COMP9313: Big Data Management

Introduction to Big Data Management

What is big data?

Dan Ariely

January 6, 2013 at 6:17pm ·

Big data is like teenage sex: everyone talks about it, nobody really knows how to do it, everyone thinks everyone else is doing it, so everyone claims they are doing it...

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Tweeted by Prof. Dan Ariely, Duke University

What is big data?

- No standard definition!
- Wikipedia:
  - Big data is a field that treats ways to analyze, systematically extract information from, or otherwise deal with data sets that are too large or complex to be dealt with by traditional data-processing application software.
- Amazon:
  - Big data can be described in terms of data management challenges that – due to increasing volume, velocity and variety of data – cannot be solved with traditional databases.

What is big data?

Word could which is generated from the top-20 results when search “what is big data” in Google.

What is big data?

- A set of data
- Special characteristics
  - Volume
  - Variety
  - Velocity
  - …
- Traditional methods cannot manage
  - Store
  - Analyse
  - Retrieve
  - Visualization
  - …

That’s why we need this course

Big Data Definitions Have Evolved Rapidly

- 3 V's
  - In a research report by Doug Laney in 2001
  - Volume, Velocity and Variety
- 4 V's
  - In Hadoop – big data tutorial, 2006
  - Veracity
- 5 V's
  - Around 2014
  - Value
- 7 V's, 8 V's, 10 V's, 17 V's, 42 V's, …

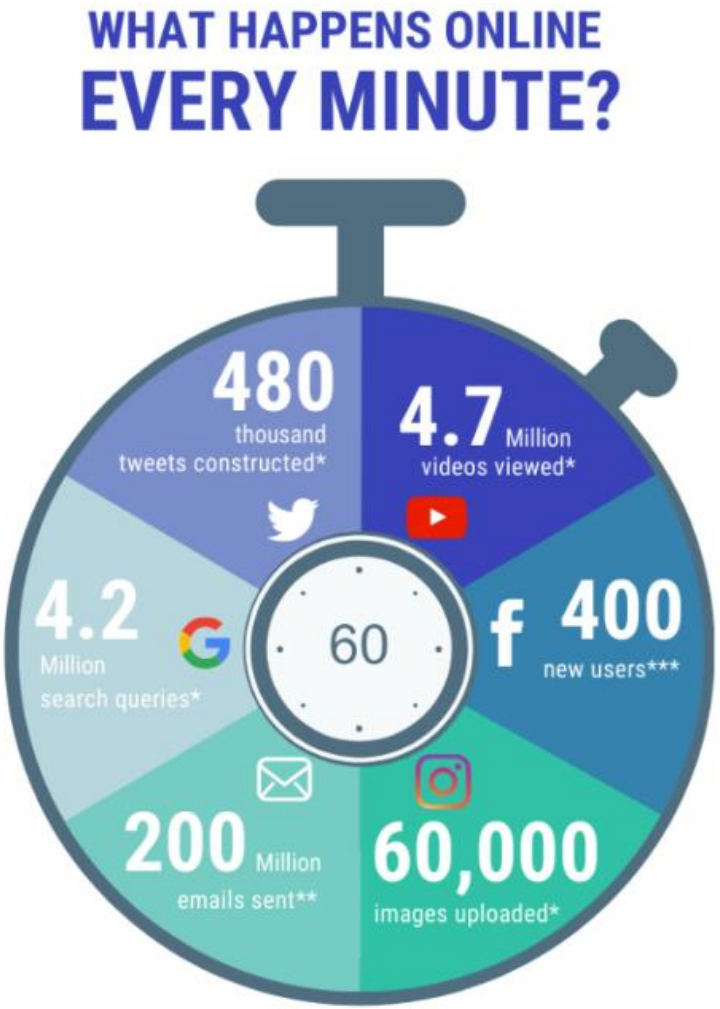
Major Characteristics of Big Data

Volume (Scale)

- Quantity of data being created from all sources
- The fundamental of big data

- 18 Zetabytes (ZB) of data in 2018, will grow to 175 ZB in 2025
  - 1 zettabyte $\approx 10^3$ exabytes $\approx 10^9$ terabytes
  - Source: https://www.seagate.com/files/www-content/our-story/trends/files/idc-seagate-dataage-whitepaper.pdf

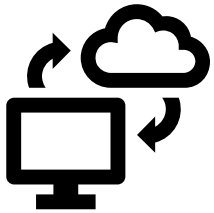
Volume



Source: https://www.nodegraph.se/how-much-data-is-on-the-internet/

Volume – Why Challenging?

Model	RAM	Disk	Data
Macintosh Classic (1990)	1MB – 4MB	0 – 40MB	
Power Mac G4 (2000)	256MB – 1.5GB	20GB – 60GB	5 EB in 2003
iMac (mid 2010)	4GB – 16GB	500GB – 2TB	1 ZB in 2012
iMac (early 2019)	8GB – 64GB	1TB – 3TB	~40 ZB



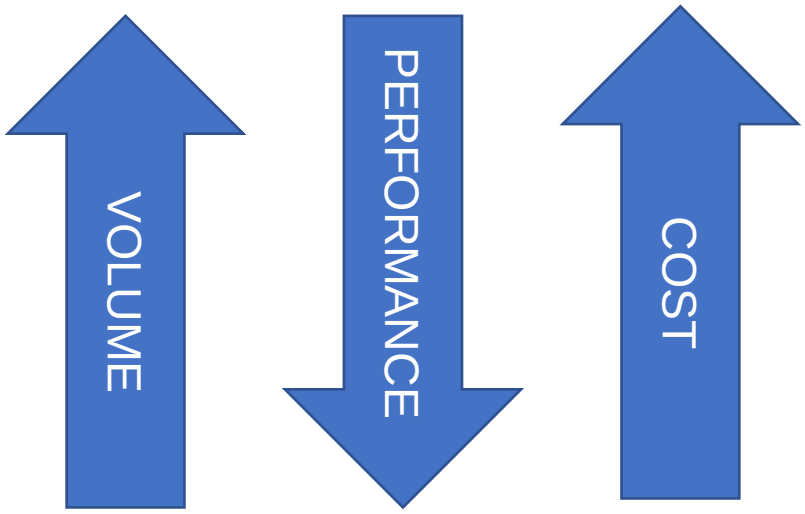
?

1990s 2000s 2010s future

DBMS Storage

Volume – Why challenging?

- Time complexity
  - Sort algorithms: O(N logN)
  - Merge join: O(N logN + M logM)
  - Shortest path: O(V logV + E logV)
  - Nearest neighbor search: O(dN)
  - NP hard problems



Variety (Diversity)

