	156.110	175.600	195.000	214.500	227.500
Taiwan	32.455	37.252	42.600	47.600	51.400	56.300
Thailand	17.116	20.337	24.400	29.300	34.500	40.100
other Asia/Australia	25.163	29.188	33.400	37.100	41.200	45.500
Europe	**380.546**	**392.227**	**411.500**	**430.700**	**450.300**	**476.800**
Czech Rep.	6.830	8.097	9.800	11.300	13.500	15.500
France	33.624	32.301	31.600	30.900	30.500	30.200
Germany	161.988	167.579	175.200	181.600	188.200	199.200
Italy	60.750	59.078	58.400	58.200	57.700	57.800
Spain	28.911	28.091	28.700	30.100	30.900	32.000
United Kingdom	15.046	15.591	17.300	19.200	21.600	23.800
other Europe	73.397	81.490	90.500	99.400	107.900	118.300
Africa	**2.858**	**3.501**	**4.200**	**5.000**	**5.800**	**6.600**
not specified by countries**	16.079	21.070	25.600	30.600	36.100	41.800
Total	**1.235.389**	**1.332.218**	**1.467.900**	**1.618.400**	**1.779.000**	**1.946.000**

Sources: IFR, national robot associations

*forecast

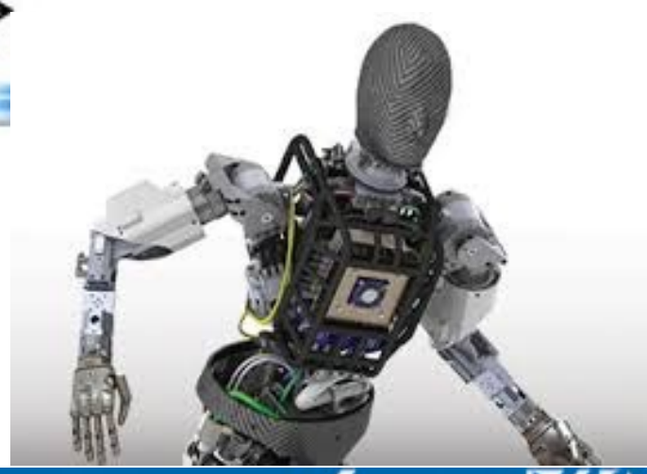
** reported and estimated sales which could not be specified by countries

The Second Wave



New applications

DARPA ROBOTICS CHALLENGE
WWW.THEROBOTICSCHALLENGE.ORG
DARPA



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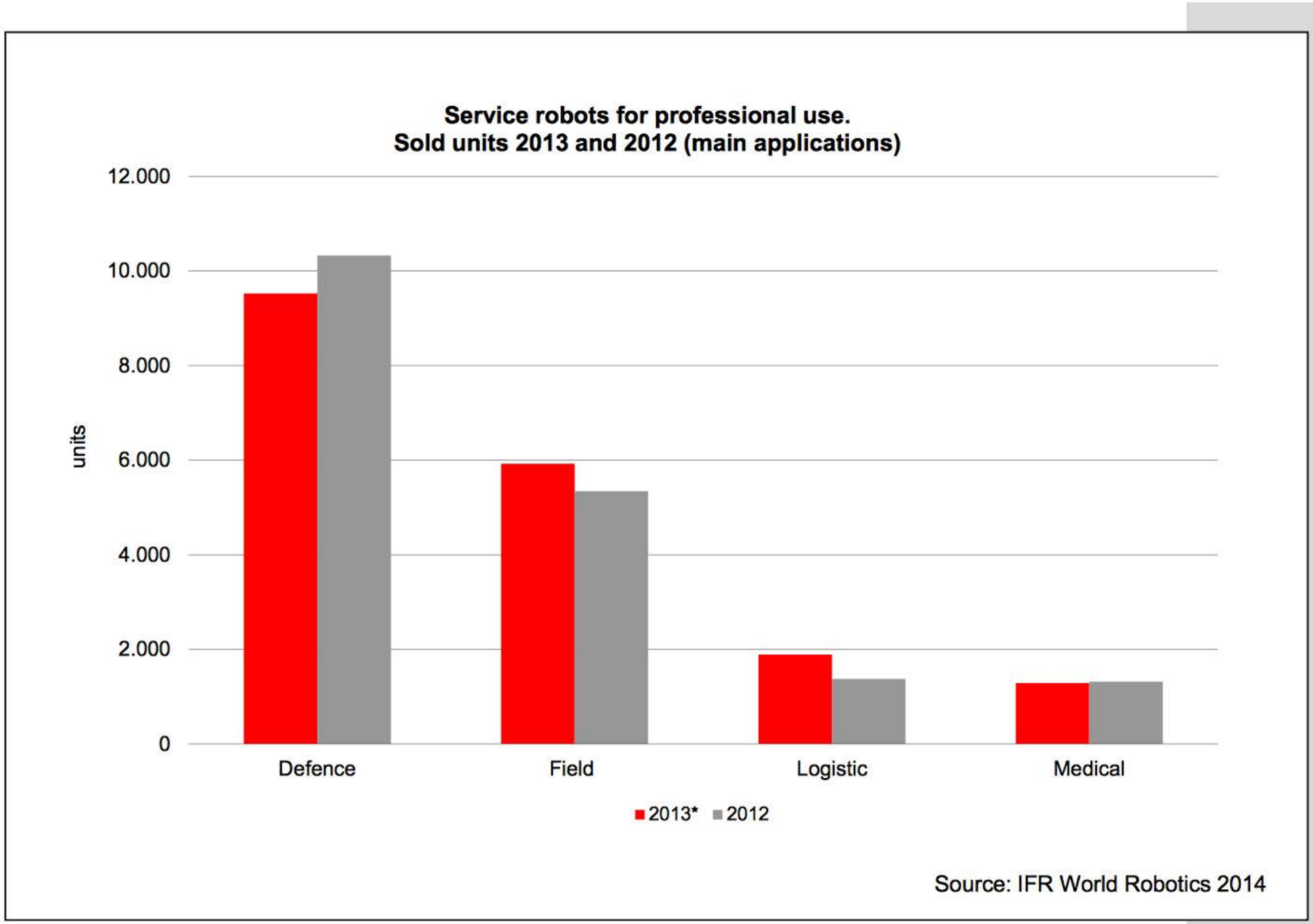

