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Big Data

Instructor: Peter Baumann

email: p.baumann@jacobs-university.de

tel: -3178

office: room 60, Research 1

Data Deluge

- „It is estimated that a week‘s work at the New York Times contains more information than a person in the 18th Century would encounter in their entire lifetime and the thought is that within 10 years the rate of information doubling will occur every 72 hours.“
  - -- P. „Bud“ Peterson, U Colorado
- “global mobile data traffic 597 petabytes per month in 2011
  - 8x the size of the entire global Internet in 2000
  - estimated to grow to 6,254 petabytes per month by 2015”
  - -- Forbes, June 2012

2012

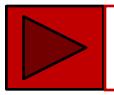
[saubere-zaehne.de]

[atlasformen.de]

[thenextweb.com]

Big Data

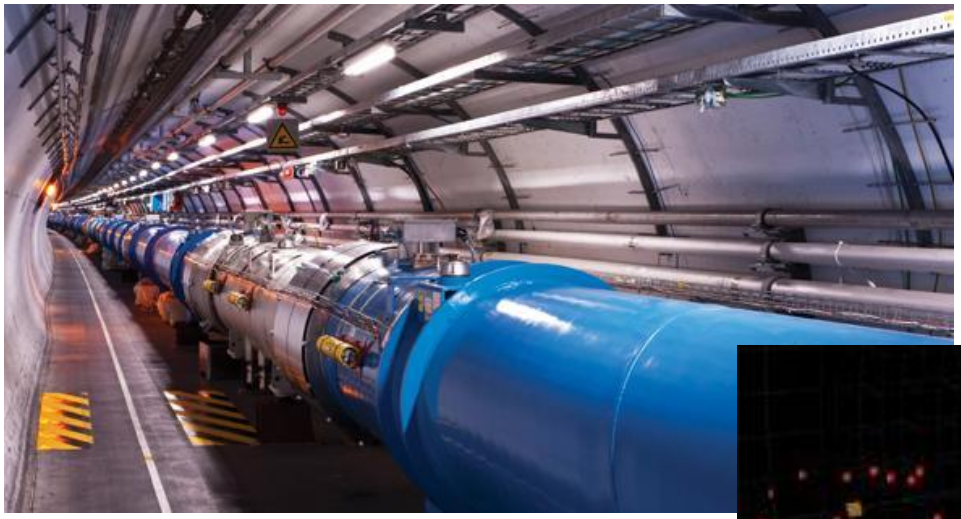
- Internet: the unprecedented information collector
  - May 2012: 200m Web servers [Yahoo]
  - estd 50+b static pages [Yahoo]
  - 2012: 31b searches / month [Google]
  - Wayback Machine: 240 billion web pages archived from 1996
- Typical Big Data:
  - Social networks - facebook, twitter, GPS, ...
  - Business: Data Warehousing
  - Geo: Satellite imagery, weather data, ...
  - Petrol industry: „more bytes than barrels“
- ...plus „Deep Web“

