

CentraleSupélec 2018-2019 MSC DSBA / DATA SCIENCES

Big Data Algorithms Techniques & Platforms

Hugues Talbot

Introduction

- ❖ Course set in collaboration with Pr. Céline Hudelot, department of mathematics, CentraleSupélec.
- ❖ 25h, lectures and project.

Objective of the course

- ❖ *Big Data* and data-intensive information processing.
- ❖ Algorithms that scale on Big data and programming paradigms.
- ❖ Distributed computing strategies (e.g. Map Reduce) - Distributed File
- ❖ Systems - Distributed Access Structures
- ❖ Basic practice on some Big Data platforms (Hadoop, Spark, Cassandra, AWS...)

Essence of the course

- ❖ Small introductions to the main concepts.
- ❖ Some references to understand deeper.
- ❖ Practice to learn (Confucius: I hear, I forget ; I see, I remember ; I practice, I understand).

Prerequisite

- ❖ Knowledge on Programming and Advanced Programming.
- ❖ IS1220BC : Object oriented Software design [http://
cours.etudes.ecp.fr/claroline/course/index.php?cid=TI1220](http://cours.etudes.ecp.fr/claroline/course/index.php?cid=TI1220)
- ❖ Knowledge on Algorithm Design and Data structures.
- ❖ Knowledge on Database systems : SQL, relational algebra, ACID properties.
- ❖ IS1210 : Introduction aux bases de donnees [https://
chewbii.com/is1230/](https://chewbii.com/is1230/)

Syllabus

1. Part 1 : Object-oriented programming in JAVA : H. Talbot, C. Hudelot, P. Ballarini, MICS, CentraleSupélec
2. Part 2 : Distributed Computing : Map Reduce - Hadoop
3. Part 3 : No SQL Nicolas Travers, Assistant Professor, CNAM, <http://chewbii.com/>
4. Part 4 : Stream Computing : Real-time Processing of Massive Data ; Spark, Mlib Regis Behmo, Data Architect
<https://fr.linkedin.com/in/regisb/fr>

- ❖ Data Architect path in progress in OpenClassRoom with the team of this course (in French) <https://openclassrooms.com/paths/data-architect>
 - ❖ Follow it, Become a Mentor : <http://jobs.openclassrooms.com/o/mentor--parcours-data-architect>