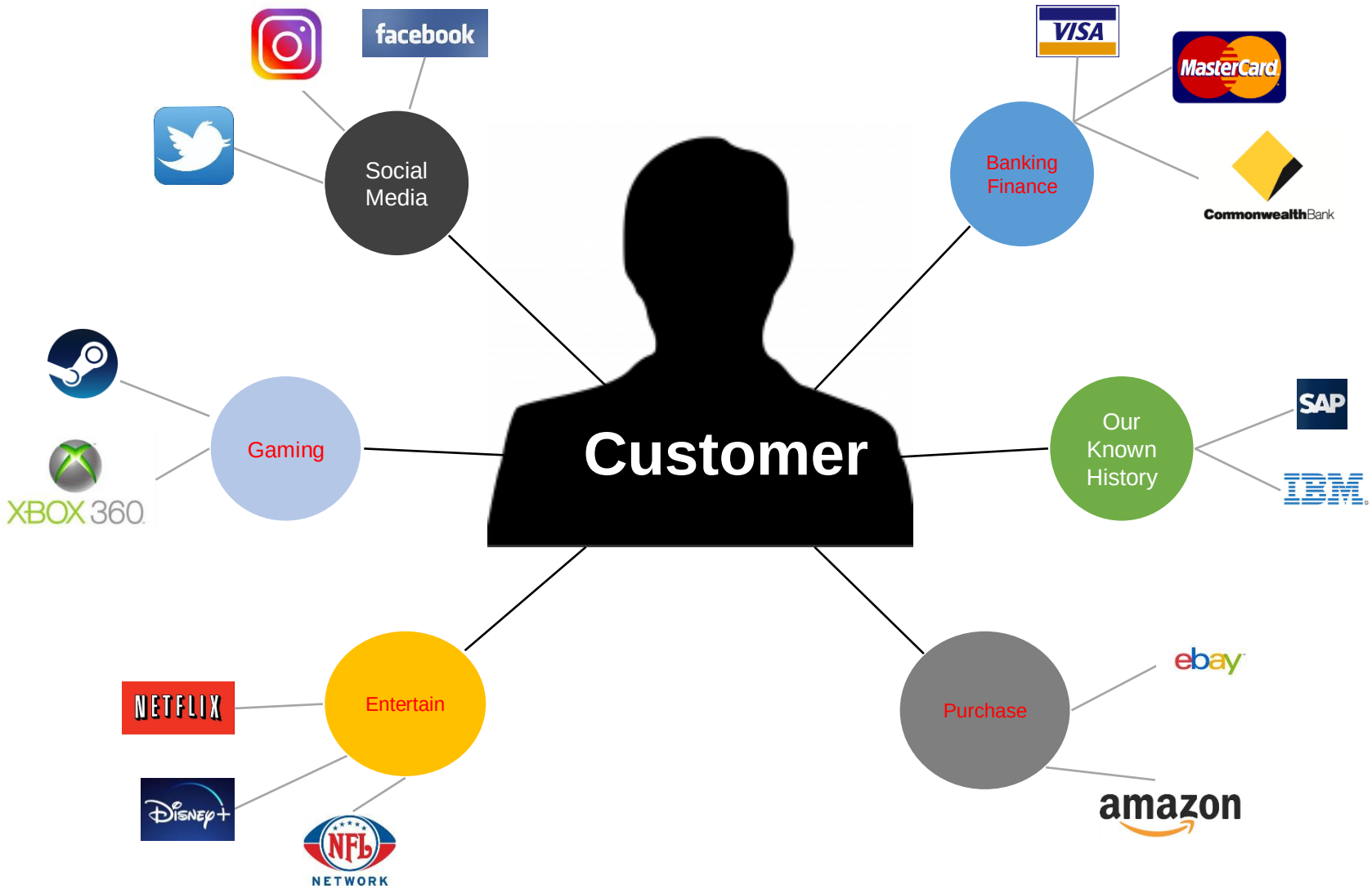
- Different Types
  - Relational data (tables/transactions)
  - Text data (books, reports)
  - Semi-structured data (JSON, XML)
  - Graph data (social network, RDF)
  - Image/video data (Instagram, Youtube)
- Different sources
  - Movie reviews from IMBD and Rotten Tomatoes
  - Product reviews from different provider websites
  - Personal information from different social apps

Variety

- A single application can be generating or collecting multiple types of data
  - Email
  - Webpage

- If we want to extract knowledge, then all the data with different types and sources need to be linked together

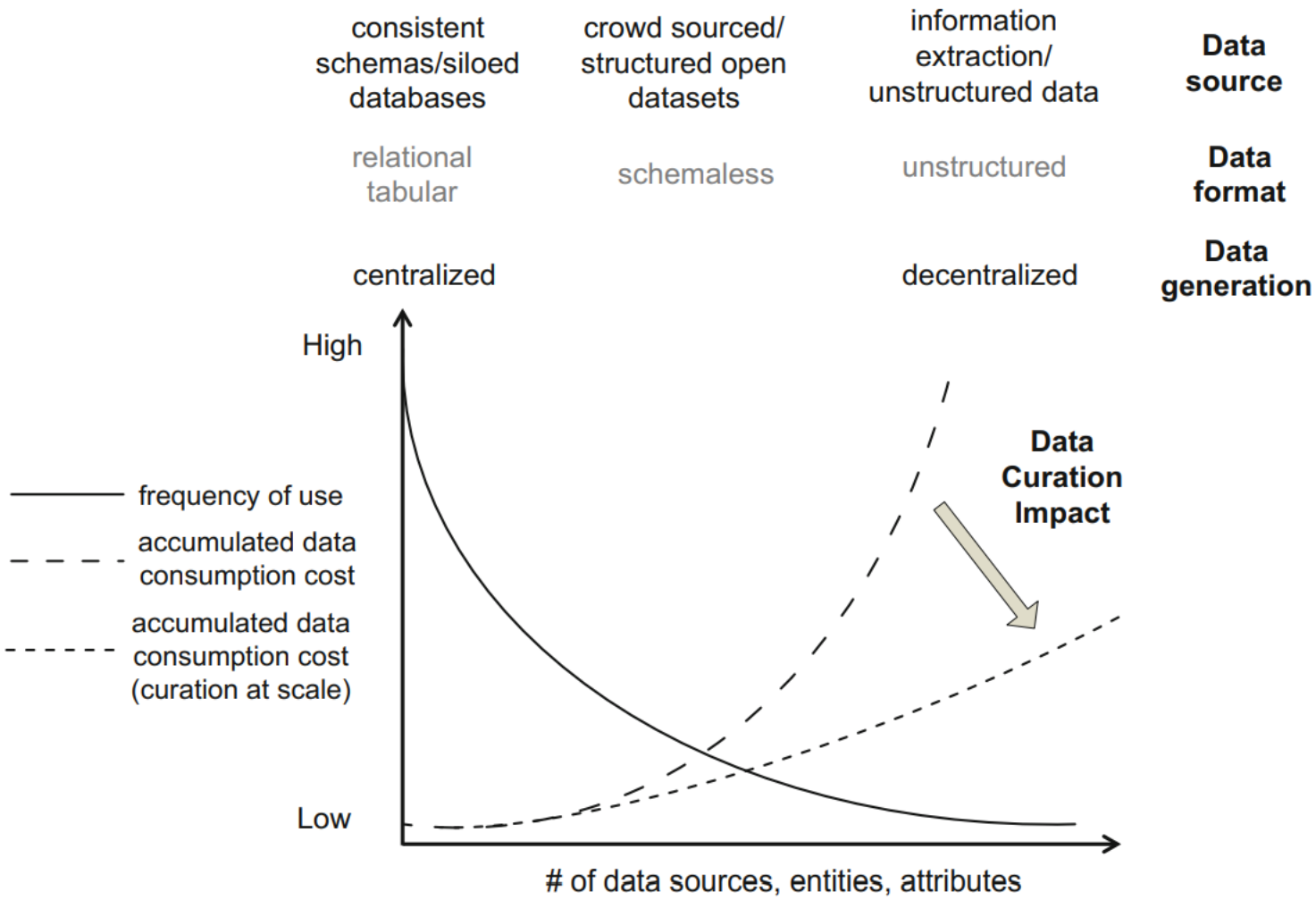
Variety - A Single View to the Customer



Variety – Why Challenging?