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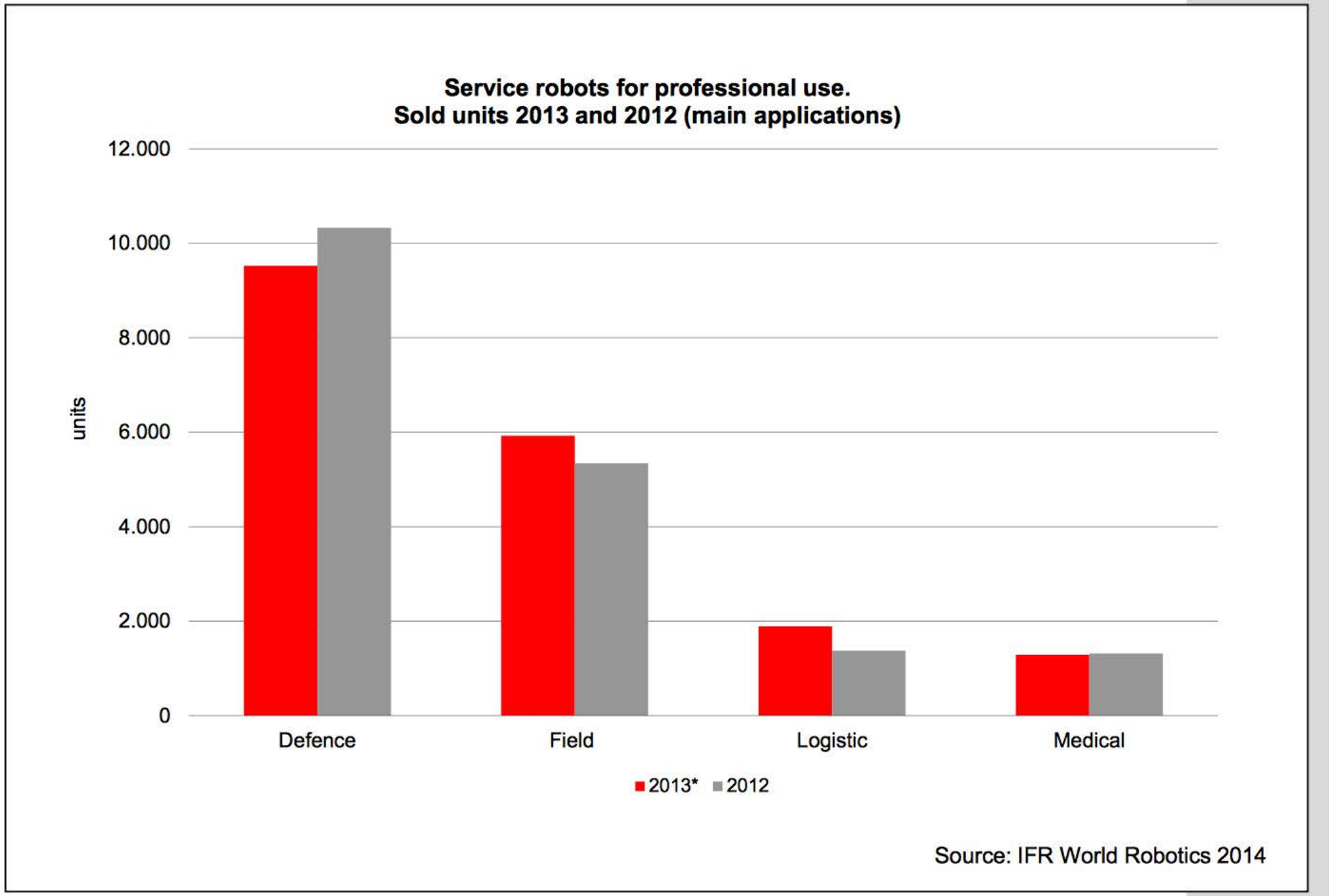

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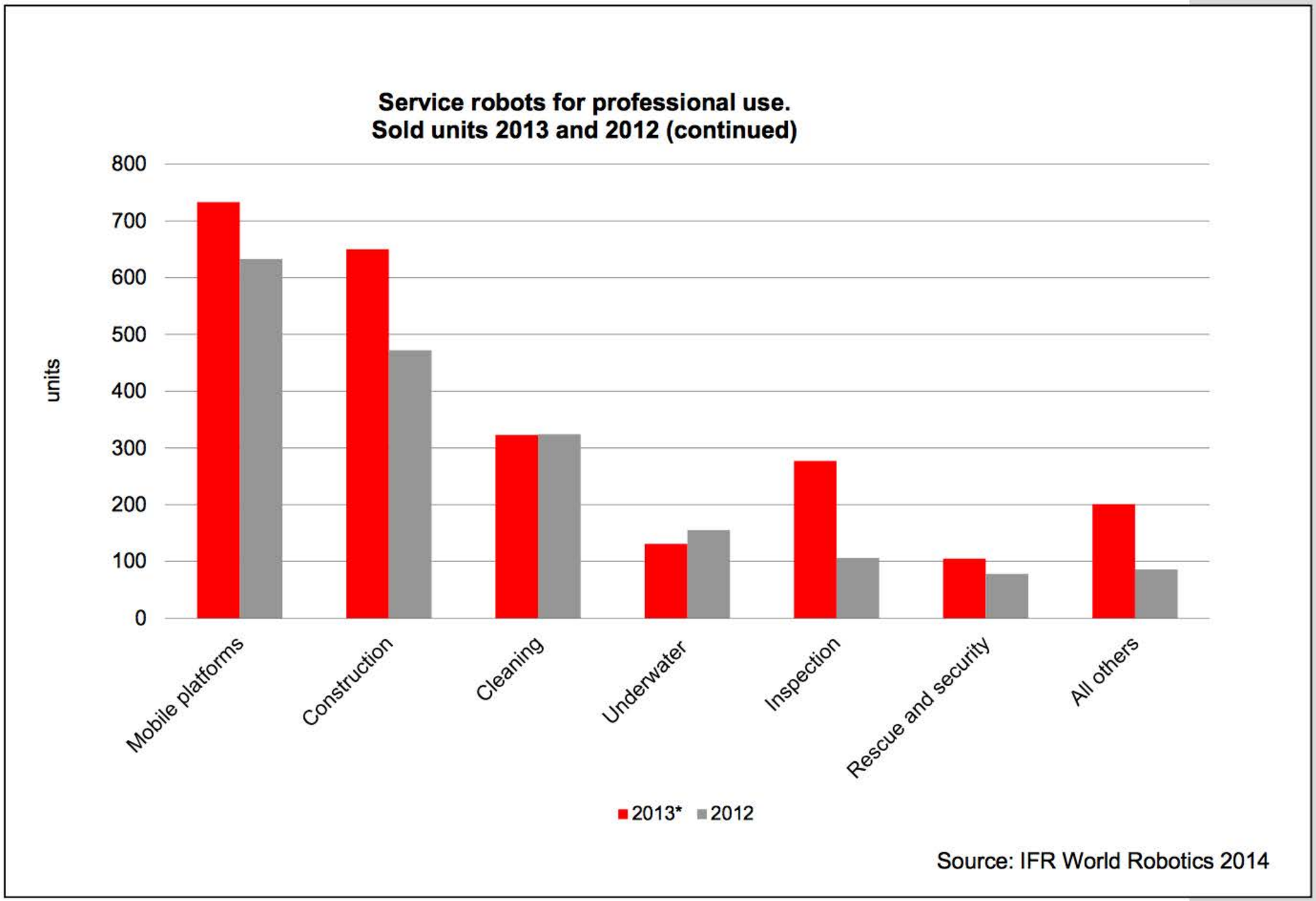