DEVENEZ
DATA ARCHITECT

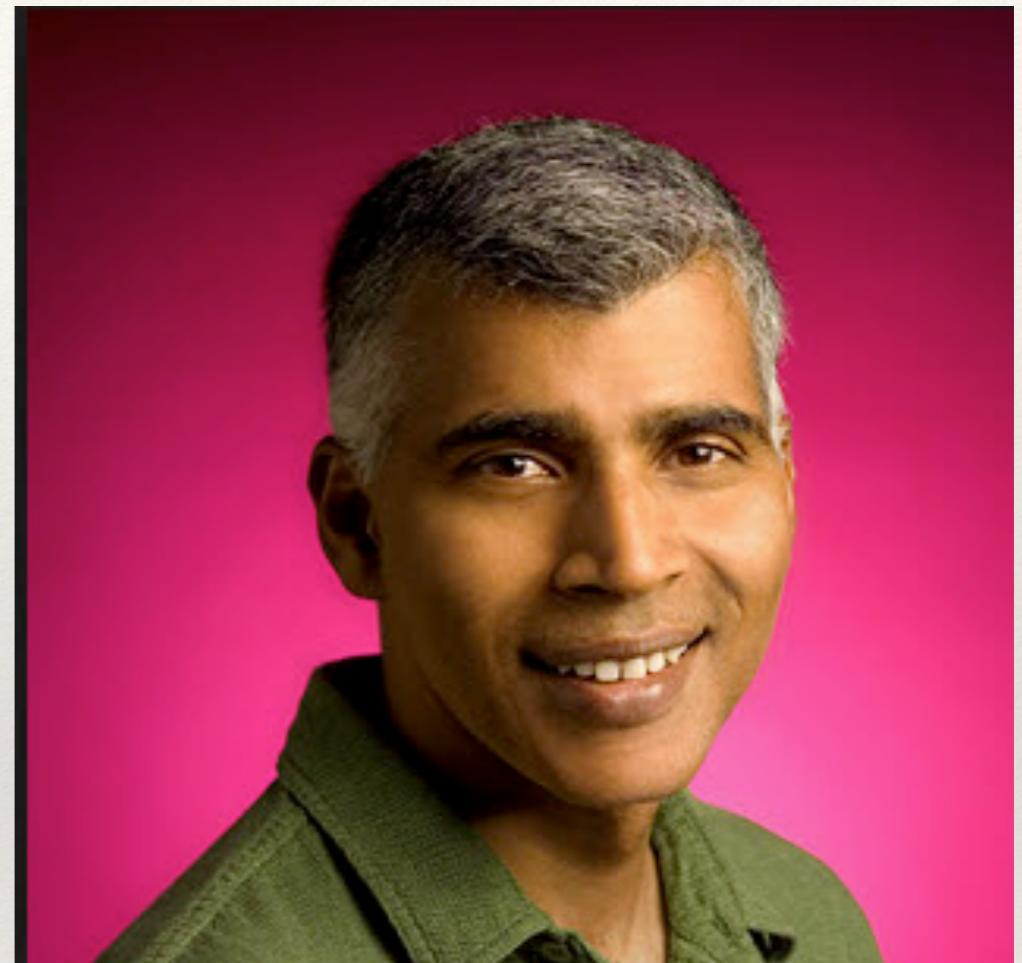
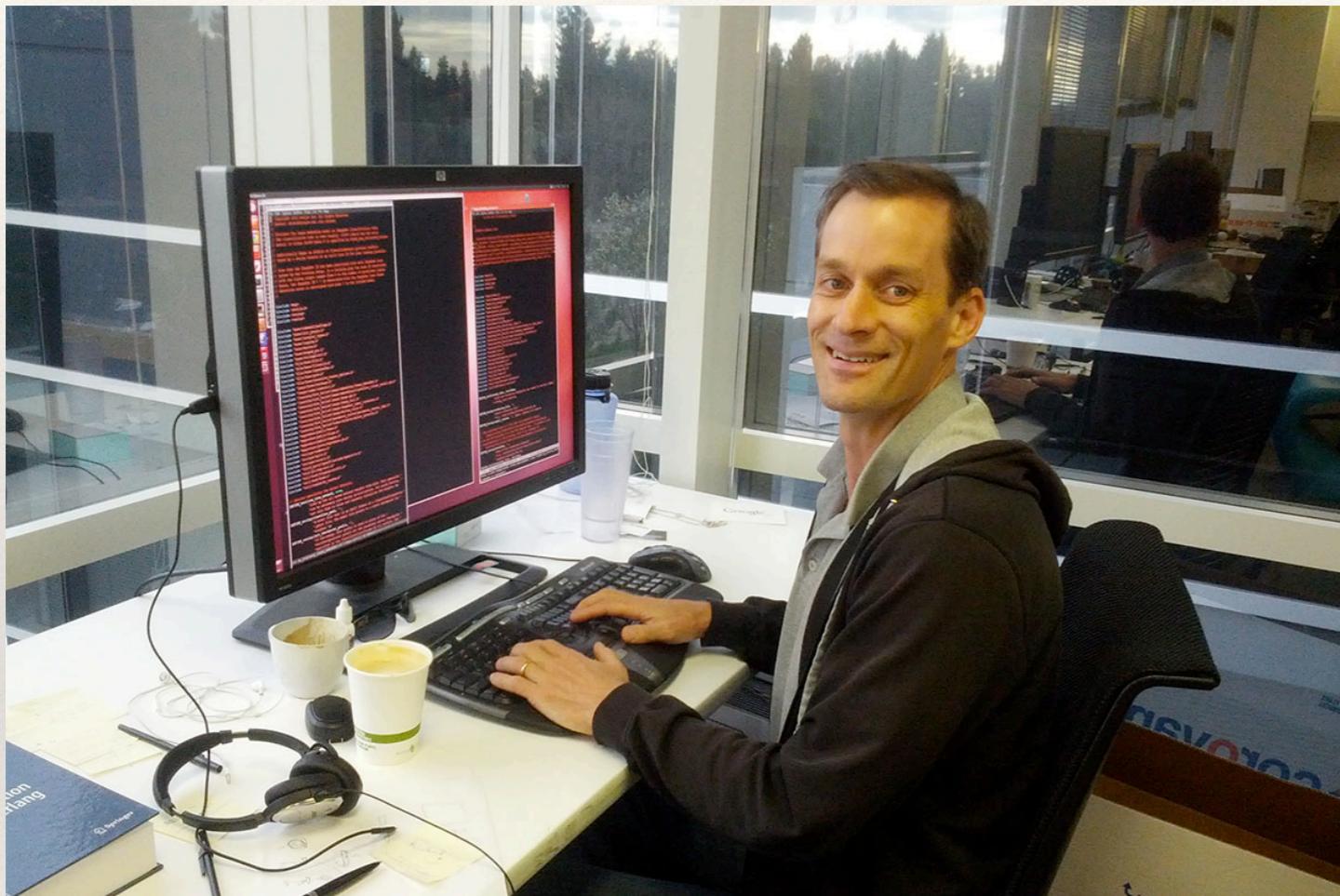
Relevez le défi du Big Data ! Concevez des infrastructures pour exploiter des données massives.



