Occupational Robotics:

An Emerging Field

John Howard
National Institute for Occupational Safety and Health

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Overview

- Human and robot capabilities
- Theory of the robot
- Occupational robotics
  - Types and Uses
  - Benefits and Risks
- Ethics, Economics, and Job Loss
- Occupational Data Analytics

Human Capabilities

- Humans have three major capabilities:
  - Physical
  - Cognitive
  - Emotional

- Machines that can perform any of these three human capabilities are commonly known as “robots.”
  - Robot derives from Czech word “robota,” meaning forced labor
  - *R.U.R*. (Rossum’s Universal Robots) is a 1920 play by Karel Čapek

The Theory of the Robot

- Model we use to describe how a robot works is as follows:
  - The robot **senses**, the robot **thinks,** and the robot ***acts***…

- How?
  - **Sensing** is done through interpretation of data from environmental sensors.
  - **Thinking** is done through the use of machine learning and deep learning—both forms of artificial intelligence.
  - **Action** is done through *effectors* for robots operating *in physical space*, or through data outputs from intelligent assets *operating in virtual space*.

Sensing

Sensor Technology Is Expanding

- **Enabling capabilities increasing exponentially**
  - Improvements in measurement science
    - Powered by high-speed and low-cost electronic circuits, novel signal processing methods, and advanced manufacturing technologies
  - Readily available geographic and spatial information locators
  - Miniaturization of sensing instruments
  - Promising technical solutions increasing the quality, reliability, and economic efficiency of technical products.

- **Types of Sensors**
  - Placeables
    - Air, water environment
    - In-vehicle monitoring
  - Wearables
    - Clothing
    - Hard hats
  - Implantables
    - Ingested and transcutaneous

Internet of Things (IoT)

- **Sensors are at the heart of the Industrial Internet**
  - Deploying sensors, the entire workplace and everything and everyone in it can become data inputs.
  - Workplace sensors become intelligent assets operating in physical and virtual space.

- **Sensor data can be easily uploaded to the cloud**
  - Sensor connectivity
  - Sensor upgradability

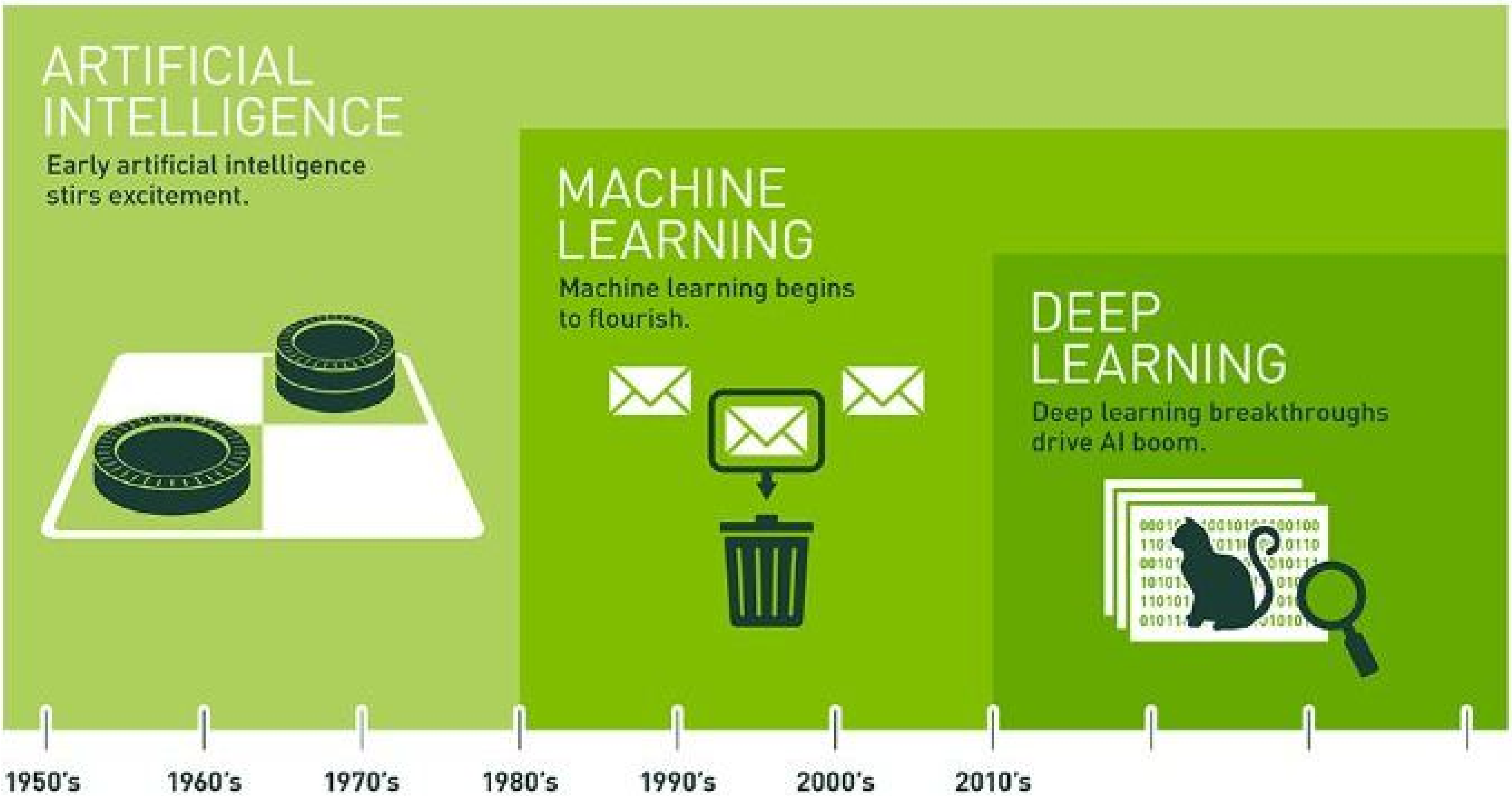
- **Cloud-based sensor data inputs create field of occupational data analytics**
  - Placing sensors, interpreting data inputs and developing sensor-derived controls
    - Occupational data scientist
  - Maintaining sensors
    - Technician

Marty Ellis, of Inman Mills in South Carolina, checks a machine manufacturing fabric developed through AFFOA.

Wearable Sensors: Functional Fabrics

- **DEFENSE**
  Functional fabrics will lighten soldiers' gear, enhance situational awareness on the battlefield, and decrease fratricide. High value-added products based on advanced woven & nonwoven technologies.
- **TRANSPORTATION**
  Join the wave of intelligent transportation systems with functional fabrics.
- **MANUFACTURING MACHINERY**
  Producing new fibers and textiles will require next-generation equipment and machinery.
- **ARCHITECTURAL & INTERIOR TEXTILES**
  'This old house' can now monitor, act, and re-act all by itself.
- **APPAREL**
  Smart clothes that can cool, change color, adjust size, last longer, mask or transmit odors, take photos, and so much more.
- **SOFTWARE & DATABASES**
  IT combined with functional fabrics enables highly insightful and useful information.
- **MEDICAL TEXTILES & SCANNERS**
  Clothing that can detect impending medical events and save lives.
- **RAW MATERIALS**
  Manufacturers of advanced functional materials for fibers and fabrics.
- **CONSUMER ELECTRONICS**
  Enabling the "internet of wearables" transforming apparel into consumer electronics.

Thinking


ARTIFICIAL INTELLIGENCE
Early artificial intelligence stirs excitement.
MACHINE LEARNING
Machine learning begins to flourish.
DEEP LEARNING
Deep learning breakthroughs drive AI boom.
1950's
1960's
1970's
1980's
1990's
2000's
2010's

Intelligence

Type	Simulation Potential	Human Tools	Description
Visual-Spatial	Moderate	Charts, graphs, 3-D modeling, video	Mobile robots require this capacity, but is proving difficult to simulate
Kinesthetic	Moderate	Specialized equipment—da Vinci surgical device	Differentiate between human augmentation and truly independent moves
Creative	None	New patterns of thought, inventions, innovations	For AI to create, it would have to possess self-awareness
Interpersonal	Low	Any form of communication	Computers can answer questions because of key word inputs
Intrapersonal	None	Privacy, time, diaries, books	Human kind of intelligence only
Linguistic	Low	Spoken words, books, games, voice recorders	Computers don’t separate written and spoken linguistic like the human brain
Logical/Mathematical	High	Logic games, mysteries, and brain teasers	When computer beats human at a game—only form of intelligence computer has

Artificial Intelligence

- **Central idea**
  - You can represent reality by using a mathematical function that an algorithm (stepwise procedure) does not know in advance, but which it can guess after seeing some data, recursively accuracy of the probability guess.

- **Origin**
  - At a 1956 Dartmouth College workshop computer scientists predicted that machines that could reason as well as humans would require, at most, a generation to come about. We think of this as "General AI."
  - They were wrong and several AI winters followed.
  - And then in 2010s, AI exploded because of the wide availability of (1) **GPUs** that make parallel processing ever faster, cheaper, and more powerful; (2) practically infinite **storage capacity**; and (3) a flood of data (***big data***).

  - **How does artificial intelligence come about?**

Machine Learning:

Approach to Achieve Artificial Intelligence

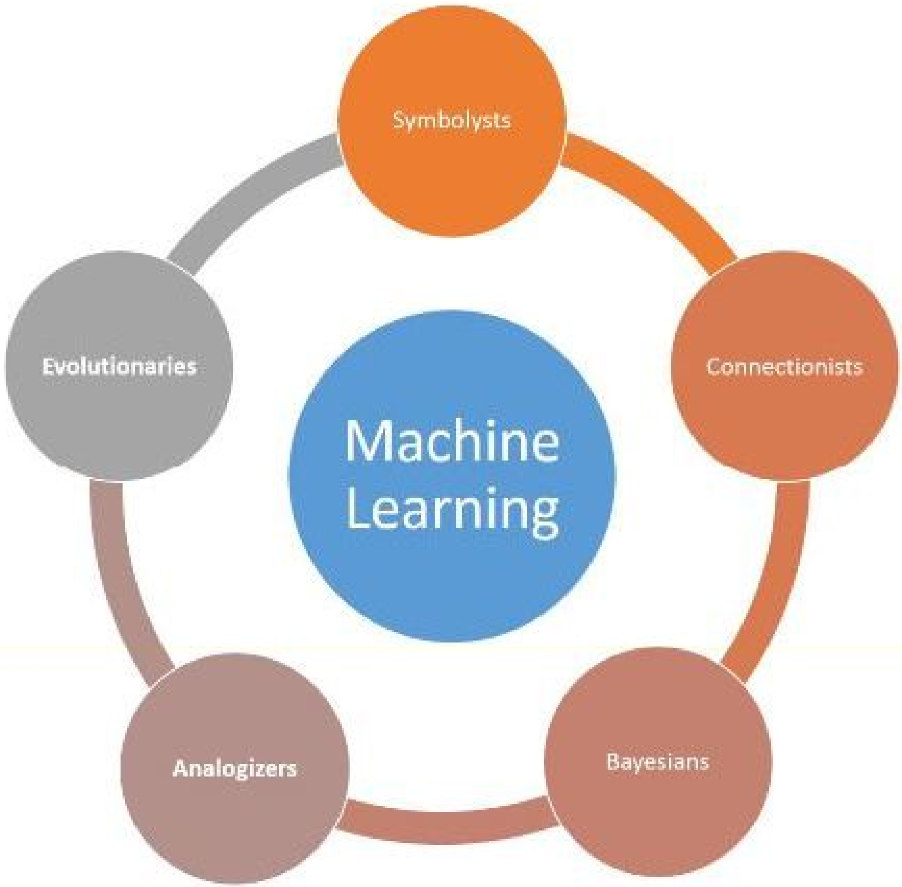
- Machine learning at its most basic is the practice of using algorithms to parse data, learn from it, and then make a determination or prediction about something in the world.

- Machine is “trained” using large amounts of data and algorithms that give it ability to learn how to perform the task more and more accurately.

- Machine learning came from original AI thinkers and includes 5 major “schools of algorithmic approaches.”

Machine Learning

- **Symbolists***
  - Rules from data, e.g., decision trees
- **Connectionists***
  - Reproduce brain's functions using silicon instead of neurons using backpropagation of errors.
- **Evolutionists**
  - Uses recursion to generate algorithms that evolve.
- **Bayesians***
  - Learning occurs as continuous updating of previous beliefs.
- **Analogizers**
  - Uses similarity to determine best solution to a problem.