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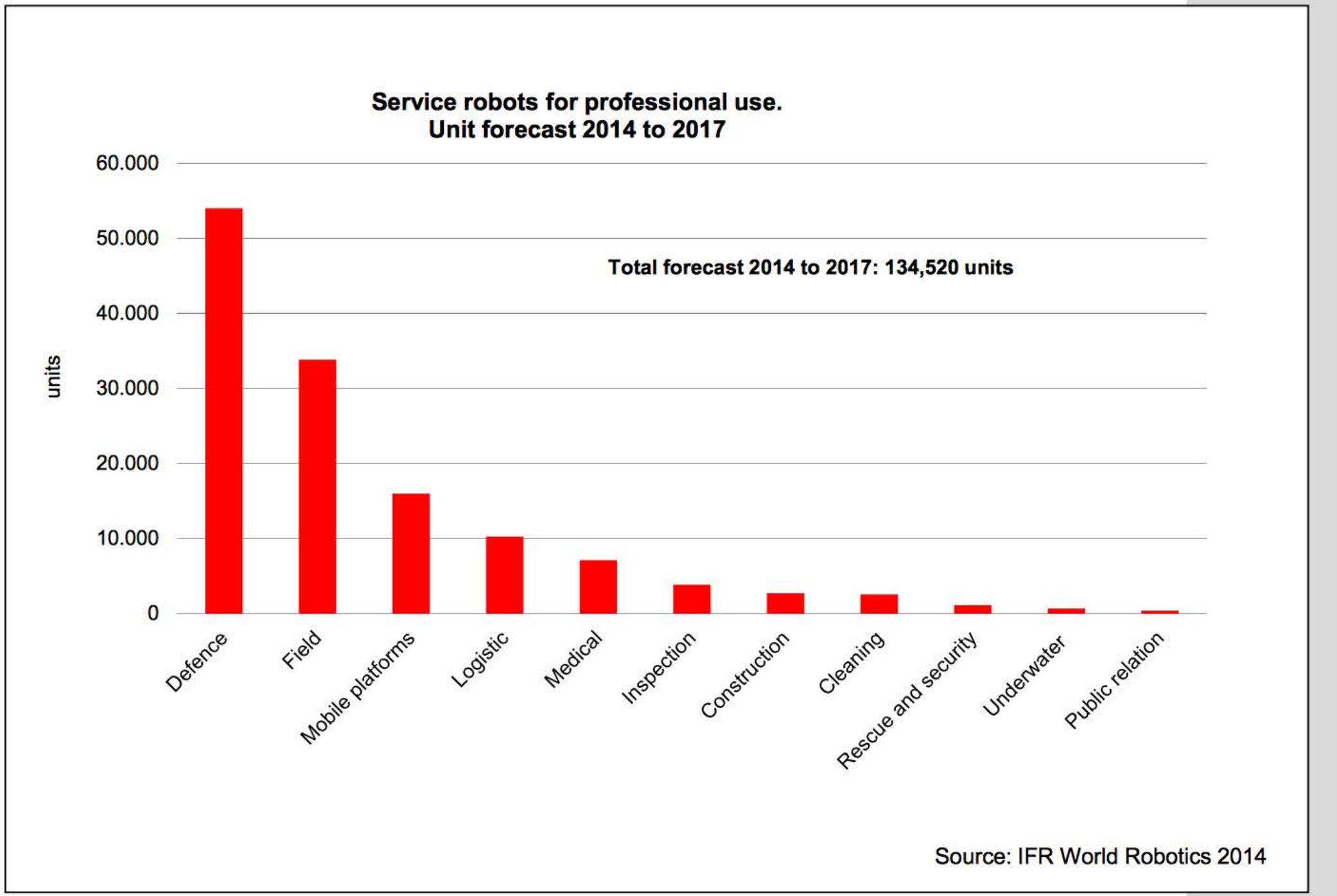