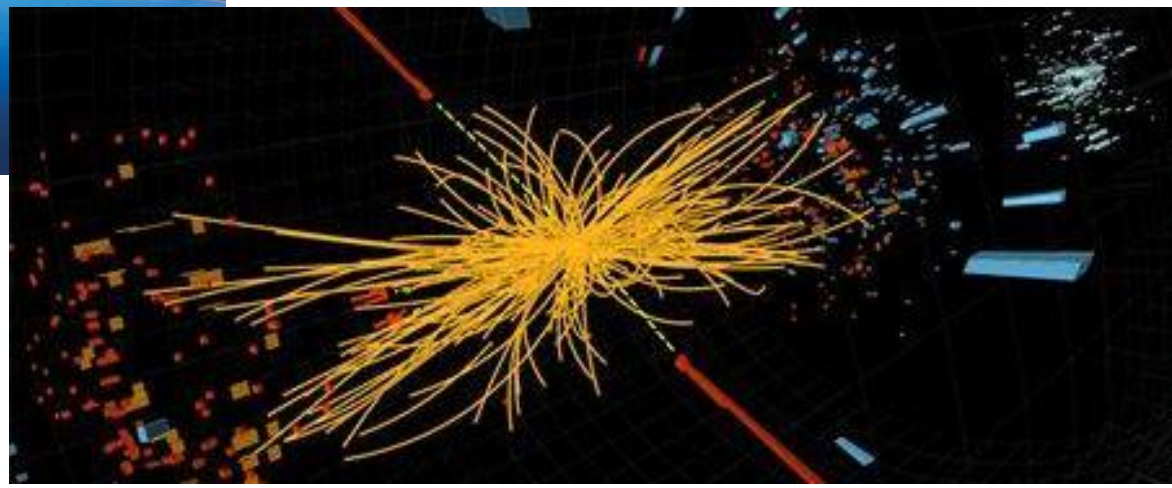


http://www.sgi.com/go/twitter/#heatmaps

Big Data in High Energy Physics

- CERN, Large Hadron Collider:
  13 PB in 2010





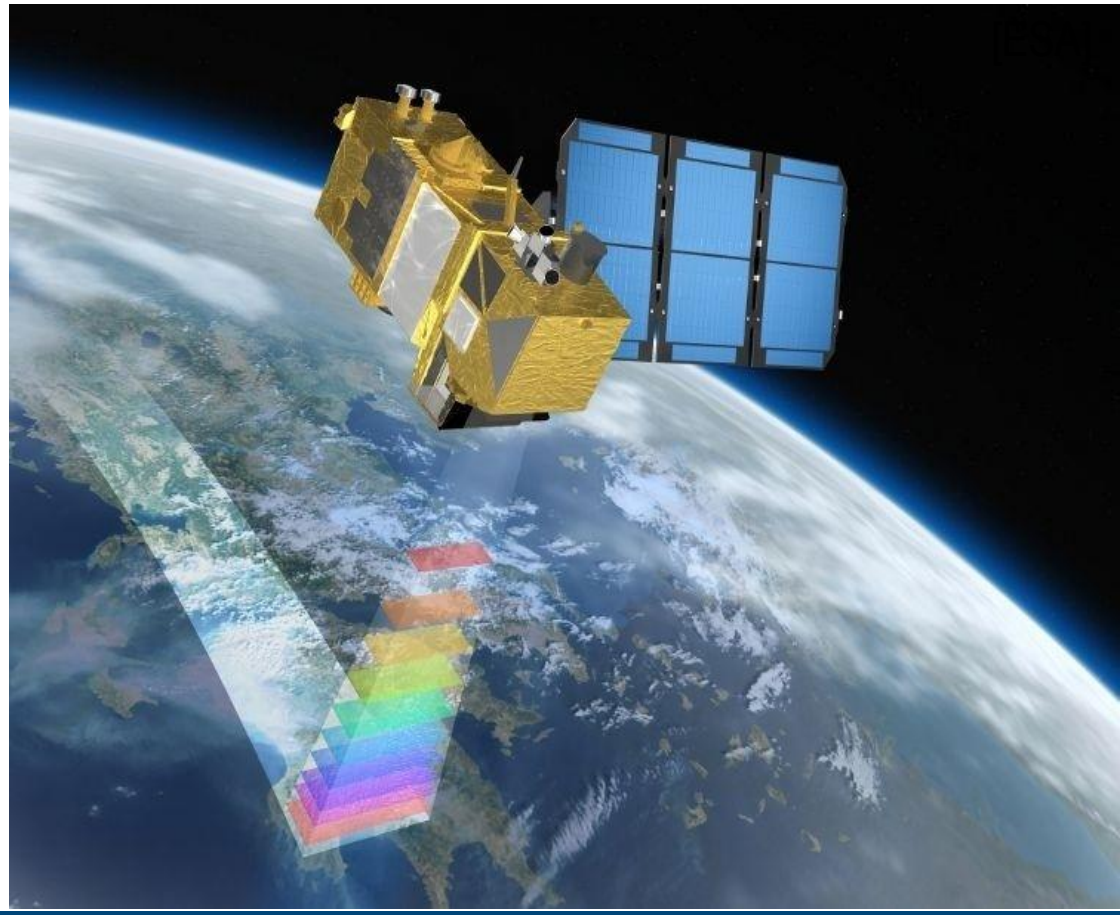
[CERN]

