Big Data Science

Prof.dr.ir. Geert-Jan Houben

TU Delft

Web Information Systems

Delft Data Science

KIVI chair Big Data Science

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big data: it's there, it's important

it is interesting to study it,
to **understand** it,
and to know how to **engineer** it

scientifically, we are driven by many **questions** and unprecedented challenges

Questions driving Big Data Science

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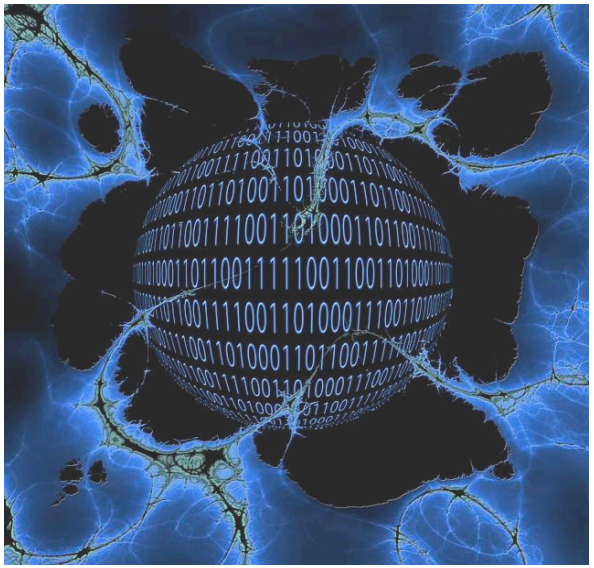
100 billions in
economic and societal **value**

millions of new jobs and
millions of new talent to educate
in **technology** to get knowledge
and value out of big data

often, (massive amounts of)
data from **outside** the system
with properties that systems are
grappling with –
“data, too big to handle”



Big Data can fuel our economy & society

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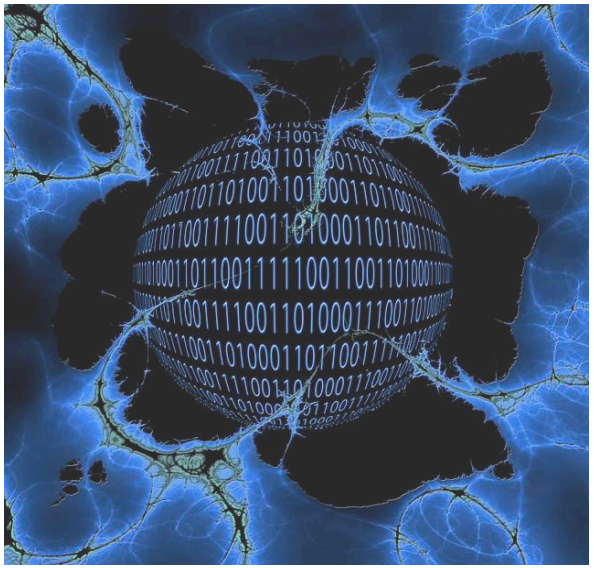
- decentralized & sustainable energy systems
- smart mobility
- personalized health
- smart industry
- digital society
- smart enterprises
- integral water management
- secure society
- intelligent living environments



Smart sectors rely on Big Data

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typically information technology, **computing** science,
and a natural focus on software