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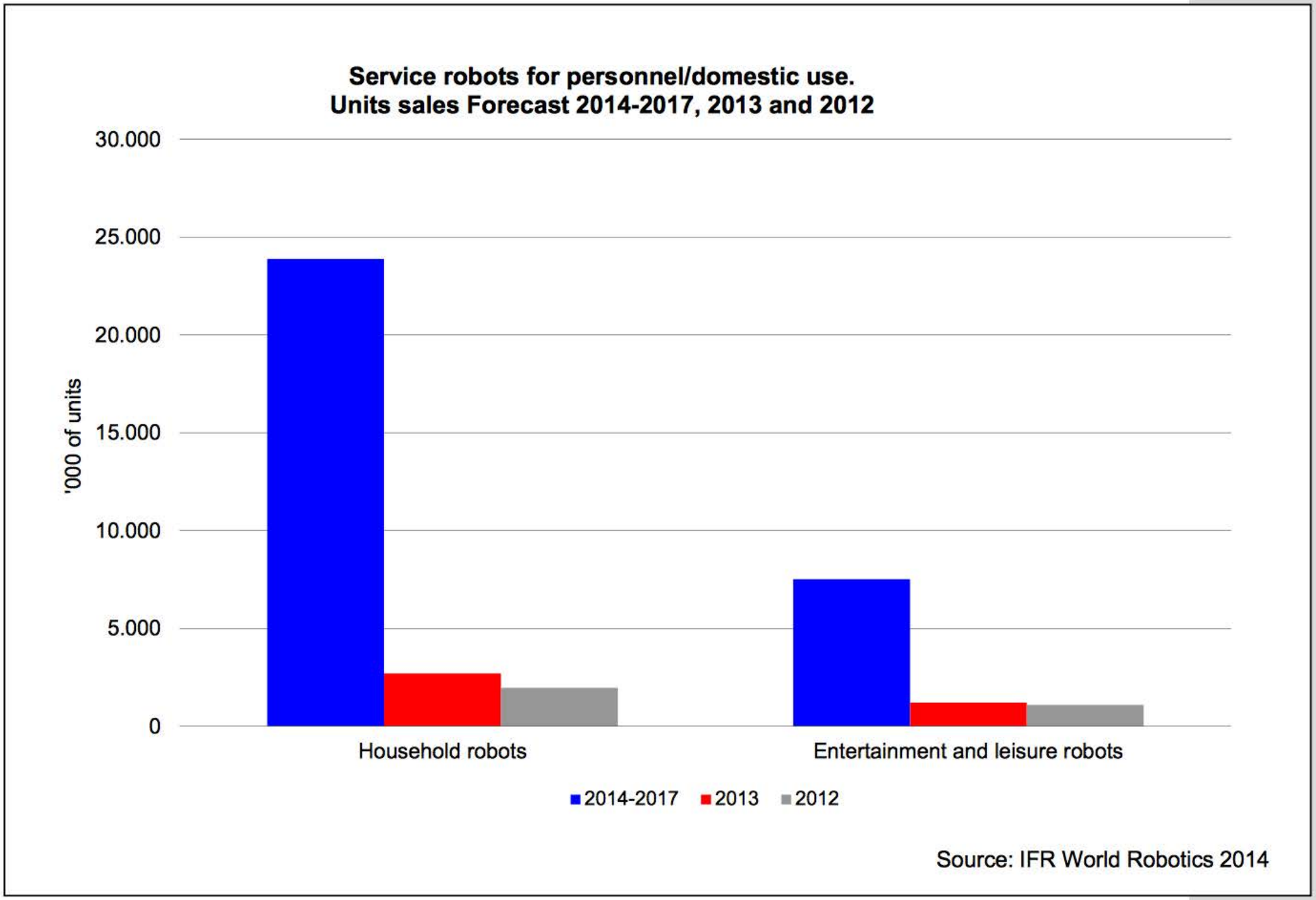

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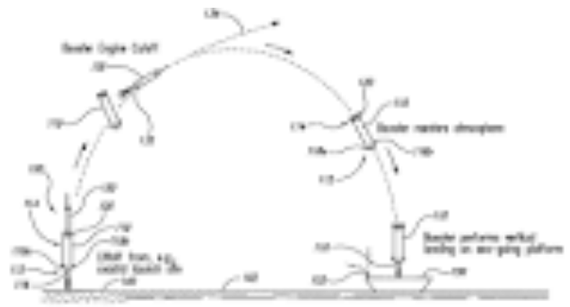
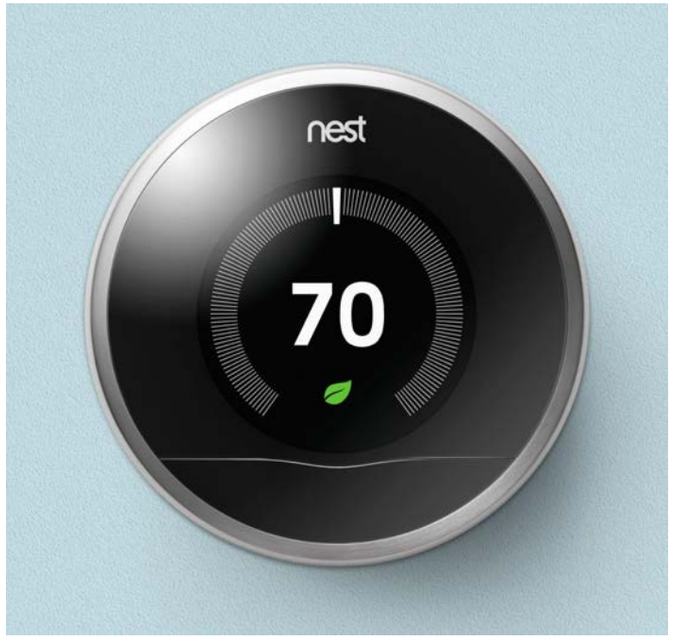




The Second Wave

The Second Wave

New applications (continued)

Societal issues/ Opportunities

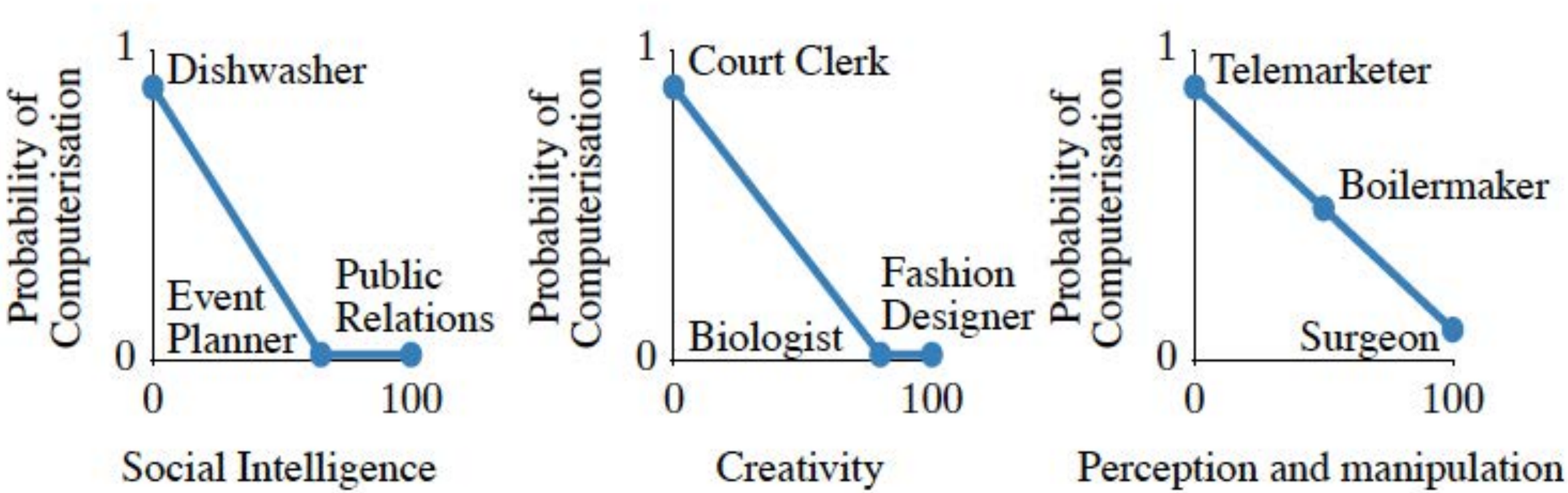


FIGURE I. A sketch of how the probability of computerisation might vary as a function of bottleneck variables.