Big Data in Life Sciences

- Data aggregation & integration → cost effective and improved patient care
  - biological & biomedical research: next-generation sequencing (TB of raw data)
  - How to store, achieve, index, manage, learn, mine, visualize those data?
- 23andme.com: „Discover your ancestral origins and lineage with a personalized analysis of your DNA”
  - “Learn what percent of your DNA is from populations around the world.”
  - “I understand that 23andMe only sells ancestry reports and raw genetic data at this time. I understand 23andMe will not provide health-related reports. However, 23andMe may provide health-related results in the future, dependent upon FDA marketing authorization. “ [23andme.com, 2013-12-15]

Big Data in Earth Observation

- „Exaflood“: 100s of Exabytes in 2020 expected [Climate WS 2011]
  - Spectral bands:
    from 5 (Landsat)
    to 250 (ALI/Hyperion)
  - Resolution: few meters
- Sentinel-2 (ESA):
  2.4 TB / d ⟶ 876 TB / y
  - 10-20m ground resolution
  - 13 bands
  - One of 5 Sentinels



Big Data in Astronomy: LOFAR

- Sloan Digital Sky Survey: first few weeks in 2000, more data than all collected in history of astronomy
  - 200 GB per night, 140+ TB now
- LOFAR (Low frequency phase-coupled array)
  - Distributed radio telescope
  - Processing output <50 gbps (0.5 PB/d)
  - Long term: 2.5 PB/y
- Analytics also on Long-Term Archive
  - Ex: 10,000 x 10,000 FFT


[LOFAR]


[W. Reich, MPIfR]

Big Data in Business

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- business data worldwide, across all companies, double every 1.2 years, according to estimates [Wikipedia]
- FICO Falcon Credit Card Fraud Detection System protects 2.1 billion active accounts world-wide
- Walmart:
  - 1+ million customer transactions every hour
  - imported into databases, estimated 2.5+ petabytes of data
  - =167 times all books in the US Library of Congress
- London bus networks not known in completeness; reconstructed (also) using pickpocket statistics [gossip]

Big Data in Industry

- Industry 4.0: integration of production & ICT
  - Optimization of value chain & life cycle
- Automotive
  - Typical upper-class car: ~100m lines of code
  - Getting networked with traffic, lights,...
    - *2.8 ZB in 2012, plus 2.5 PB / day [Computerwoche]*
- Aircrafts:
  - A380: 1 billion lines of code
  - Per engine: 1 TB / 3 min
    - *LHR → JFK = 640 TB*

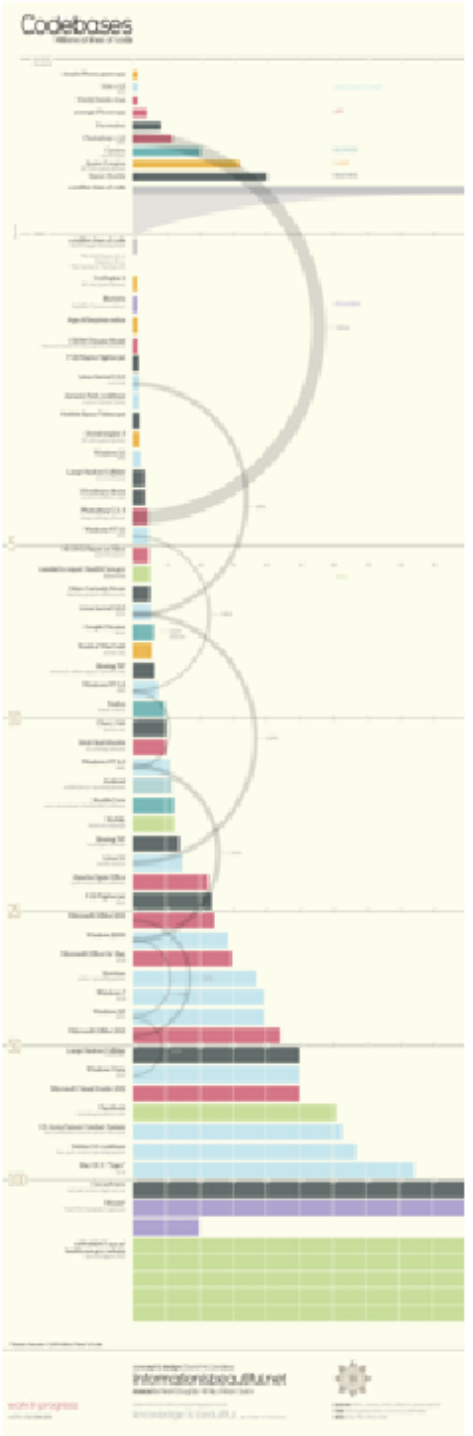
[image: Kristen Nicole]