Recent Milestones: Narrow AI

- **2011**
  - AI researchers around the world discovered NVIDIA GPUs. The Google Brain project had learned to recognize cats and people by watching movies on YouTube. But it required 2,000 CPUs in servers powered and cooled in one of Google's giant data centers.

- **2012**
  - Alex Krizhevsky of the University of Toronto won the *ImageNet* computer image recognition competition. He beat — by a huge margin — handcrafted software written by computer vision experts. Krizhevsky wrote no computer vision code. Rather, their computer learned to recognize images by itself. They designed a network and trained it with a million example images that required trillions of math operations on NVIDIA GPUs.

- **2015**
  - Using deep learning, *Google* and Microsoft both beat the best human score in the ImageNet challenge. Shortly thereafter, *Microsoft* announced a Deep Neural Network that achieved IQ test scores at the college post-graduate level. Then *Baidu* announced that a deep learning system called Deep Speech 2 had learned both English and Mandarin with a single algorithm.

Machine Learning: Achievements

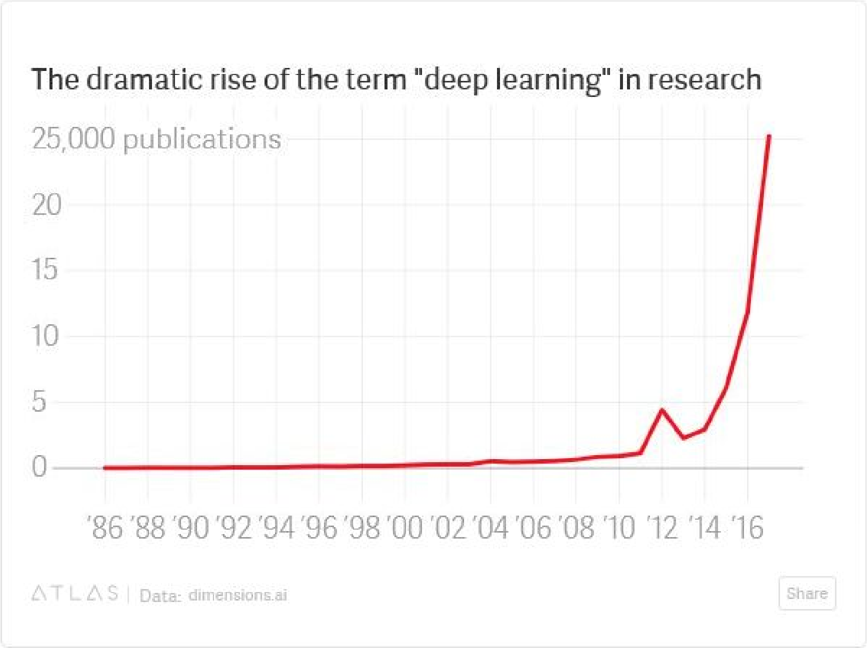
- Machine-learning technology powers many aspects of modern society: from web searches to content filtering on social networks to recommendations on e-commerce websites, and it is increasingly present in consumer products such as cameras and smartphones.

- Machine-learning systems are used to identify objects in images, transcribe speech into text, match news items, posts or products with users' interests, and select relevant results of search.

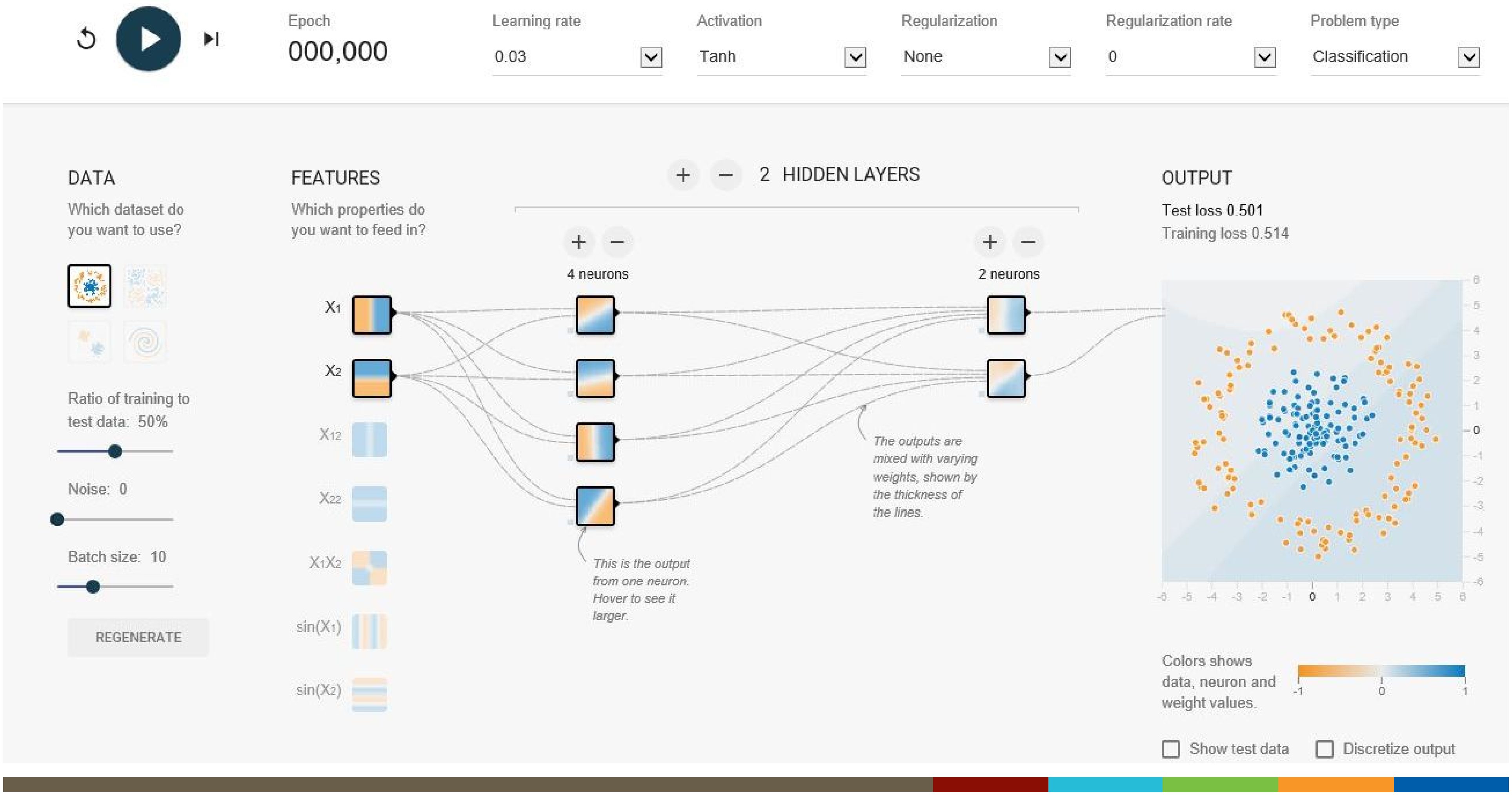
- Increasingly, these applications make use of a class of ML techniques called **deep learning**.

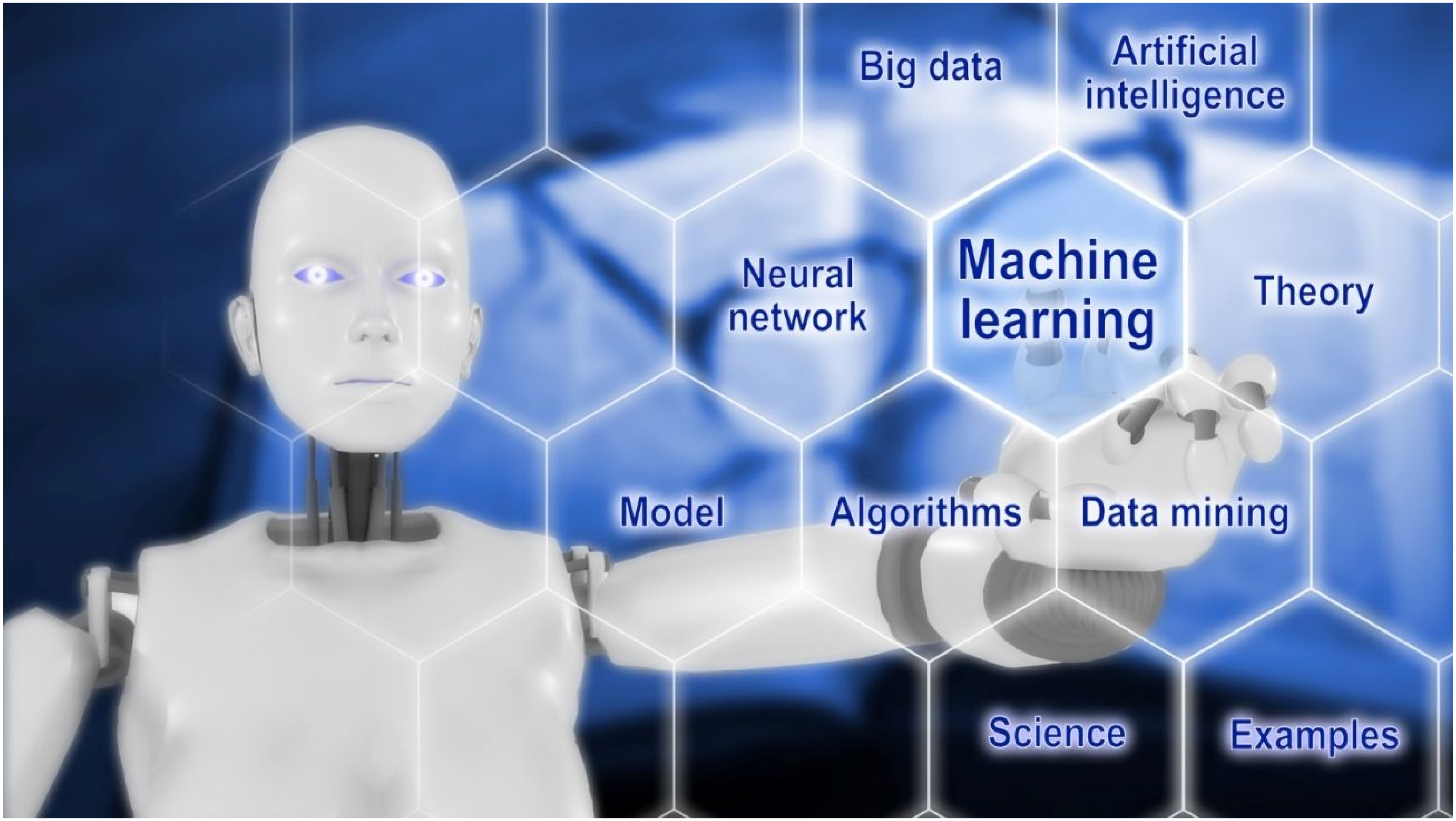
Deep Learning--Connectionists

- Technique for building an algorithm that learns from data. It is based very loosely on how we think the human brain works.
  - First, a collection of software "neurons" are created and connected together, allowing them to send messages to each other.
  - Next, the *neural network* is asked to solve a problem, which it attempts to do over and over, each time strengthening the connections that lead to success and diminishing those that lead to failure.



