Industry 4.0:
The New Industrial Revolution

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Goal: introduce the key concepts related to the 4th industrial revolution

- What it is
- What it will bring
- How it will impact us
- How ensuring it makes the world a better place

Audience: **who is interested in our future**

Outline

- ✓ **Human – Technology Coevolution**
- ✓ **Industry 4.0: Iconic and Pillar Technologies**
- ✓ **Technology: the Dark Side**
- ✓ **An Interpretation of the Moment We are Living**
- ✓ **Conclusions**

Human – Technology Coevolution

Human – Technology Coevolution

HUMAN EVOLUTION:

- a sequence of **breakthroughs** (abrupt, radical and structural changes of nature of family and work, skills of people, quality of life, health, society organization)
- **incremental** advancements in the years between breakthroughs

- about **1.800.000** years ago: capability to **light and control fire** (a **first technology**(1) together with Neolithic tool fabrication) lead to the invention of **cooking** and massive **increase of calories** available
- **growth of brain size** in **Homo erectus**(2) and development of brain areas related to **speech**

(1) Technology: collection of techniques, skills, methods and processes (even tools and machines) that may be used to solve real-world problems

(2) This hypothesis by the primatologist Richard Wrangham is criticized because of the lack of evidence that cooking fires began long enough ago. The traditional explanation is that human ancestors scavenged carcasses for high-quality food that supported the evolutionary shift.

Human – Technology Coevolution

- about **15.000** years ago: awareness of **seasonal crop rotation** and **animal domestication** led to the **AGRARIAN REVOLUTION** (breakthrough from **foraging** to **farming**), so increasing productivity, transportation, communication, population and human settlements.
- about **10.000** years ago: farming resulted in **URBANIZATION REVOLUTION**, leading to **specialist artisans** and **writing**

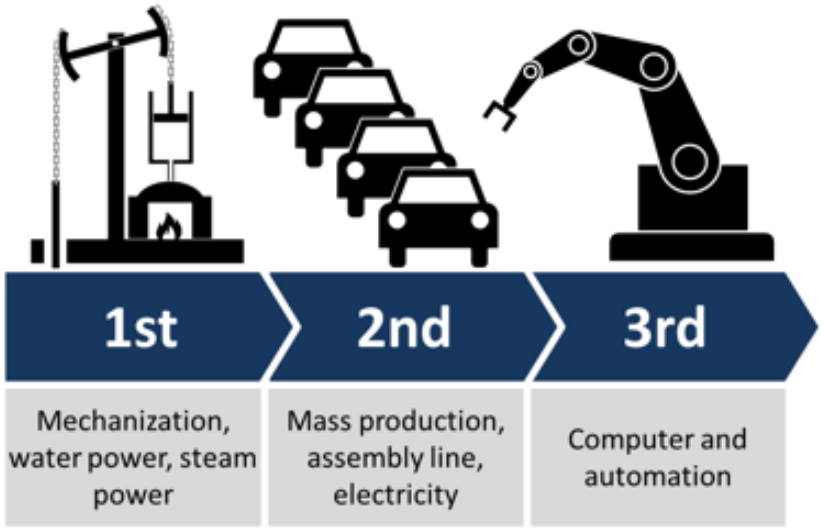
Human – Technology Coevolution

in the **19th century**: the invention of **steam engine** marked the transition from **muscle** (men, animals) and **environment** (wind, water) power to **mechanical power** leading to the **INDUSTRIAL REVOLUTION**:

1) mechanics – weaving loom – textile (~1760-1830)
started in Great Britain
120 years to spread outside Europe

2) electricity – assembly line – automotive (~1880-1930)
started in Great Britain and Germany
~1.3G people (~ 17%) still without access to electricity

3) electronics – automation (~1970-1990)
started in Western world
~3.5G people (~ 50%) without access to internet



ICT Evolution

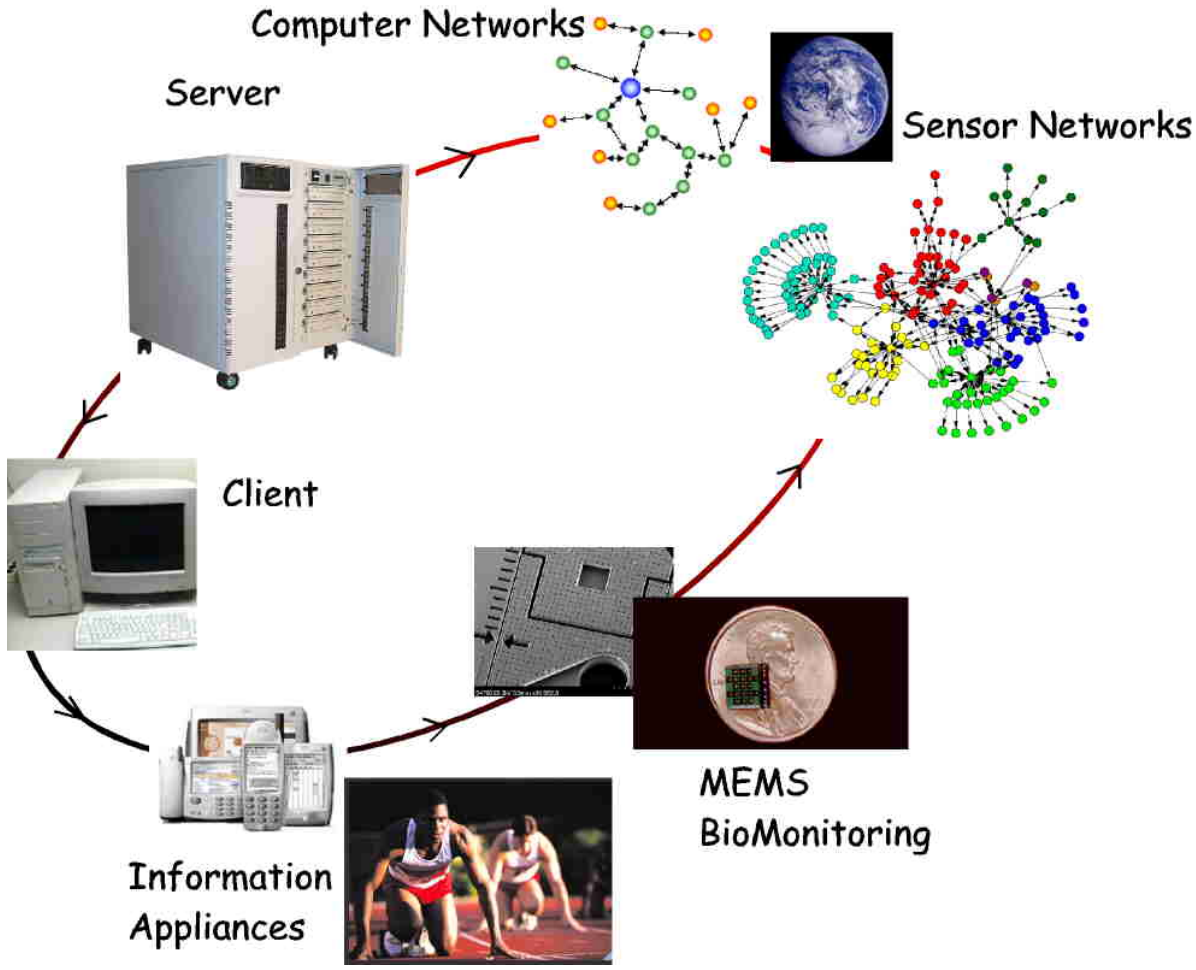
- 1970s **Computer**
- 1980s **Personal Computer**
- 1990s **Internet**
- 2000s **Telefono cellulare**
- 2010s **Smart Phone**

processing power comparison:

- **1 tablet** = **5000 desktop PCs** (1980)
- **1 Cray-2** (the fastest machine in 1985) = **1 iPhone 4** (2010)
- **1 Apple Watch** (2015) = **2 iPhone 4s**

storage:

1 GB: 10 k$/year (1985), ~3 c$/year (2016)



ICT Evolution

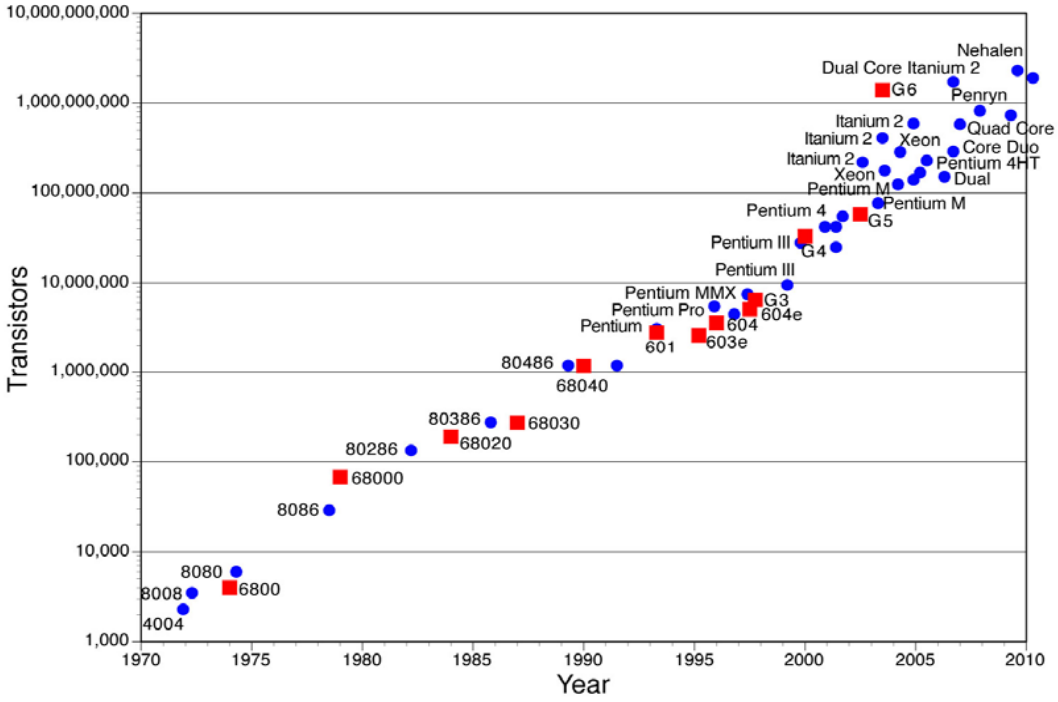
"it takes about the same amount of computing to answer **one Google search query** as all the computing done – in flight and on the ground – for the **entire Apollo program**"!
(Google inside search team, 2012)

ICT performance increase is due to three main determinants:

1) the **Moore law**, which is related to shrinking of transistor size

2) conceptual design of computing systems (**hardware architectures**) that allows to effectively interconnect huge n° of transistors

3) **algorithms**



Human – Technology Coevolution

Historical shifts (**breakthroughs**) mainly enabled by **radical**:

- **technology advancement**
- **cultural transformations**: new ways of **perceiving the world**, generating **values**, **identities**

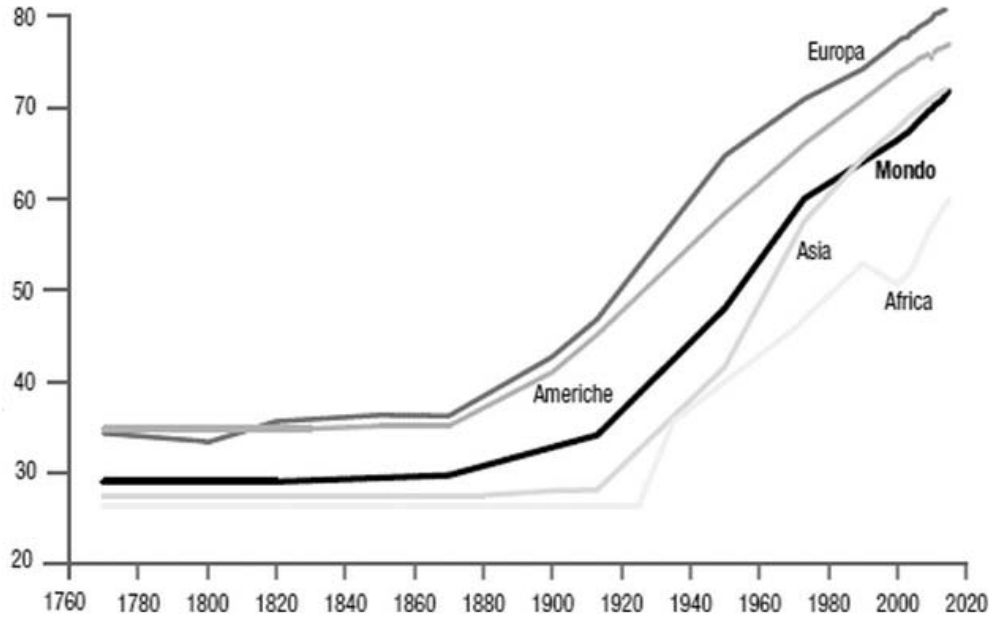
shift not only "**what**" and "**how**" doing things,

but also "**who**" **we are**

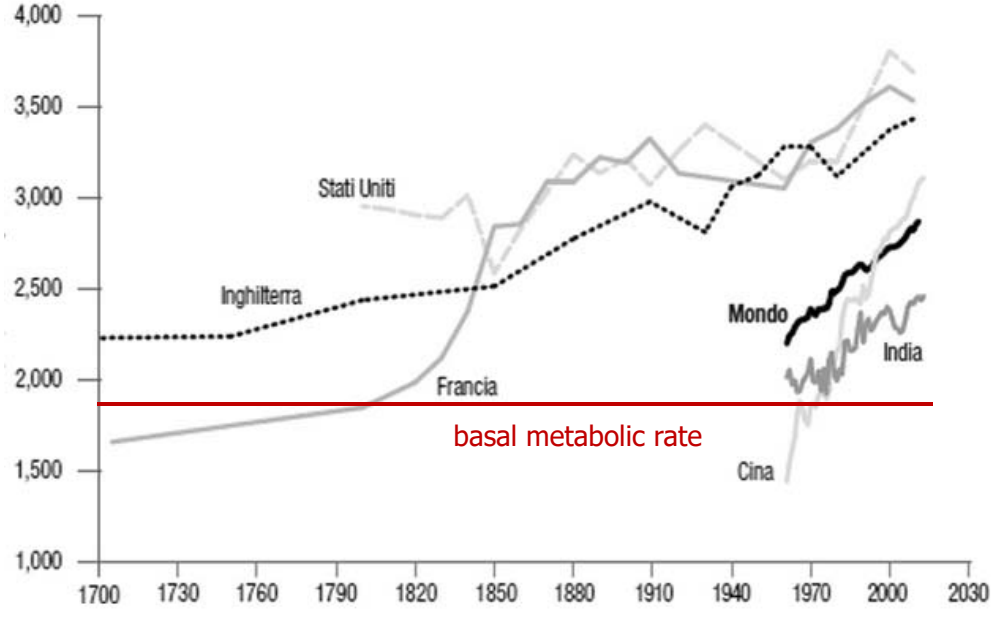
Human Progress

exponential increase in population and living standards

life expectancy [years]



food/person [calorie/day]