[Airbus]

Big Code – Lines of Code

Average iPhone app	= 50.000 lines
Hubble Space Telescope	= 2 million lines
Windows 3.1 (1992)	= 2.5 million lines
Control software for US military drone	= 3.5 million lines
Windows NT 3.1 (1993)	= 4.5 million lines
HD DVD Player Xbox	= 4.5 million lines
World of Warcraft Server	= 5.5 million lines
Google Chrome	= 6.5 million lines
Windows NT 4 (1996)	= 11 million lines
MySQL	= 12 million lines
Boing 787 Flight Software	= 14 million lines
F35 Fighter jet	= 23 million lines
Microsoft Office 2013	= 44 million lines
Large Hadron Collider	= 50 million lines
Facebook	= 61 million lines
US Army Future Combat System	= 63 million lines
MacOS X 4.1 Tiger	= 85 million lines
Average high-end car	= 100 million lines
1.3+ million iPhone apps, 1.3+ million Android apps	= 170billion lines

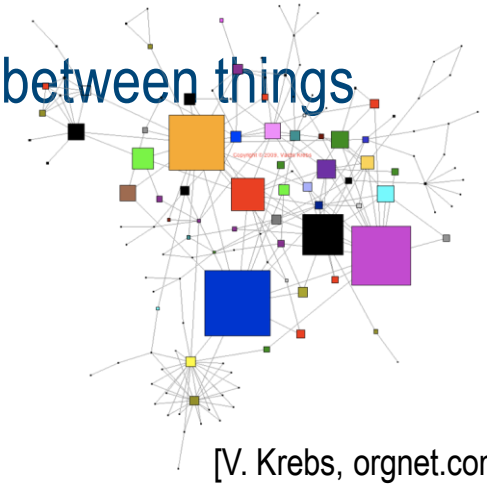
source: http://www.informationisbeautiful.net/visualizations/million-lines-of-code/



Big Data in Social Networks

- Facebook: 1m users 2004, 1.11b in 2013 [Fb]
  - 40b user photos [Wikipedia]
- Chats via MS Messenger [Leskovec, WWW 2008]
  - 30b chats between 240m participants
    → communication graph with 180m nodes, 1.3b undirected edges
  - Result : everybody knows everybody over at most 7 edges
- Social Network Analysis (SNA): map & measure links between things
  - How highly connected is an entity within a network?
  - What is an entity's overall importance in a network?
  - How central is an entity within a network?
  - How does information flow within a network?

[M. Rodriguez, Aurelius]


[V. Krebs, orgnet.com]

Internet of Things (IoT)