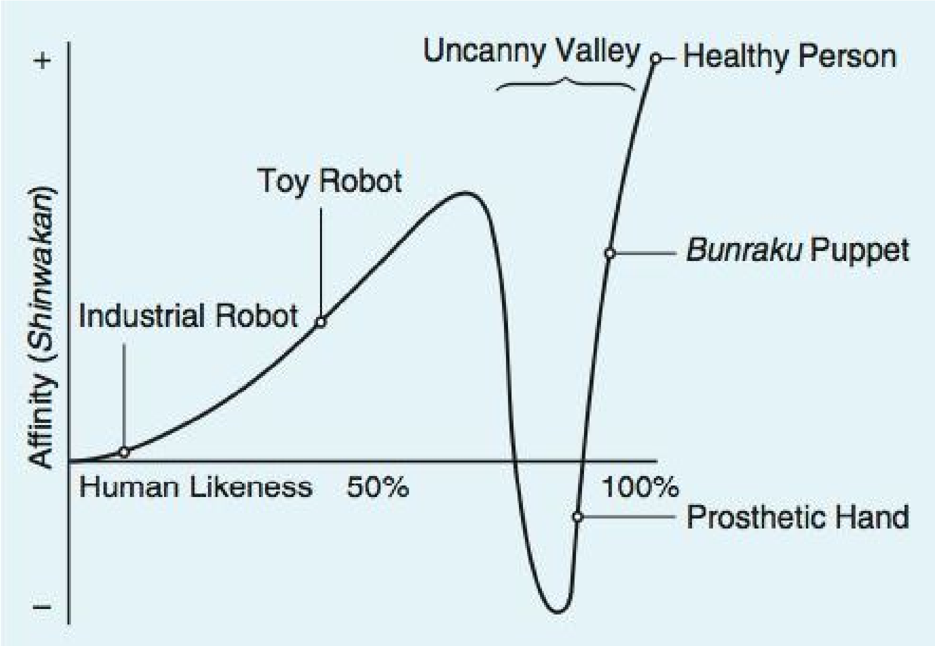
- Open source framework at http://playground.tensorflow.org/


Epoch
000,000
Learning rate
0.03
Activation
Tanh
Regularization
None
Regularization rate
0
Problem type
Classification
DATA
Which dataset do you want to use?
Ratio of training to test data: 50%
Noise: 0
Batch size: 10
REGENERATE
FEATURES
Which properties do you want to feed in?
X1
X2
X12
X22
X1X2
sin(X1)
sin(X2)
2 HIDDEN LAYERS
4 neurons
2 neurons
This is the output from one neuron. Hover to see it larger.
The outputs are mixed with varying weights, shown by the thickness of the lines.
OUTPUT
Test loss 0.501
Training loss 0.514
Colors shows data, neuron and weight values.
Show test data
Discretize output


Big data
Artificial intelligence
Neural network
Machine learning
Theory
Model
Algorithms
Data mining
Science
Examples

Creating a Humanoid Robot: Uncanny Valley

- If we need humanoid robots because we want them to assist humans, we must also consider their level of realism to allow users to accept help.
- Even robots with little human resemblance generate attachment.
- U.S. soldiers report feeling loss with their small tactical robots for explosives detection and handling are destroyed in action.
- https://www/technologyreview.com/s/609074/how-we-feel-about-robots-that-feel/



Acting

Occupational Robotics

- New field of practice for safety and health practitioners

- Robotic capabilities:
  - In physical space
    - Manipulators (robot arms)
    - Mobile
      - Flying robots or drones
      - Robotic-controlled truck platoons
      - Self-driving cars
    - Humanoid
  - In virtual space
    - Intelligent assets

- Risky interactions between human and robot workers?

Organizational Profile

- **Superior Performance**
  - Robot workers are simply better than people at precise and repetitive tasks
  - With perfect memories, internet connectivity, and high-powered processors for data analysis, robots can also provide informational support beyond human capabilities.
    - Keep perfect record of project progress
    - Provide real-time scheduling and decision support
    - Have perfect recall
  - Can complete dangerous tasks
    - Venturing into dangerous environments
    - Completing hazardous activities
- **Managerial Cognitive Capabilities**
  - Remind a team of deadlines, procedures, and progress
- **Operational Cost Reduction**
  - Human employees cost money—30 to 40% more than salary in benefits
  - Costs barely $8 an hour to use a robot for spot welding in the auto industry, compared to $25 for a worker—and the cost savings gap is only going to widen.

Commercial Types of Robots

- **Traditional Industrial robots**
  - Fixed in location
  - Humans and robots are separated
- **Collaborative robots**
  - Designed to work together with humans
- **Service robots**
  - Autonomous ground vehicles
  - Unmanned aerial vehicles
  - Household service robots
- **Social Robots**
  - Detect and express human emotion
  - Act as companions
- **Wearable Robots**
  - Exoskeletons

Traditional Industrial Robots

- Decades of safety experience
- Used since the 1970s in auto manufacturing industry
- Safety measures that keep human workers ***separated*** from robot workers

Industrial Robots: Safety Record

- Estimated 61 robot-related deaths, 1992-2015, CFOI*
  – Identified using keywords
- < 1% of more than 190,000 workplace injury deaths during that timeframe**

*Unpublished analyses by NIOSH. Through a MOU with BLS, NIOSH receives Census of Fatal Occupational Injury (CFOI) research files with restricted access requirements. Views expressed herein to not necessarily reflect the views of BLS.
** Data from publicly available CFOI data.

Collaborative Robots or Cobots

ROBOTICS

Collaborative Robots: Risk and Challenge

- Designed to work alongside human workers.
- Controlled by human workers, by an algorithm, or by both.
- Equipped with sensors designed to stop robot when contact with human worker occurs.
- Grasping a previously unknown object, one for which a 3-D model is not available, is a challenging problem.
  - https://berkeleyautomation.github.io/dex-net/

Filling a bin with objects for the Dex-Net 4.0 robot grasping research. Credit: Adriel Olmos, UC Berkeley


ELEMENTS OF
ORDINARY

Service Robots: Large Vehicles

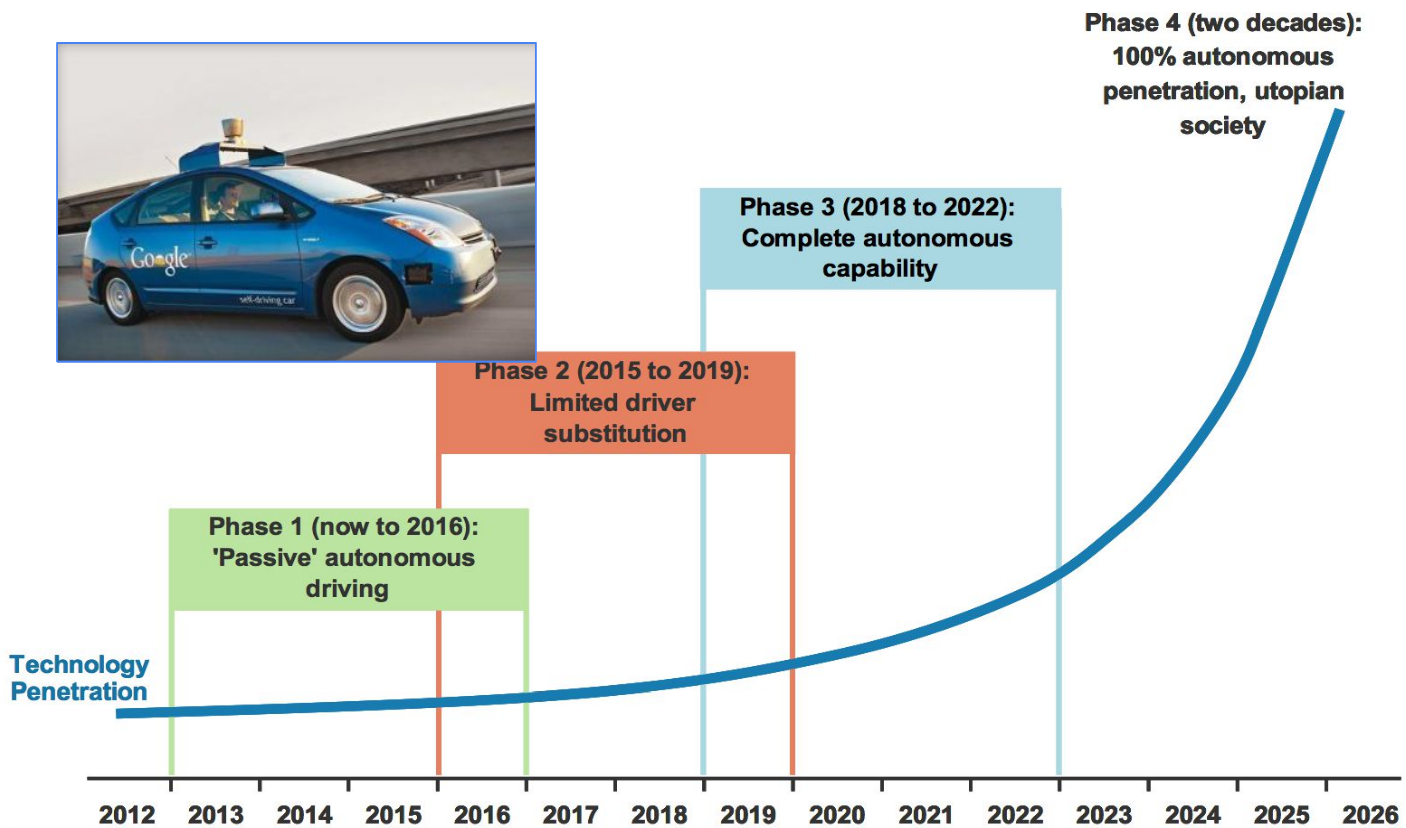
- Service robots used by Rio Tinto in Pilbara, Western Australia
  - No coffee breaks, fatigue and driver changeovers.
  - Stops only once a day for refueling.
- Engineers at Rio's operations center in Perth (2 hours flight away) remotely control trucks.
- Workforce at the mine is already about one-third lower as a result of automation.
- Autonomy enables drilling to run for almost a third longer on average than with manned rigs, and to churn through 10% more meters/hour.

Service Robots: Truck Platoons

- **Safety**
  - With the following trucks braking immediately, with zero reaction time, platooning can improve traffic **safety**.
- **Cost**
  - Platooning is also a **cost-saver** as the trucks drive close together at a constant speed. This means lower fuel consumption and less CO_2 emissions.
- **Efficiency**
  - Platooning **efficiently** boosts traffic flows thereby reducing tail-backs. Meanwhile the short distance between vehicles means less space taken up on the road.

Service Robots: Self-Driving Cars

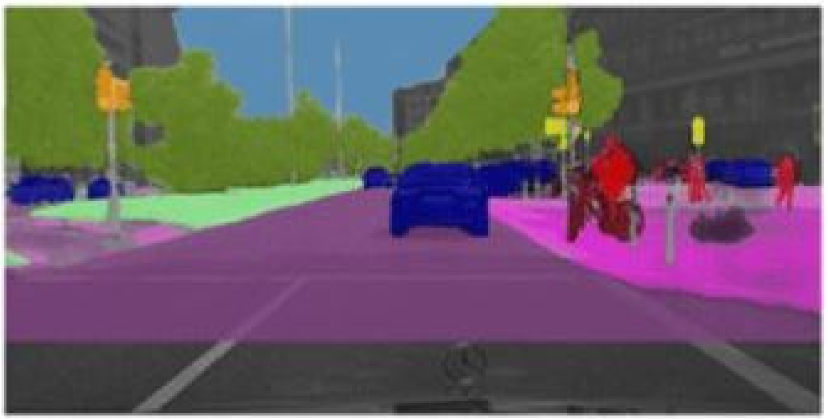
Timeline for Adoption



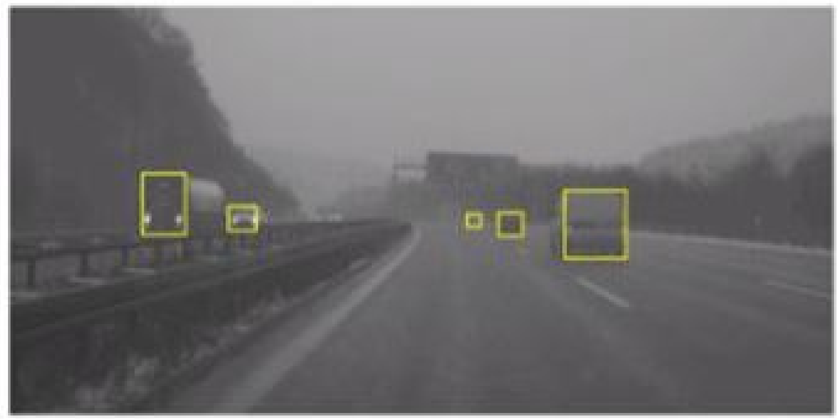
Source: Company data, Morgan Stanley Research

Self-Driving Car Challenge: Computer Vision

- You can't write software that anticipates every possible scenario a self-driving car might encounter. That's the value of deep learning; it can learn, adapt, and improve. Science is building an end-to-end deep learning platform called NVIDIA DRIVE PX for self-driving cars — from the training system to the in-car AI computer.

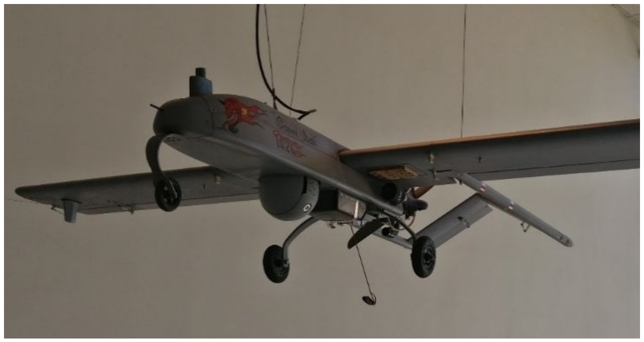


Daimler was able to bring "the vehicle's environment perception a significant step closer to human performance and exceed the performance of classic computer vision" with NVIDIA DriveNet.