- Data integration
  - Heterogeneous
    - Traditional data integration relies on **schema mapping**, the difficulty and time complexity is directed related to the level of heterogenity and data sources
  - Record linkage in variety data
    - needs to identify if two records refer to the same entity. How to make use of different types of data/information from different sources?
- Data curation
  - Organization and integration of data collected from various sources
  - Long tail of data variety

The Long Tail of Data Variety and Data Curation



Source: Curry, E., & Freitas, A. (2014). Coping with the long tail of data variety.

Velocity (Speed)

- Data is being generated fast, thus need to be
  - stored fast
  - processed fast
  - analysed fast

- Every second
  - **8,991** Tweets sent
  - **994** Instagram photos uploaded
  - **4,683** Skype calls
  - **93,508** GB of Internet traffic
  - **83,165** Google searches
  - **2,915,385** Emails sent

Source: http://www.internetlivestats.com/one-second/

Velocity

- Reason of growth
  - Users:
    - 16 million in 1995 to 3.4 billion in 2016
  - IoT:
    - sensor devices, surveillance cameras
  - Cloud computing:
    - $26.4 billion in 2012 to $260.5 billion in 2020
  - Website:
    - 156 million in 2008 to 1.5 billion in 2019
  - Scientific data:
    - weather data, seismic data

Velocity

- Data is now streaming into the server in real time, in a continuous fashion and the result is only useful if the delay is very short.

- Many application need immediate response
  - Fraud detection
  - Healthcare monitoring
  - Walmart's real-time alerting

Velocity – Why Challenging?

- Batch processing

- Real time processing

- Transmission
  - Transferring data becomes a prominent issue in big data
  - Balancing latency/bandwidth and cost
  - Reliability of data transmission

Veracity (Quality)

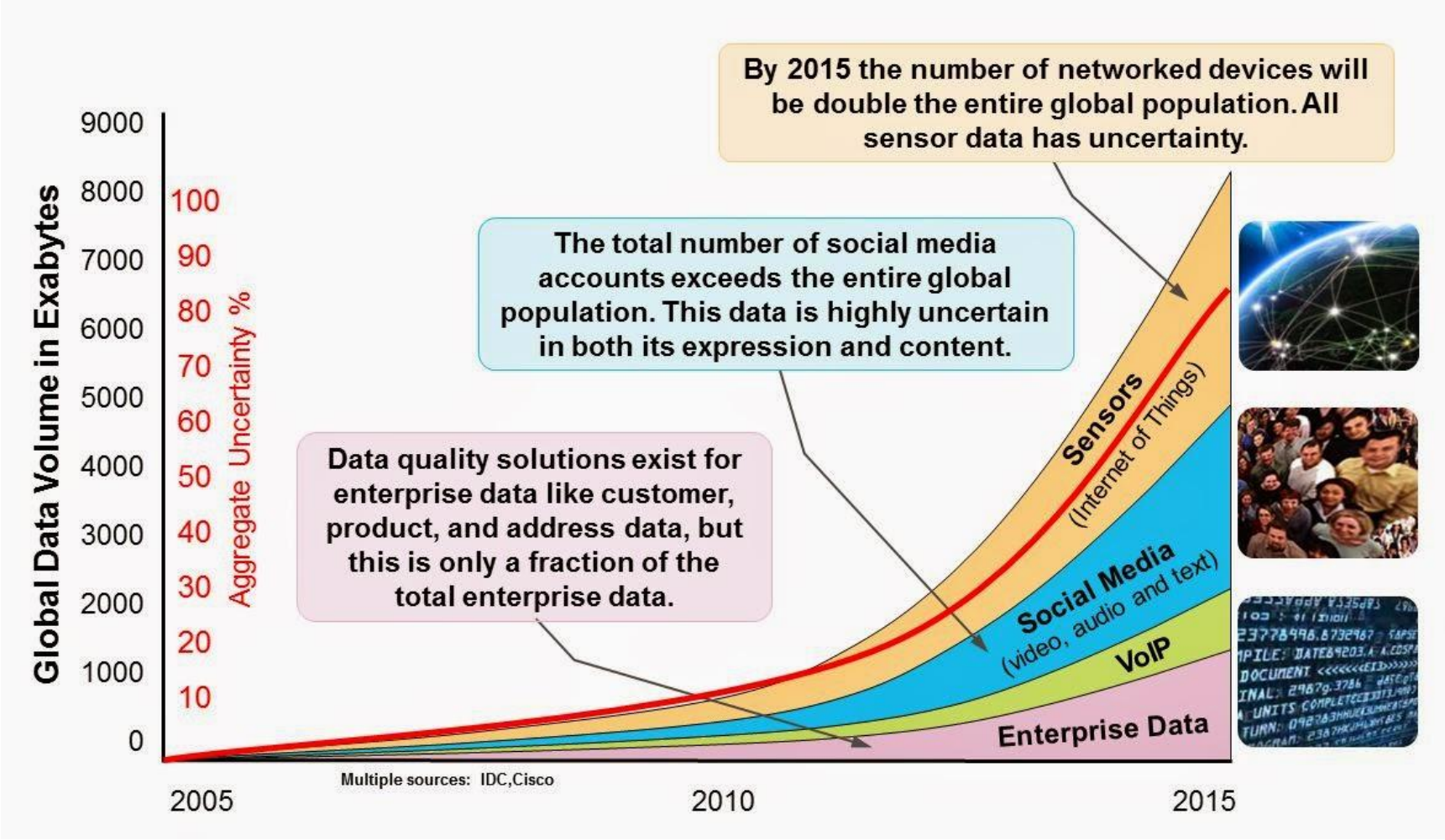
数量 质量

- Data = quantity + quality
  - Some argues that veracity is the most important V in big data
  - 4-th V in big data

- Can we trust the answers to our queries and the prediction result?
  - Dirty data routinely lead to misleading financial reports, strategic business planning decision ⇒ loss of revenue, credibility and customers, disastrous consequences
  - Example: machine learning