the complexity is thought to be in **efficiency**

a **prescriptive** design approach: closed, fixed, centralized

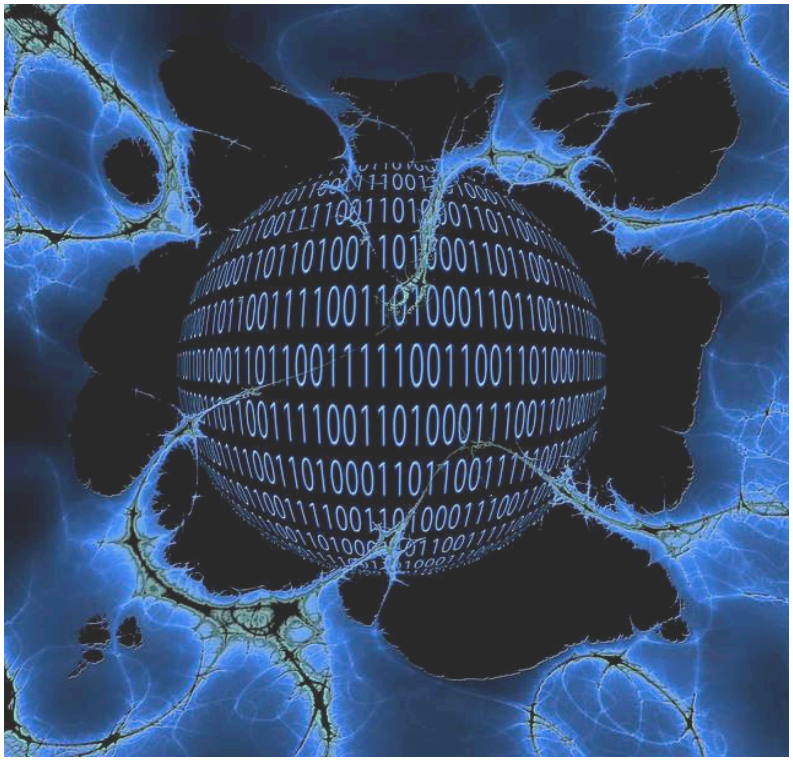
data representing the ‘world’ is **made** to fit the software

Traditional role of data

the Web brought linking **data** & connecting it to **people** for adaptation: utility

a **descriptive** approach: open, dynamic, decentralized

an **unprecedented** source of data about the ‘world’ (that people are part of) - “big data, too big to handle”



Web & Data

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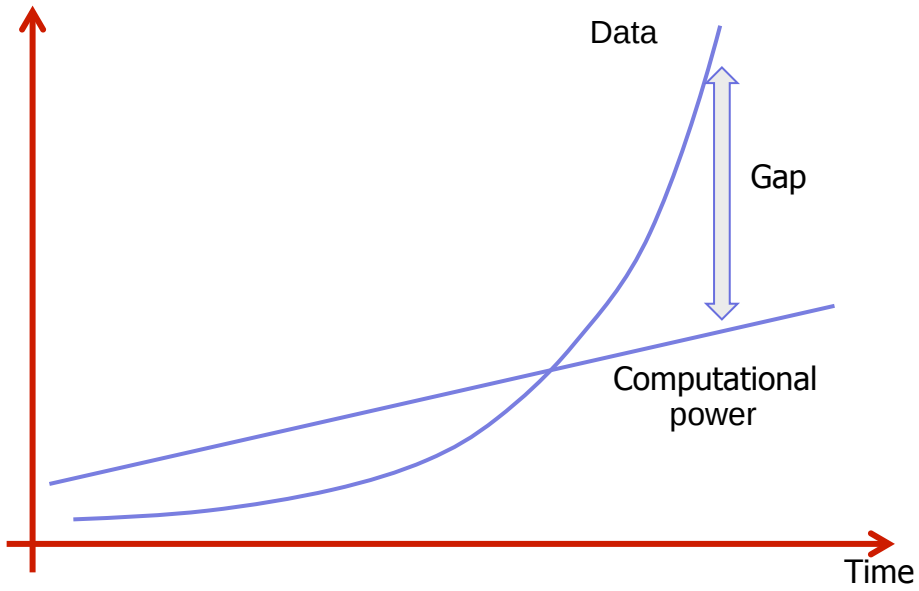
technology to handle big data asks for a **fundamentally** new computing science