Using a dataset from our partner Audi, NVIDIA engineers rapidly trained NVIDIA DriveNet to detect vehicles in an extremely difficult environment — snow.

Service Robots: UAVs



Military

Recreational

Public Safety

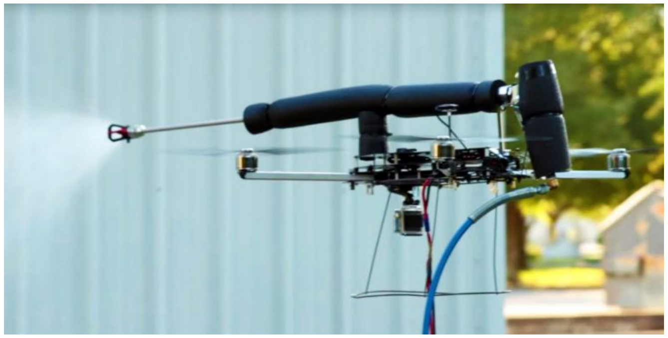
Commercial

UAVs Uses in Construction

Monitoring

Inspection

Maintenance



Hazardous Applications

Sources of Risk from UAVs

- **Engineering**
  - Errors in the drone's mechanics (e.g., loose connections across parts, faulty electronics and sensors).

- **Human**
  - Errors in programming, interfacing peripheral equipment, and connecting input/output sensors resulting in unpredicted movement or action by the drone;
  - Errors in judgment resulting from "over-attributing" to autonomous robots more human-like qualities and capabilities;
  - Errors in remote operating.

- **Environmental**
  - Unstable flying conditions, extreme temperature, poor sensing in difficult weather or lightning conditions leading to incorrect response

Service Robots: Ground Robots

- Automated Ground Robots
  - Currently operate in less controlled environments
    - May include human workers and manned vehicles
    - Agriculture and mining
    - Public roads and highways?

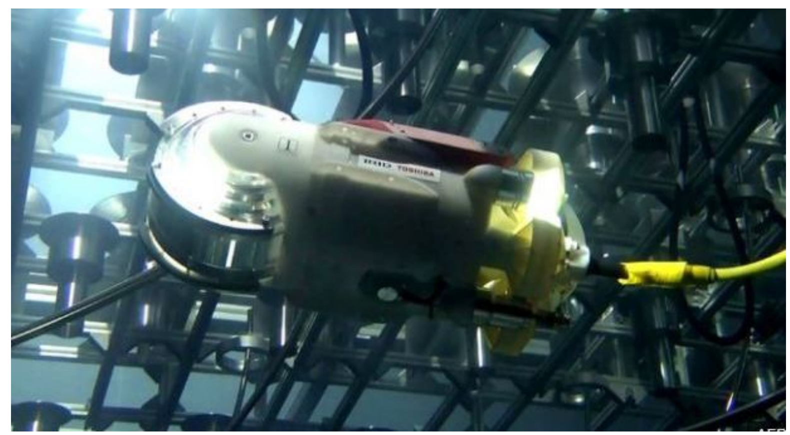
Newer Service Robots

- Move alongside, and in shared space, with human workers

Service Robot: 'Little Sunfish'

- When a tsunami devastated parts of Japan's coastline in 2011, killing more than 18,000 people, it also hit the Fukushima nuclear power plant, triggering the most serious nuclear accident since Chernobyl.

- Parts of the damaged reactors are still highly contaminated with radiation and robotics are playing a crucial part in the clean-up.



Service Robots—Some Not Ready Yet

MATT SIMON SCIENCE 12.06.17 05:00 PM

SAN FRANCISCO JUST PUT THE BRAKES ON DELIVERY ROBOTS

WIRED

Making Human Beings More Capable

Exoskeleton Robotics

- Mobile with the human and reduces mechanical stress on wearer
  - Rehabilitation for amputees
  - Robotic-assisted surgery (da Vinci)
  - Amplifies or transforms worker or warfighter movements
    - March or run longer with less fatigue
    - Increase lifting capacity

- Industrial market projected to grow 229% per year between 2016 and 2021
    - Suit X, U.S. Bionics
    - Winter Green Research, Inc. (2015). Wearable Robots, Exoskeletons: Market Shares, Market Strategies, and Market Forecasts, 2015 to 2021. https://www.marketresearchreports.biz/reports/716060/wearable-robots-industrial-exoskeletons-shares-market-research-reports.pdf

Exoskeleton Challenges

- Make power source light enough to work at human scale.
- In warehouses, a forklift truck typically weighs 1.6 to 2 times the intended weight to be carried.
  - For a 150 pound human worker intending to carry 200 additional pounds, that ratio would put the human's exoskeleton in the 650-pound range, unloaded, so that a fully loaded package would weigh about 1,000 pounds.
- Lowering the battery weight is the quickest way to shrink the weight of the total assembly—a great deal of battery power would be expended in simply carrying the battery and a frame sufficiently robust to support the battery.
- Finally, training a human to leave part of the task to a machine, and not to overthink the exoskeleton relationship will be a musculoskeletal safety challenge.

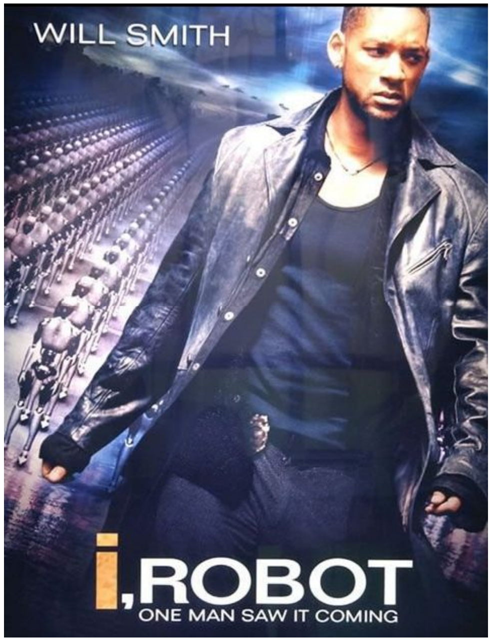
Robot Ethics

Robot Ethics: The Trolley Problem

- **Two cars sinking in the water**
  - Detective Del Spooner (Will Smith)
  - Young girl, Sarah

- **Robot could save only one of them, Spooner yells *"Save the girl!"***
  - Probability of survival for Spooner was 45%
  - Probability of survival for Sarah was 11%

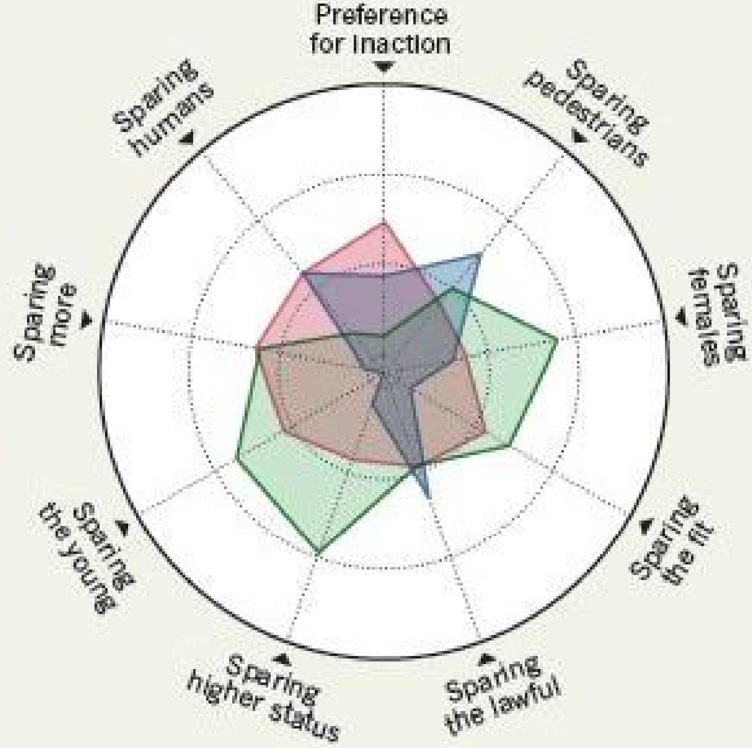
- **Robot saved Spooner; girl drowned.**



  - Fleetwood, J. Public Health, Ethics, and Autonomous Vehicles. *Am J Pub Health*. 2017; 107(4): 532-537

MORAL COMPASS

A survey of 2.3 million people worldwide reveals variations in the moral principles that guide drivers' decisions. Respondents were presented with 13 scenarios, in which a collision that killed some combination of passengers and pedestrians was unavoidable, and asked to decide who they would spare. Scientists used these data to group countries and territories into three groups based on their moral attitudes.



Western Eastern Southern

MORAL MACHINE

Home Judge Classic Design Browse About Feedback En

Welcome to the Moral Machine! A platform for gathering a human perspective on moral decisions made by machine intelligence, such as self-driving cars.

We show you moral dilemmas, where a driverless car must choose the lesser of two evils, such as killing two passengers or five pedestrians. As an outside observer, you **judge** which outcome you think is more acceptable. You can then see how your responses compare with those of other people.

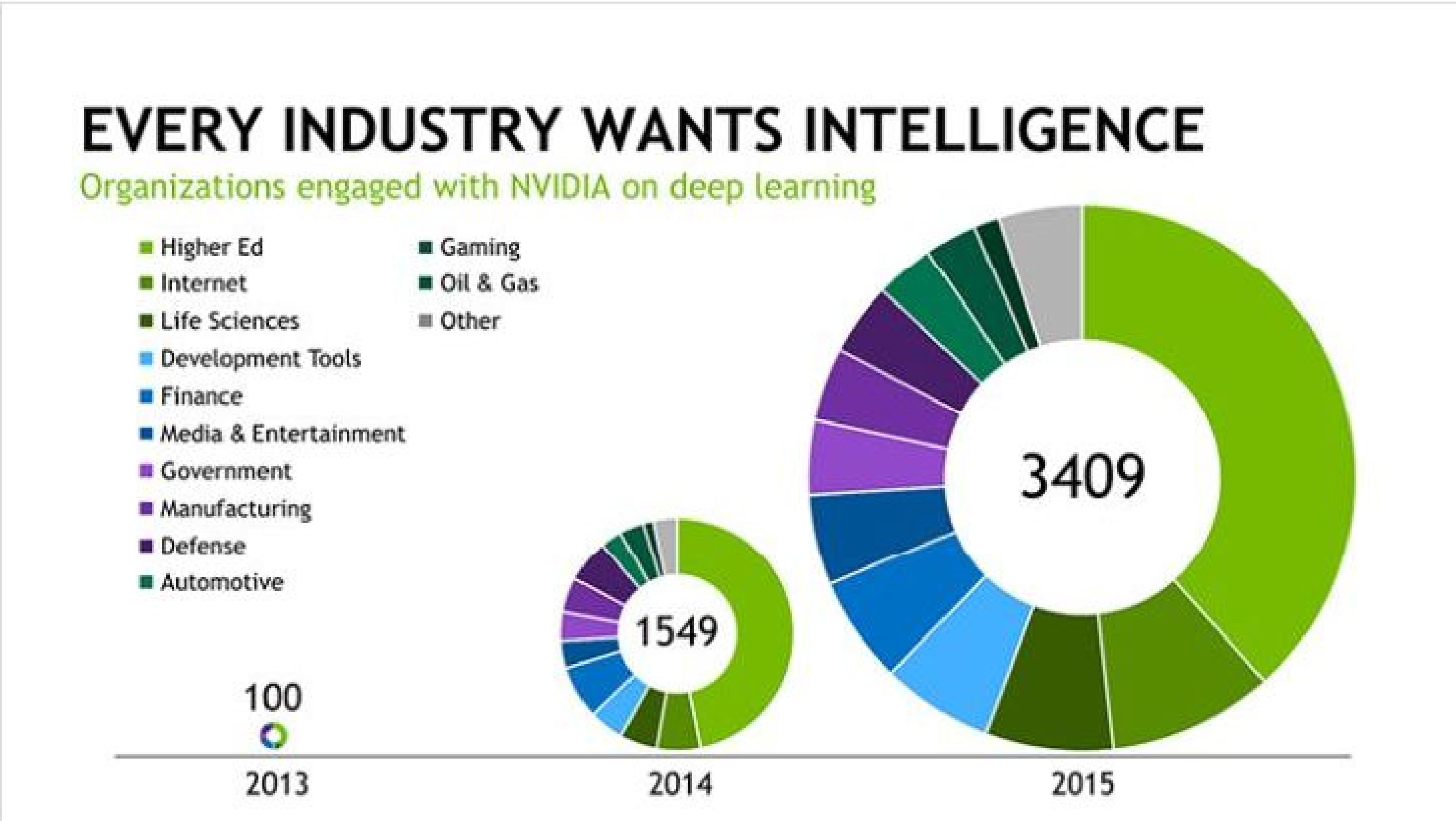
If you're feeling creative, you can also **design** your own scenarios, for you and other users to **browse**, share, and discuss.