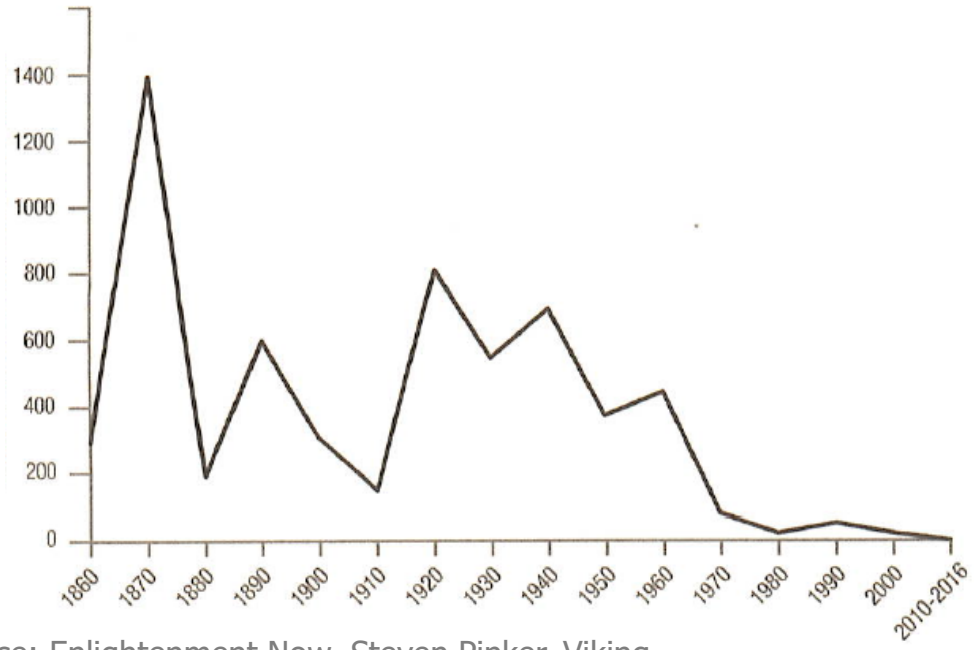


Source: Enlightenment Now, Steven Pinker, Viking

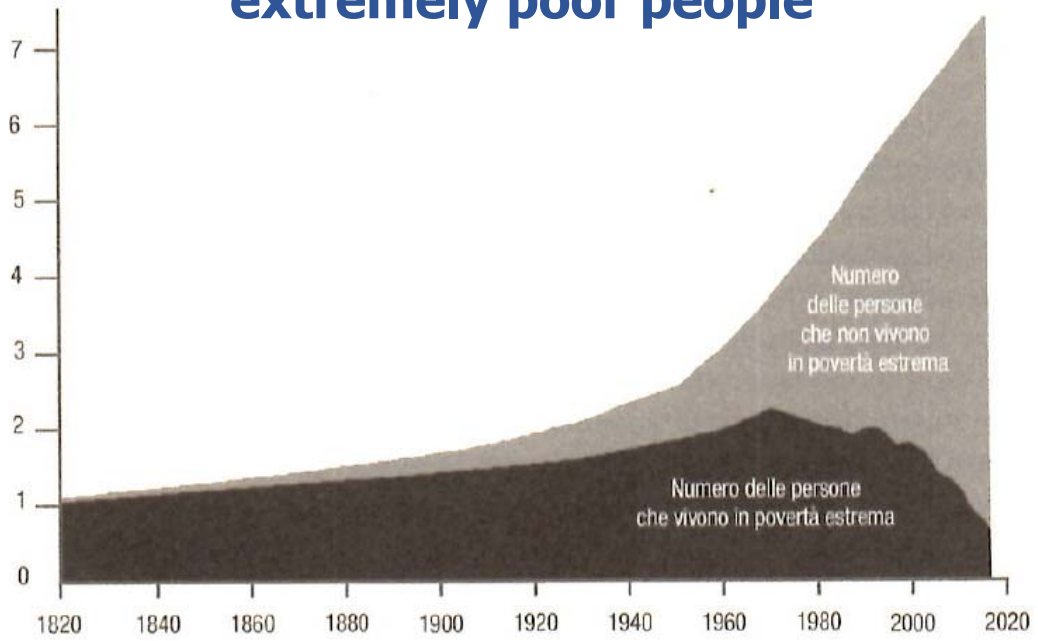
Human Progress

The "Great escape" from poverty, illness, famine, illiteracy, dangers, early death

victims of famine in 10 years / 100.000 persons



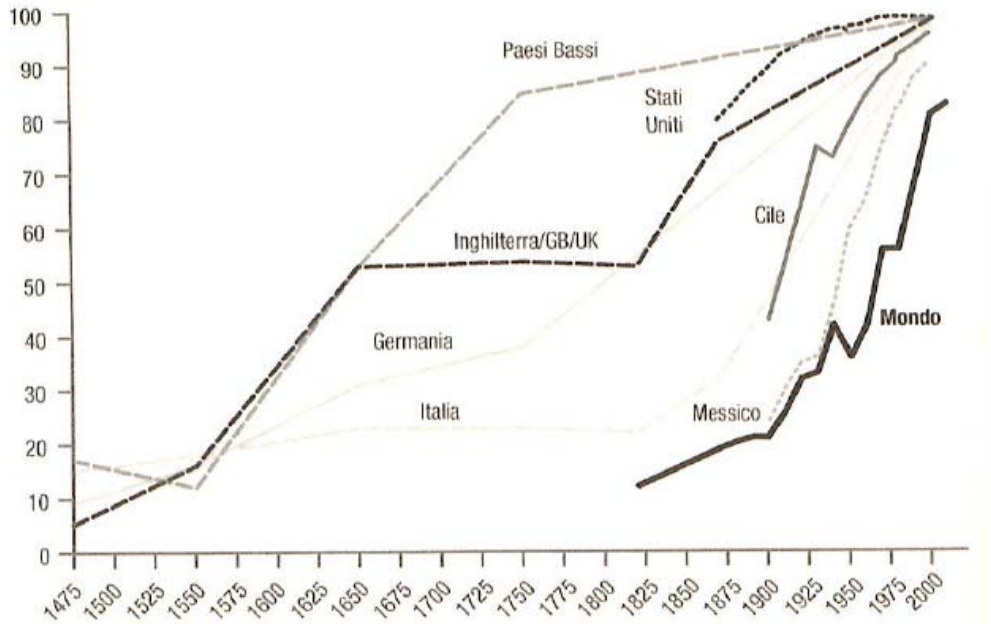
population (billions) and extremely poor people



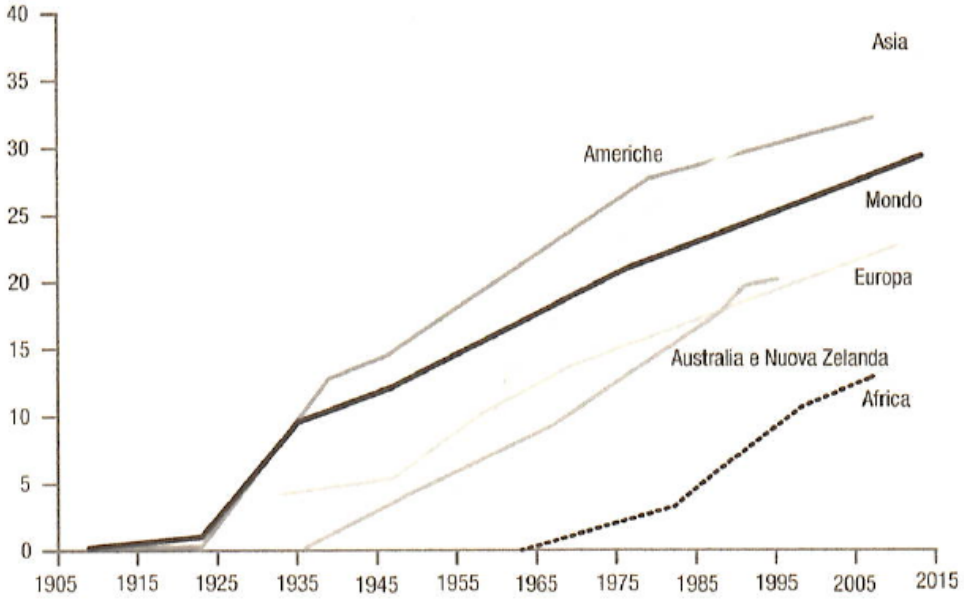
Source: Enlightenment Now, Steven Pinker, Viking

Human Progress

literacy



QI increase



Source: Enlightenment Now, Steven Pinker, Viking

4th Industrial Revolution

HOW: **INFORMATION enabled COORDINATION, INTEGRATION and CONVERGENCE of CLASSICAL AND EMERGING TECHNOLOGIES**

RESULT: **exponential PERFORMANCE AMPLIFICATION and strong INTERCONNECTIONS between PHYSICAL, BIOLOGICAL and DIGITAL WORLDS**

SMART MANUFACTURING: **machines**, **systems** and **products** equipped with **cognitive power** enabling **real-time** :

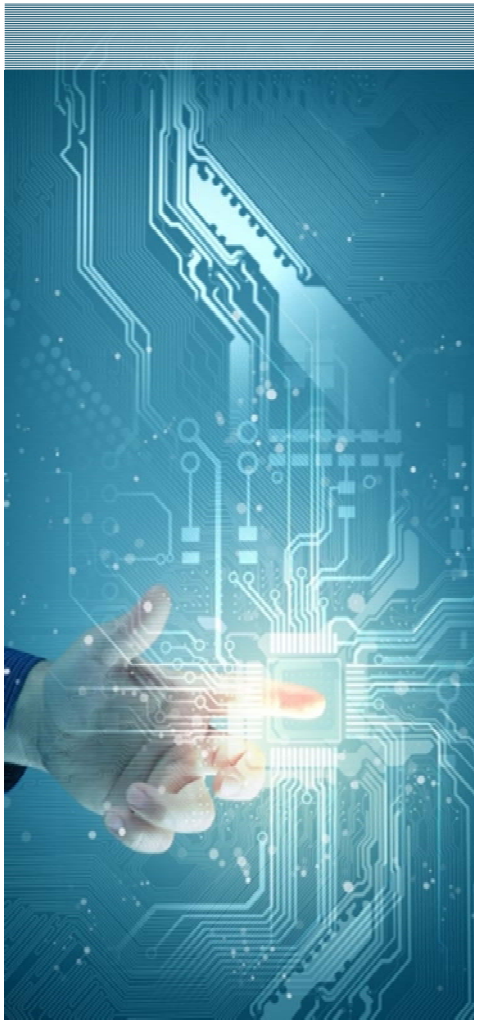
- **communication** and **cooperation** with each other and humans
- **perception** of their environment
- **self-awareness**: they know their own model and their own state
- autonomous context-dependent **decision making**
- **reactions** to changes by **self-configuration** and **adaptation**

4th Industrial Revolution

WHY: **MEGATRENDS** that are driving the changes:

- **demographic** change
- **sustainability** requirements: - shortage of resources
  - climate change
- **technology** evolution
- **globalization**: need to improve competitiveness
  - **mass customization** = almost individualized cost-efficient mass production
  - **servitization** = service-orientated production:
    - from one-time product selling, to continuous profit by service offering
    - products replaced by temporary access to goods
    - services added to products ⇒ blurring of the product – service boundary

4th Industrial Revolution



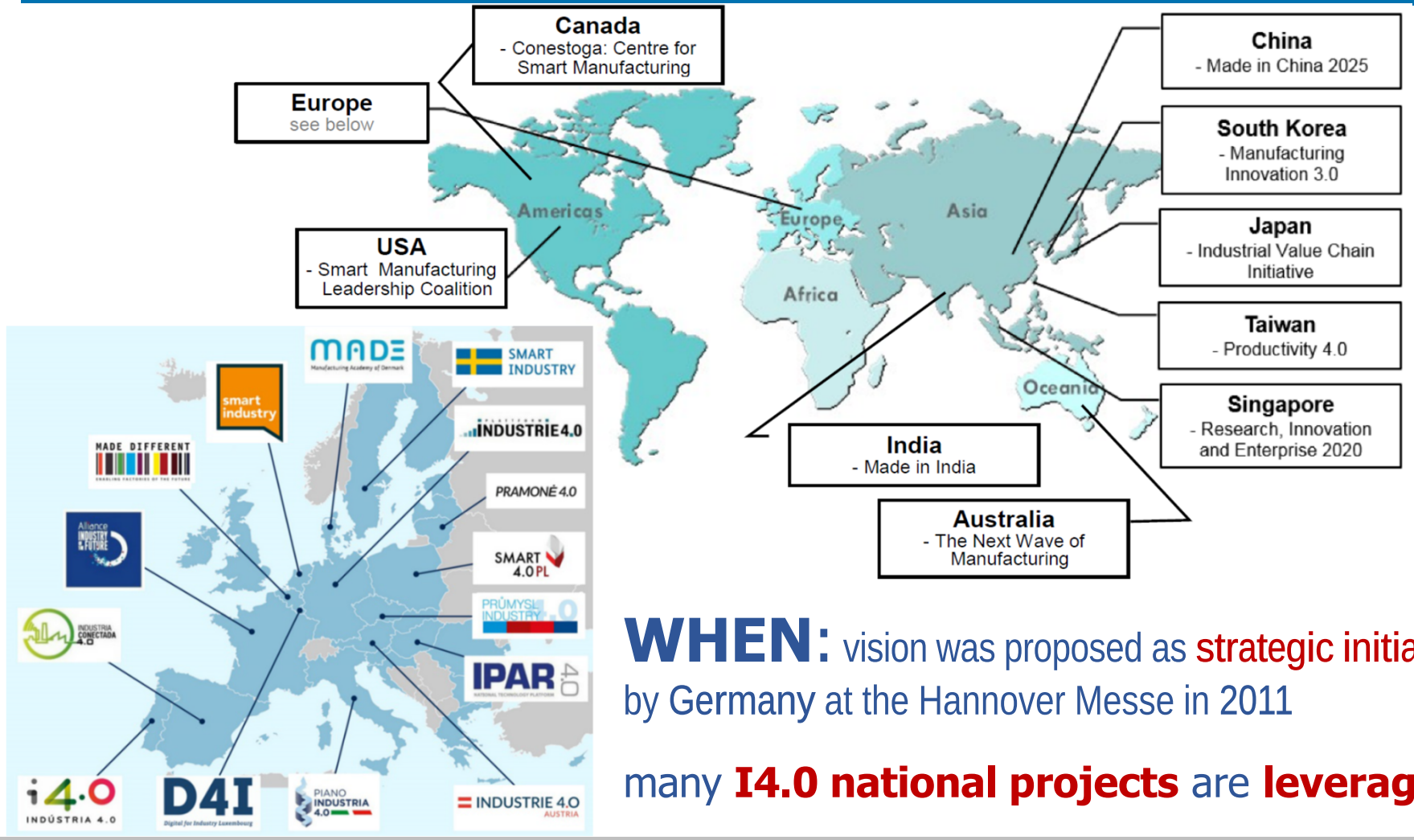
WHERE and WHO are involved:

- **MANUFACTURING** and **SERVICE SECTORS** (+ public administration)
- whole **SOCIETY** (daily life, health, energy, environment, cities, agriculture, …)

WHAT (**DISTINTIVE FEATURES**)

- exponential **evolution rate**
- **systemic impact**: entire systems and whole society are involved
- deep **interconnections**, **convergence**, **integration**, **cooperation**

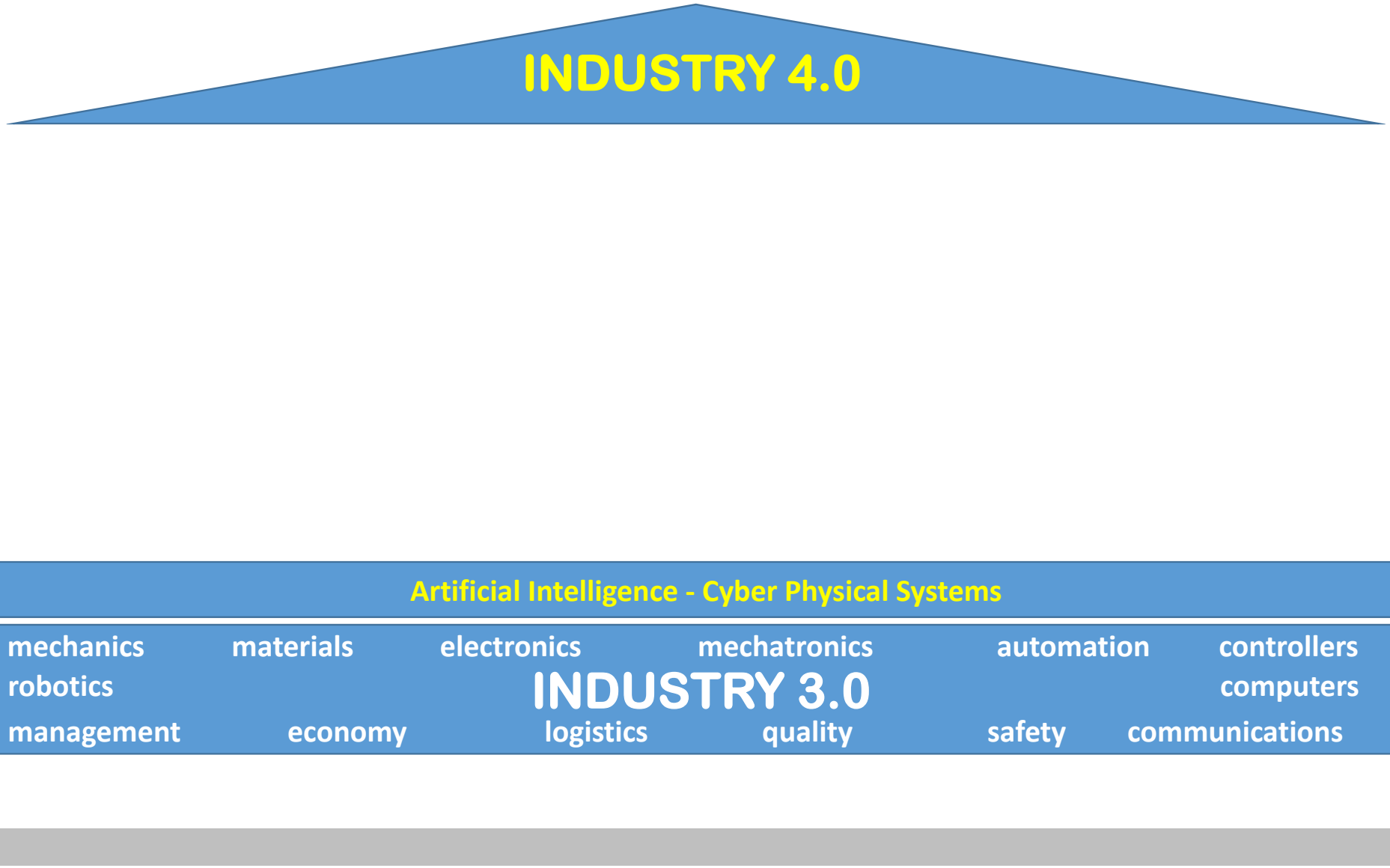
Industry 4.0: National Plans



WHEN: vision was proposed as strategic initiative "Industrie 4.0" by Germany at the Hannover Messe in 2011

many **I4.0 national projects** are **leveraging the 4th IR**

Industry 4.0:
Iconic Technologies

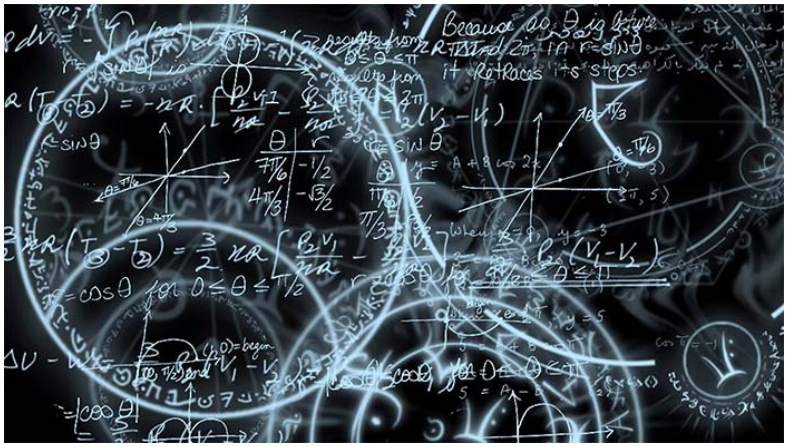

INDUSTRY 4.0
Artificial Intelligence - Cyber Physical Systems
mechanics
materials
electronics
mechatronics
automation
controllers
robotics
INDUSTRY 3.0
computers
management
economy
logistics
quality
safety
communications

Artificial Intelligence

AI fundamentally **impact society** (jobs, wealth distribution, resource sustainability ...)