digital (Web) data and its descriptions of the world bring a new **complexity**

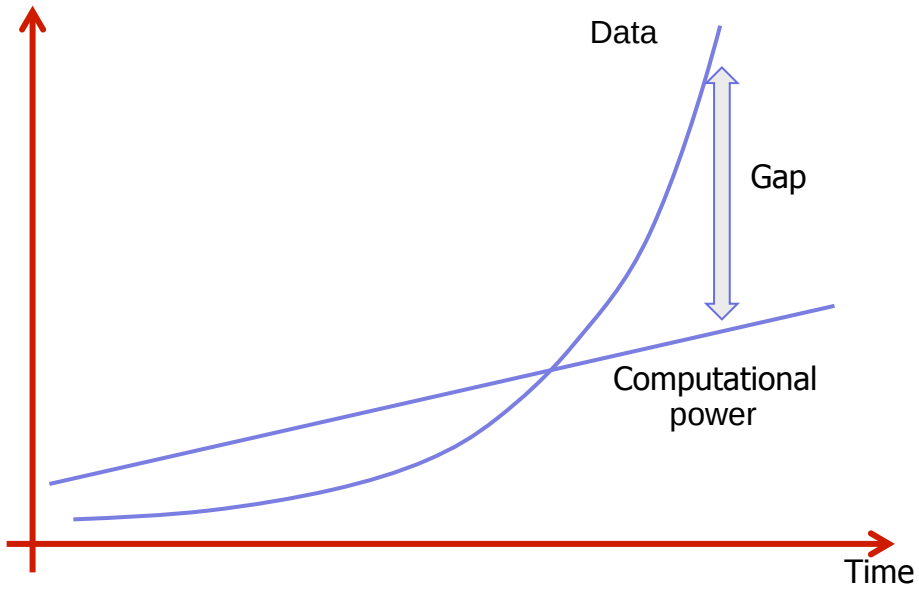
to make sense of the data, data science is all about **S**emantics, w. **S**cale, **S**peed & **S**ustainability



Complexity in data

data science is
a new scientific discipline for
scientific **understanding** and
creating **technology** for
how to create, process, and
understand digital data

data science is the foundational
discipline for **engineering**
data-driven systems



Data Science for advancing technology

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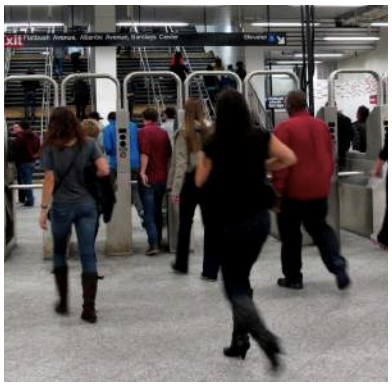
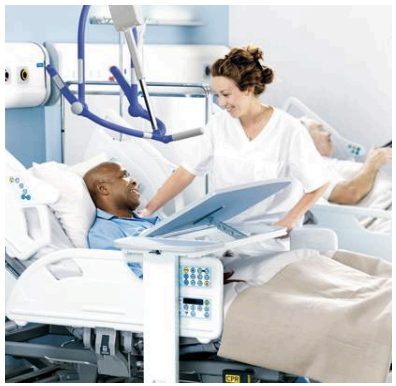

big data sets can be interpreted with **new scientific methods**

the world can be observed in **more detail**, leading to new knowledge and insight, and potentially better products, service or decisions

more detailed reflections of the world come with **new** questions

Data reflects the world

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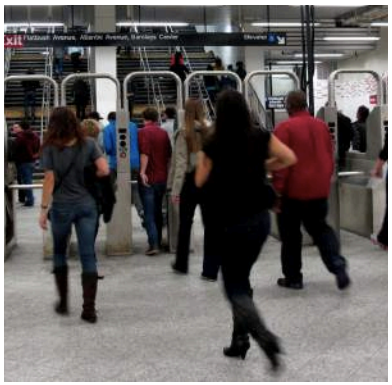
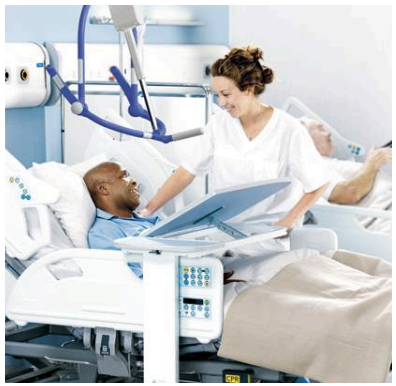

how to **conclude** from heterogeneous, incomplete, unverifiable, sensitive, distributed data with **unknown** errors?

how to relate big data to **small** data?

how to **check** and **repeat** analyses?