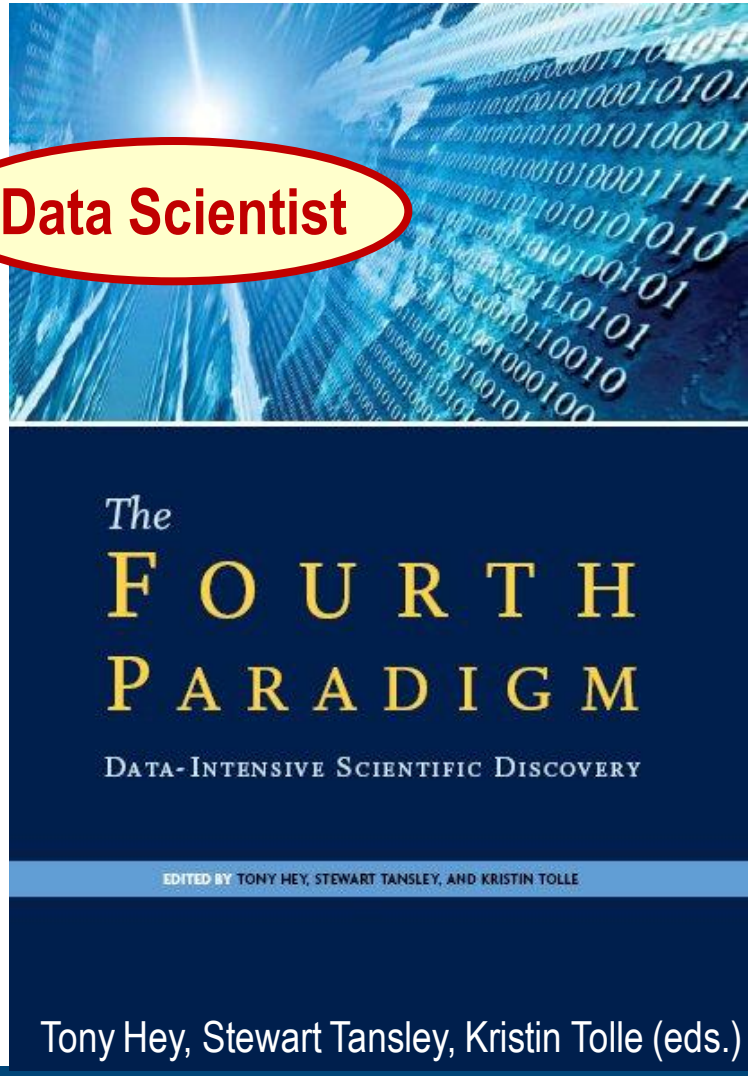
- Every (physical) thing is connected to the Internet
  - „the Internet“ knows state of physical world – more and more comprehensively
- Not new on principle
  - Anti-blocking brakes, engine emergency shutoff, RFIDs in car & discos, ...
- New: extent, integration, comprehensive evaluation ...in real-time
  - T-Shirt, fridge, beer bottle, fitbit, car, family, neighbours, insurance, boss, ...
- Data protection, data security?
  - Known issues, novel dimension

[Shutterstock, Forbes]

Reading: „The 4th Paradigm“

- eScience: computationally intensive science
  - Complex computing and/or immense data
  - “where IT meets scientists“
- Experimental Budgets 1⁄4 to 1⁄2 Software
  - Sloan Digital Sky Survey (SDSS): Telescopes 15 ~ 20 m US$, but software dominates
  - Neptune ocean observatory: 30% of 350m US$ budget for cyberinfrastructure =100m US$
- Joint effort of various CS domains
  - databases, data mining, workflow management, visualization, cloud computing, …

Data Scientist



Tony Hey, Stewart Tansley, Kristin Tolle (eds.)

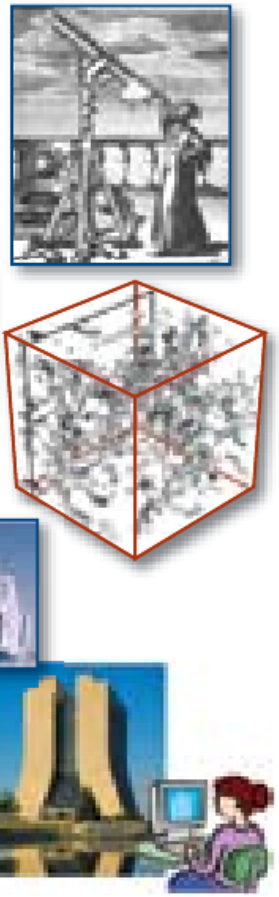
Reading: „The 4th Paradigm“

Tony Hey, Stewart Tansley, Kristin Tolle (eds.)