AI **exponential progress** is due largely
to convergent advances across **three enablers**:

- computing power
- training data
- learning algorithms



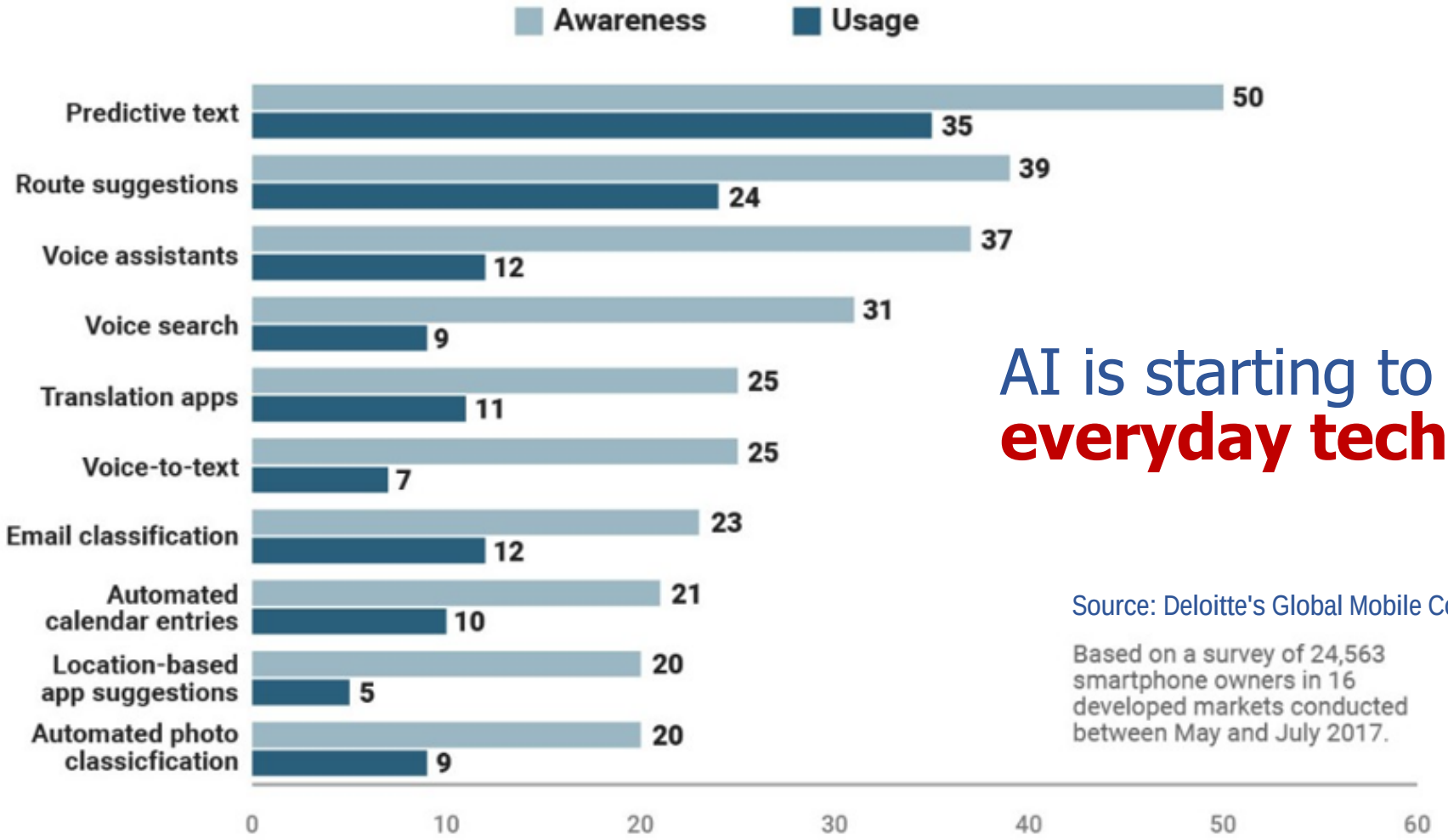
only **13% of workers** exhibits **skills at higher level**
than state-of-the-art AI (OECD, October 2017)

AI will be "**either the best or worst thing**" for humanity (Stephen Hawking, 2016)

AI "is **the biggest risk** that we face as a civilization" (Elon Musk, 2016)

Whoever becomes the leader in AI "**will be the ruler of the world**" (Vladimir Putin, 2017)

AI in Smartphones



AI is starting to **permeate everyday technology**

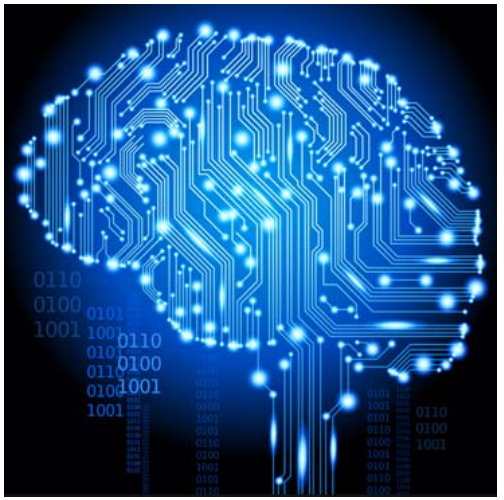
Source: Deloitte's Global Mobile Consumer Survey

Based on a survey of 24,563 smartphone owners in 16 developed markets conducted between May and July 2017.

AI: Goal Achievement

AI goal of mimic (**general**) **intelligence** has been broken down into sub-goals, that is in specific **capabilities** that an intelligent system is expected to display

General intelligence:
a synergic combination of all the capabilities above



many problems require different capabilities to be solved

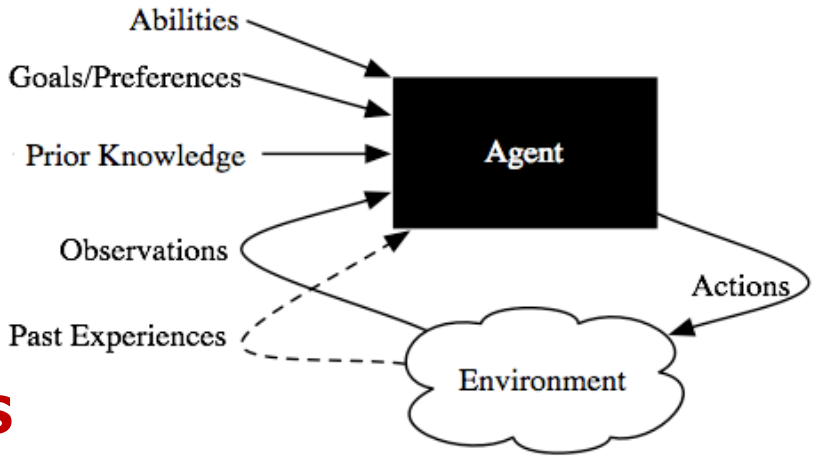
Ex.: to reach human-level performance, **translation** requires to simultaneously solve the following problems: read and write in both languages (NLP), know the context of the content (**knowledge**), understand the content (**reasoning**), faithfully reproduce the speaker original intent (**social intelligence**).

AI: Goal Achievement

INTELLIGENT AGENT: an entity (device, system, software program) that

- perceives its environment
- capable of autonomous reasoning
- capable to take actions that maximize its chance to achieve specified goals

– simplest agents: software programs that solve specific problems
– complicated agents include human beings and organizations of human beings (such as firms)



agents **solve specific problems** using an effective (symbolic or sub-symbolic) **approach**

most AI problems solved by **MULTI-AGENT SYSTEMS** based on the **integration of intelligent agents**

Ex.: hierarchical control system integrates sub-symbolic agents at its lowest levels (satisfying strict time constraints) and symbolic agent at its highest levels (relaxed time constraints allow planning and world modelling)

AI: Capabilities

Reasoning, problem solving

imitate human reasoning when making logical **deductions**
(also when information is uncertain or incomplete)

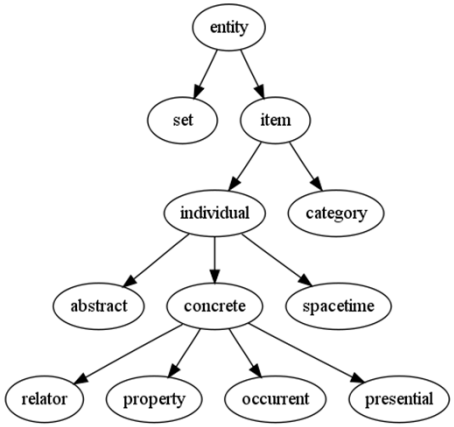
Knowledge representation

- extensive knowledge about the world is **required to solve problems**
- **new knowledge** can be discovered via automated reasoning

Planning

to achieve their goals, intelligent agents must be able:

- to **predict** the future state of the world
- to determine how their **actions** will change it



Learning

AI algorithms that **improve automatically** through **experience**

Natural Language Processing

to interact and acquire knowledge using human language (written or spoken)

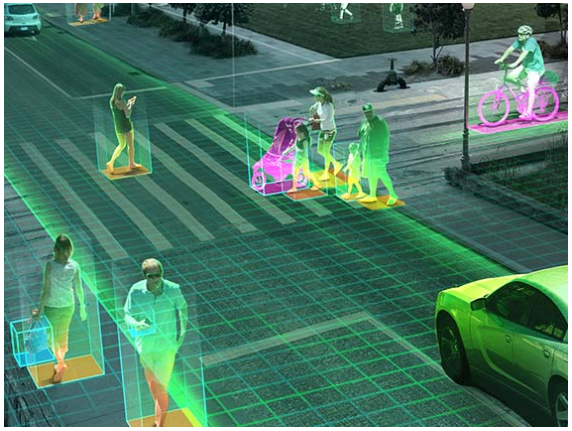
- NL **understanding**: phrases → internal representation (harder than NLG, due to NL ambiguity)
- NL **generation**: internal representation → meaningful phrases (verbal of displayed on screen)

AI: Capabilities

Perception
analyze and extract information from data acquired using **sensors** (cameras, microphones, …)

Computer vision (through Image processing):
analyze, extract, and understand information from single/array of images
relevant role in many domains (safety, security, surveillance, health, biometrics, automotive, robotics, entertainment, …)

Ex:
OCR (Optical Character Reader): convert scanned documents into editable text
Handwriting Recognition: recognize letters in a written text
Face Detection: enables to read the face and take correctly the picture
Face Recognition: match the face of a person with stored portraits
Object Recognition: recognize specific object in photos (also taken by satellites)
Estimating Position: estimating the position of an object w.r.t. camera (e.g. a tumor)



AI: Capabilities

Speech recognition (through Speech processing)
understand WHAT was spoken (ex. google)
- training non necessary because it is speaker independent
- systems difficult to develop

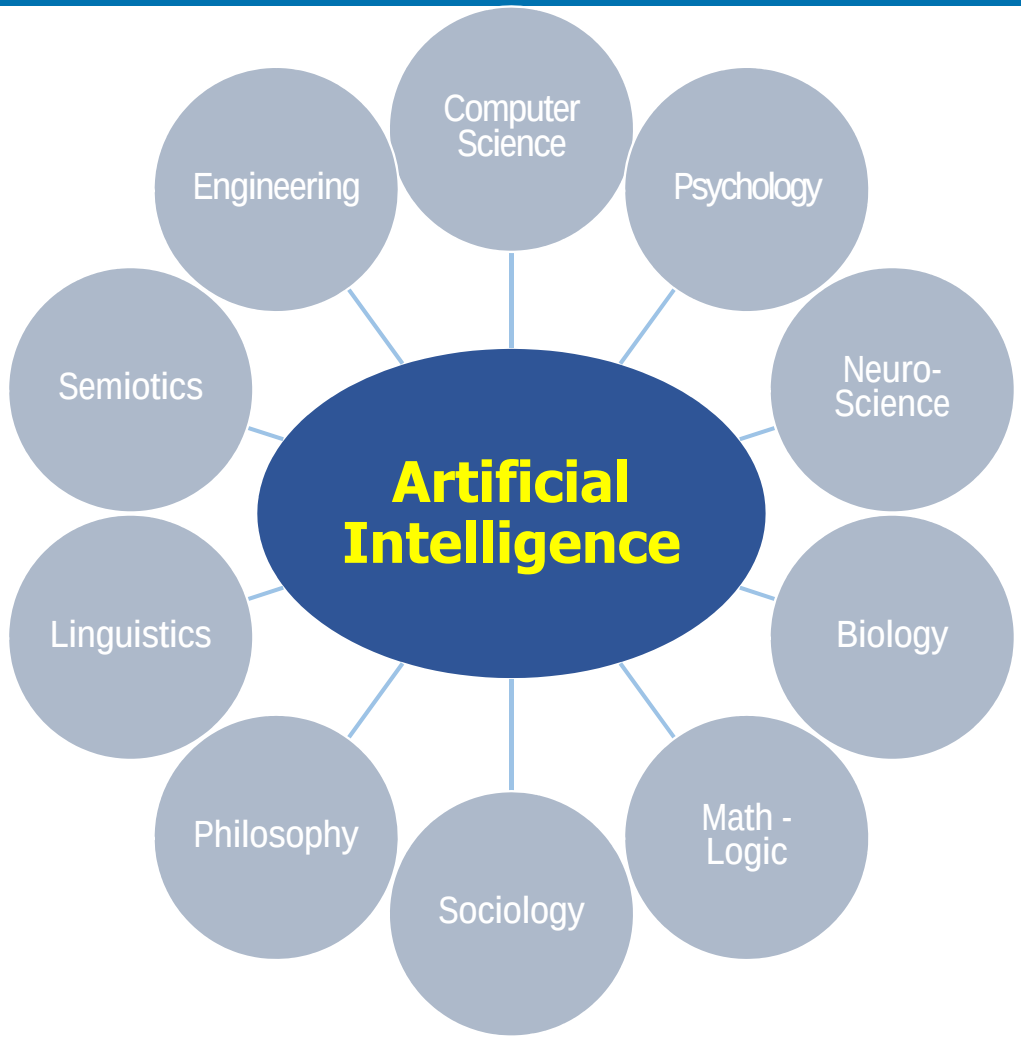
Voice Recognition (through Speech processing)
Recognize WHO is speaking
- training necessary as it is person-oriented
- systems are quite easy to develop

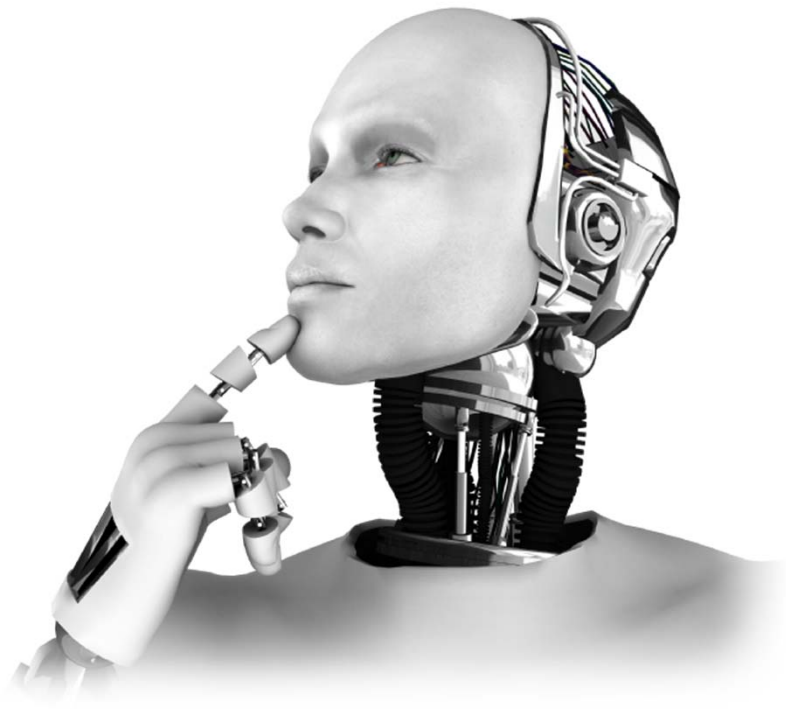
Motion and manipulation
handle tasks such as object manipulation and navigation, solving sub-problems such as localization, mapping, motion planning

Social intelligence
recognize, interpret, and simulate emotion and social skills
- to facilitate and enhance human-computer interaction
- to predict the actions of humans as consequence of machine selected action

Ex.: "Social robots" aimed at assisting humans physically and psychologically, acting as companions and diminishing the social isolation of elderly