Unprecedented reflections

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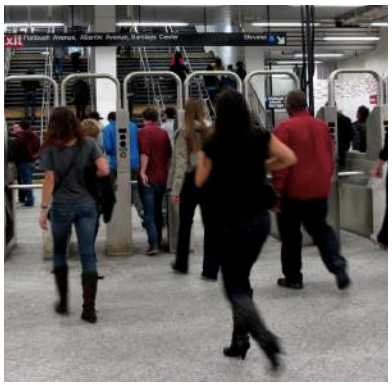
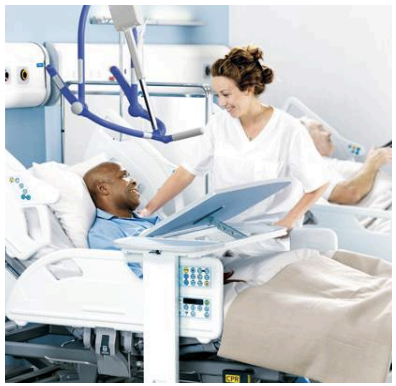

how to prevent **false** conclusions?

how to answer questions without revealing **secrets**?

how to answer questions without stopping **time**?

how to handle **ownership** of data and satisfy personal and legal **contexts**?

Unprecedented reflections

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TU Delft coordinating initiative for research, education and training in data science and technology

Delft Data Science – research & education for technology & talent

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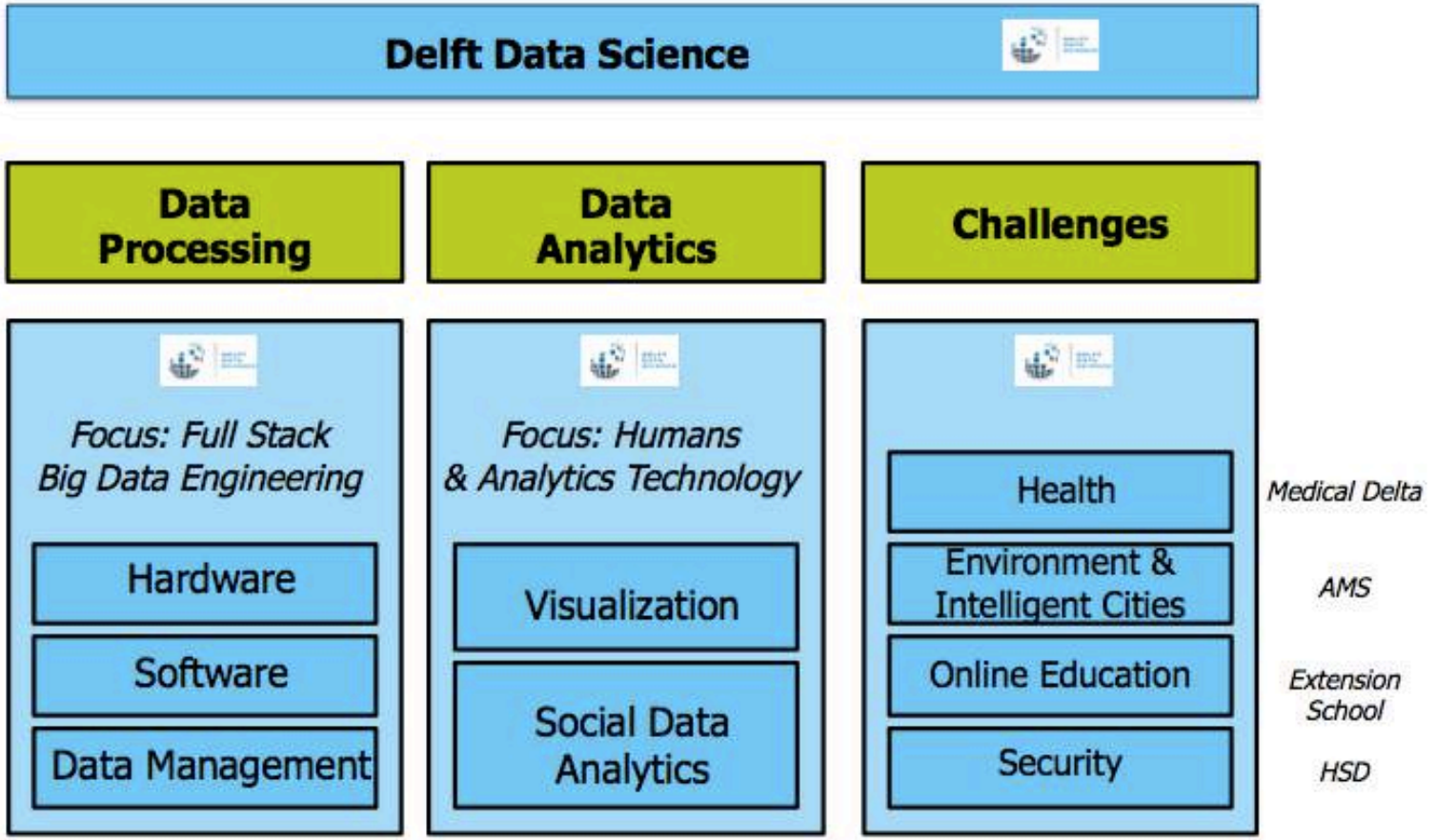