TABLE I. O*NET variables that serve as indicators of bottlenecks to computerisation.

Computerisation bottleneck	O*NET Variable	O*NET Description
Perception and Manipulation	Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
	Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
	Cramped Work Space, Awkward Positions	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Creative Intelligence	Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
	Fine Arts	Knowledge of theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
Social Intelligence	Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
	Negotiation	Bringing others together and trying to reconcile differences.
	Persuasion	Persuading others to change their minds or behavior.
	Assisting and Caring for Others	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patients.

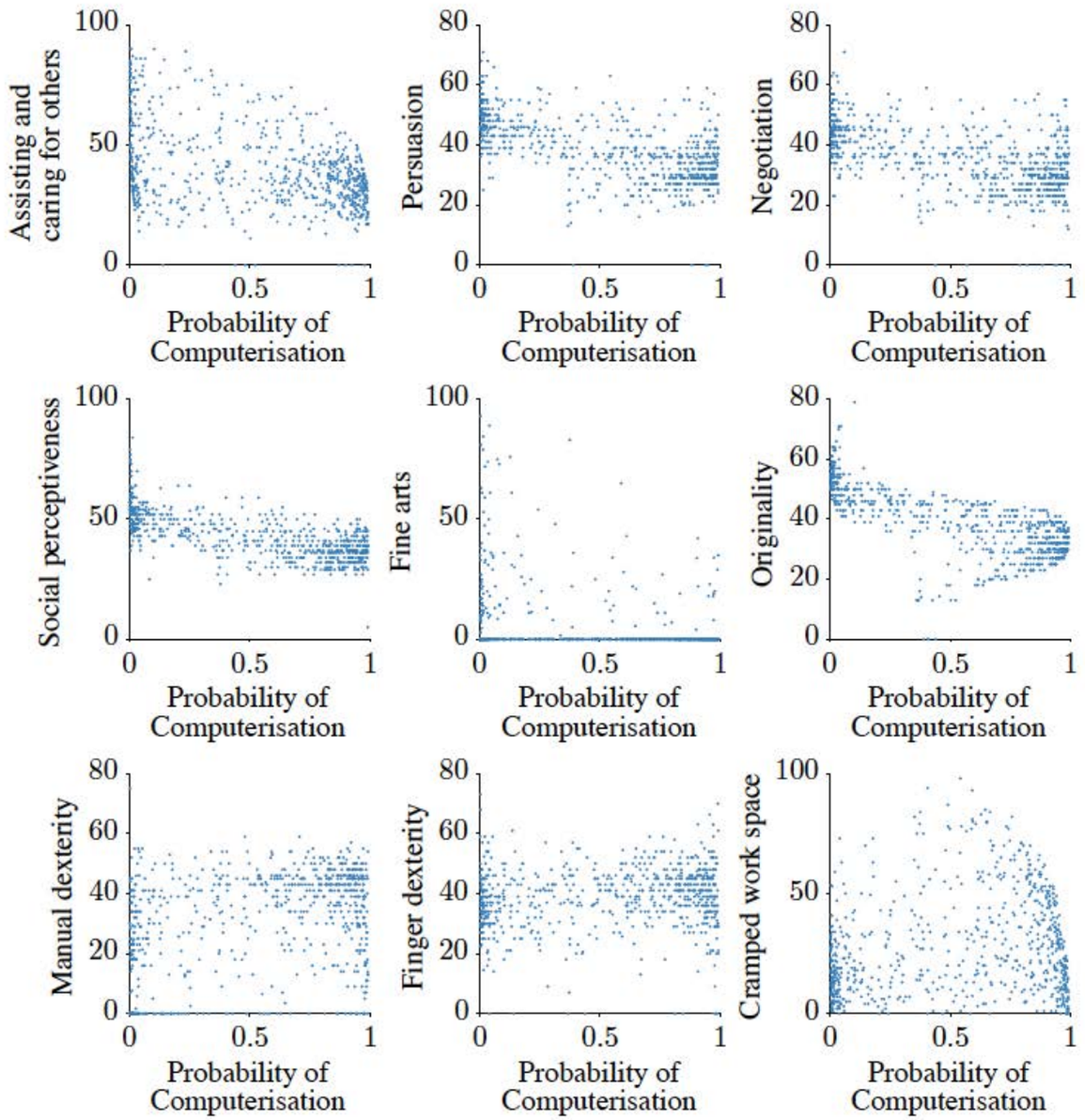


FIGURE II. The distribution of occupational variables as a function of probability of computerisation; each occupation is a unique point.