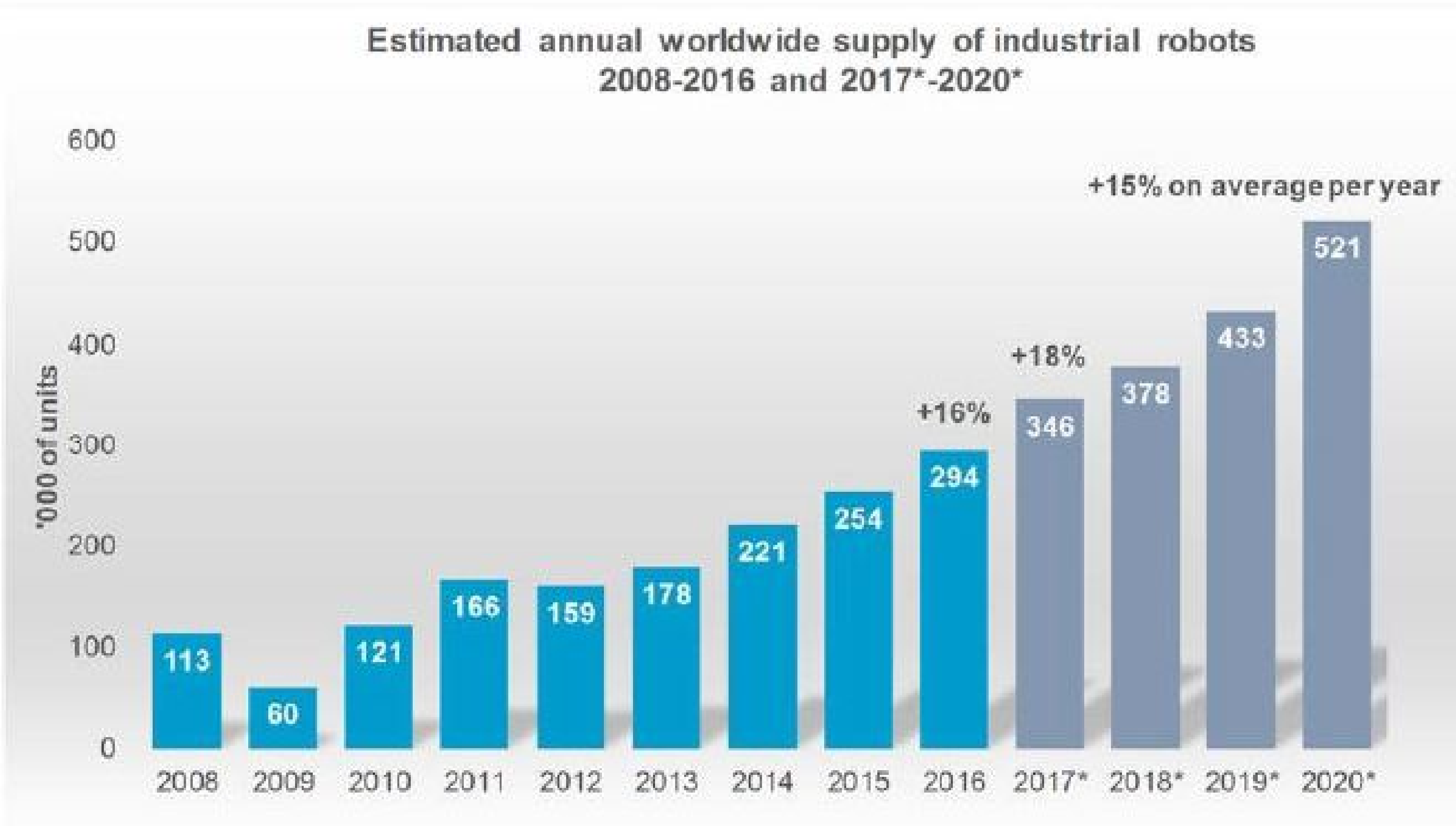
Start Judging

Browse Scenarios

View Instructions

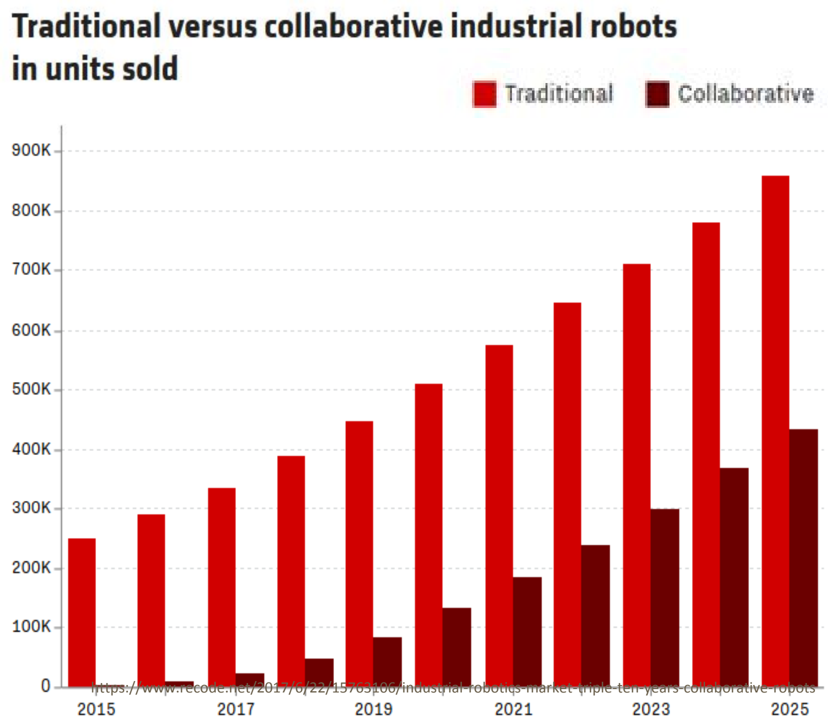
Robotics Industry Profile


EVERY INDUSTRY WANTS INTELLIGENCE
Organizations engaged with NVIDIA on deep learning
Higher Ed
Internet
Life Sciences
Development Tools
Finance
Media & Entertainment
Government
Manufacturing
Defense
Automotive
Gaming
Oil & Gas
Other
100
1549
3409
2013
2014
2015



Estimated annual worldwide supply of industrial robots
2008-2016 and 2017*-2020*
'000 of units
600
500
400
300
200
100
0
+15% on average per year
+18%
+16%
113
60
121
166
159
178
221
254
294
346
378
433
521
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017*
2018*
2019*
2020*

Robot Sales Are Increasing, Including Cobots

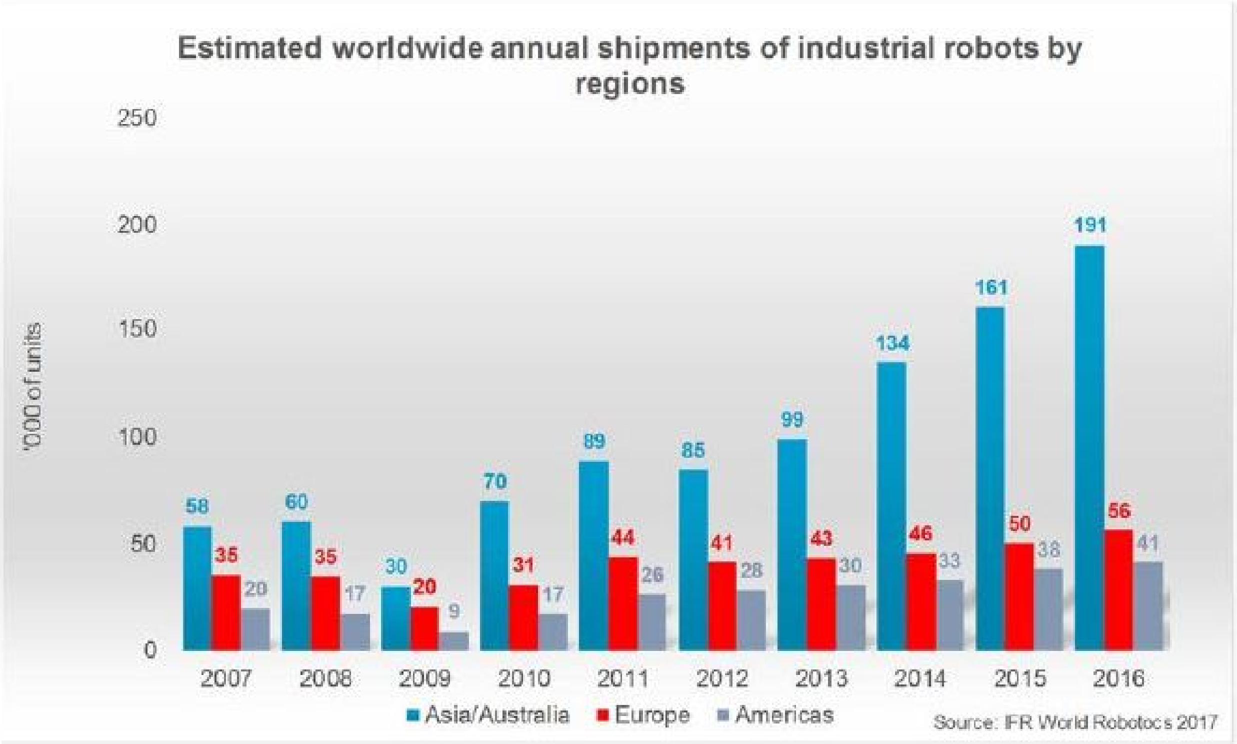


https://www.recode.net/2017/6/22/15763106/industrial-robotics-market-triple-ten-years-collaborative-robots

Regional Distribution

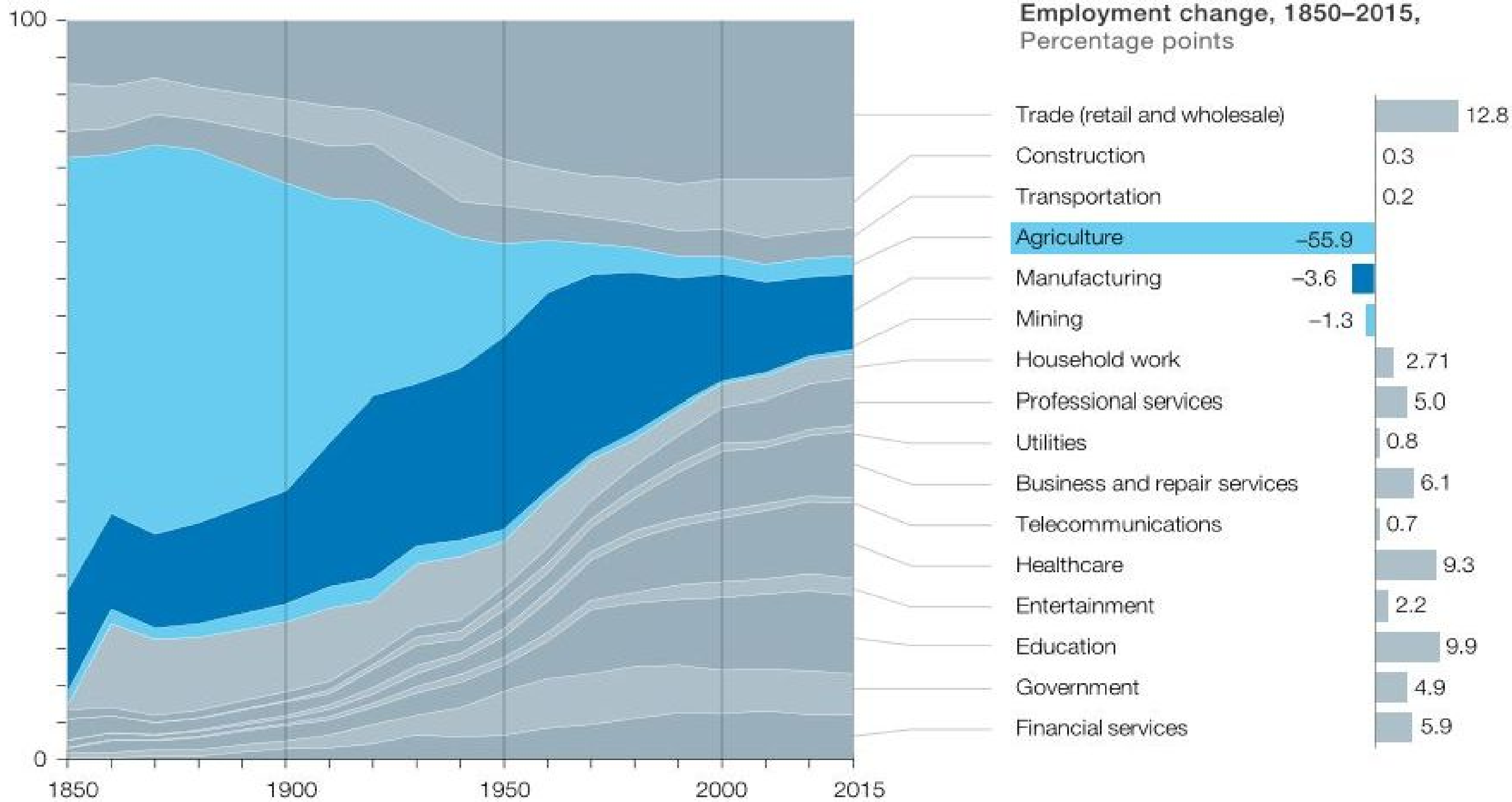
- There are five major markets representing 74% of the total sales volume in 2016: **China, the Republic of Korea, Japan, the United States, and Germany**.