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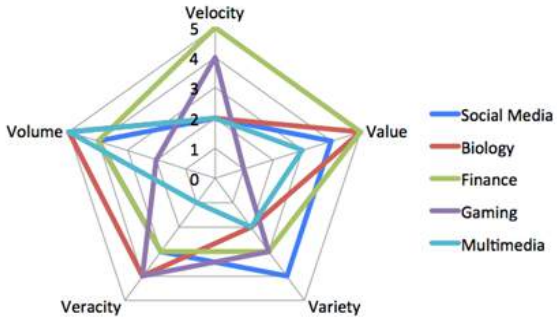
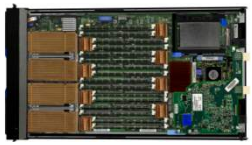
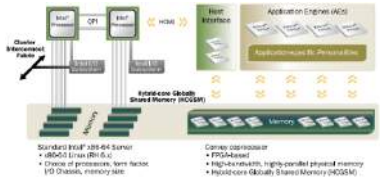
Hardware for Data Science

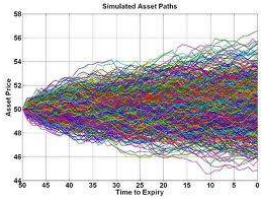


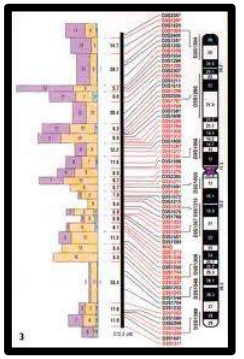
Big Data Computing Systems:
application specific
computing systems and hardware





New Algorithms & Architectures:
application and domain specific
e.g. finance/bio-informatics/seismic





Enabling big data computing systems to adapt to the challenges

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Software for Data Science

Problem: programming multi-core distributed cloud machines with Von Neumann programming languages

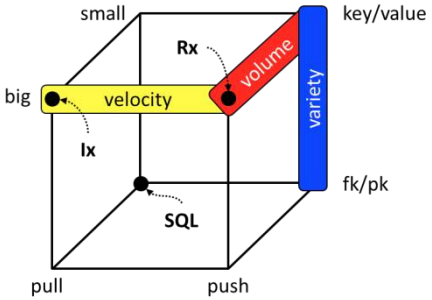
Problem: data engineers and scientists not trained as software engineers

Solution: programming languages that abstract from hardware, close to domain experts

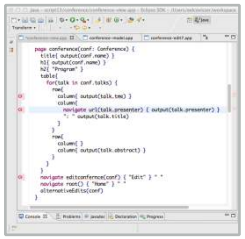
Cloud Programming:
composing computations using mathematically solid foundations

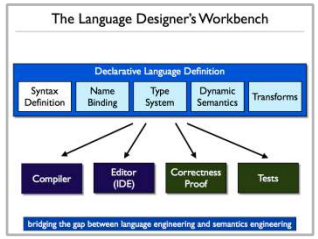
reactive extensions

interactive extensions



Domain-Specific Languages:
enabling software engineers to systematically design & apply DSLs