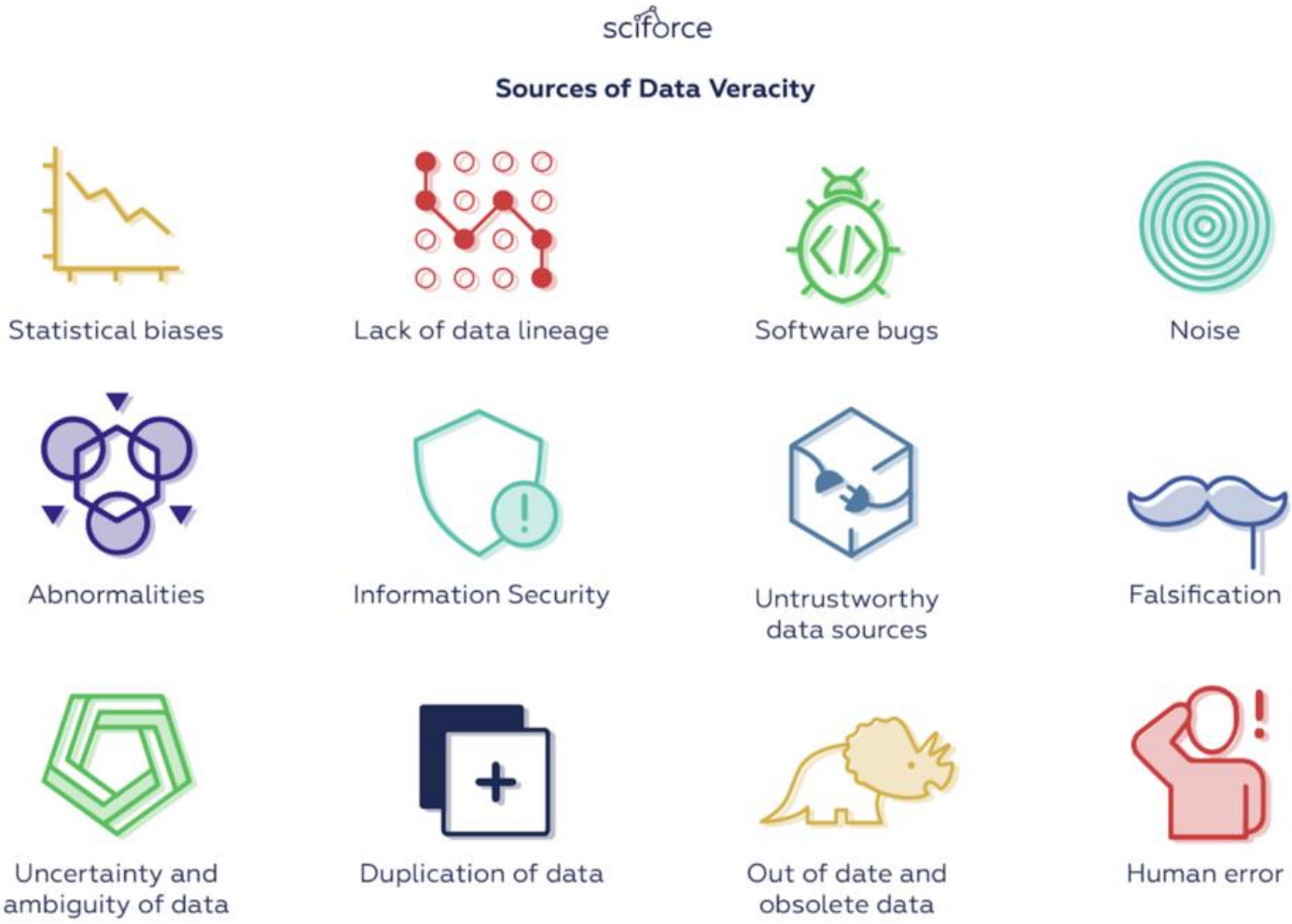
真实性

Veracity



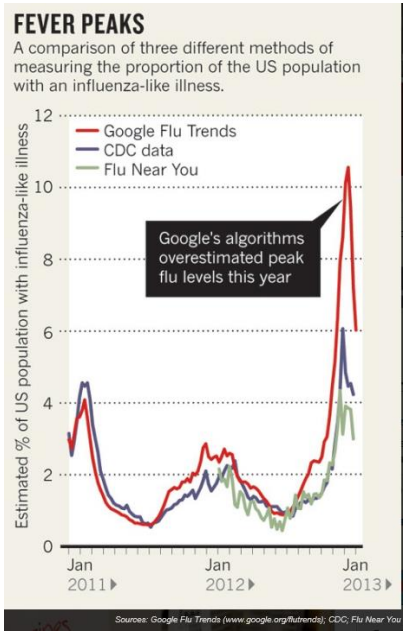
Source: IBM

真实性
Veracity – Where the Uncertainties Come From



Veracity – Why challenging?

- Easy to occur
  - Due to other Vs
- Huge effect to downstream applications
  - E.g., Google Flu Trends
- Difficult to control
  - Identify errors
  - Handle errors
    - correction
    - eliminate the effects



Source

可变性

Variability

Variety:
same entity,
different data

Variability:
same data,
different meaning

Variability

- Meaning of data changing all the time
  - This is a great experience!
  - Great, it totally ruined my day!

- Requires us to have a deeper understanding of the data
  - E.g., make use of the context of the data

Visibility

- Visualization is the most straightforward way to view data
  - Benefits of data visualization

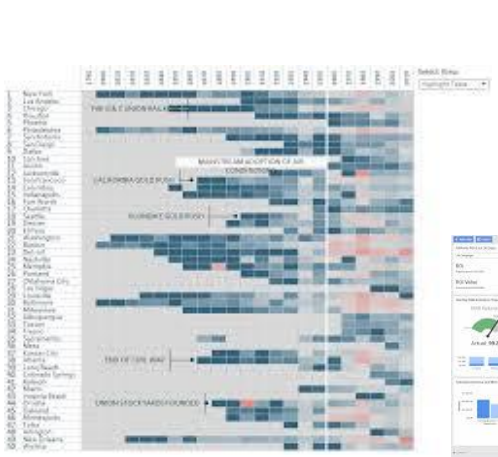
Benefits	Percentages (%)
Improved decision-making	77
Better ad-hoc data analysis	43
Improved collaboration/information sharing	41
Provide self-service capabilities to end users	36
Increased return on investment (ROI)	34
Time savings	20
Reduced burden on IT	15

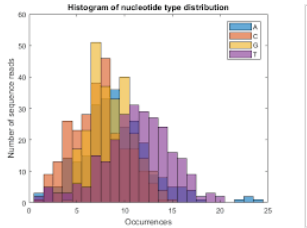
Source: V. Sucharitha, S.R. Subash and P. Prakash , Visualization of Big Data: Its Tools and Challenges

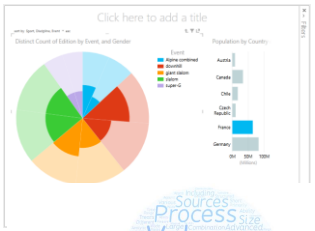
Visibility

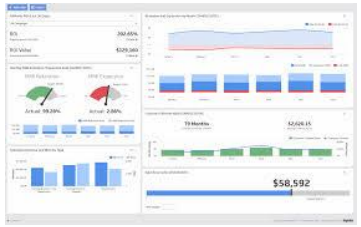
- How to capture and properly present the characteristics of data

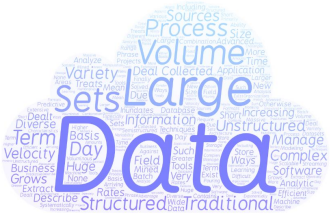
- Simple graphs are only the tip of the iceberg.
- Common general types of data visualization:
  - Charts
  - Tables
  - Graphs
  - Maps
  - Infographics
  - Dashboards











Visibility – Why challenging?

- Choose the most suitable way to present data
  - Characteristics of data
  - Purpose of presentation

- Difficulty of data visualization
  - High dimensional data
  - Unstructured data
  - Scalability
  - Dynamics