Science Paradigms

- Thousand years ago:
  science was **empirical**
  describing natural phenomena
- Last few hundred years:
  theoretical branch
  using models, generalizations
- Last few decades:
  a **computational** branch
  simulating complex phenomena
- Today: **data exploration** (eScience)
  unify theory, experiment, and simulation
  - Data captured by instruments or generated by simulator
  - Processed by software
  - Information/knowledge stored in computer
  - Scientist analyzes database/files using data management and statistics

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G p}{3} - \mathrm{K}\frac{c^2}{a^2}$$



„Big Data“: Definition

- 4V definition [Doug Laney / Gartner & IBM]:
  - Volume
  - Velocity
  - Variety
  - Veracity
  - plus more in blogs: Value, Verisimilitude, Variability, Visualization, ...
- ...or simply: „Data too big to transport“

The 7 Computational Giants of Massive Data Analysis

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- Basic Statistics
- Generalized N-Body Problems
- Graph-Theoretic Computations
- Linear Algebraic Computations
- Optimizations
- Integration
- Alignment Problems

[Frontiers in Massive Data Analysis. US National Research Council, 2013]

Prominent Big Data Technologies

- MapReduce = programming model for processing large data sets with a parallel, distributed algorithm on a cluster
  - MapReduce program = Map() + Filter()
  - MapReduce system orchestrates parallelization
  - Most popular implementations: Hadoop, Spark
    - *"MapReduce" originally referring to proprietary Google technology, now generic name*
- TopTen Databases Program 2005 [www.wintercorp.com]:
  - size of production databases tripled since 2003; 100 TB landmark in 2005
  - Yahoo! database first production data warehouse >100 TB (100.4 TB; Unix; Oracle)
  - largest Windows database: 19.5 TB (2x over 2003)
  - highest throughput: 1.1m SQL statements per hour (z/OS, IBM UDB DB2)

Big Data Initiatives

- Research Data Alliance – www.rd-alliance.org
- NIST Big Data Initiative – bigdatawg.nist.gov
- ISO /IEC JTC1 SC32 Big Data Analytics
- OGC Big Data WG – external.opengeospatial.org/twiki_public/BigDataDwg
- all remotely data oriented conferences tackle Big Data
  - Core DB conference: VLDB

Big Data Initiatives / contd.

- United Nations and Governments Initiatives
  - United Nations: Global Pulse
  - United States: "BIG DATA" Initiative ($200m US$), March 29, 2014
  - European Union: Big Data at your service, July 25, 2014
- Industry Initiatives
  - IBM Big Data;
  - SAS Big Data
  - Oracle Big Data
  - Google BigQuery
  - Microsoft Big Data

Big Data Buzzwords

- Big Data Architecture
- Big Data Modeling
- Big Data As A Service
- Big Data for Vertical Industries (Government, Healthcare, etc.)
- Big Data Analytics
- Big Data Toolkits
- Big Data Open Platforms
- Economic Analysis

- Big Data for Enterprise Transformation
- Big Data in Business Performance Management
- Big Data for Business Model Innovations and Analytics
- Big Data in Enterprise Management Models and Practices
- Big Data in Government Management Models and Practices
- Big Data in Smart Planet Solutions

[IEEE Big Data Conf.]

Big Data Requires Many Disciplines

Using techniques from:

- Databases
- Supercomputing
- Data Mining
  - Artificial Intelligence
  - Machine Learning
  - Statistics
- Natural language processing
- Visualization

Domains:

- Business Intelligence
- Social networks
- Online trading
- Geospatial (& temporal) data
- + *many more...*

Caveat: not a strict definition;
see also this discussion:
http://wmbriggs.com/blog/?p=6465

Impact of „Big Data“

- New job profile: Data Scientist
  - CS (databases, data mining, visualization, HPC, ...) + statistics + sci domain
- New data management & analytics paradigms
  - MapReduce, No/NewSQL, ... far from consolidated
- New ethical dilemmas
  - NSA spying of Chancellor Merkel phone & other incidents

Summary

- Science, and even society, more and more data driven
  - „drowning in data, starving for information“
- Big Data = summary term for data too big / complex to transport, to analyze
  - Internet of Things; sensors; social networks; business data; science data; network traffic; ...
  - Some say: Big Data = Big Hype
  - But Vs leading to clarification of issues
- “*Big Data is a marketing term, for sure, but also shorthand for advancing trends in technology that open the door to a new approach to understanding the world and making decisions*.” [ACM 2013]