Enabling programmability of big data analytics

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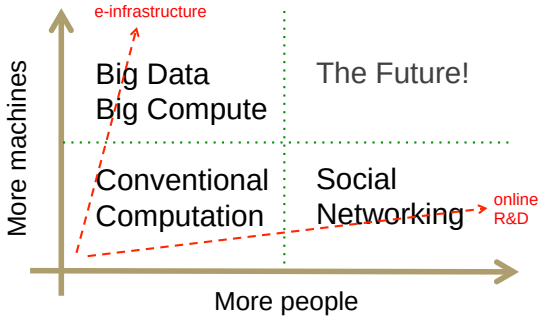
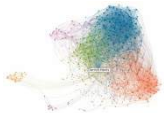
Data Management for Data Science

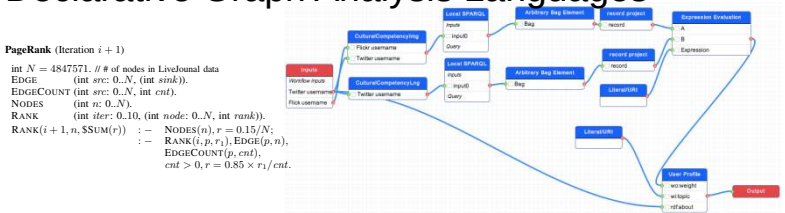


Graph & Network Data Processing:
processing graphs and networks
at big data and web scale



Web-Scale Graph Indexing

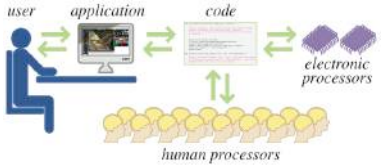
Declarative Graph Analysis Languages



Optimizing Big Data Processing Workflows

Humans Interacting in the Process:
enabling systems to include
human computation & interpretation

Crowdsourcing and Human Computation



Crowd Capacity

Data Generation & Data Curation

Enabling big data management at scale and with human interpretation

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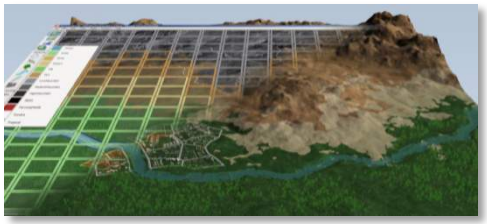
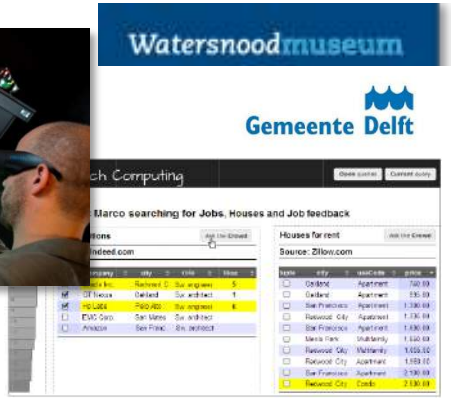
Visualisation for Data Science



Big Data Visualisation:
for real-time visual analytics
e.g. medicine, environment

Big Data Interaction:
for intuitive big data
exploration and manipulation



Enabling big data visual analytics

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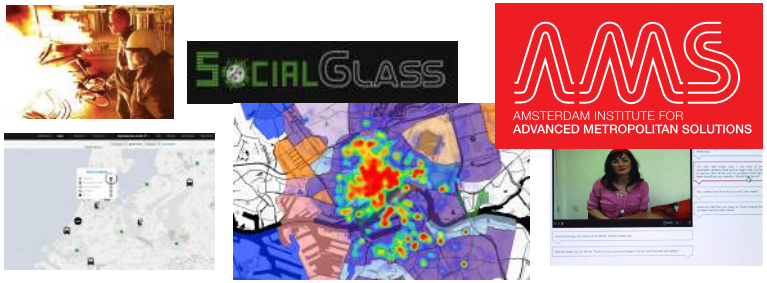
Science of Social Data

Opportunity:
data generated by humans, (re)presenting their take on the world

Challenge: largest source ever made, with yet-to-discover semantics

Social Data Analytics Machines:
repurposing social data that is out there, in controlled & well-understood manner

- Emergencies & incidents
- Intelligent cities
- Massive online education



Data Creation & Interpretation Machines:
including humans & human computing helping software in pro-actively creating & interpreting social data