Value

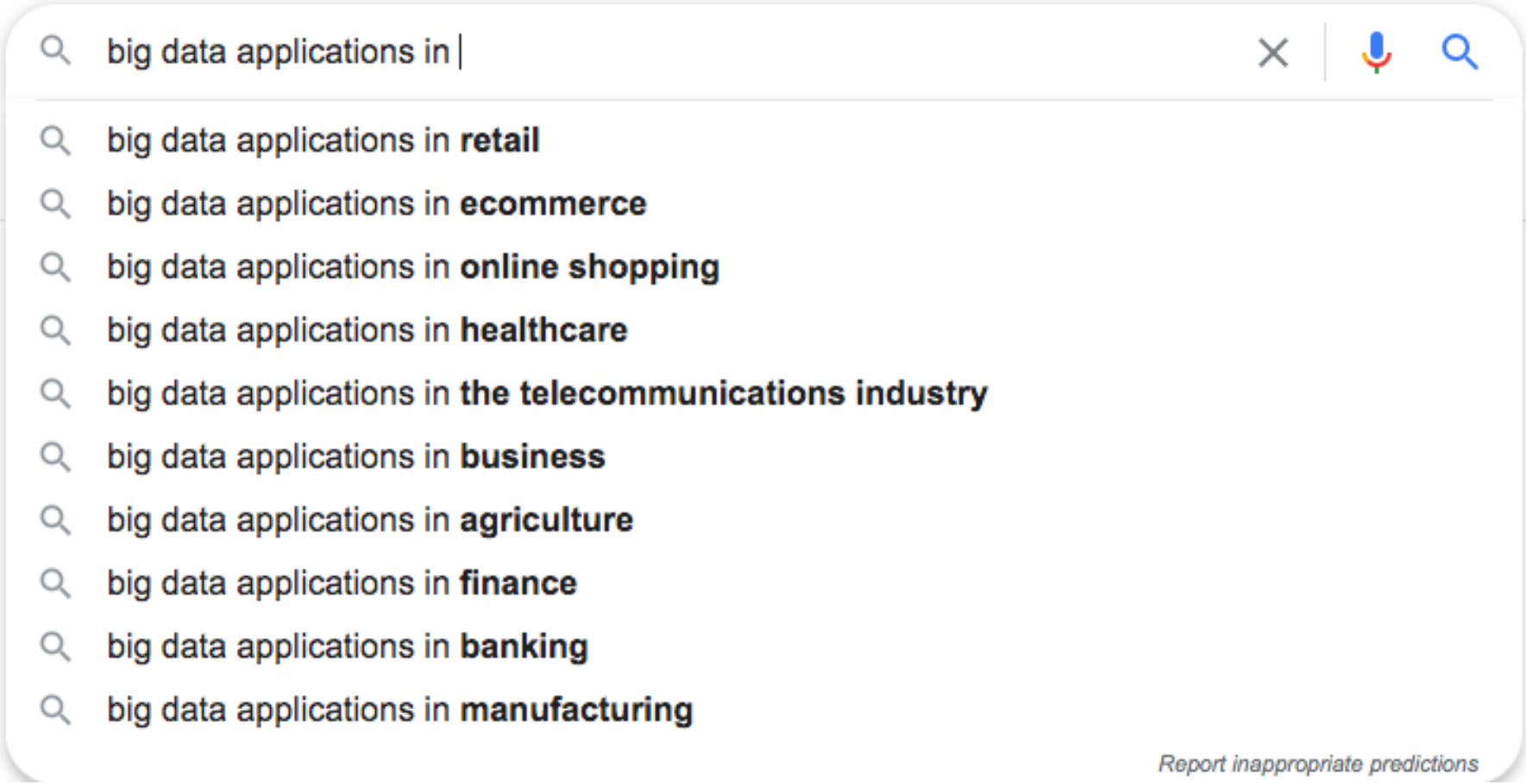
- Big data is meaningless if it does not provide value toward some meaningful goal
- Value from other Vs
  - Volume
  - Variety
  - Velocity
  - …
- Value from applications of big data

Summary of 7 V's in Big Data

- Fundamental V's
  - Volume
  - Variety
  - Velocity
- Characteristics/difficulties
  - Veracity
  - Variability
- Tools
  - Visibility
- Objective
  - Value

- And many other V's …

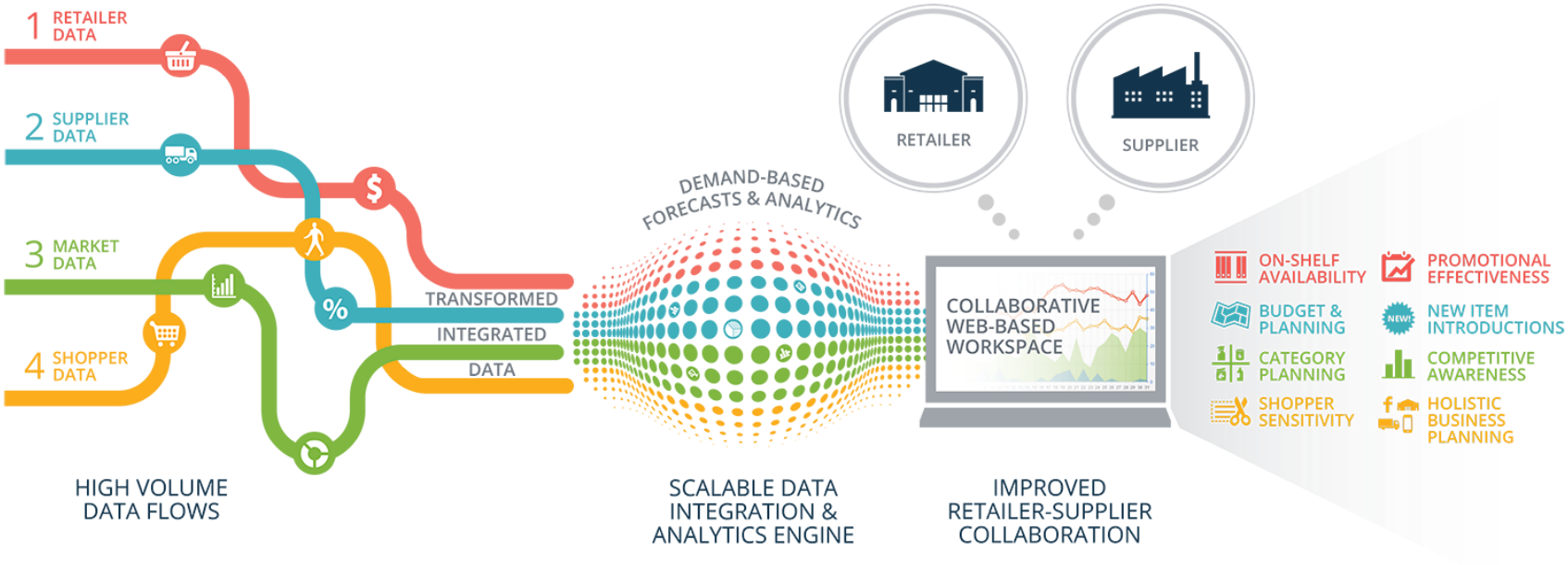
Big Data Applications



Source: google.com

Big Data in Retail

- Retailer:
  - Adjust the price
  - Improve shopping experience
- Supplier:
  - Adjust the supply chain/stock range



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Big Data in Entertainment

- Predict audience interests
- Understand the customer churn
- Suggest related videos
- Advertisement target