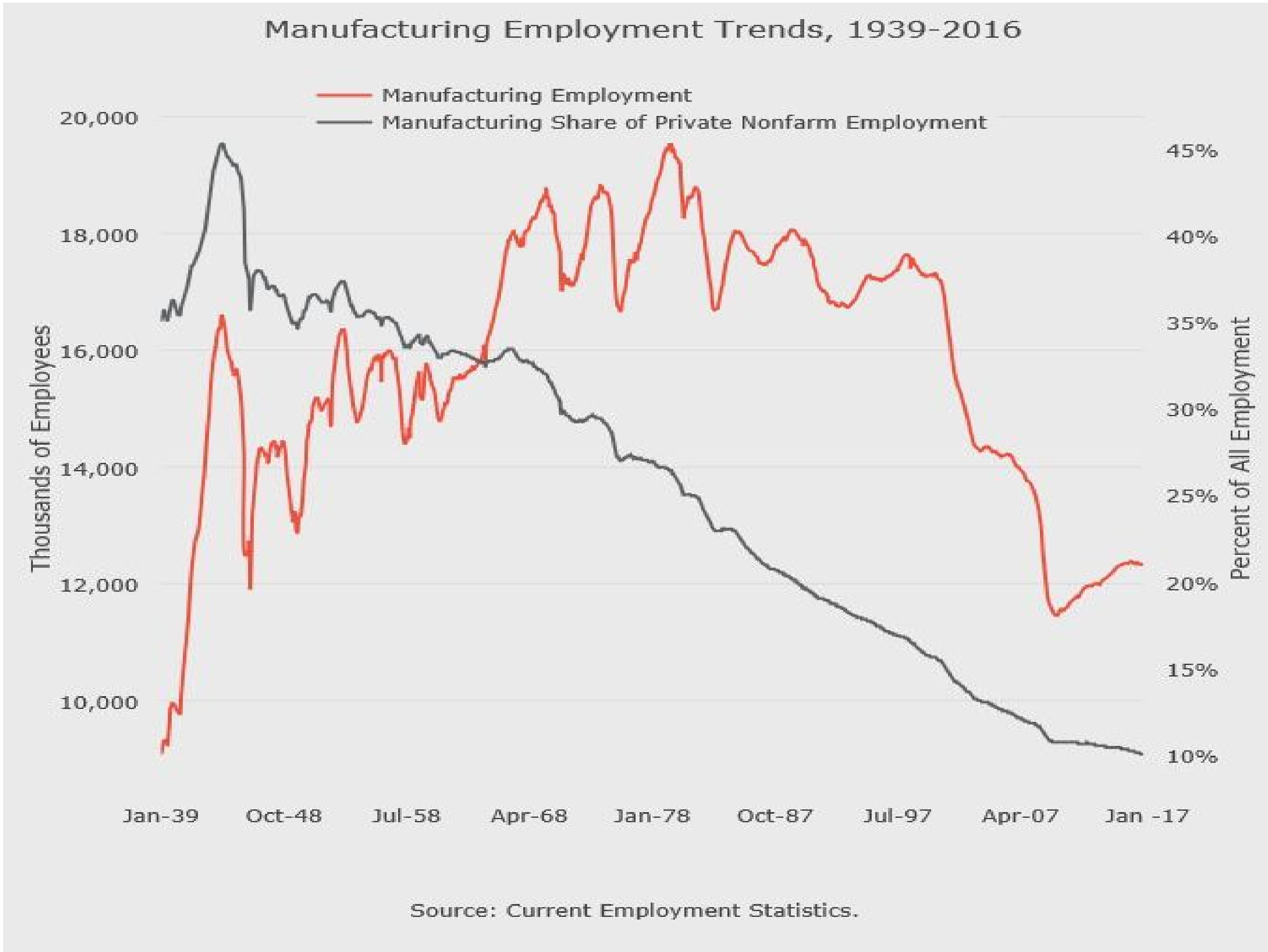
- Since 2013 China has been the biggest robot market in the world with a continued dynamic growth.



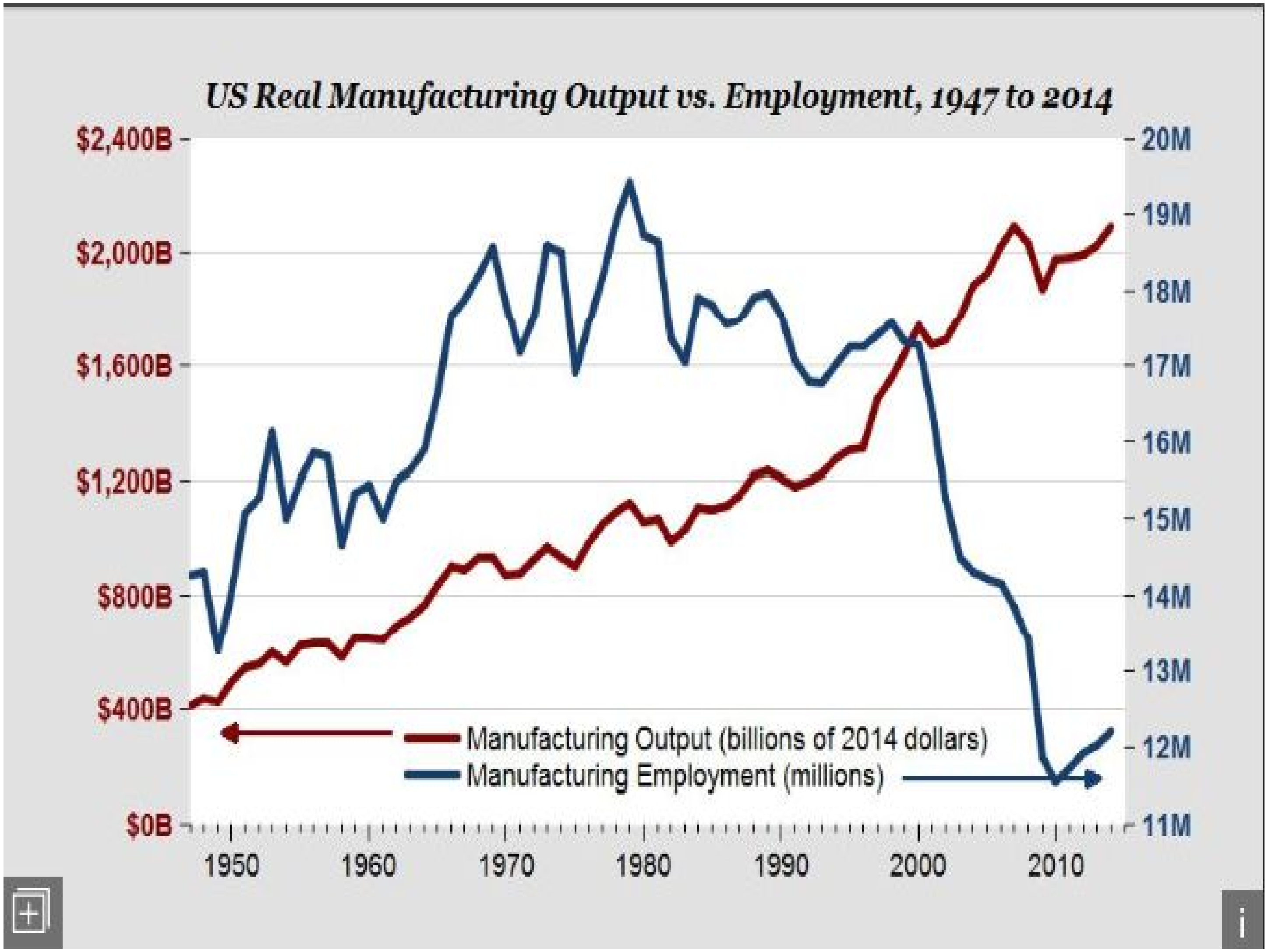
Robotic Automation and Job Loss:
The Case of Manufacturing

Share of total employment by sector in the United States, 1850–2015, % of jobs





Manufacturing Employment Trends, 1939-2016
Manufacturing Employment
Manufacturing Share of Private Nonfarm Employment
Thousands of Employees
20,000
18,000
16,000
14,000
12,000
10,000
Percent of All Employment
45%
40%
35%
30%
25%
20%
15%
10%
Jan-39
Oct-48
Jul-58
Apr-68
Jan-78
Oct-87
Jul-97
Apr-07
Jan -17
Source: Current Employment Statistics.



US Real Manufacturing Output vs. Employment, 1947 to 2014
$2,400B
$2,000B
$1,600B
$1,200B
$800B
$400B
$0B
20M
19M
18M
17M
16M
15M
14M
13M
12M
11M
1950
1960
1970
1980
1990
2000
2010
Manufacturing Output (billions of 2014 dollars)
Manufacturing Employment (millions)

Technology & Job Density

- In manufacturing, as in other industries, job density—the number of jobs per process—is declining.
- The reason—automation—and robotics—and advanced manufacturing techniques.
- More generally, the "job intensity" of America's manufacturing industries—and especially its best-paying advanced ones—is only going to decline.
- In 1980 it took 25 jobs to generate $1 million in manufacturing output in the U.S..
- Today it takes five jobs.

Job Loss:
Is it Technology or Trade?

- **It's Technology (Robots)**
  - Erik Brynjolfsson, MIT Sloan School of Management
    - *Race Against the Machine*
    - *Second Machine Age*
- **It's Trade (China)**
  - David Autor, MIT Department of Economics
    - *The China Syndrome: Local Labor Market Effects of Import Competition in the United States. American Economic Review 2013, 103(6): 2121–2168*

KIVA

A Kiva Systems robot can scurry about the floor of a large warehouse to find ordered products. It then fetches the correct rack or pallet and brings it to a worker who packages the goods.

Technological Unemployment

- Competition from China only explains about a fourth of decline in manufacturing during the 2000s.

- Skills mismatch, as manufacturing sector shifts from low-skilled to high-skilled work—has also contributed to the decline.

- Occupational polarization:
  - Workers involved in tasks that are fully *codifiable* are most vulnerable to replacement by automations--*substitute*
  - Workers, parts of whose jobs are *codifiable*, will experience dislocations--*complement*

- Technology is reshaping the skills need for work—enhancing cognitive skills over physical skills.

Substitute or Complement?

- In the workplace, robots can perform:
  - A job that a human worker once did
    - The robot acts as a *substitute* for a human worker.
  - The robot can assist a human worker to perform a job
    - The robot acts as a *complement* to a human worker.