- Social sensing
- Workforce engagement
- Crowd annotation & knowledge creation

Unlocking human-generated data

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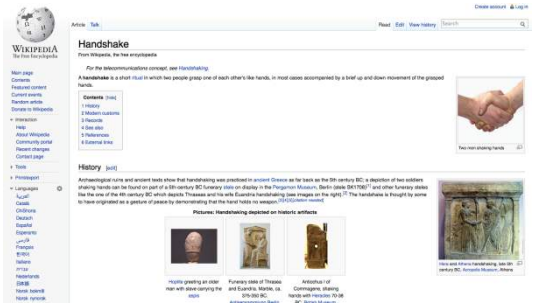
Example: Online Education



Learning analytics

with Delft Extension School for Open & Online Education

*analytics to make online education truly **learner-centric** and to adapt to the students & their backgrounds*

***massive** online education is about massively adapting to the context of use*

*with increasing diversity comes importance of social and cultural features: **inclusion***

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Unlocking Social Data:
Software & Human-enhanced Machines with Well-Understood Properties

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WIS - Web Information Systems

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Science of social data

1. Social data gives us one of the **largest reflections** of the world, but/and it is a **man-made** reflection
   'unique opportunity turning into interesting research problem'

2. Sense & value come from big data, but even more so from what (software and human-enhanced) **machines** can make of the data
   *'V = M * D'*

3. The **power** of what machines can do with the data needs to be well-understood and transparent for solid engineering and uptake
   'what machines can do and what they cannot do'

4. Science and technology follow the principles of the **Web**
   'fundamental & experimental'

Data Science for **Intelligent Cities**
Data Science for **Environmental Monitoring**
Data Science for **Finance**
Data Science for **Health**
Data Science for **Online Education**
Data Science for **Cybersecurity**
Data Science in **Open Data**
Data Science for **Workforce Management**
…

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Delft Data Science & domains

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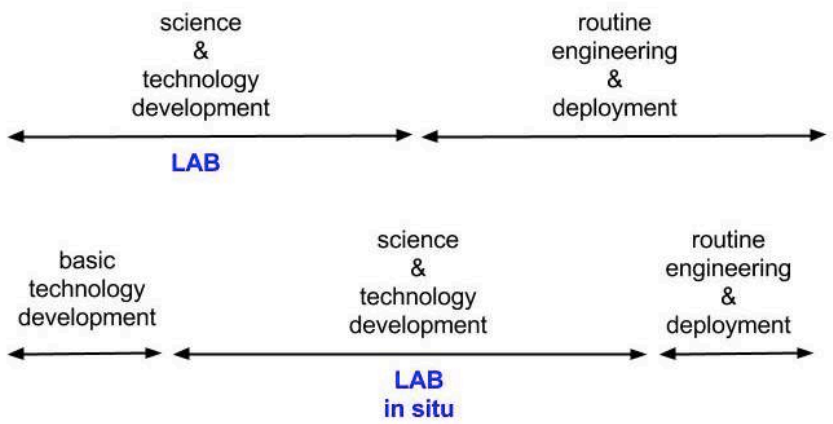
data science comes with **new methods** for doing science and new **ways** to **collaborate**

data science labs are **in-situ**

data science research shows the importance of **local understanding** of how to apply [seemingly global] technology



New scientific methods & collaborations

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Research Agenda

Over the coming years, researchers engage with engineers for inspiration, experimentation, and valorization.

We invite to collaborate.

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Next?

Today, the first three master classes.

Get introduced to three branches of data science.

Engage with this research after today.