Source

Big Data in National Security

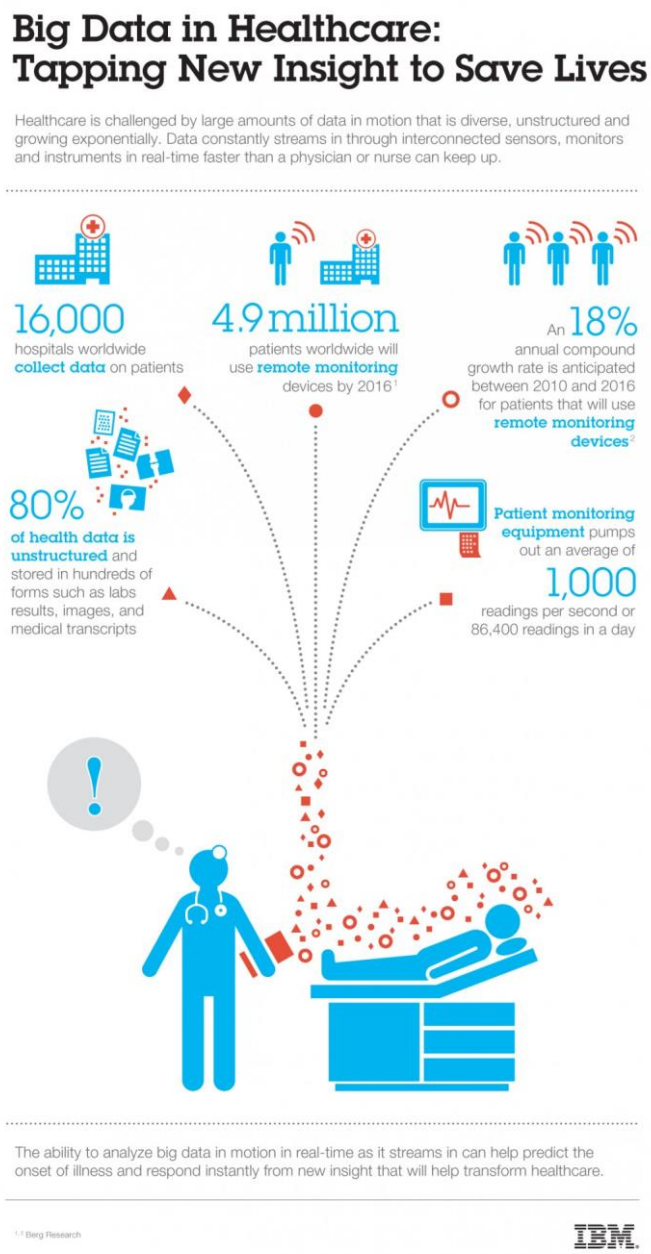
- Integrate shared information
- Entity recognition and tracking
- Monitor, predict and prevent terrorist attacks

Big Data in Science

- Physics
  - The large hadron collider in CERN collect 5 trillion bits of data every second
- Chemistry
  - Extract information from patents
  - Predict the property of compounds
- Biology
  - UK's project alone will sequence 100,000 human genomes producing more than 20 petabytes of data
  - Also helps a lot in medicine domain

Big Data in Healthcare

- Diagnostics
  - Data mining and analysis
- Preventative medicine
  - Prevent disease or risk assessment
- Population health
  - Disease trend
  - Pandemics



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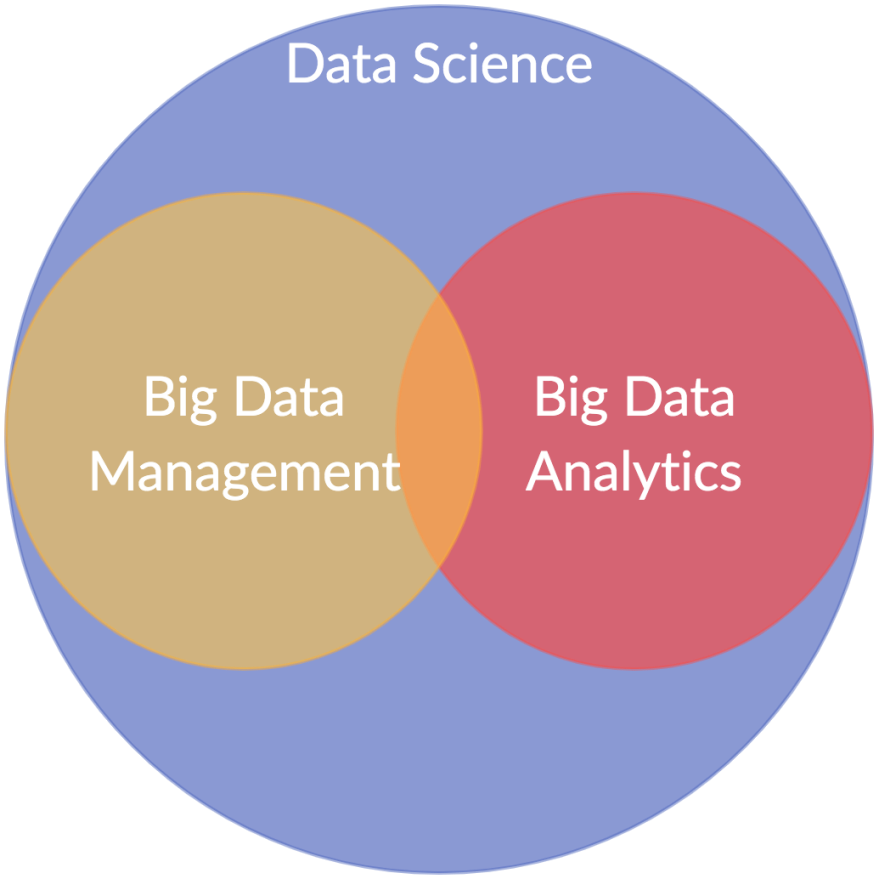
Introduction to Big Data Management

- Big data management
  - Acquisition 获得
  - Storage
  - Preparation
  - Visualization
- Big data analytics
  - Analysis
  - Prediction
  - Decision making
- Gray (orange?) areas
  - E.g., index construction
- Data science



Example

index	Data Type	Query Type	Accuracy
Binary Search Tree	Sorted keys (1D)	Existence	Exact
B-Tree	Sorted keys (1D)	Range search + NNS + Existence	Exact
Voronoi Diagram	2D	Nearest neighbor search	Exact
R-tree	Multiple dimension	Range search + NNS	Exact
Product Quantization	High dimension	NNS	Approximate
LSH	High dimension	NNS + Range search	Approximate
Bloom Filtering	Any	Existence	Approximate
Count Min	Any	Counting	Approximate

Many other dimensions 尺寸；规模

- Disk-oriented or memory oriented 面向磁盘或内存方向
- Scalability 可扩展性；可伸缩性
- Approx. with or without worst case guarantee

It is meaningful to build indexes only when we know what we need!

获得数据，数据采集

Data Acquisition

- Application oriented
  - Identify data that is relevant to your problem

综合的；广泛的

- Comprehensive
  - Leaving out even a small amount of important data can lead to incorrect conclusions
- Handle data 处理数据
  - from different sources
  - with different types
  - with different velocities

Data Acquisition

- Data in relational databases
  - Structured data
  - Access by SQL
- Data in text files and excel spreadsheets
  - Unstructured or structured data
  - Access by scripting languages (e.g., python, perl)
- Data from website
  - Semi-structured data (e.g., XML) and unstructured data (e.g., image)
  - Access
    - Web socket services
    - REST
    - Crawler

Data Acquisition

- Scientific data
  - E.g., physics experiments, genome data
  - Structured, semi-structured, unstructured
  - Access by specially designed software
- Graph data
  - E.g., knowledge graphs, social networks
  - Access by specially designed programs
  - Difficult to handle (e.g., graph isomorphism problem)
- …

Hybrid in Real Applications

- Usually need to acquire data from multiple resources
- E.g., COVID-19 Map from JHU
  - WHO, CDC, …
    - Structured data (tables)
  - Media reports and Social media (e.g., DXY)
    - Unstructured text data
  - Acquire data from website
  - Extract information from text/tables

Data Storage

- Big data storage is challenging
  - Data Volumes are massive
  - Reliability of Storing PBs of data is challenging
  - All kinds of failures: Disk/Hardware/Network Failures
  - Probability of failures simply increase with the number of machines …