Impact on the Global Workforce

Technical automation potential	**~50%** of current work activities are technically automatable by adapting currently demonstrated technologies	**6 of 10** current occupations have more than 30% of activities that are technically automatable

Impact of adoption by 2030

	Slowest	Midpoint	Fastest
Work potentially displaced by adoption of automation, by adoption scenario, % of workers (FTEs[1])	0% (10 million)	15% (400 million)	30% (800 million)
Workforce that could need to change occupational category, by adoption scenario,[2] % of workers (FTEs)	0% (<10 million)	3% (75 million)	14% (375 million)

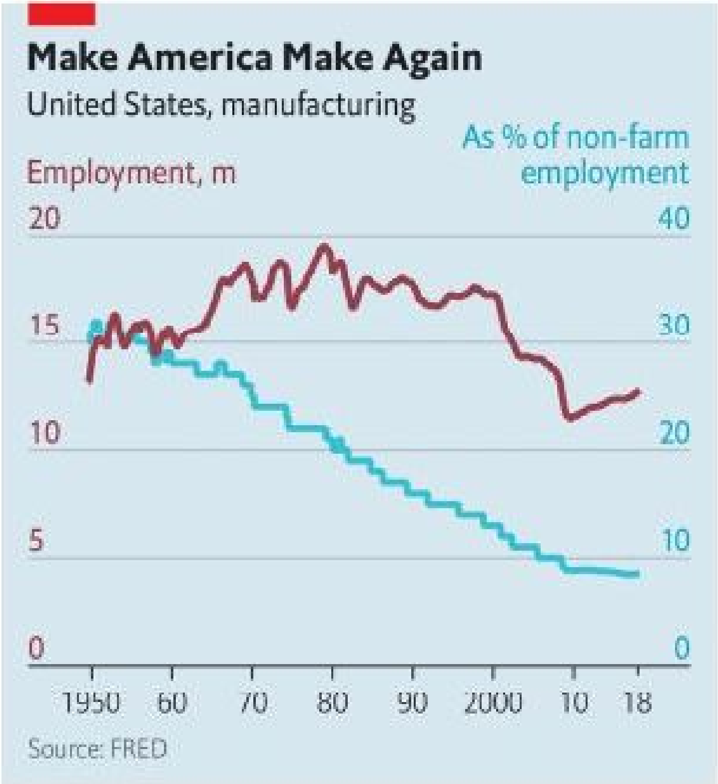
Impact of demand for work by 2030 from 7 select trends[3]

	Low	High
Trendline demand scenario, % of workers (FTEs)	15% (390 million)	22% (590 million)
Step-up demand scenario, % of workers (FTEs)	6% (165 million)	11% (300 million)
Total, % of workers (FTEs)	21% (555 million)	33% (890 million)

In addition, of the 2030 workforce of 2.66 billion, 8–9% will be in new occupations[4]

Recent Manufacturing Employment

- Employment composition has shifted toward managerial and professional jobs, and away from jobs that can be done with less schooling.



The Economist

Safety and Health Data Analytics: Role of AI

Worker Protection Informatics

- The ***science and practice*** of determining ***which sensor information is relevant*** to protecting worker safety, health, well-being, and productivity, and then developing and implementing effective ways:
  - To collect, validate, store, share, analyze, model, and apply the information,
  - To confirm achievement of the intended outcome from use of that information,
  - To convey experience to the broader community, contributing to generalized knowledge, and updating standards and training.

Adapted from http://www.internano.org/nanoinformatics/ and Hoover et al. 2015

Sensor Data Analytics: The Questions

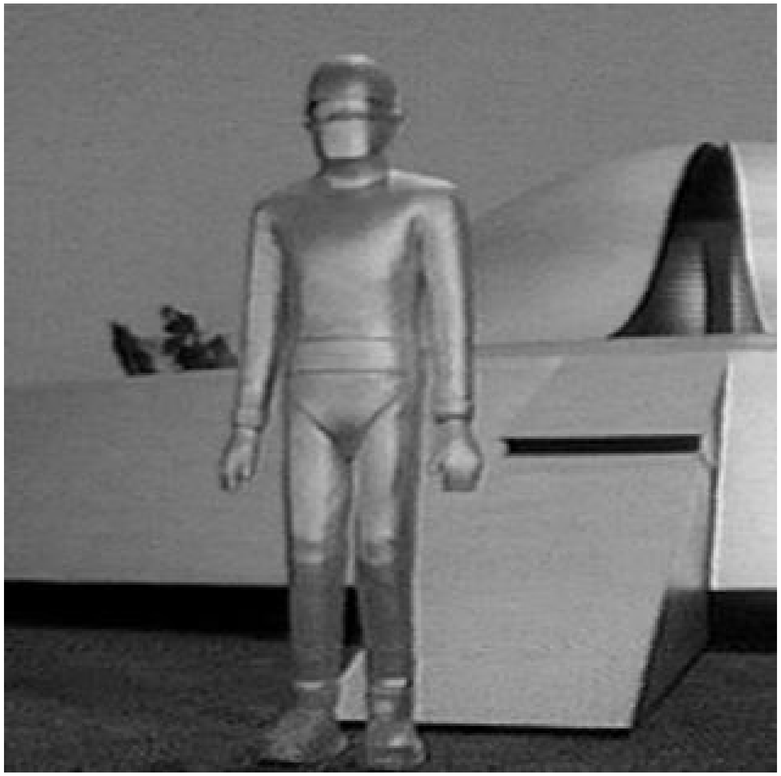
- Do existing and proposed sensor methods **accurately measure** what they are supposed to be measuring?
- How can they be **adequately calibrated and validated**?
- When are they limited to use for screening and **when can they provide accurate characterizations** of specific hazards?
- Given the large to vast amounts of sensor data that may be collected, **how can those data be feasibly analyzed and interpreted by an occupational data scientist**?



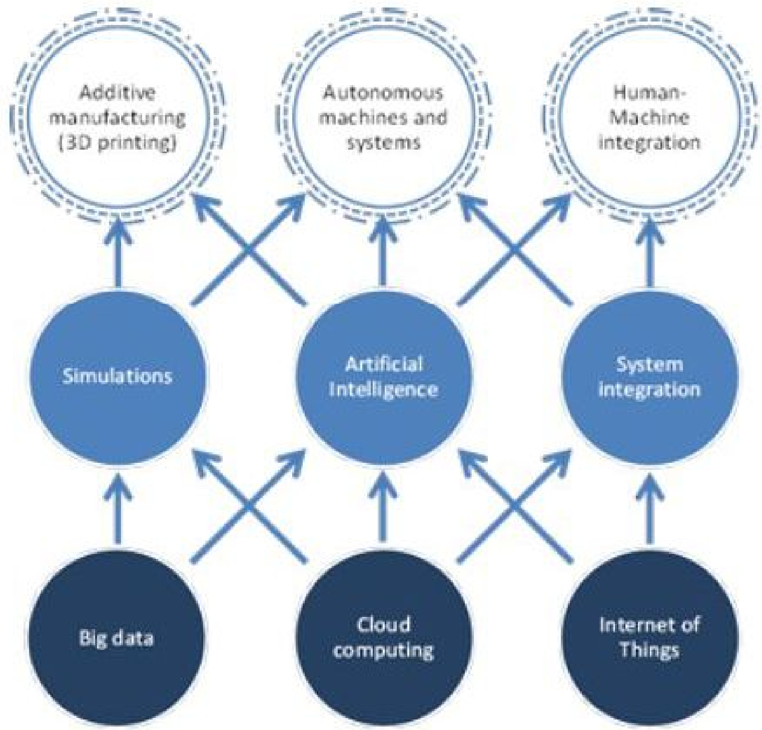


AI Safety Management

- Can AI recognize a near-miss?
- Can AI assess data to present a risk assessment probability?
- Can AI offer risk mitigation recommendations based on real-time sensor data and historical situations?
- Can AI take control to prevent human actions that may create safety hazard?



Confluence of Key Technologies Enabling Industrial Digital Transformation (Industry 4.0)



Source: OECD (2017a)

OCCUPATIONAL SAFETY AND HEALTH

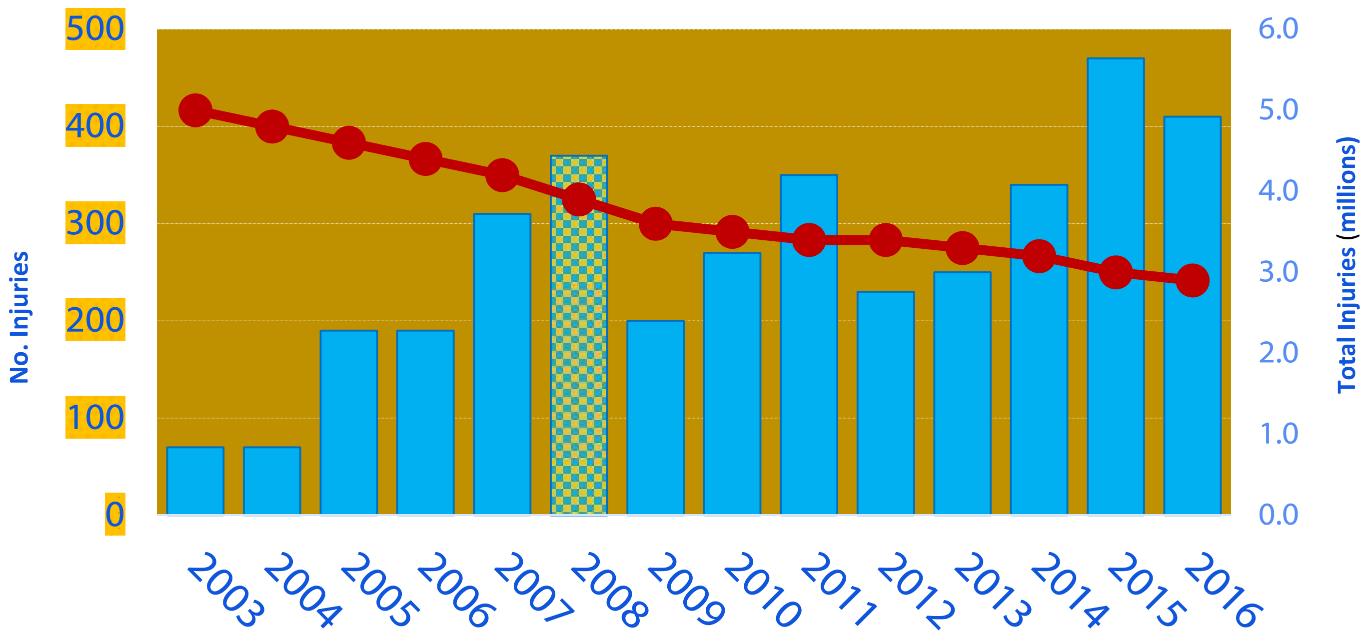
Pros

- Expand dangerous work done by robots
- Robotic systems augment workers' abilities

Cons

- Likely increase in injuries from manipulators, mobile robots
- New types of robots will require refined and new protection strategies
- Rapid advances in technology may outpace standards setting
- Stress associated with changing workplace and potential for displacement

Estimated 3,730 Robot Injuries in U.S., SOII 2003-2016



NIOSH Center for Occupational Robotics Research

- NIOSH has been aware of an increase in the use of robotics in the workplace for a number of years.

- We decided to focus research attention on understanding the aspects of robotics that may affect human workers and the 21st century workplace.

- Established a Center for Occupational Robotics Research in September 2017

Contact CORR

Program Manager:
Dawn N. Castillo, MPH
Director, Division of Safety Research
1095 Willowdale Rd
MS 1900
Morgantown, WV 26505
304.285.6012
DCastillo@cdc.gov

Program Coordinator:
Hongwei Hsiao, PhD

ROBOTICS

About the Center

NIOSH conducted extensive robotics safety research when robots began appearing in the workplace in the mid 1980s. This research was limited to robots designed to work in isolation from workers, such as robots in cages or cells. With the increase in robots and advances in their capabilities, the Center was established in September 2017 to address the safety of today's workers who use, wear, or work near robots.