Tiny quiz: explain code below

- ❖ 1. class HumptyDumpty
- ❖ 2. {
- ❖ 3. void myMethod() {}
- ❖ 4. }
- ❖ 5.
- ❖ 6. class HankyPanky extends HumptyDumpty
- ❖ 7. {
- ❖ 8. public void myMethod() {}
- ❖ 9. }

Who are these two people ?



Have you hear of Hadoop?



What does this number represent?



40 000 000 000 000 000 000

What is big-data ?

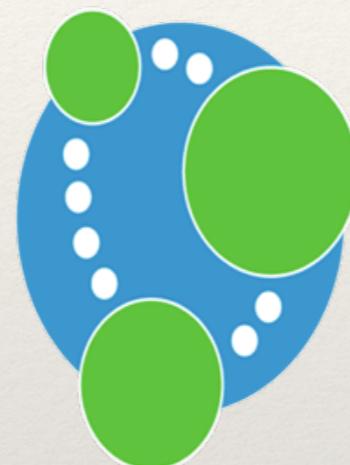
What is big-data ?



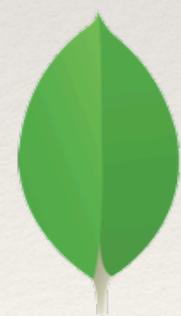
“Big Data se réfère à des ensembles de données dont la taille est au-delà de la capacité des outils logiciels de base de données classiques pour capturer, stocker, gérer et analyser.”

McKinsey Global Institute

What is the difference between CASSENDRA, Mongo-DB and Neo4J ?