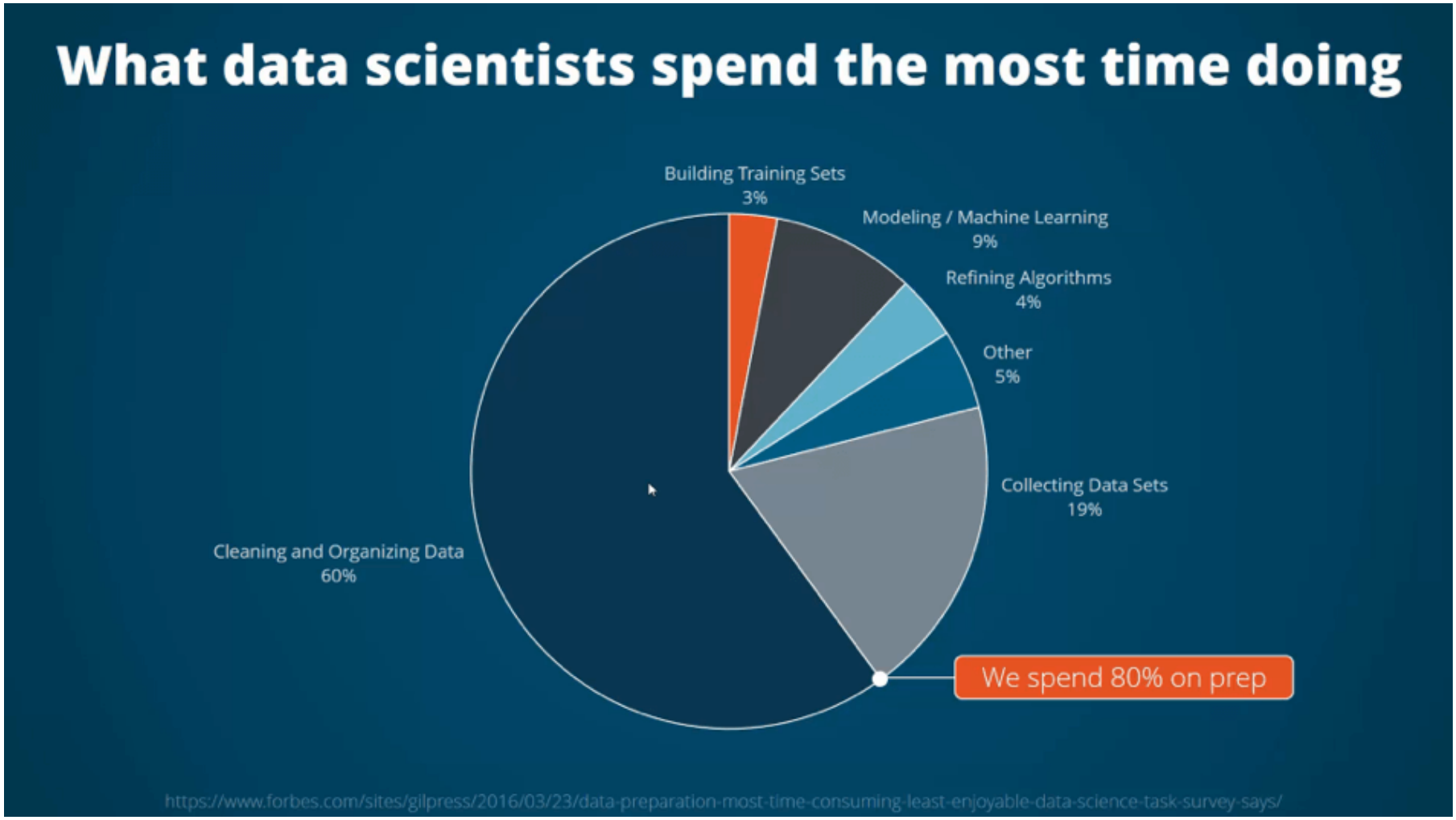
- You don't want to find a needle in your big data haystack.

Data Storage

- Traditional way (e.g., RDBMS)
  - Designed for structured data
  - Disk-oriented

- Big data era
  - RDBMS
    - SAP HANA
  - NoSQL
    - HBase, Hive, MongoDB
  - Distributed file systems
    - HDFS
  - …

Data Preparation



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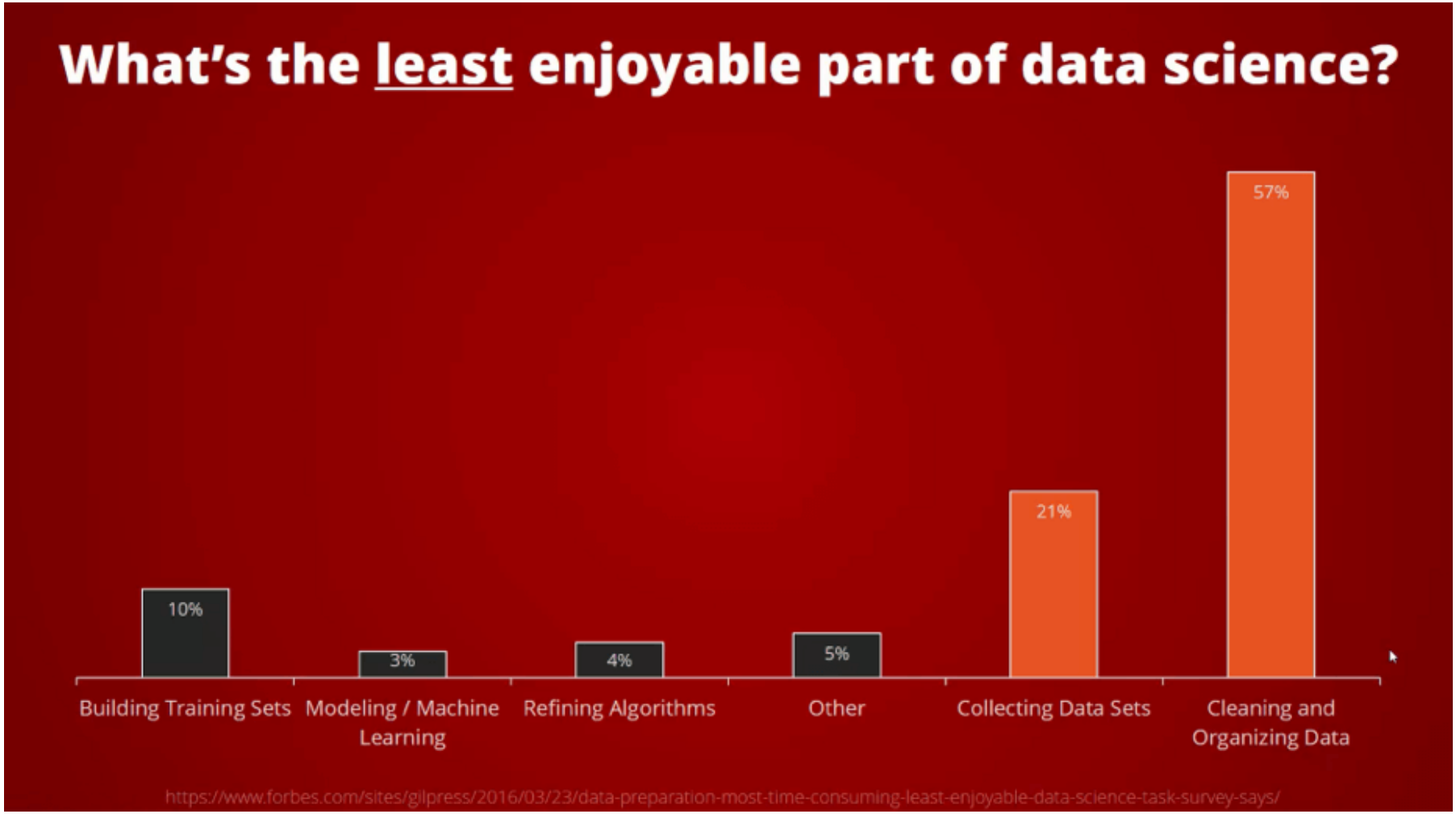