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Alexandru Iosup

Scalable High Performance Systems

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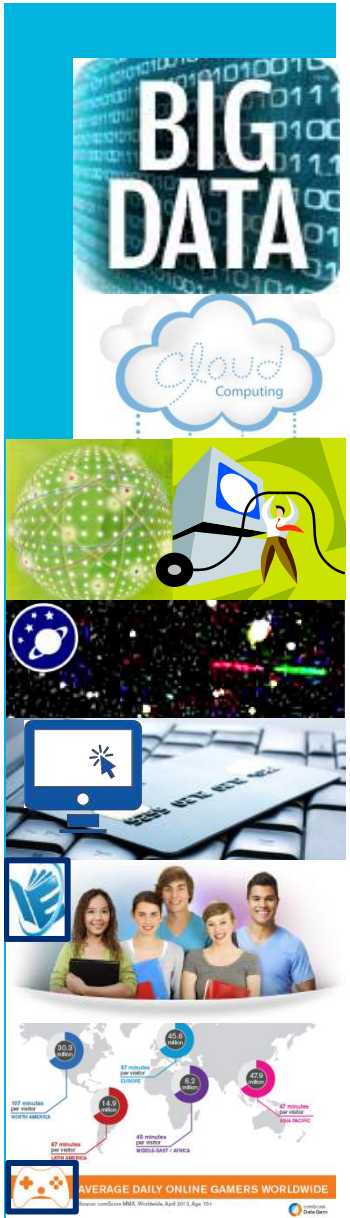

Scientific and Societal Challenges

How to massivize datacenters?

- Super-scalable, super-flexible, yet efficient
- End-to-end automation
- Dynamic workloads
- Evolving hardware and software
- Strict performance, cost, energy, reliability, and fairness requirements

The quadruple helix: prosperous society & blooming economy & inventive academia & wise governance

- Enable data access & processing as a fundamental right in Europe
- Enable big science and engineering (2020: €100 bn., 1 mil. jobs)
- “To out-compute is to out-compete”, but with energy footprint <5%
- Keep Internet-services affordable yet high quality in Europe
- The Schiphol of computation: Netherlands as a world-wide ICT hub

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Alessandro Bozzon

Crowdsourcing in Enterprise Environments

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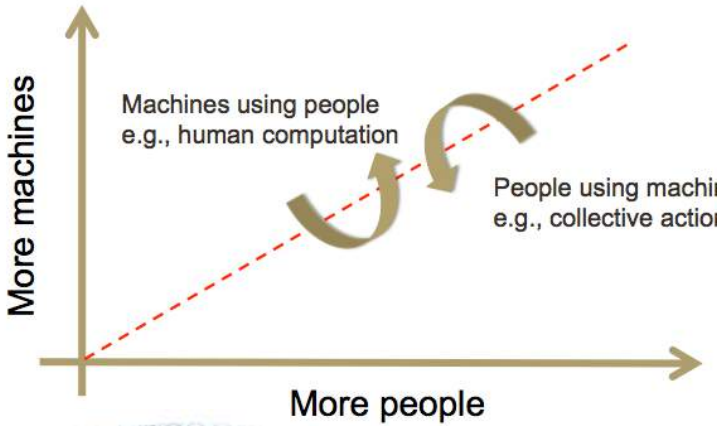
Challenges

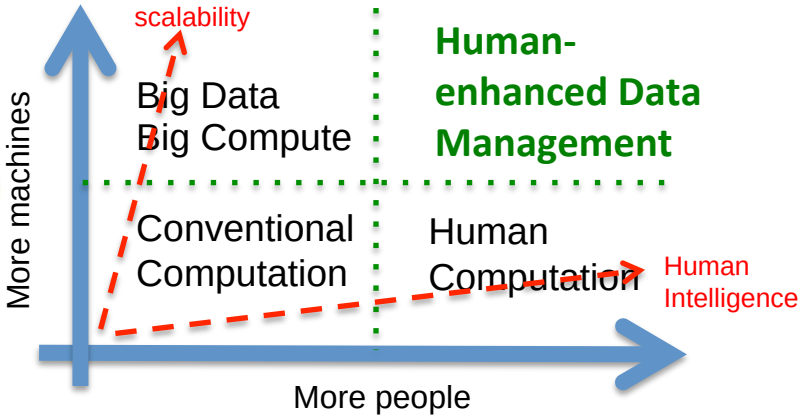
Scientific Challenge:

- How can humans and machines better collaborate in computation problems?

Societal (and business) challenges

- Knowledge Creation
- Inclusion and Well-being
- Employment





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Zaid Al-Ars

Acceleration of Personalized Medicine Applications

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Scientific and societal challenges

- Urgent clinical diagnostics, for example
  - Targeted cancer & neo-natal diagnostics
  - ➔ We provide techniques to ***reduce compute time***
- Cost prohibitive for society
  - More patients & diseases to be treated
  - ➔ We provide techniques to ***reduce cost***

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