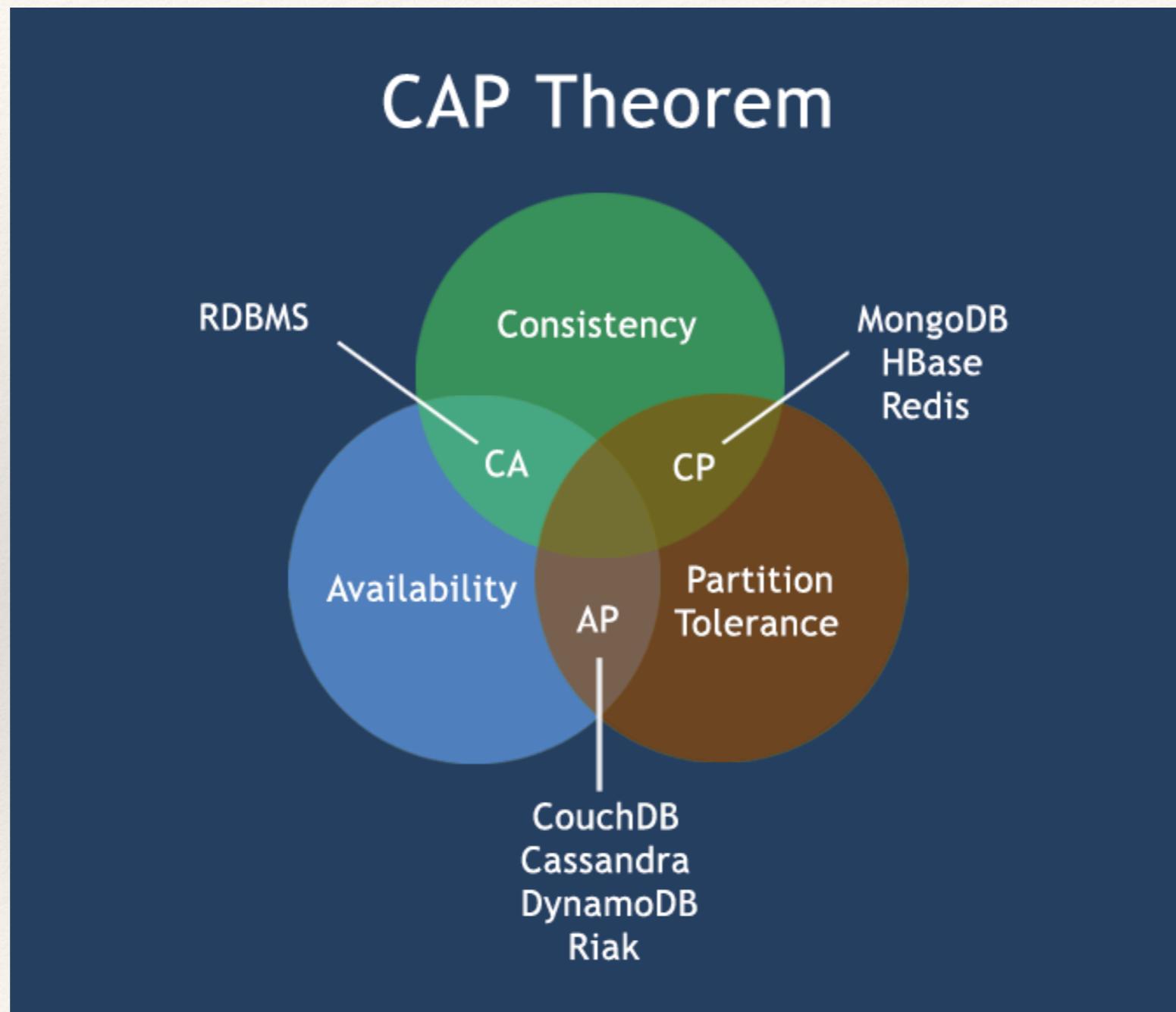
neo4j



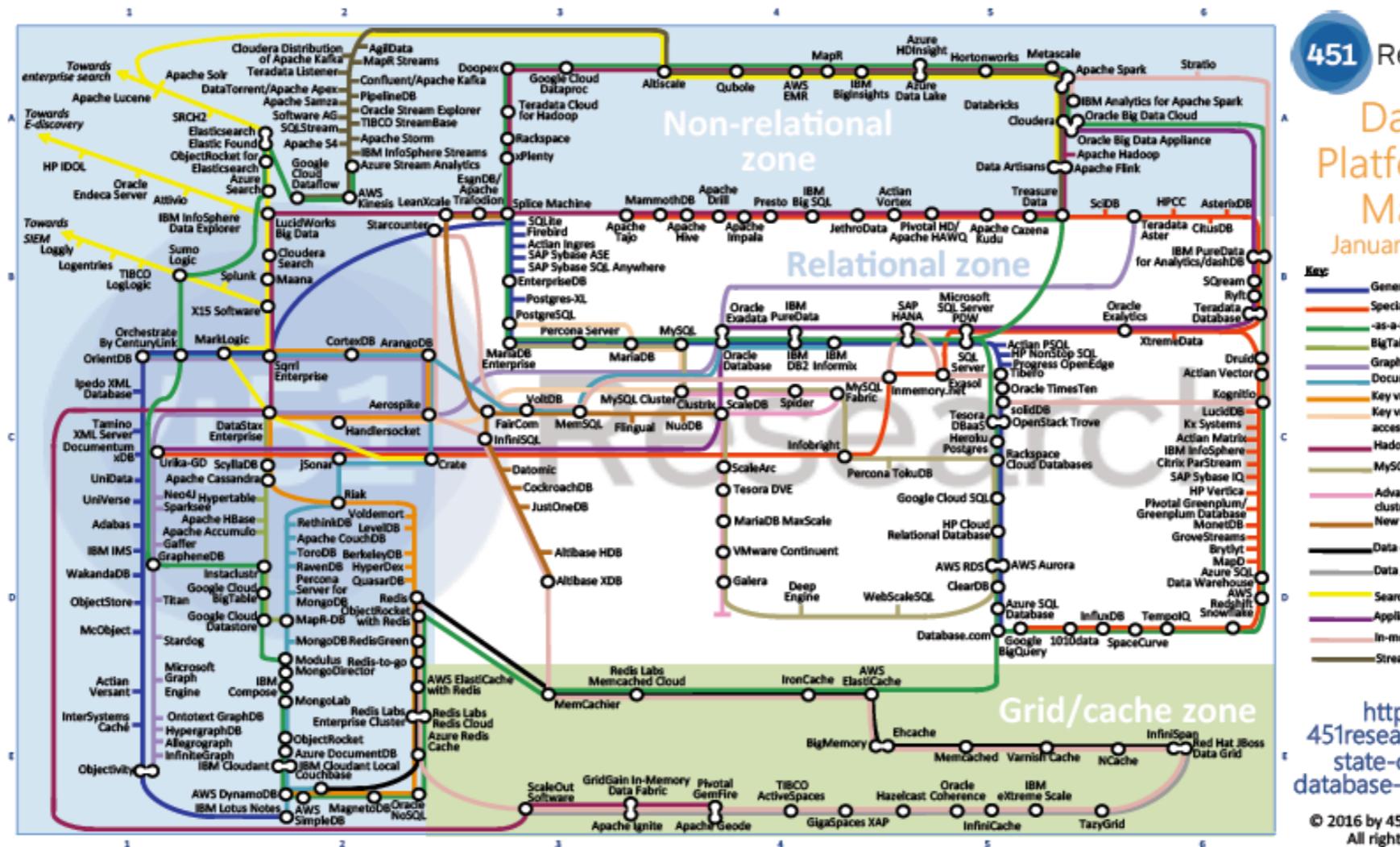
mongoDB®

What is the CAP theorem?

What is the CAP theorem?



Can you travel on that map?



451 Research
Data Platforms Map January 2016

[https://451research.com/
state-of-the-database-landscape](https://451research.com/state-of-the-database-landscape)

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Big Data: data is everywhere

-
- ❖ Massive data are collected and warehoused.
 - ❖ Web data, e-commerce
 - ❖ Bank / Credit Card transactions or other card transactions (e.g. navigo pass)
 - ❖ Social network.
 - ❖ Internet of Things.
 - ❖ but also *scientific data* .

POPULAR SCIENCE

THE CONTROL CENTERS

Using Data to Feed the World, Solve Cold Cases, Battle Malware, Predict Our Fate p.52

OFFICER ALGORITHM

Can a Crime Be Prevented Before It Begins? p.38

NEW WAYS OF SEEING

A Gallery of Extraordinary Infographics p.68

SPECIAL ISSUE

DATA IS POWER

HOW INFORMATION IS DRIVING THE FUTURE

NOVEMBER 2011 \$5.99

PLUS

Juan Enriquez Reprograms Life p.31

James Gleick Unsplits the Bit p.58

AND

Lawrence Weschler Questions the Cloud p.76

cisco

Data is the new oil.

We see in data the same transformative, wealth-creating power that 19th-century visionaries once sensed in the crude black ooze trapped underground.