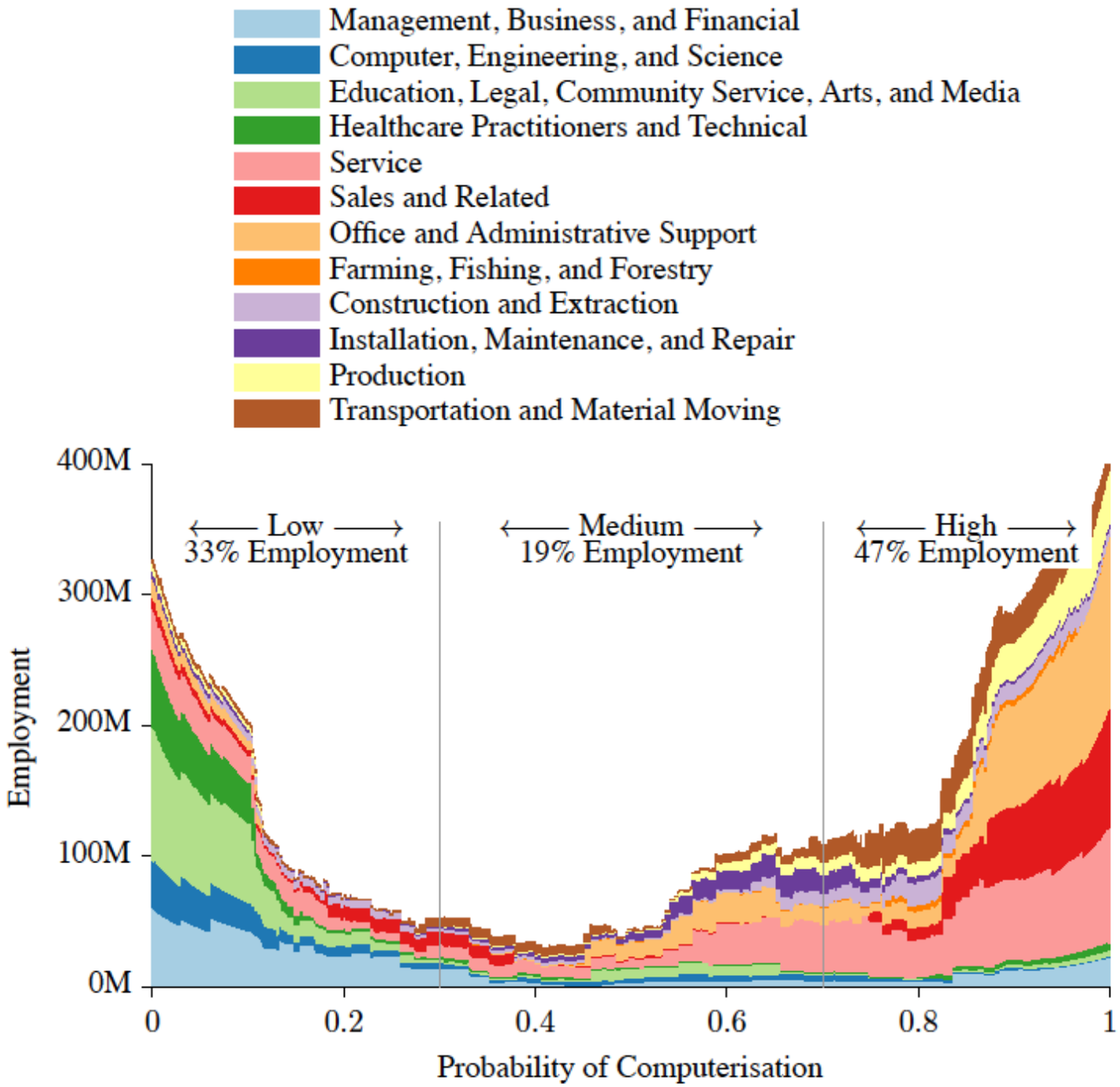


FIGURE III. The distribution of BLS 2010 occupational employment over the probability of computerisation, along with the share in low, medium and high probability categories. Note that the total area under all curves is equal to total US employment.

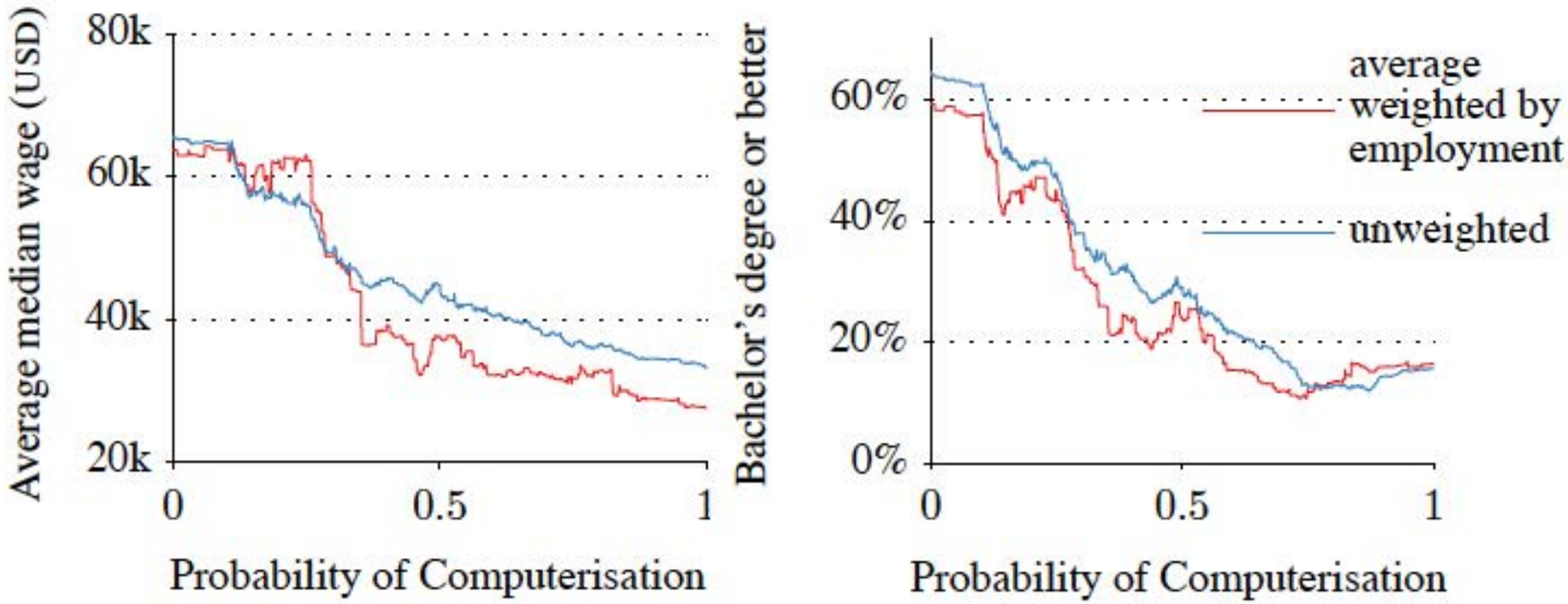


FIGURE IV. Wage and education level as a function of the probability of computerisation; note that both plots share a legend.

The evolution of robotics in the second wave

“ Robots can fundamentally change how work gets done. They can match human performance and even improve upon it in many areas. To prepare for and profit from the robotic megatrend, companies can start by identifying the following:

Areas of Operations with High Labor Costs. Robotics can provide cost-saving alternatives in many areas and complement human workers in others.

Tasks That People Can’t, Won’t, or Shouldn’t Do. Some jobs are too hazardous, unpleasant, or difficult for human beings—no matter how high the pay. Other tasks are just too mindless, repetitive, and boring. Robots can liberate workers from hazardous or unappealing jobs.

Human Skill Gaps. In Japan, developers are exploring ways robots might provide nursing and elder care. Other scarce and needed skills and capabilities that robots can offer—such as data mining, rapid analysis, and super speed or strength—exist at levels not present in human beings.

Mission-Critical Applications. Tasks that demand exceptional precision, flexibility, or speed—such as electronic-chip production—or that require maneuvering in small spaces lend themselves to robotics.