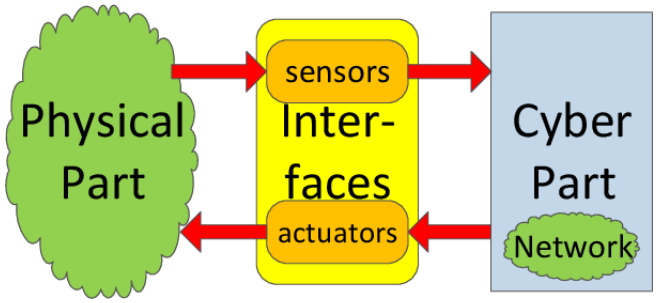
AI: Involved Disciplines





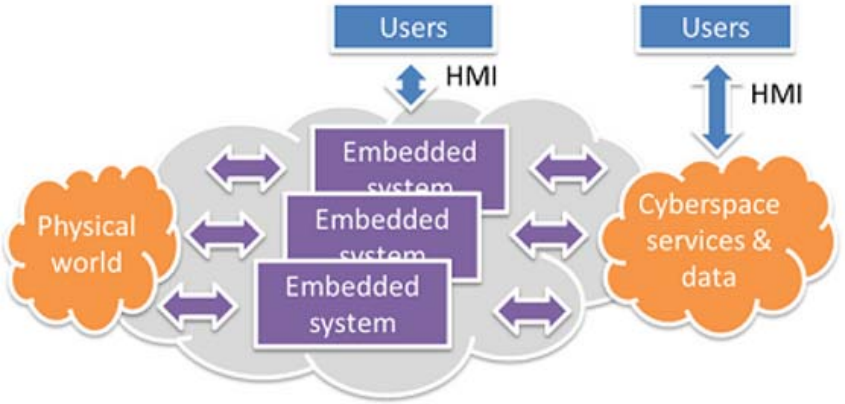
Cyber-Physical Systems (CPSs)

tight **integration** of **computation, communication, sensing, control** and **actuation** with **physical processes**



merge the physical and cyber worlds:

- **cyberizing the physical**: by modeling physical systems and interacting with them
- **physicalizing the cyber**: by acquiring and processing information about physical systems

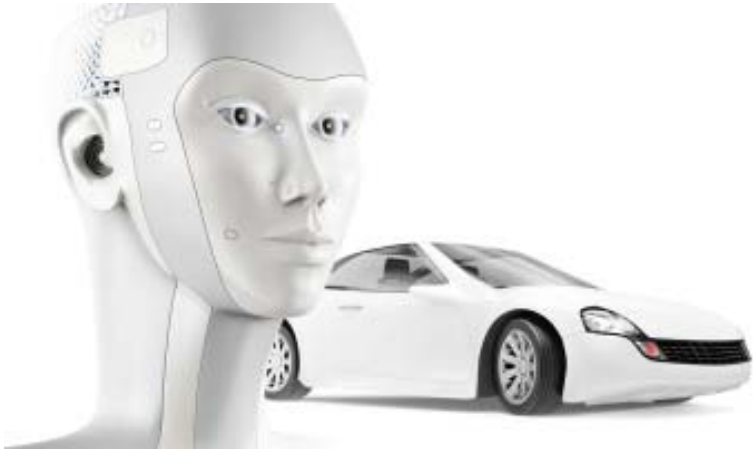


Cyber-Physical Products

SMART PRODUCTS:

products with **integrated CPSs** that store all the relevant information about:

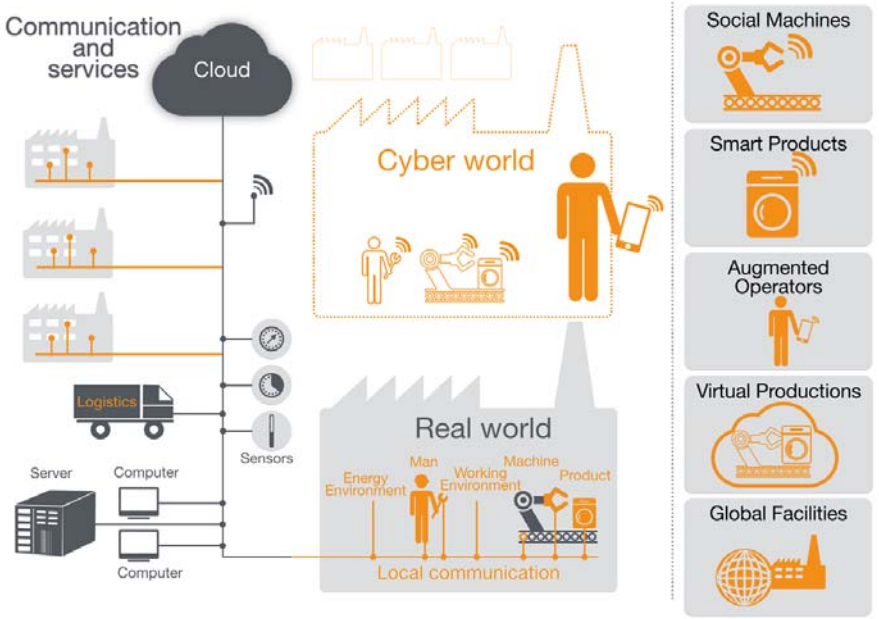
- sequence of **production steps** (e.g. using RFID) so to steer their production autonomously
- information useful to **optimize their usage**
- whole **story of the product** so to optimize diagnostics and maintenance



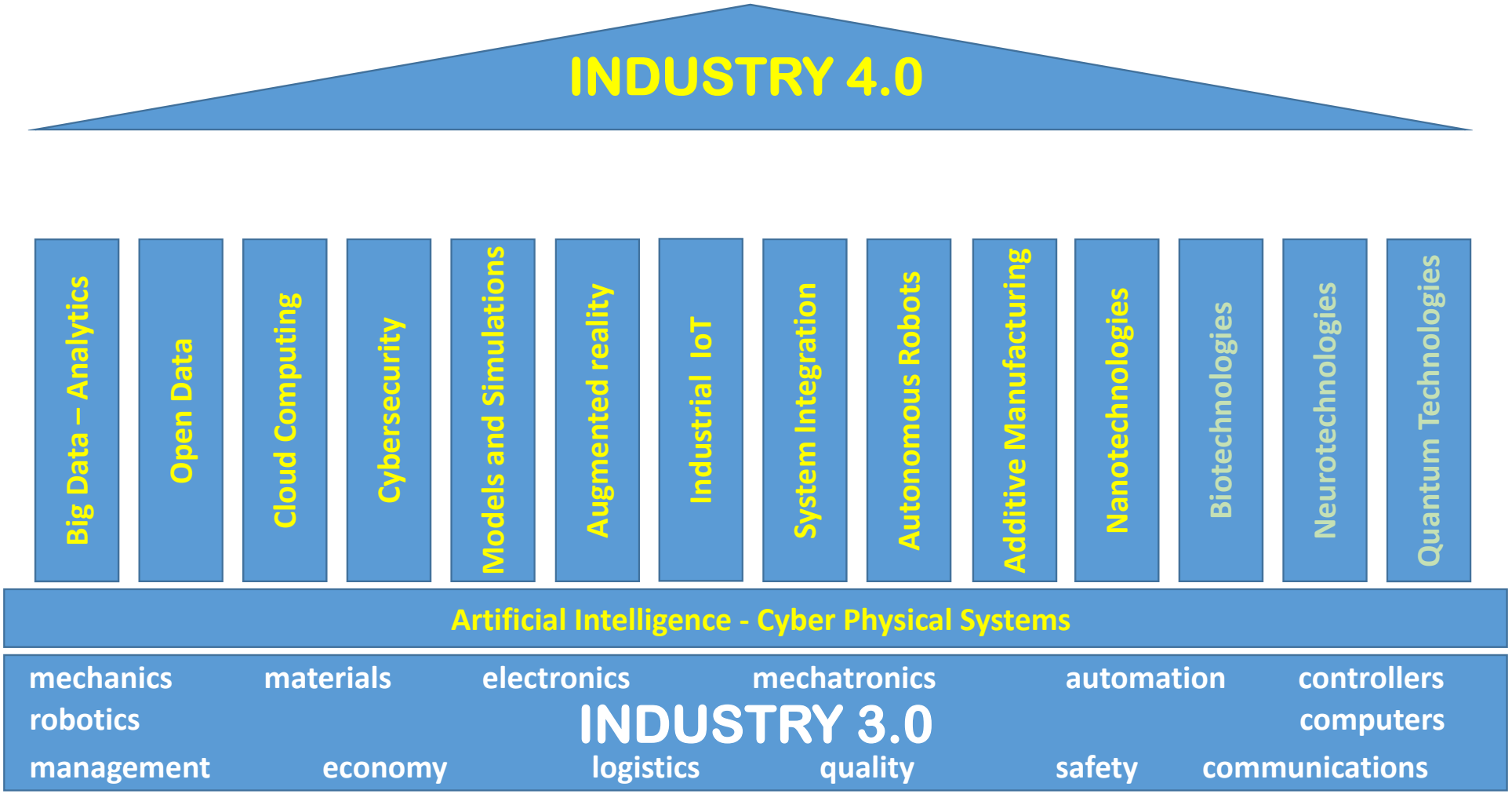
Cyber-Physical Production Systems (CPPSs)

C. P. PRODUCTION SYSTEM (CPPS):

- networks of **connected machines, products and individuals** throughout the entire value chain and the full product life cycle
- **acquire and store data** in order to predict failure, self-optimize production and logistic systems, reduce costs and increase resource availability and efficiency
- monitoring and control systems are **decentralized**
- production steps are **configured flexibly** in response to changing situations



Industry 4.0:
Pillar Technologies


INDUSTRY 4.0
Big Data – Analytics
Open Data
Cloud Computing
Cybersecurity
Models and Simulations
Augmented reality
Industrial IoT
System Integration
Autonomous Robots
Additive Manufacturing
Nanotechnologies
Biotechnologies
Neurotechnologies
Quantum Technologies
Artificial Intelligence - Cyber Physical Systems
mechanics
materials
electronics
mechatronics
automation
controllers
robotics
computers
INDUSTRY 3.0
management
economy
logistics
quality
safety
communications

Big Data and Analytics

DATA TSUNAMI from:

- the real world (**world datafication**)
- internet, mobile phones and ICT devices

aimed at supporting:

- better and automated **decision making**
- **insight discovery**, by identifying patterns in the datasets

BIG DATA: data sets so **large and/or structurally complex** that **information** cannot be extracted using traditional processing techniques

one of the most **disruptive technologies**: it is **changing everything** (organizations, government, global economy, …) transforming **how we live, work, think**

new forms of processing (**ANALYTICS**) needed to extract information

if big data is the **oil**, then smart data is the **fuel** that drives good decisions

Big Data

volume

amount of data
(doubles every 1.2 years)

variety

various shapes, forms
(sensors, text, images, audio)

velocity

speed of data generation

variability

various data context, meaning and inconsistence

4Vs characteristics of big data

related to data **quantity** and **technology**

size is celebrated instead of **effectiveness** in support decision

quantity is an aspect of the (seductive) **dark side** of data:
a "quick and easy path" to reach the goal

tons of **noise** are useless

data quality: a **huge problem** (given the BD characteristics)

smart data: **useful** part of big data must be **filtered out**

Smart Data

VALIDITY

usefulness of data for its intended use

VERACITY

accuracy + contextual data needed to check it

2Vs characteristics of smart data

effectively managed using principles, methods and tools of **metrology**

- to make **aware** about potential **uncertainty** sources
- to ensure **quality** of **data** and **information extracted** from them
- to assess and manage the **effects of uncertainty** on the **risk** of wrong decisions

metrology, a science of **data quality**

body of knowledge aimed at **identifying, quantifying, assessing** the contributions (**uncertainty sources**) that affect the **quality of information** acquired from empirical world

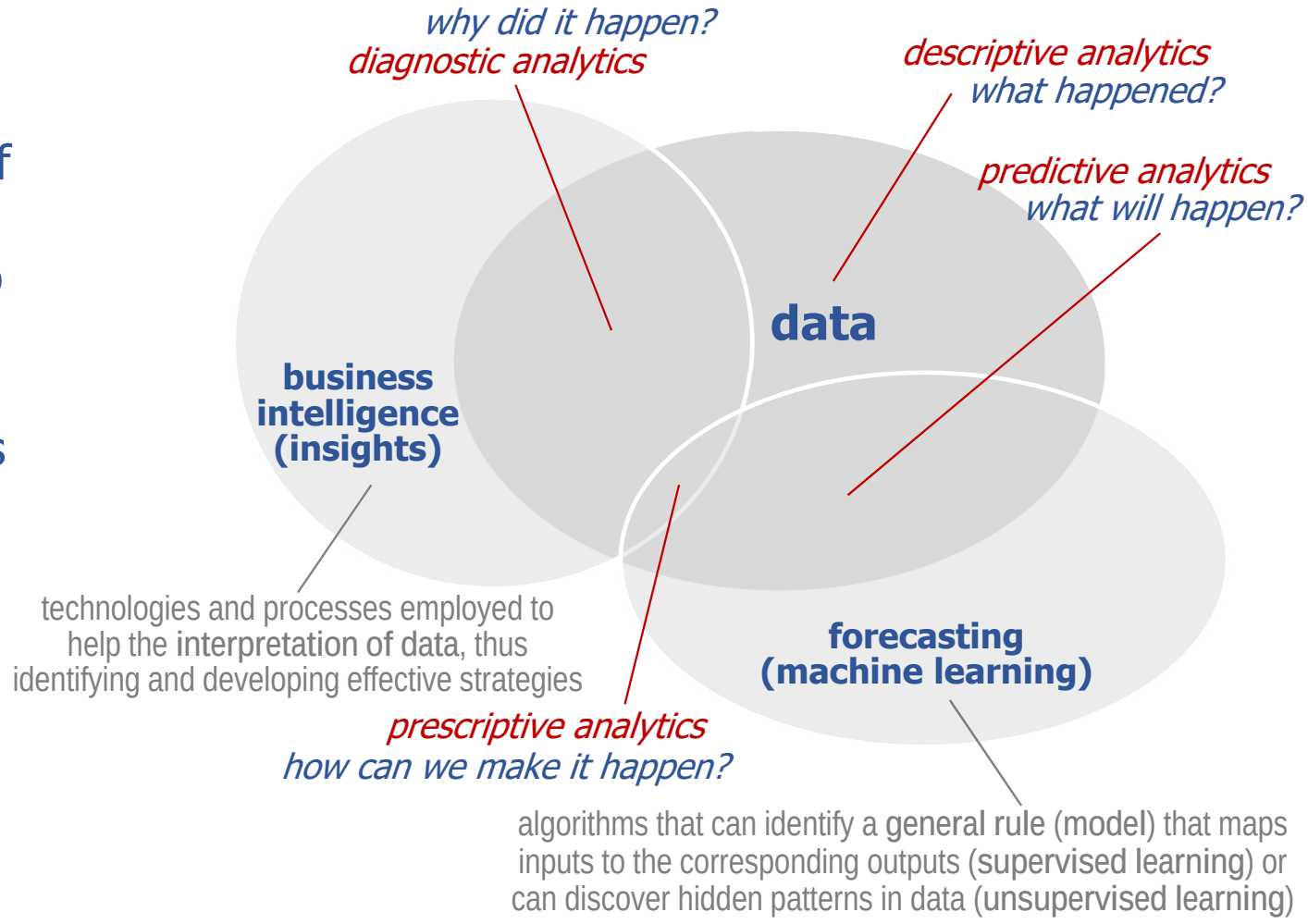
metrological culture is crucial to manage **decision confidence**

Data Analytics

analytics aim at real-time detection and interpretation of useful **patterns** in **massive unstructured data sets ,** so revealing **relationships and interdependencies** that are useful to draw conclusions

analytics relies on:

- **statistics**
- **machine learning**
- **operations research**, …



Open Data

data have **commercial value** (textual, maps, genomes, chemical compounds, mathematical formulae, medical data, …) ⇒
restricted access through **licenses**, **copyright**, **patents**

open data advocates assumptions:

- **government** data: facilitate **transparency**, **accountability** and **participation**
- **scientific** data: facilitate **knowledge** dissemination, technological **innovation** and economic **growth** (e.g. *Structural Genomics Consortium* show that the open data approach can be used productively by industrial R&D)

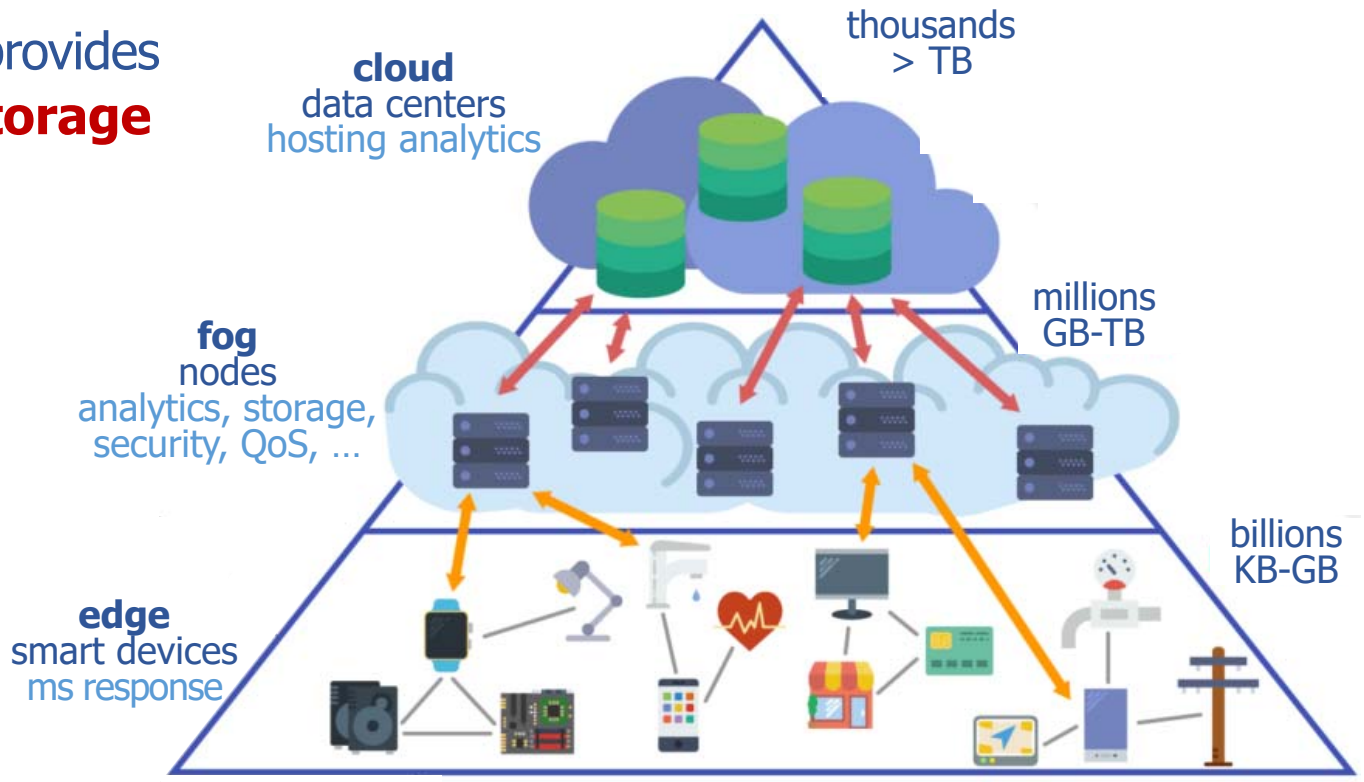
⇒ **restrictions are against the common good**