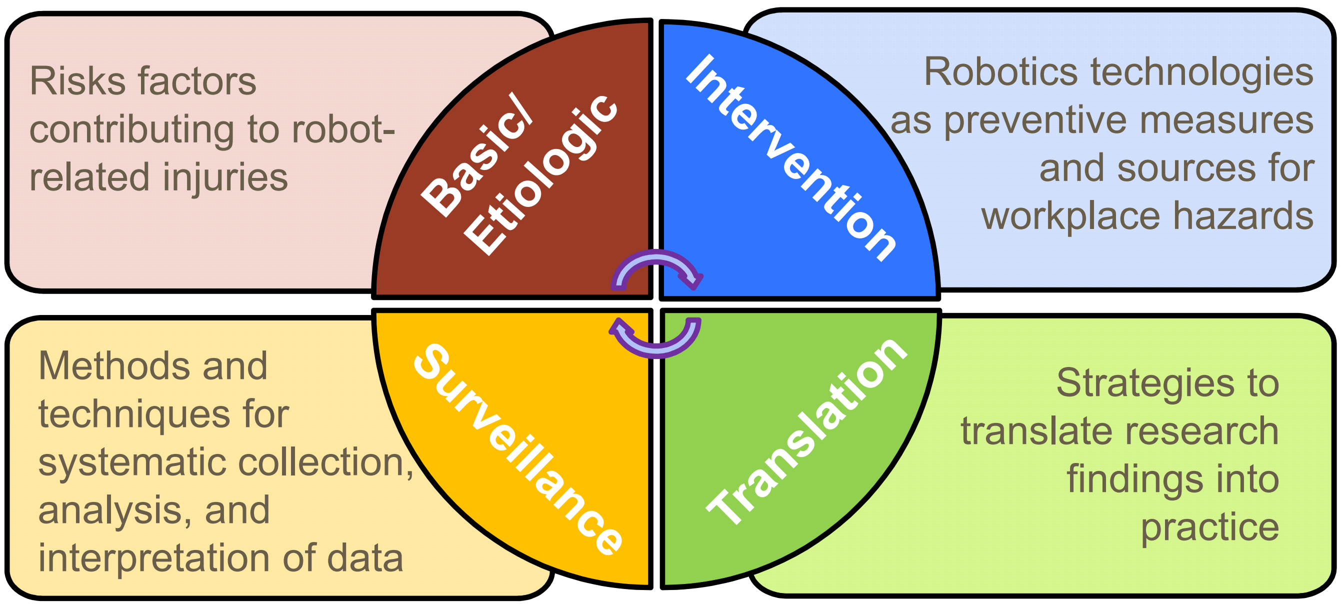
The Problem

Current injury surveillance systems are not able to easily identify robot-related injuries due to a lack of standard classification codes. However, NIOSH

Occupational Leadership Needed

RESEARCH BY PRIVATE SECTOR	NIOSH
• Advancing technology • Productivity and economic growth • **Minimal attention to worker safety and health**	• Enhances the worker safety and health mission • Broaden breath of disciplines • Engaging in human subject research • Increasing laboratory capacity • Refining approaches to prevention • Promoting partnerships

RESEARCH NEEDS



Strategy and Priorities

- **Strategies**
  - Bring attention to worker safety and health
  - Leverage expertise and resources with partners
  - Focus on work not likely to be accomplished by others
- **Priorities**
  - Increase understanding of human and robot interactions
  - Improve the ability to identify and track injuries
  - Provide guidance for working safely with robotics technologies

Approaches to Expanding Capacity in OSH

- Raising awareness of issue
- Establishing infrastructure for research
- Developing partnerships to leverage expertise and resources
- Actively participating on key standards setting committees

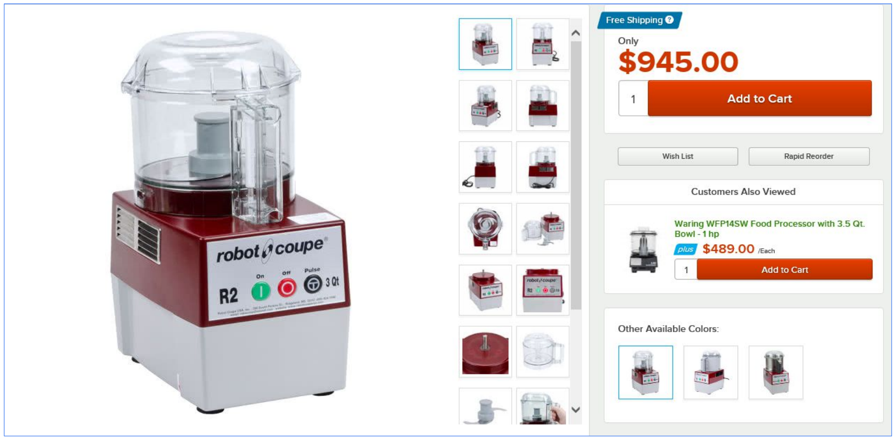
Ability to Identify and Track Injuries

- Refining keyword searches and methods
- Exploring ability to identify cases in different databases
- Made recommendations to Bureau of Labor Statistics for potential changes to Occupational Injury and Illnesses Classification System

Recommendations to BLS

- BLS currently lacks a direct way to identify robotic systems in machinery, motor vehicles, or industrial vehicles

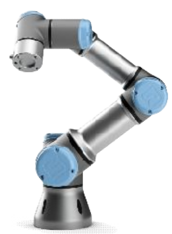
- Solutions:
  - Add a 5th digit to the source codes to denote robotic systems (or)
  - Create a standalone variable for robotic systems



Infrastructure: NIOSH Laboratory Capacity

- **Robotics Safety Lab under development**
  - Collaborative robot arms and mobile warehouse robots

- **Virtual Reality Lab Upgrade**
  - Simulation of Human-Robot Interaction

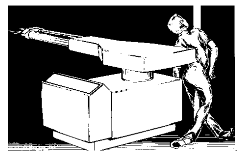



Contributing to Consensus Standards

- ANSI/RIA R15.06 – Industrial **Robots and Robot Systems Safety** (*Update)*
- ANSI/RIA R15.08 – Industrial **Mobile Robot Safety** *(New)*
- ASTM F48 – **Exoskeletons and Exosuits** *(New)*
- ANSI/ASSP/NSC Z15.3- Safety Management of **Partially and Fully Automated Vehicles** *(Technical report)*
- ANSI **Unmanned Aircraft Systems** Standardization Collaborative Roadmap *(Groundwork for consideration of a new standard*)

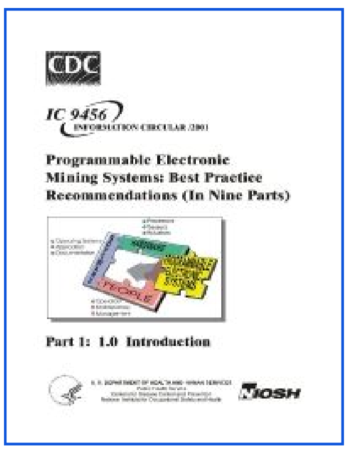
Existing Guidance on Working Safely with Robots

Preventing the Injury of Workers by Robots, NIOSH Pub. No. 85-103



1740. Robots and Robotic Equipment

Safe Maintenance Guidelines for Robotic Workstations, NIOSH Pub. No. 88-108



CDC

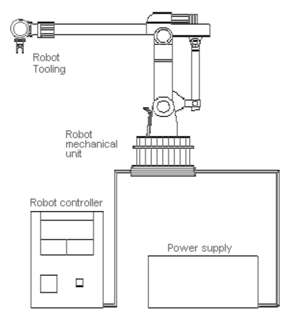
IC 9456 INFORMATION CIRCULAR /2001

Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts)

Part 1: 1.0 Introduction

NIOSH

OSHA Instructional Manual, Chapter 4: Industrial Robots and Robot System Safety



ANSI/RIA R15.06-2012

american national standard

for Industrial Robots and Robot Systems — Safety Requirements

ANSI

ria

ANSI/RIA Robotic Safety Standards

- **ANSI/RIA R15.06-2012**
  - American National Standard for Industrial Robots and Robot Systems- Safety Requirements
    - Approved March 28, 2013
    - Revision of ANSI R15.06-1999
  - Provides guidelines for the manufacture and integration of industrial robots and robot systems
    - Emphasis on their safe use, the importance of risk assessment and establishing personnel safety.
    - Key feature in the standard is “collaborative operation,”
      - Introduction of a worker to the loop of active interaction during automatic robot operation.

Robotics and Economies

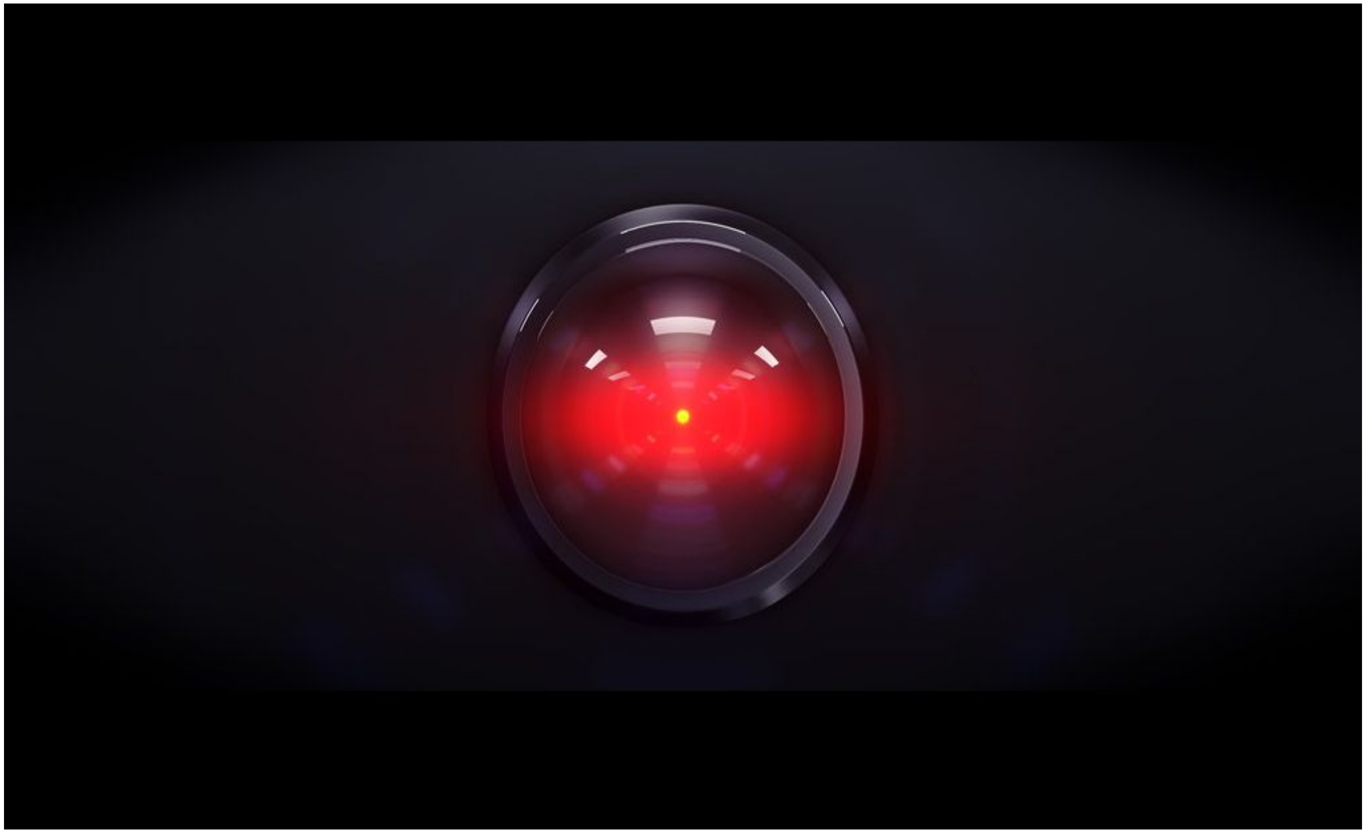
- **Effect on employment**
  - Technological unemployment
    - Probably overstated in near term, probable in longer term
    - Job destruction and job creation do not proceed in parallel creating sociopolitical issues
- **Effect on productivity**
  - Enhancement
- **Effect on national security**
  - Threat?
- **Effects on production technologies**
  - **Substitute** for low-skill labor and **complement** for high-skill labor
  - Decrease importance of labor costs in total production costs
    - Making relocation of productive activities attractive—reshoring
  - Enhance the flexibility of productive process—enabling greater customization of goods—autonomous machine will allow for producing smaller batches of a wider variety at a lower cost

U.S. Government is on AI Lockdown

- On 19 November, the U.S. Department of Commerce proposed new restrictions on the export of AI technologies, including neural networks and deep learning, natural language processing, computer vision, and expert systems. *See* https://www.gpo.gov/fdsys/pkg/FR-2018-11-19/pdf/2018-25221.pdf

- ***Representative Technology Categories***
  - Artificial intelligence (AI) and machine learning technology, such as:
    - Neural networks and deep learning
    - Computer vision (*e.g.,* object recognition, image understanding);
    - Expert systems (*e.g.,* decision support systems, teaching systems);
    - Speech and audio processing (*e.g.,* speech recognition and production); and
    - Natural language processing (*e.g.,* machine translation).
  - AI cloud technologies; and
  - Quantum information and sensing technology (among others).

"I'm sorry Dave, I'm afraid I can't do that"



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