Data preparation

- Two-step data preparation process
- Data Exploration
  - understand your data
- Data pre-processing
  - Data cleansing
    - Veracity
  - Data Integration
    - Variety

Data Exploration

- Explore
  - Trends
  - Correlations
  - Outliers
  - Statistics
    - Mean, Mode, Median, Standard deviation, Range
- Visualization also helps data exploration

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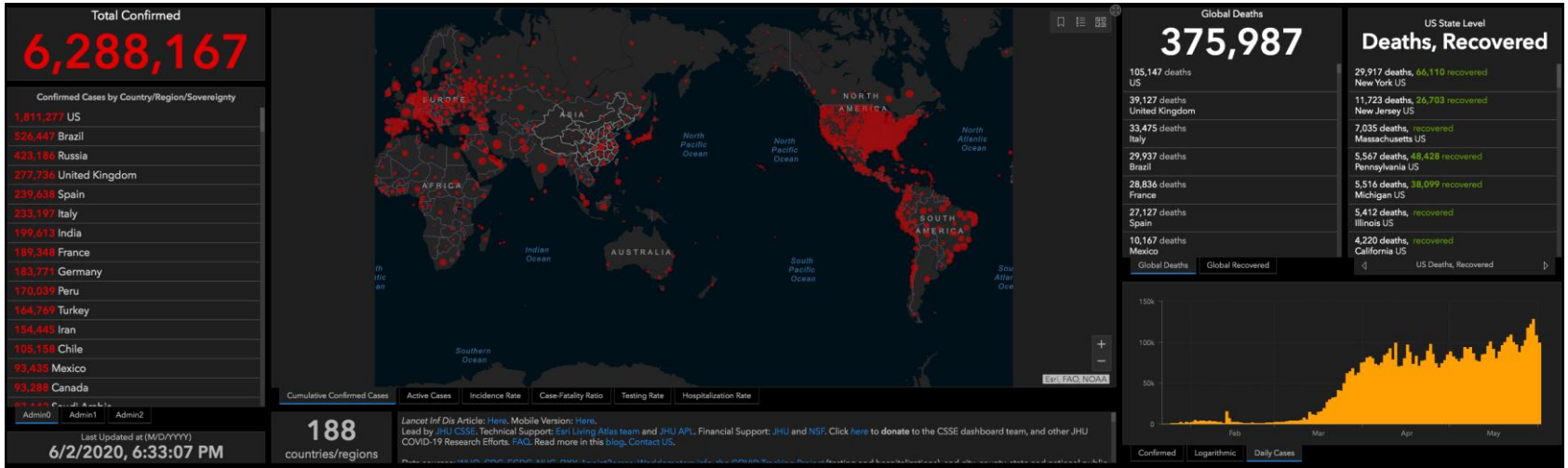


数据清洗 Data Cleansing

- Dirty data types
  - Miss values/records
  - Invalid data 不正确的数据
  - Inconsistency 不一致；不一致性
  - Duplicate 复制；复印
  - Outliers 异常值

- Data cleansing requires data understanding and domain knowledge

Data Integration

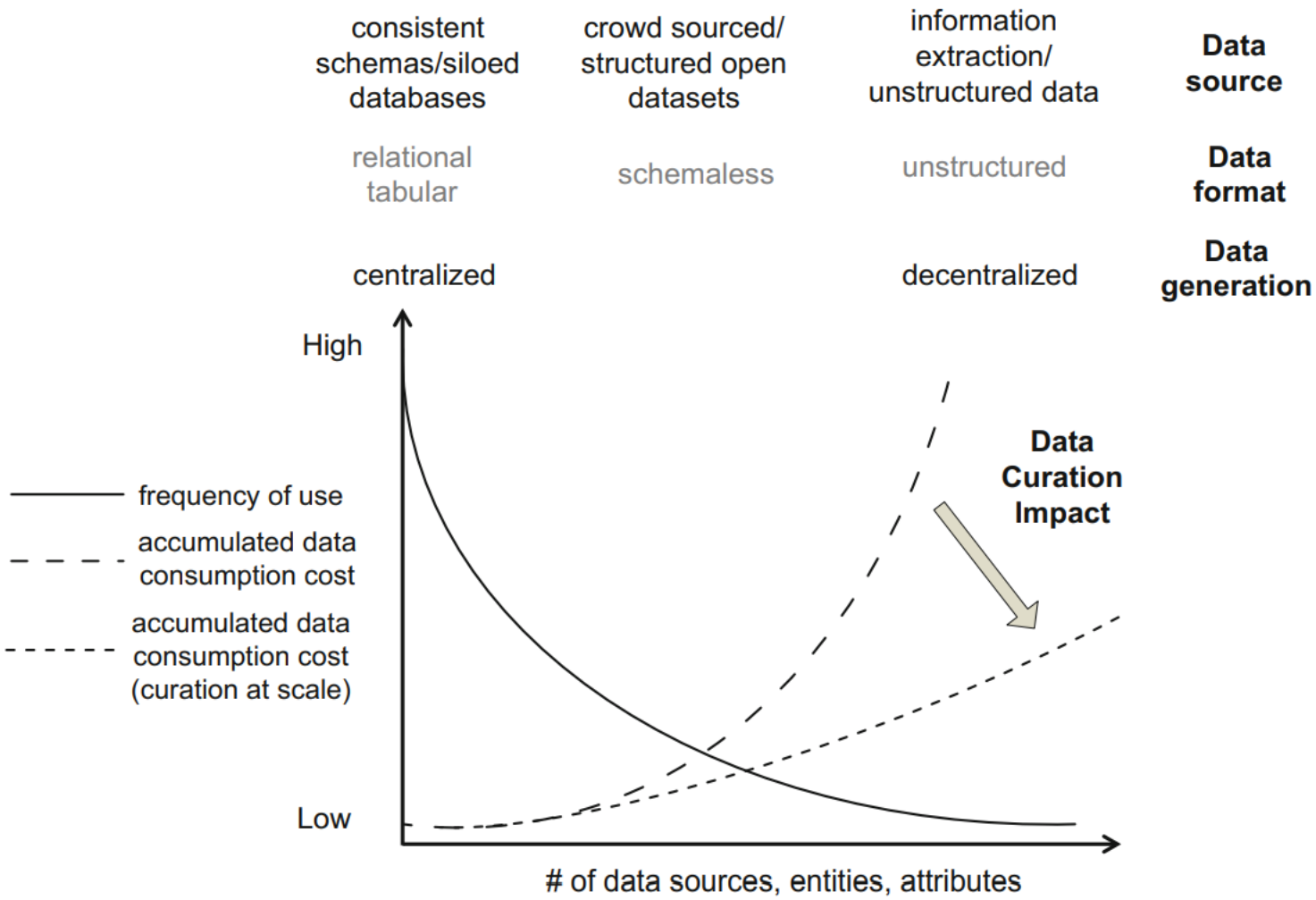
合并

- Merge data from multiple, complex and heterogenous resources.
  - To perform a unified view of data
- Mature field in traditional databases
  - Schema mapping
    - Variety
  - Record linkage
    - Identify if two records refers to same entity
    - Variety, velocity
  - Data fusion
    - Resolving conflicts
    - veracity

Data Curation

- Data curation includes all the processes needed for principled and controlled data creation, maintenance, and management, together with the capacity to add value to data.
  - Analogy to an art curator…
  - make decisions regarding what data to collect,
  - oversee data care and documentation (metadata)
  - conduct research based on the collection
  - data-driven decision making
  - ensure proper packaging of data for reuse
  - share that data with the public
  - …

The Long Tail of Data Variety and Data Curation



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