⇒ restricted access only when **privacy** concerns

Cloud Computing

internet-based computing that provides **on demand processing and storage** in third-party **data-centers**

- evolution towards **utility** (like electricity grid)
- **sharing of IT resources** to achieve economy of scale, minimize management effort, facilitate data sharing



millisecond response times will enable industrial process monitoring and control

Cybersecurity

cyber attacks aimed at theft or damage, as well as service disruption or misdirection ⇒ cybersecurity is a **top priority**

POLITICAL RELEVANCE AT GLOBAL LEVEL

cyber attacks costs:

- **$400 billion/year** (Lloyd's estimate, Jan 2015)
- **$2 trillion/year by 2019** (Forbes projection, Jan 2016)

$2.5 billion in premiums on policies in 2014

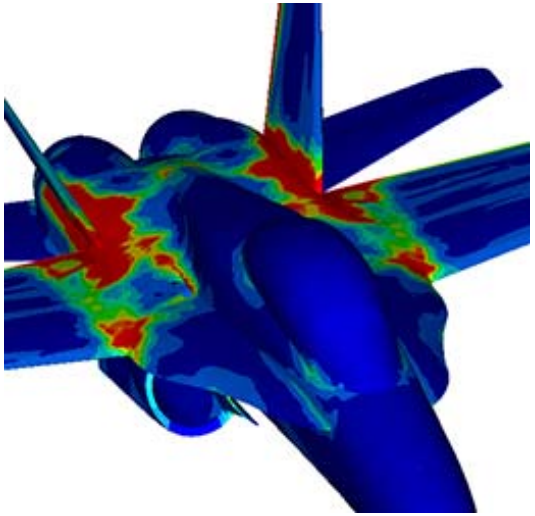
industrial-equipment vendors are making **partnerships** with cybersecurity companies

3D Models and Simulations

virtual copy (**digital twin**) of a physical object, with properties in the digital world (including the object story) that **mirror** real-world behavior

GOALS:

- **foresee and optimize** processes behavior, machine **settings** at design phase (reducing costs and time-to-market while increasing quality)
- replacing **prototyping**
- virtual environment for **training** workers
- **monitoring** processes and machine status



Augmented and Virtual Reality

information displayed by:
tablet, **smartphone**, **augmented-reality glasses**

workers:
better interaction with products, processes and machines
adding textual/graphical information to:

- **maintain** or **repair**
- handle **emergencies**

customers:

- receive **information** about product (ways of use, ingredients for foods, …)
- enter in **virtual e-commerce markets** to choice/personalize the product that will be produced only after the order

Internet of Things

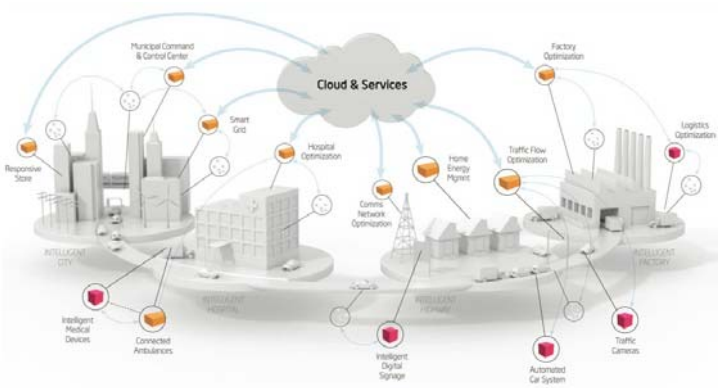
current manufacturing: few **sensors** and **field devices** with limited intelligence, typically send information to centralized process control systems

INTERNET OF:

- data: exchange of data
- services: specific services on demand
- people: people and organizations contacts
- things: autonomous communication between physical objects equipped with electronics (also CPSs)
- automation: autonomous communication between CPSs involved in industrial automation (next future)

IoT is an enabling technology for **ubiquitous computing** (invisibly embedded in the environment)

IoT expected to contribute 10-15 trillion USD over the next 20 years (*General Electrics*)



Internet of Things

7 trillions devices servicing 7 billion people!

1,000 devices per person by 2025

the immersed human

real-life interaction between **humans** and **cyberspace**, enabled by enriched input and output devices on and in the body and in the surrounding environment

Industrial Internet of Things

I²oT: infrastructure that **connects Operational Technology OT** (that is the hardware – sensors and actuators - and software aimed at detecting or causing changes in physical processes) with **Information Technology IT** (embedded computing and communication components) to:

- assure real-time interaction with one another and with centralized controllers
- decentralize real-time analytics and decision making (e.g. for self-diagnostic)

I²oT is the **convergence of IT and OT**

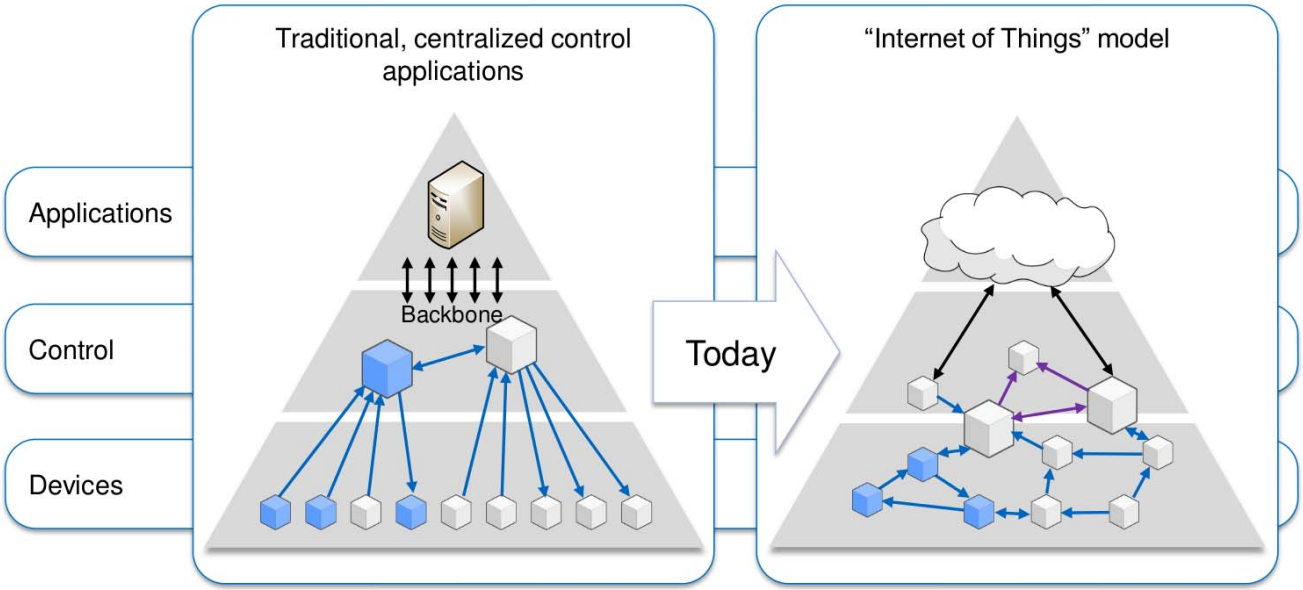
Ex: manufacturing processes that adjust their own parameters as they sense properties of the unfinished product

Ex: workstations know which specific operation must be performed on a product identified by RFID

Industrial Internet of Things

The strictly hierarchical automation pyramid is replaced by **decentralized**, **self-organized and networked controls**

Decisions are no more made only at the peak of the pyramid, but at the lowest possible level
⇒ quick reactions, increase of flexibility and productivity



System Integration

Types of integration:

- entire value creation networks: **horizontal integration**
- hierarchical manufacturing levels: **vertical integration**
- entire value chain and product life cycle: **through engineering**

benefits of system integration allowed by ICT:

- a high level of **flexibility** to respond quickly to problems and faults
- enforce **best practices** and facilitate global **optimization**
- improve **performance** by bringing together multiple minds and multiple viewpoints
- reduce **redundant** spending and effort, avoiding wasteful duplication
- generate new **business models** and new models for **cooperation**

Autonomous Robots

current manufacturing:
robots **separated from humans** in safeguarded spaces

robots are becoming capable:

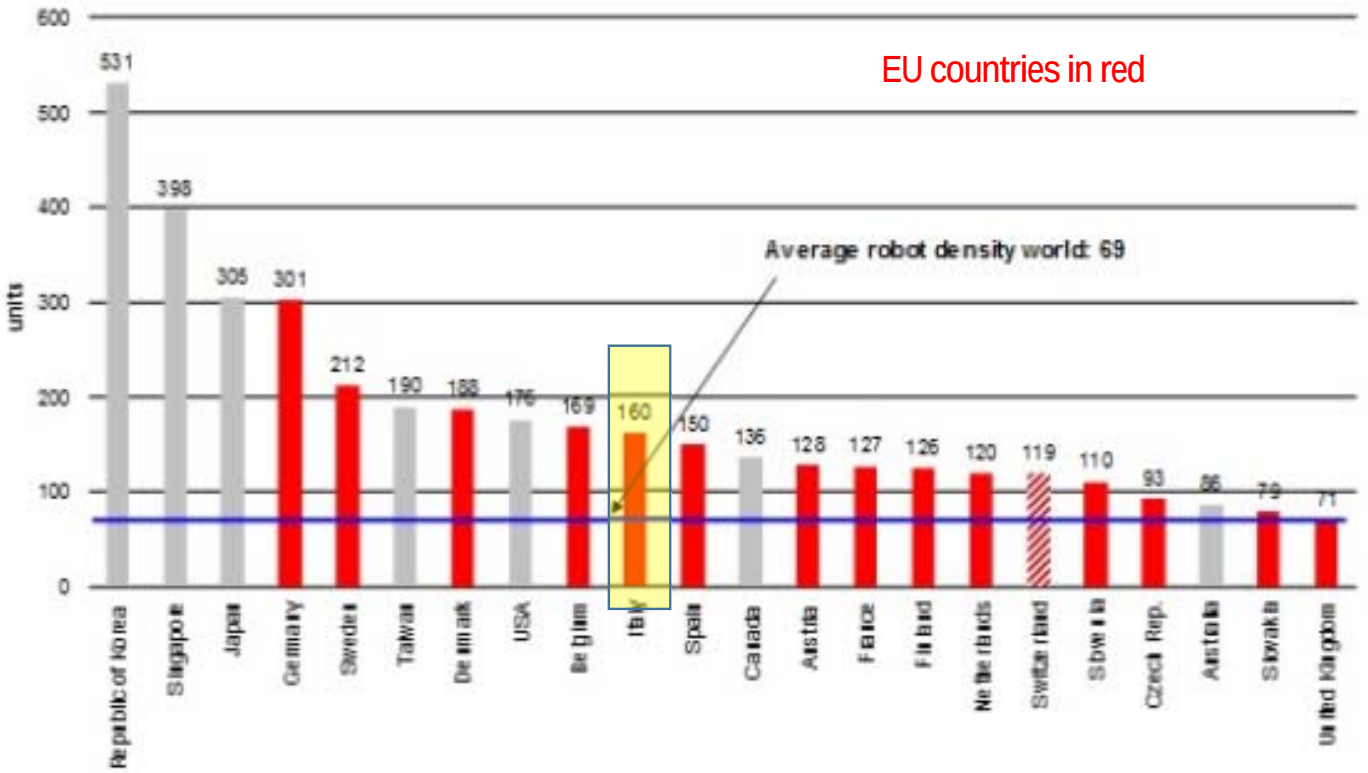
- to be more **autonomous**, **flexible**, **interconnected**
- to perform tasks that require human **intelligence**
- of **learning** from their mistakes
- to **adapt** to changes in the environment
- to be **collaborative** (**cobots**), i.e. to work safely with humans and learn from them

fusion of human (creativity and cognitive abilities) with robot (speed, precision and strength) will open new possibilities

Ex: automated logistics, based on autonomous vehicles and robots
drones deliver medical supplies in war zone, used in precise agriculture or for checking electric power lines
agents in today cars: braking, lane changing, collision prevention, navigation, mapping, ...

Robot/Worker Distribution by Country

multipurpose industrial robots / 10.000 employees in the manufacturing industry, by country, 2015



Fear of Robots

Robophobia: fear about **autonomous decisions** of robots

intelligence and **awareness** are **independent features**

AI can solve problems better than humans without be aware

same achievement, but a different process

Ex. airplanes and birds, submarines and fish, hand and machine washing

true risk:

robots strictly obey their programmers, **without emotions**

Ex. military drones, autonomous weapons

Digital Cars

Ford GT has **10M lines of code** (more than Boeing 787)
http://blogs.ca.com/2015/08/13/iot-is-bringing-lots-of-code-to-your-cars-hackers-too

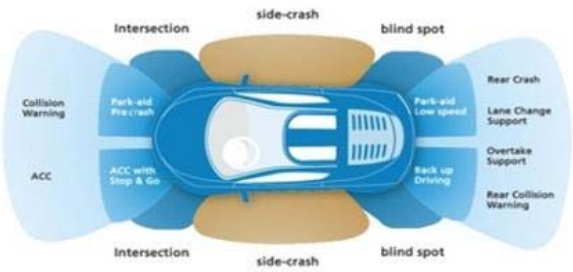
VW Golf has **54 computers, 700 data points**
http://digitalstrategies.tuck.dartmouth.edu/wp-content/uploads/2016/10/IoTEuropeanOverview.pdf

BMW estimates that **84M cars** (8%) worldwide are **connected to the internet** (**2015**) and it forecasts that **290M cars** will be connected by **2020**
http://www.politico.eu/article/google-vs-german-car-engineer-industry-american-competition

hackers controlled dashboard functions (steering, brakes, ..) of a moving car through vehicle entertainment system
https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway

Tesla **sold semi-autonomous cars** (2015)
https://www.wired.com/2015/10/tesla-self-driving-over-air-update-live

Google **autonomous cars** available to the public by 2020
http://www.ibtimes.com/google-inc-says-self-driving-car-will-be-ready-2020-1784150



Nevada was the first state in the US to pass a law **authorizing driverless cars** (2012)
http://www.forbes.com/sites/alexknapp/2011/06/22/nevada-passes-law-authorizing-driverless-cars

Autonomous Cars

autonomous (or driverless, self-driving, robotic) car: a vehicle capable of sensing its environment and navigating without human input

many **sensors** are used to identify navigation paths, obstacles and relevant road signs: radar, laser light (lidar), GPS, video cameras, infrared and ultrasound sensors, …

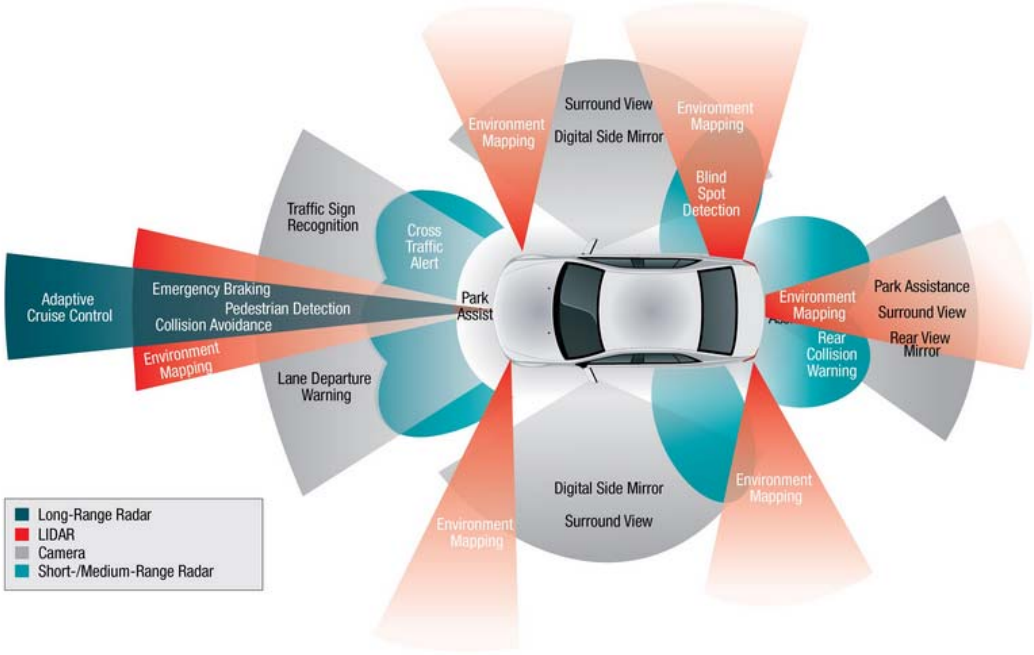
2012: Nevada assigned the first car driving license to Google's self-driven car