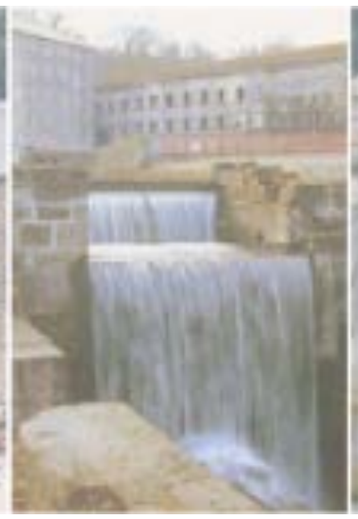
High Complexity. The global nature of business has given rise to convoluted supply chains and vast supplier networks. Robotics offers a way to centrally manage and execute complex logistics and to customize products for different markets and even for individual customers. The evolution of robotics (fabio:i.e., textile and shoes)”

Alison Sander, Meldon Felgong, Boston Consulting Group, BCG’s Center for Sensing & Mining the Future

Yet *we still have problems*….while in the auto industry….

It is *not even possible to think of selling a car not produced by a huge number of robots* in an highly automated plant. A similar situation occurs for many other products (washing machines, big pieces of equipment etc….)

in the textile industry….

Although the first cotton mill at Cromford, Derbyshire, UK, is usually considered the first example of a modern factory (the spinning jenny is considered one of the first modern industrial machines)….

the level of automation reached in this field of manufacturing engineering is *far from* being *complete*.

in the textile industry….

This is the current situation

The next generation of robots will realize longstanding visions of robotics researchers and also of industry, transforming daily life on a scale potentially comparable to the internet.
The secret of the coming "**robotics revolution**" will be a profound re-thinking of robotics, based on an **intimate fusion of science and technology**.

Interview to Paolo Dario, World Economic Forum, March 2015
https://agenda.weforum.org/2015/03/qa-what-will-the-robots-of-the-future-look-like/

WORLD ECONOMIC FORUM

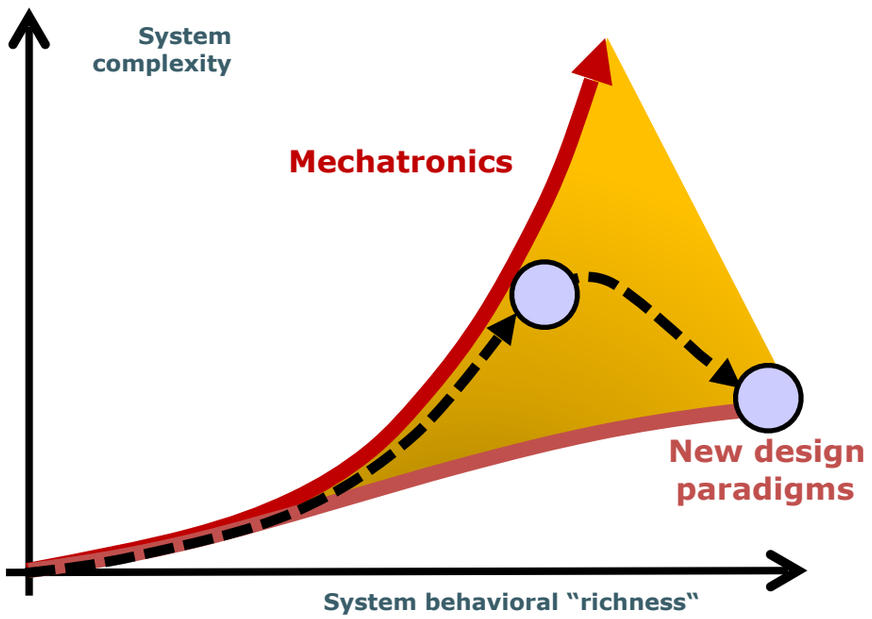
Q&A: What will the robots of the future look like?

"Next generation robotics" is one of 10 emerging technologies of 2015 highlighted by the World Economic Forum's Meta-Council on Emerging Technologies.

The market of robots grows, but it faces a bottleneck

By using current mechatronic technologies, more functionality means

- **more** complexity, energy, computation, cost
- **less** controllability, efficiency, robustness, safety



While targeting advances on established technologies, in parallel we need to RETHINK current design paradigms, and to explore a new one pursuing **SIMPLIFICATION** and **INTEGRATION**