2015: testing of autonomous cars on public roads is allowed in the US states (Nevada, Florida, California, Virginia, and Michigan, Washington, D.C) and Europe (Germany, the Netherlands, Spain, France)

cities in Belgium, France, Italy and UK are planning to operate **transport systems** using autonomous cars

2018: trials of convoys of semi-automated trucks (platooning) will be allowed in UK motorways

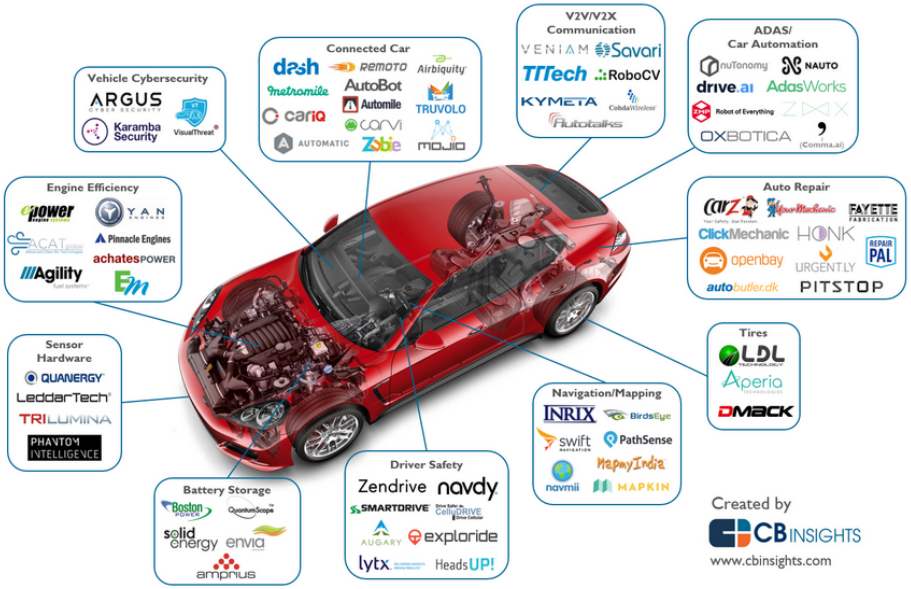
Audi A8 is capable of self-driving at speeds up to 60 km/h



Autonomous Cars

Intel Corp. forecasts a **$7 trillion "Passenger Economy"** by **2050**

Prediction based on **services and emerging applications generated from autonomous cars**, not on the future sales of self-driving cars

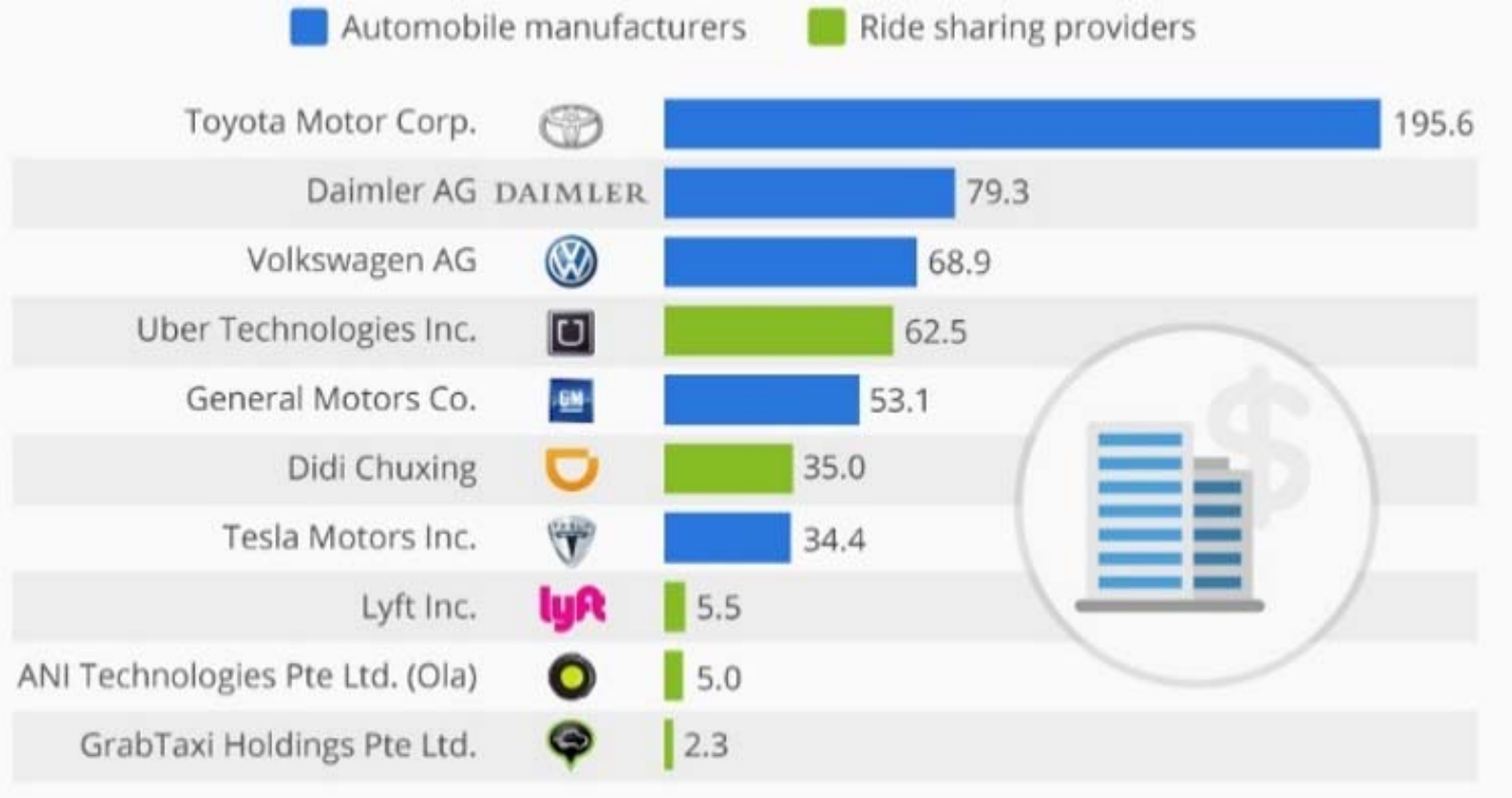


MARCH 21, 2017

21 Industries Other Than Auto That Driverless Cars Could Turn Upside Down

Car and Transportation Industry

Market capitalization/valuation of selected companies in 2016 (billion USD)



Sources: Bloomberg, Morningstar, Satista Digital Market Outlook

Additive Manufacturing

opposite to (traditional) **subtractive manufacturing**, creates objects by printing layer upon layer of loose material:

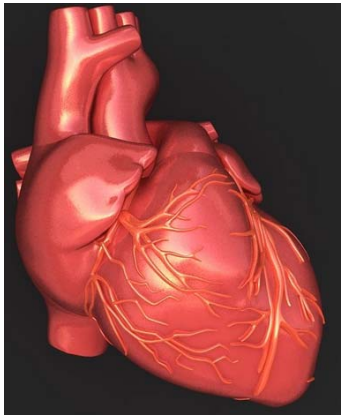
- from a **digital file**
- using **computer tomography** (3D laser scanner of existing object)

creation of **complex products** without complex equipment

materials: polymers, metal powders (aluminum, stainless steel), ceramics, alloys

Ex: 3D printing used to produce:

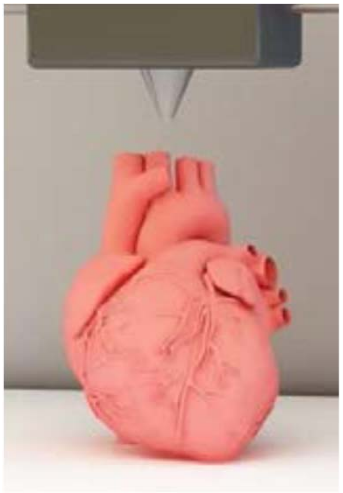
- circuit boards, toys, houses, wind turbines components, lightweight aircraft components (titanium saving)
- human organs and living tissues (**bio-printing**): skin, bone, heart and vascular tissue
- unique combinations of food ingredients (**food-printing**)



Additive Manufacturing

additive vs subtractive manufacturing:

- **high cost of mass production plants** ⇒ advantages for high volumes
- yet **limited range** of printable materials
- **limited size, speed**
- **high cost** of printers (price rapidly falling), and materials



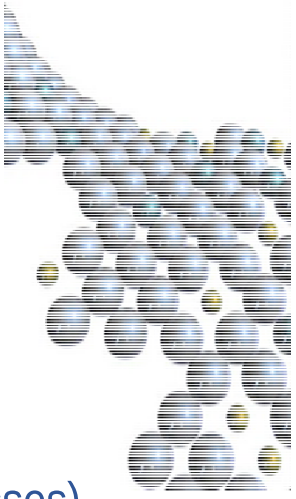
4D printing: **object shape changes** as result to a suitable environment stimulus (ex. gradient of pressure or temperature); proposed for clothing, footwear, space structures, ...

next future: 3D printing expected to **integrate** (not displace) **traditional manufacturing** (many products don't benefit from whole-scale customization)

Nanotechnologies and New Materials

Nanotechnologies:

- study and manipulation of material at molecular level (range 1-100 nm)
- currently focused on **development of new materials**



Nanomaterials:

- provide innovative solutions to **major challenges**:
  - **environmental sustainability** (e.g. energy and solvents reduction in industrial processes)
  - mitigation of **climate change** (e.g. carbon-capture and energy-storage materials)
  - **rapid diagnosis kits** (e.g. small-scale sensors for lab-on-a-chip applications)

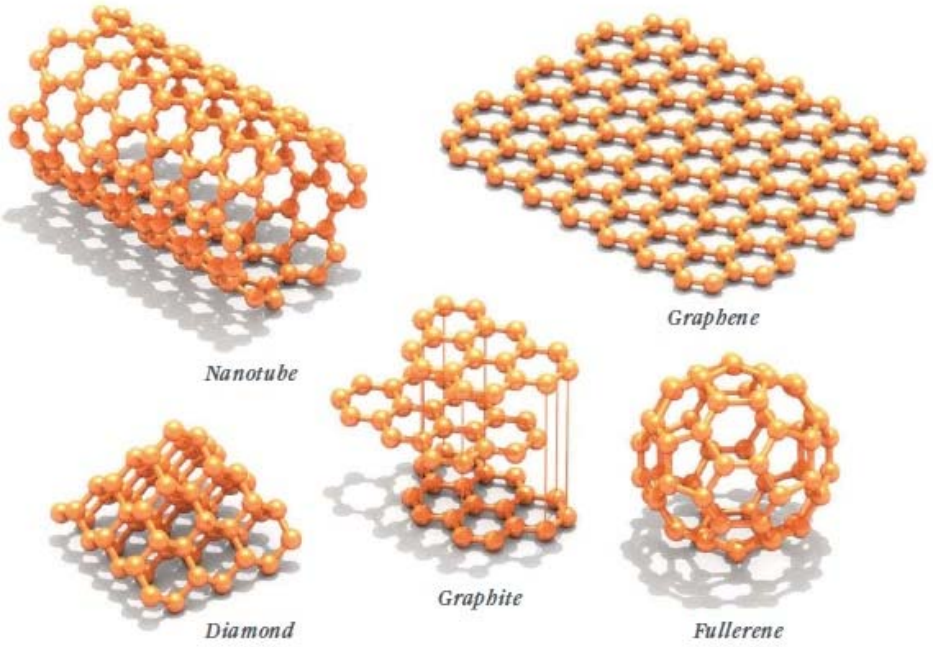
- pervasively **impact all fields**: manufacturing, food, agriculture, oil and gas, energy, aerospace, chemical, construction, biotechnology, electronics, environment, pharmaceutics …

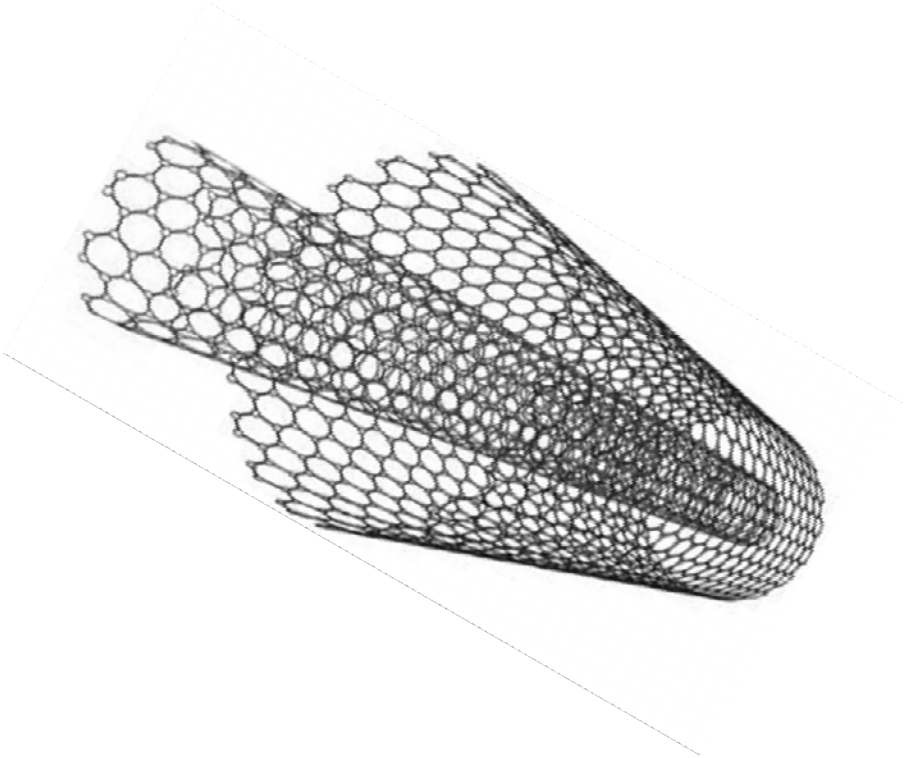
Nanotechnologies and New Materials

Ex: Carbon nanotubes: sheets of carbon atoms rolled into long, hollow threads with extraordinary properties:

- potentially a **hundred times as strong as steel**, while **weighing only one-sixth** as much
- dramatically **enhanced conductivity** of both electricity and heat

Potential new **lightweight materials** for cars and aircrafts





Nanotechnologies and New Materials

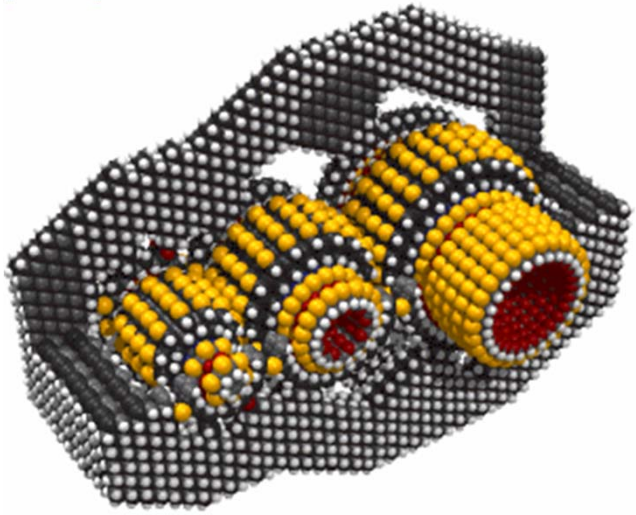
Ex of nanomaterials:

- **textiles** are becoming **smart**, through embedded **wearable electronics**
- **bacteria and food quality** monitored using **nanotechnology-based biosensors**
- customized nanoparticles can **deliver drugs** directly to diseased cells in the body
- **nano-filters** can provide **clean water** for a family of five people at just $16/year

a **futuristic vision** (feasibility is still questionable):

nanotechnology as "**molecular manufacturing**" =

ability **to create structures working atom by atom**
so obtaining fundamentally new molecular organization



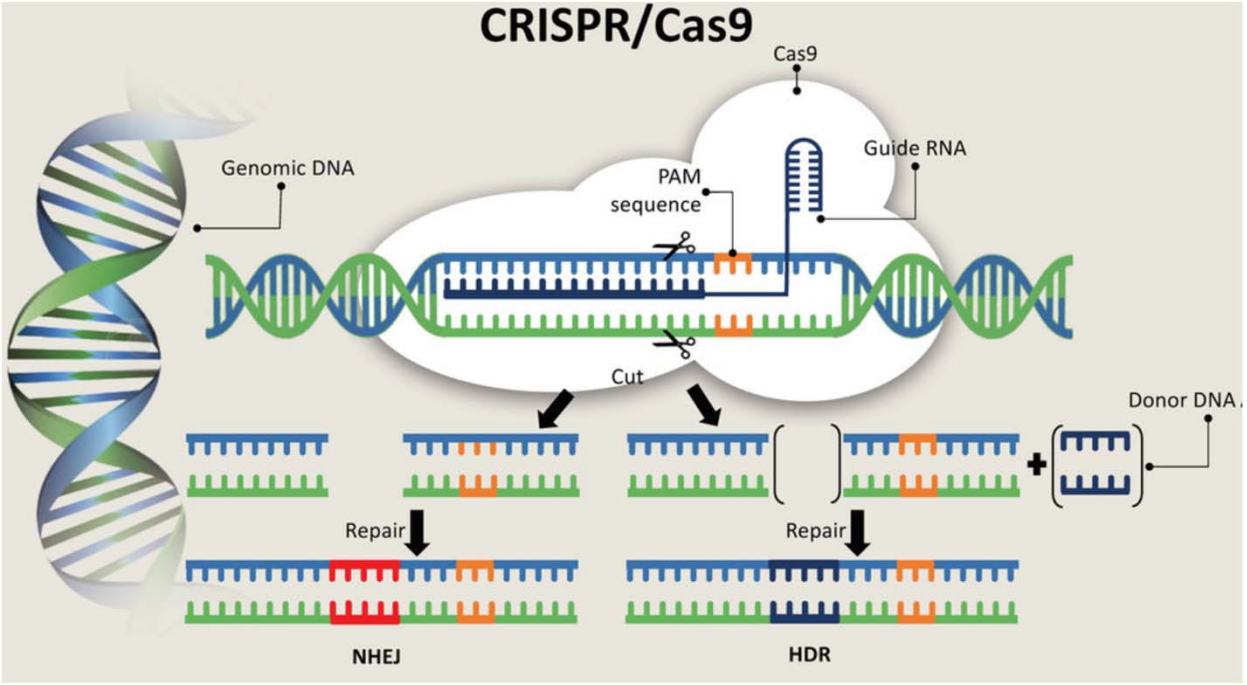
Biotechnologies

Genome editing (GE): a molecular procedure that allows to **modify the DNA** of a cell by **cutting the double strand** at desired locations (using proteins called nucleases that acts as "molecular scissors") and substituting, inserting or deleting a DNA segment.

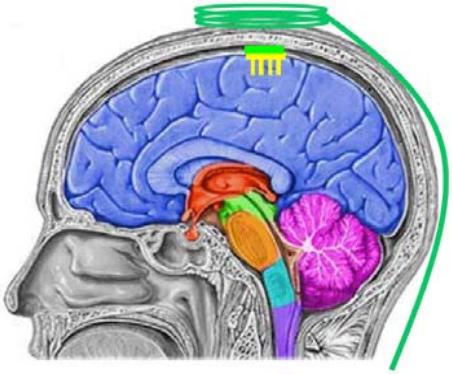
CRISPR/Cas9 technique allows the implementation of GE even in not highly equipped laboratories

⇓

huge impact in **gene therapy approaches** to human diseases (both genetic and non-genetic) is expected in the near future



Neurotechnologies



Neurotechnologies aim at the visualization, repair and improvement of brain functions

Brain computer interface (BCI) is a direct communication pathway between brain and an external device

BCIs aim at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions

Ex.: Using BCIs monkeys were able to navigate computer cursors on screen and direct robotic arms simply by thinking about the task and seeing the visual feedback.

Quantum Technologies

Quantum technology aims at transforming phenomena of quantum mechanics (in particular: entanglement, superposition and tunneling) into practical applications such as **quantum computing**, **quantum sensing**, and **quantum cryptography**

cyber security: quantum computer are considered perfectly secure because they can detect any type of intrusion

Quantum phenomena:

- entanglement allows to teleport one or more qubits between two (entangled) atoms
- superposition: a classical system can be in one state or the other; in quantum mechanics it can be in a superposition of both states at the same time; a qubit is represented as a linear combination of $|0\rangle$ and $|1\rangle$ (they represent the quantum states that always returns 0 or 1 when converted to classical logic by a measurement)
- tunneling allows a particle to "tunnel" through a barrier that it classically could not pass; it has important applications in tunnel diode, quantum computing, and scanning tunneling microscope

but technology is only an enabler ...

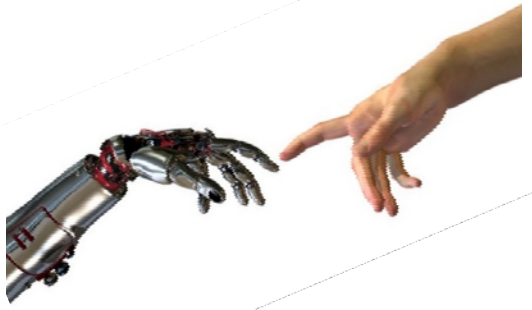
People 4.0

PEOPLE are the **main determinant** for success

- **T-shaped** (rather than specialists):
  - **"cold" skills**: technical, functional, multitasking, problem solving
  - **"hot" skills**: values, passions, participation, relational, proactivity, creativity, responsibility, adaptation, …

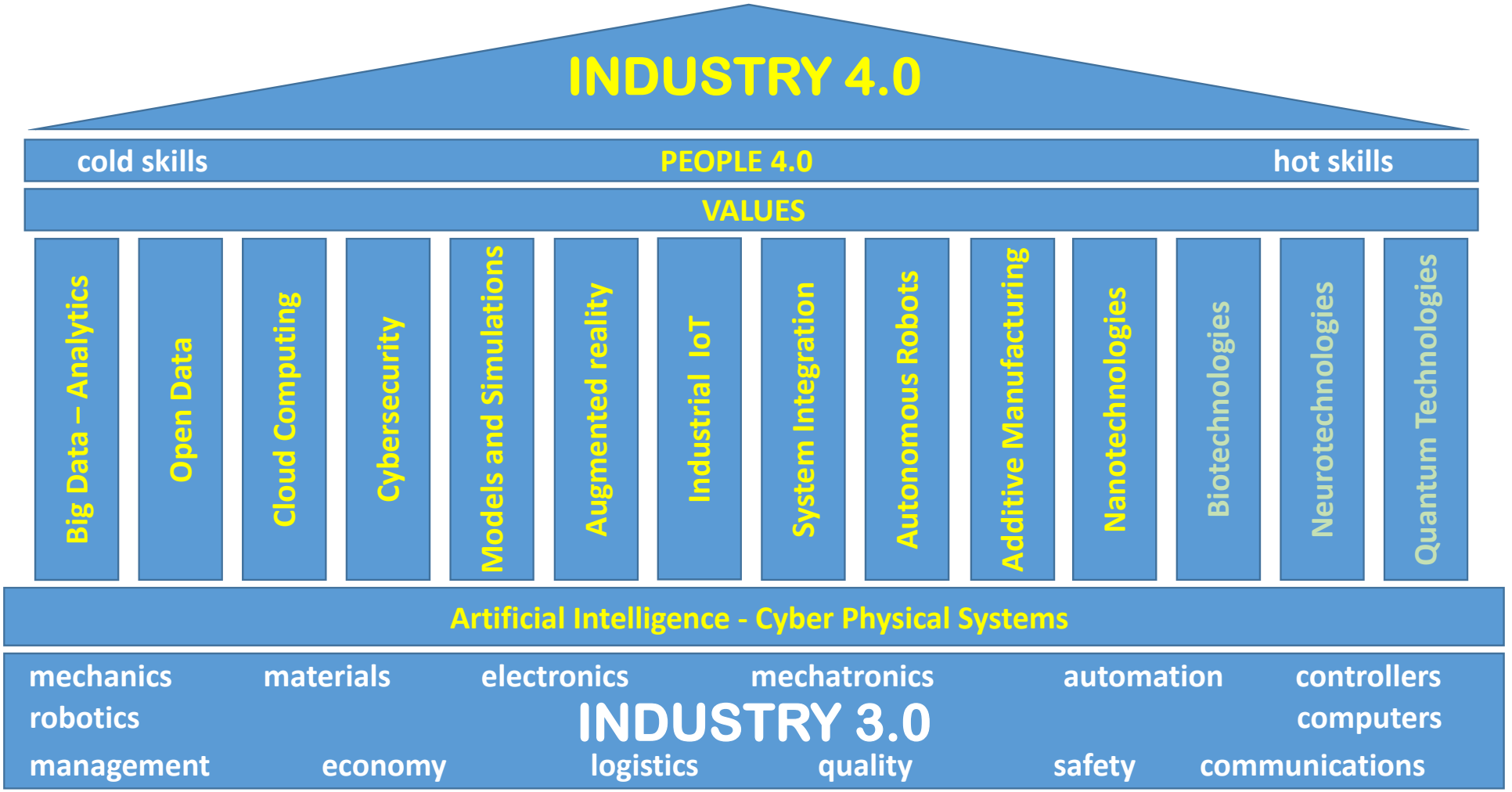
de-structured job relations:

- **independent workers** ("**human cloud**")
- **work at home**



Values 4.0

values aimed at **people and society benefit**


INDUSTRY 4.0
cold skills
PEOPLE 4.0
hot skills
VALUES
Big Data – Analytics
Open Data
Cloud Computing
Cybersecurity
Models and Simulations
Augmented reality
Industrial IoT
System Integration
Autonomous Robots
Additive Manufacturing
Nanotechnologies
Biotechnologies
Neurotechnologies
Quantum Technologies
Artificial Intelligence - Cyber Physical Systems
mechanics
materials
electronics
mechatronics
automation
controllers
robotics
computers
INDUSTRY 3.0
management
economy
logistics
quality
safety
communications

Technology: the Dark Side

The Role of Technology

technology never eliminate problems but it replaces them with **new needs** and **unintended consequences**

"*In tutte le cose umane si vede questo, chi le esaminerà bene, che non si può mai cancellare uno inconveniente, che ne surge un altro*"
N. Macchiavelli, *Discorsi sopra la prima deca di Tito Livio*

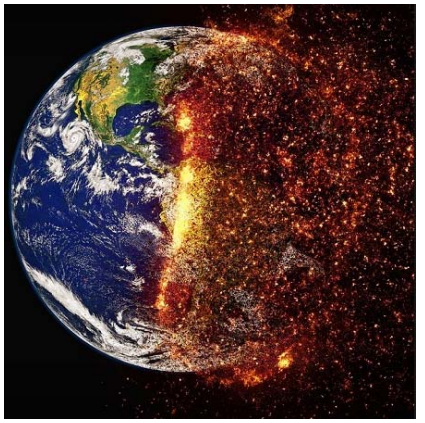
How to use technologies wisely?

probably the **most important question** facing humankind today

The Greatest Threats to Humankind

1) **nuclear war**
   a **clear** and **sudden** threat

2) **climate change**: global warming, ocean acidification, ecological degradation



3) **disruptive technologies**: breakthroughs in AI, brain computer interfaces, bioengineering, genetics, nanotechnologies, …

   vague and **gradual** threats
   (Chomsky principle of boiling frog)

Natural threats (**due to lack of knowledge**):
cold, famine, epidemics (e.g. cholera), volcanos, earthquakes, …

A New Ideology: Dataism

Data: the **raw material** of the digital economy, transformed in a major **trade asset** by the big players (trough sophisticated AI)

Dataist:

- perceives the universe as a **flow of data**
- considers **living organisms** as **biochemical processing systems**
- believes that **AI** can **outperforms human intelligence**
- makes decisions using **only indicators**

Data Science: a single overarching theory that **unifies all the scientific disciplines** (the scientific **Holy Grail**)

Ex: Beethoven's Fifth Symphony, a stock-exchange bubble and the flu virus seen as three patterns of dataflow that can be analyzed using the same basic concepts and tools

Metrological culture helps in **identifying the limits of information** acquired from the empirical world

A Big Brother

able to:

- control our minute-by-minute behavior (not only)
- control our ideas and emotions
- shape our bodies, brains and minds
- create entire virtual worlds

Chinese Social Credit System (SCS): **mass surveillance system** based on big data analytics aimed at assessing and controlling the behavior of individuals and businesses (planned to be fully implemented in 2020)

declared goal: fostering the perfect "socialist market economy" as well as strengthening and innovating societal governance

- **rewards** or
- **punishments** (flight ban, exclusion from private schools, slow internet connection, exclusion from high prestige work, exclusion from hotels, and registration on a public blacklist)

AI and Free Will

humanism shifted **authority from gods to people**

relying on **rationality** and **free will** of human beings

scientific evidences show :

- most human decisions based on **emotions** and **heuristic shortcuts**
- that people tend to think **collectively** (confirmation bias)
- "free will" results from a **biochemical mechanism**

AI systems could **know us better than ourselves**:

- medical decisions based on genetics and biometric sensors
- books read us while we are reading them (e.g. Amazon)

when AI will outperform human intelligence:

authority may shift **from humans to algorithms**

AI and Free Will

technology:

- **can help** if our life goals are clear
- otherwise it **shapes and controls** our life

Ex. The communication paradox:
easy to talk with people all around the world,
but hard to talk with relatives during meals

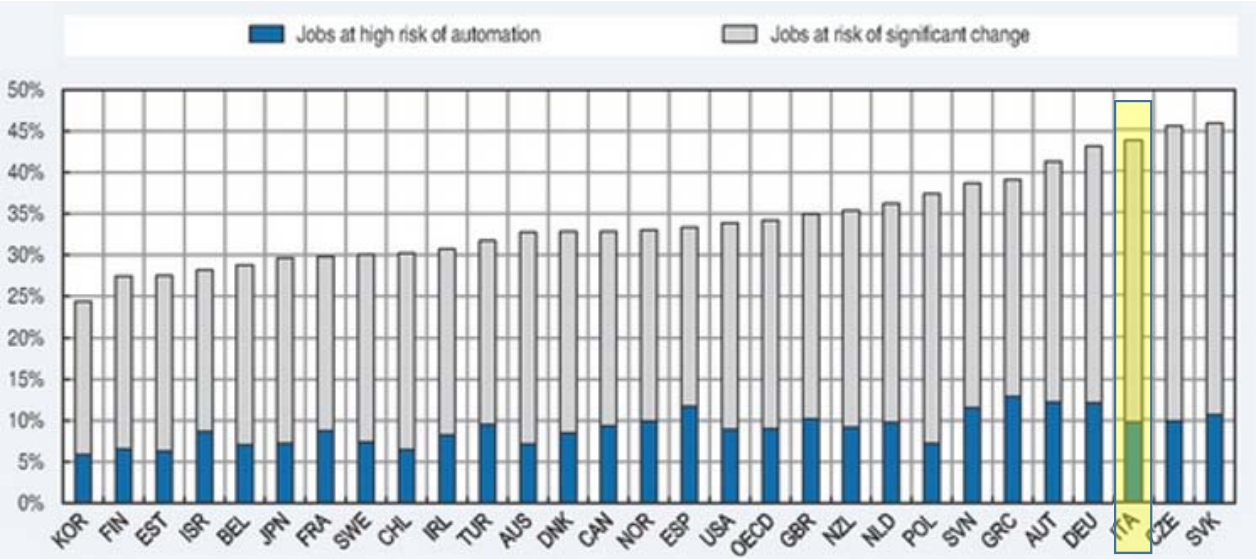
Ex. Cars and obesity

delegation **reduces our abilities**
of autonomous decision

Ex. Orientation ability and GPS

we can become **tiny chips** inside a
giant all-encompassing simulated reality

Impact on Employment



risk of automation in OECD countries

skills considered in the OECD's PIAAC: used on a daily basis at work by:

- **62%** of workers at a level that computers can reproduce
- **13% of workers at a higher level than computers**

- not used on a daily basis at work by **25%** of workers

ITALY: 10% jobs, high risk automation (P ≥ 70%); 34% jobs, risk significant changes (P = 50-70%)

Methodology based on the comparison of worker skills and computers capabilities using the OECD's Program for the International Assessment of Adult Competencies (PIAAC)

- PIAAC considers three skills (literacy, numeracy, problem solving) widely used at work by most workers
- computer capabilities at level demonstrated in the scientific literature (widespread application of a new technology usually takes one or more decades and sometimes never occurs)

Source: OECD employment outlook, 2017

Required Skills

if **computers outperform humans** in both physical and cognitive skills a **useless class** of **unemployable people** can arise

The prediction of the number of loss jobs is serious, but it is **not the main question**

The main questions are:

- **What will be the future of work?**
- **How will we define work?**
- **How will we share the wealth?**

Required Skills

19th century I.R.: continuous innovation of products and processes

21st century I.R.:

continuous innovation of ourselves

- not two well separated/complementary **life phases** (education and work), but a complex sequence of overlapped phases
- continuous **stress** due to **work instability** (place/ profession)

is the average human enough **emotionally resilient**?