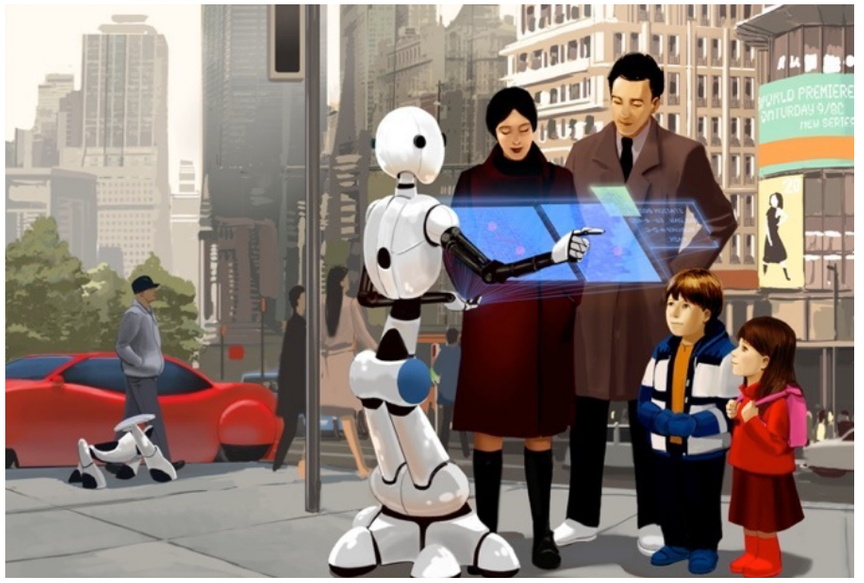
A whole new Robotics

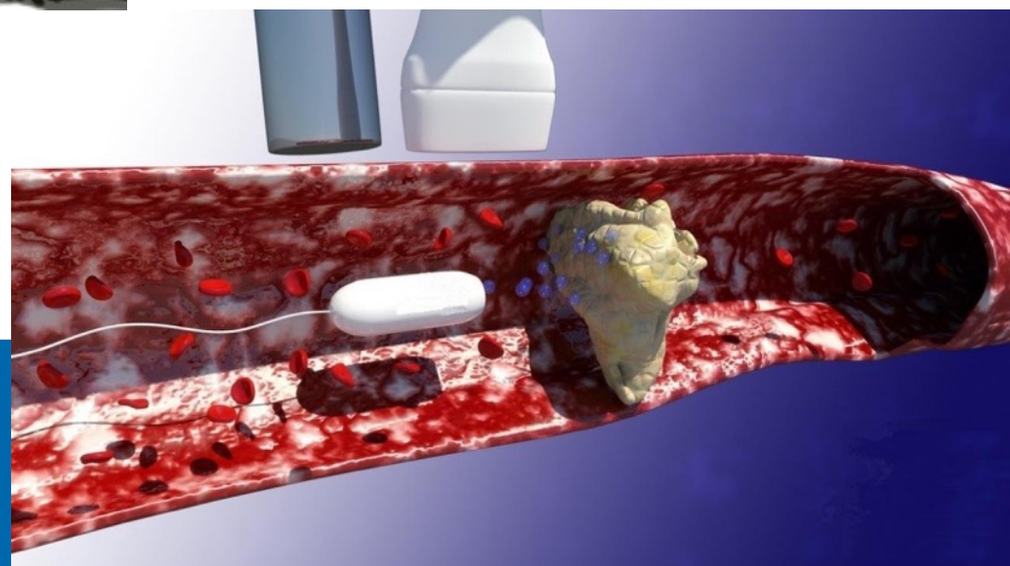
We need *simplification mechanisms and new materials*, *fabrication technologies* and *energy forms*

We want to tap
the biggest and most advanced treasure
of engineering solutions

- Studying natural organisms and understanding what makes them so smart and efficient
- Studying things only living organisms can do, and how they do it

A new generation of bionic companions will come!





Focusing on the **BODY** of future biorobots and exploring a different paradigm: **SIMPLIFICATION** and **INTEGRATION**

less **components**
higher **rubustness**
lower **computation load**
higher **energy efficiency**
higher **adaptivity**
higher **dependability**

Ultimately, lower cost

David

Our vision

Science grounded robotics

Sentience

Simplexity

Society

Morphological computation

Multifunctional nanomaterials and energy

New engineering

Others...

New European industry

New science

Robot Rescuer

Robot Housekeeper

New markets

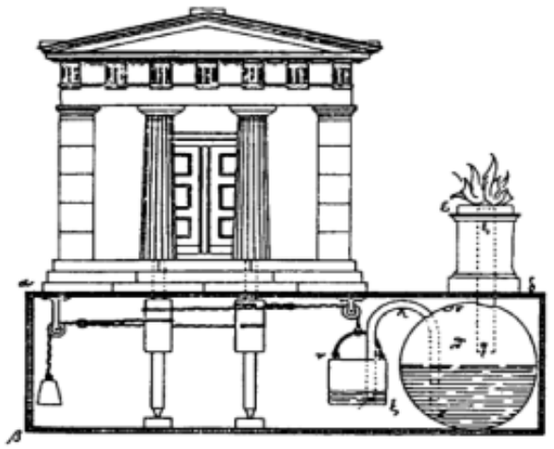
New jobs

Don’t take anything for granted

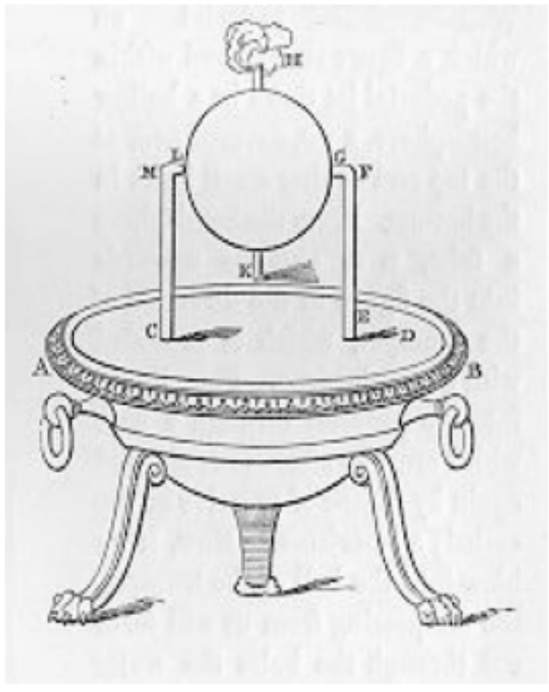
Hero or (Heron of Alexandria), who lived in the first century BC, invented the aeolipile, an early example of steam engine, almost two thousand of years before Watt

He designed many automatons and automatisms, mostly for leisure and entertainment, or religious purpose, in the hellenistic age.

The ancients never used steam engine (or automaton) for practical purposes. Why?



„Tempeltüren öffnender Automat“ des *Heron v. Alexandria*
(aus *Περι Αυτοματοποιητικης* um 50 n. Chr.)



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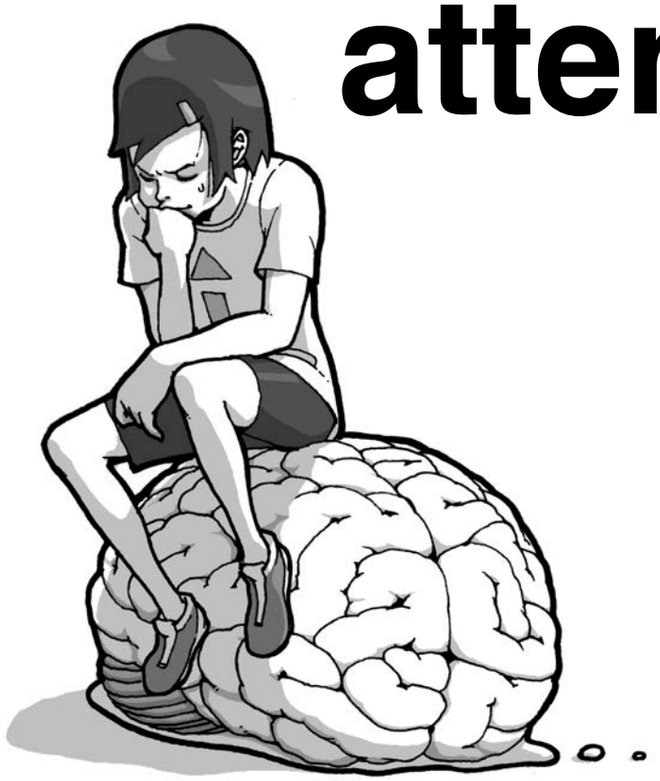
Scuola Superiore Sant’Anna

End of Lectures

Thank you for your attention!



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