Required Skills

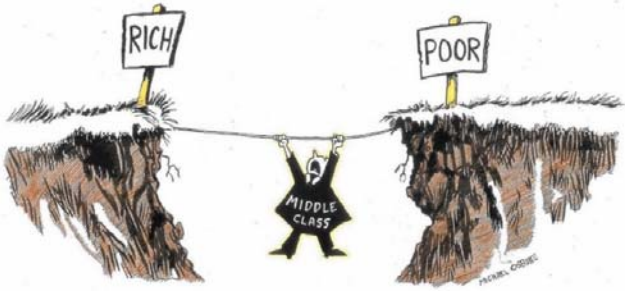
increasing demand for:

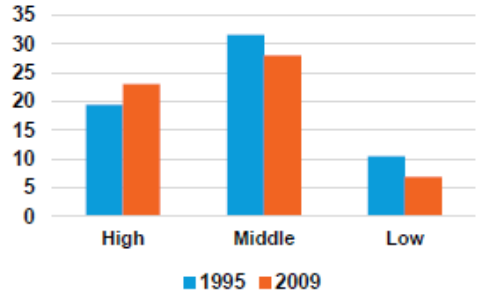
- **critical interpretation** of information
- **change** management
- **social** skills: machines cannot exhibit empathy
- **complex problem solving** and **creative** skills
- capability to **work alongside technological systems**
- ability to **adapt continuously** and learn new skills and approaches

Social Inequality

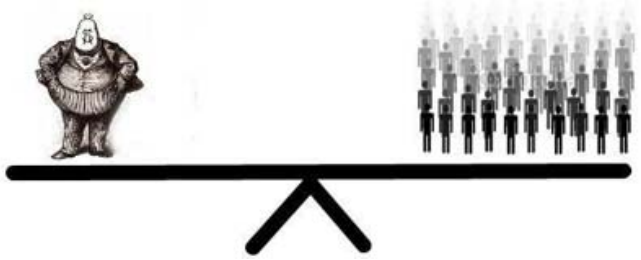
a critical mass of **middle-class households** is one of the main factors that **differentiates advanced and poor Nations**

- ✓ **50%** of all **world assets** controlled by the **richest 1%** of the global population (Credit Suisse's Global Wealth Report, 2015)
- ✓ **50%** of the **population** own less than **1% of the wealth**, the same as **42 richest people** in 2017 (61 people in 2016)
- ✓ in 2017, **82%** of wealth generated went to the **richest 1%**; no wealth increase to the poorest 50% (Oxfam, 22 Jan 2018)
- ✓ in 2017, billionaires improve earns of **$762 billion**, enough to **end global extreme poverty seven times**
- ✓ **1.5% taxation** on billionaires' wealth could pay for **every child to go to school**





Labor share in advanced economies
(Oxfam report, 22 Jan 2018)



Social Inequality

- **classic ideologies** (humanism, liberalism, socialism ...)
- **industrial revolution**

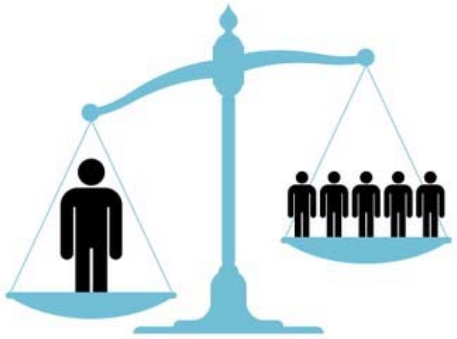
relied on masses (of workers, customers, soldiers) thus:

- masses acquired economic and political **relevance**
- **equality** became the **dominant society value**

globalization was expected to spread prosperity, freedom and equality

Digital world:

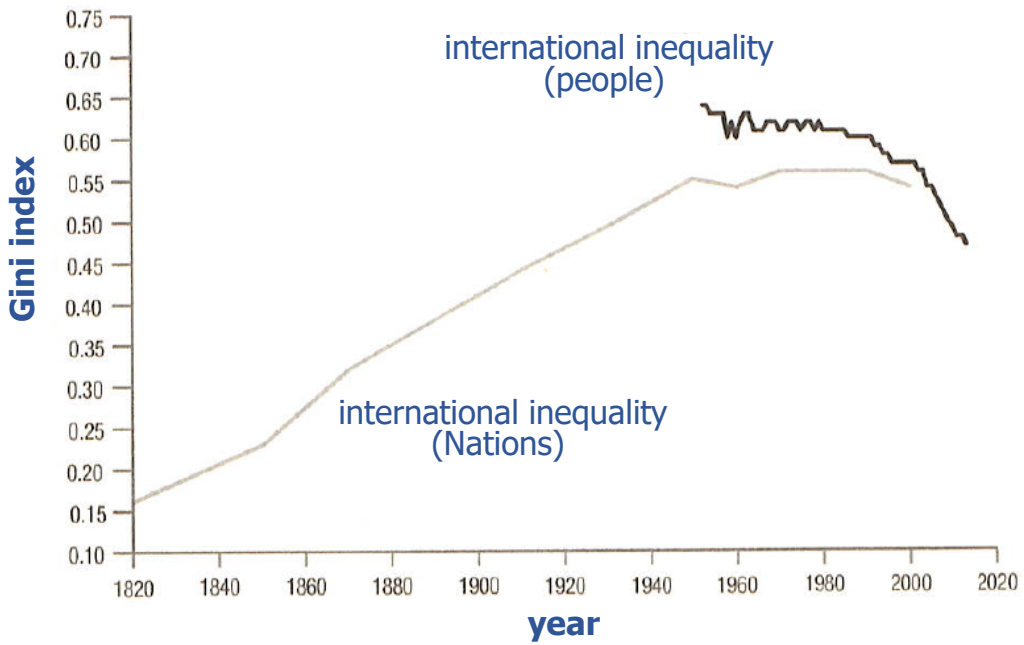
masses are not so relevant, **inequality** may arise



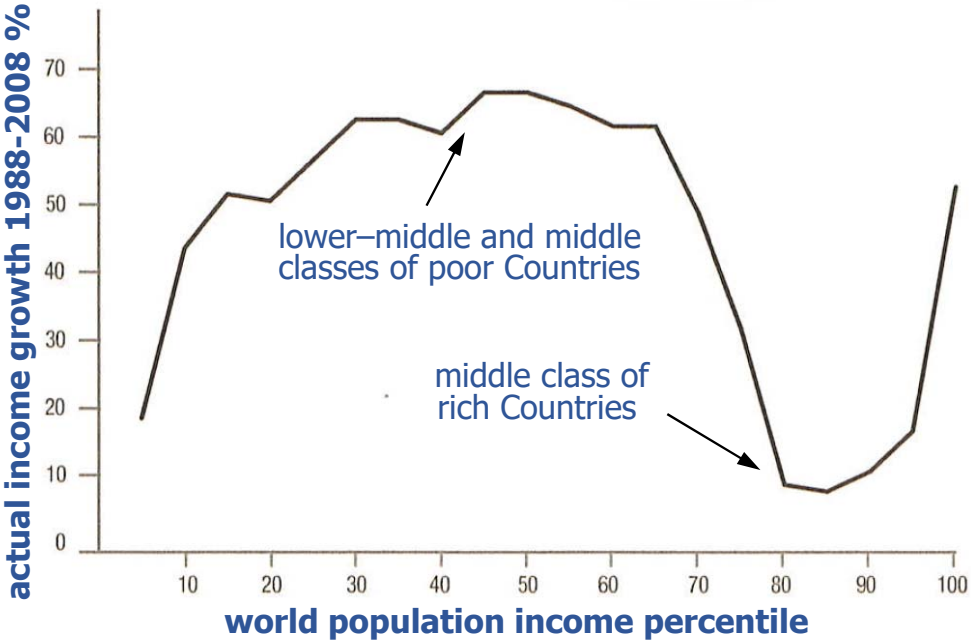
Economic Inequality

Gini index

(0 = perfect equality, 1 = max inequality)

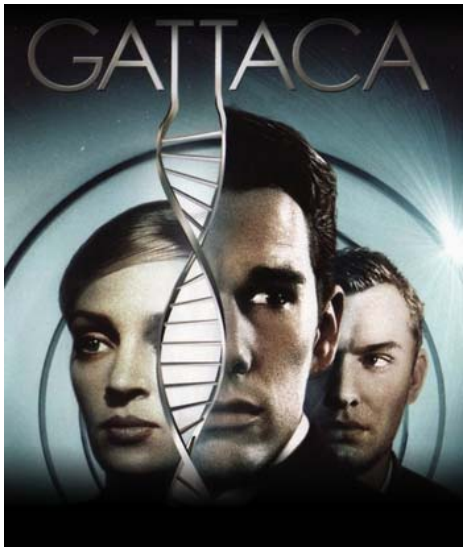


Economic inequality has increased in rich Countries



Biological Inequality

hacking humans: bodies and brains engineered to upgrade physical and cognitive abilities (e.g. design babies)



expensive treatments could shift economic inequality into **biological inequality** and **biological castes**:

- a small upper class of enhanced **super-humans**
- a massive underclass of "**useless**"

❖ **Current technology** (**extrovert**): reshapes the **world outside us** and we are disrupting the entire ecological system

❖ **Next future technology** (also **introvert**): can reshape the **world inside us** (our body and brain) and we might disrupt humankind

Industry 4.0:
An Interpretation

The Context: A Historical Interpretation

History helps in finding answers to big questions and crafting a positive vision

***Chi vuol vedere quello che ha da essere, consideri quello che è stato**; perché tutte le cose del mondo, in ogni tempo, hanno il proprio riscontro con gli antichi tempi. Il che nasce perché essendo quelle operate dagli uomini, che hanno ed ebbero sempre le medesime passioni, conviene di necessità che le sortischino il medesimo effetto*

N. Macchiavelli (1469-1527), *Discorsi sopra la prima deca di Tito Livio*

Renaissance: Breakthroughs

Communication:
- Gutenberg's printing press (1450s)
- internet, mobile and social media

Knowledge:
- Copernicus's theory of sun-centered cosmos (1510s)
- Development of perspective in painting
- cracking the human genome
- gravitational waves, extrasolar earth-like planets,

Engineering:
- cathedrals, ship design innovation, new navigation instruments
- nanotechnologies, quantum computing
- 3D printing, AI, autonomous cars

Medicine:
- human heart as a pump (not the soul)
- treatments, genetics, post-humans; life expectancy

Social organization:
- development of the customs and conventions
- globalization

Education:
- Arabic number system, higher algebra
- first generation to be near-universally literate

Urbanization:
- cities offered more incomes and protection, richer social and intellectual life
- urban epoch: majority of people live in cities (2008)

Breakdown of Barriers:
- Columbus discovered the New World (1492)
- Vasco da Gama's route to Asia (1497)
- fall of Berlin wall (and economic ideologies)
- China: from autarky to the world's biggest exporter

Renaissance: Crisis

Crisis of Faith in the Fundamentals Dogmas
- Protestant reform, Martin Luther (1483-1546)
- Apocalyptic sermons, G. Savonarola (1452-1498)

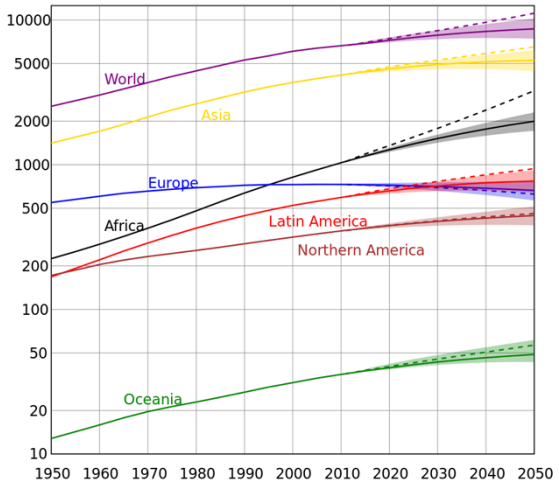
Systemic Risks
- obsolescence of communities along the Silk Roads
- new diseases rapidly spread
- religious wars and Inquisition
- popular revolts

Migrations due to:
- Turkish conquest of Constantinople
- Spain Inquisition (Catholic purity)
- Luther's Reformation (large scale EU migration)
- Atlantic slave trade

- liberal ideology and democracy are weakening
- US no more world's chief promoter of free trade
- EU dream is weakening

- global warming
- global financial crisis
- nuclear meltdowns (also in the hyper-safe Japan)
- new epidemics: SARS, Ebola, HIV/AIDS, H5N1 (bird flu)
- terrorism, extremism, protectionism, xenophobia

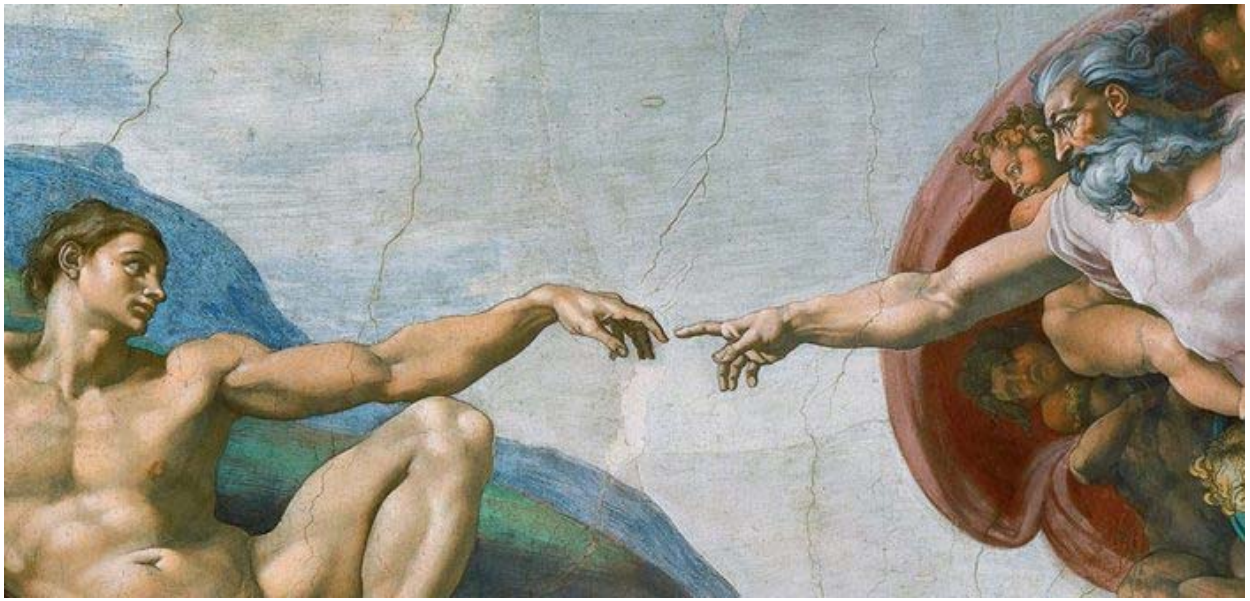
World population,
UN prediction, 2015



- world level migration

- digital world migration

Renaissance



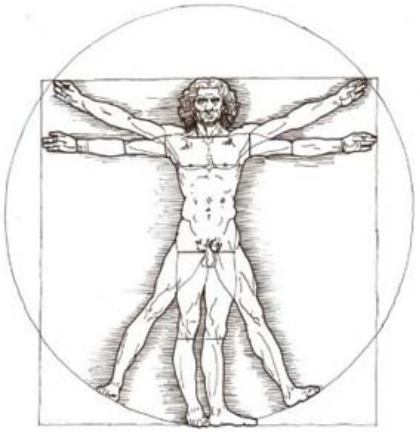
- age of **exceptional achievements** in art, science and philosophy, which paved the way to Scientific Revolution and Enlightenment, reshaping humanity and the whole world
- age of **breakthroughs**, a clash of **creative and destructive forces**

Industry 4.0: Conclusions

Conclusions

thinking about the **future that we wish** is reflecting on

WHO WE ARE and **HOW WE SEE THE WORLD**



ensuring an **empowering,**
cohesive and human centered future
(rather than divisive and dehumanizing):

A TASK FOR EVERYBODY

Conclusions

Technology evolution brings:

- ✓ **BIG OPPORTUNITIES**
- ✓ **SYSTEMIC RISKS**

for both **individuals and society**

Conclusions

- ✓ the **GREATEST RISK** (**PERFECT STORM**): soaring **inequality**, **unemployment**, **climate** change, **resource** depletion unfold together, amplifying and reinforcing each other

- ✓ the **BIG OPPORTUNITY**: the potential to address (possibly solve) the **MAJOR WORLD CHALLENGES** and **benefit all**

Conclusions

MAIN LEVERAGES for a **BRIGHT FUTURE**
(principal architects of **4 Gyears evolution**):

✓ **ADAPTION** to a **changing context** of increasing complexity

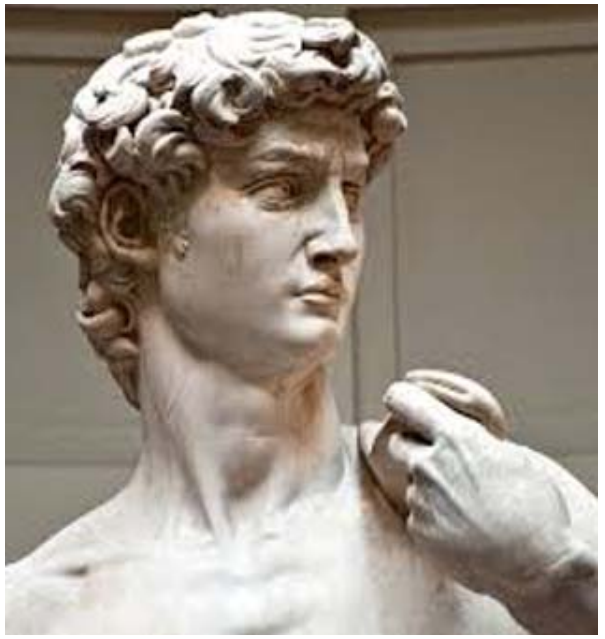
✓ **COOPERATION**

- to strengthen **cohesion** and **trust** through which progress is achieved
- **empowerment of all relationships**: government/citizens, enterprises/employees, customers …

Conclusions

Michelangelo's David (1504):

the **moment between decision and action**,
when he knows what he must do and
summoning the courage to do it



We are living that moment

"*Il vero **pericolo non è porsi obiettivi troppo alti e non raggiungerli**, ma porseli troppo bassi e raggiungerli*" (attributed to Michelangelo)

"*Se la gente sapesse **quanto duramente ho dovuto lavorare** per acquisire tanta maestria, la mia arte non sembrerebbe così meravigliosa*" (attributed to Michelangelo)

Conclusions

current technology evolution

could catalyze a

NEW CULTURAL RENAISSANCE

a true **GLOBAL CIVILIZATION**

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