If "crude" data can be extracted, refined, and piped to where it can impact decisions in real time, its value will soar. And if data can be properly shared across an entire ecosystem and made accessible in the places where analytics are most useful, then it will become a true game changer, altering the way we live, work, learn, and play.

Source: Cisco IBSG, 2012. #DataInMotion

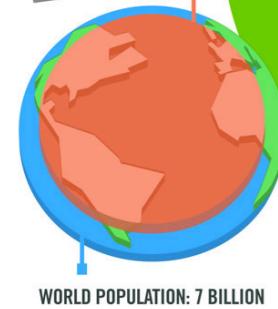
The ability to take data - to be able to understand it, to process it, to extract value from it, to visualize it, to communicate it is going to be a hugely important skill in the next decades.

Hal Varian, Chief Economist, Google

@kyleplacy
#NSD2013

40 ZETTABYTES
[43 TRILLION GIGABYTES]
of data will be created by
2020, an increase of 300
times from 2005

6 BILLION PEOPLE
have cell phones



Volume SCALE OF DATA

It's estimated that
2.5 QUINTILLION BYTES
[2.3 TRILLION GIGABYTES]
of data are created each day

Most companies in the
U.S. have at least
100 TERABYTES
[100,000 GIGABYTES]
of data stored

Modern cars have close to
100 SENSORS
that monitor items such as
fuel level and tire pressure

Velocity ANALYSIS OF STREAMING DATA

The New York Stock Exchange captures
1 TB OF TRADE INFORMATION
during each trading session



By 2016, it is projected
there will be
**18.9 BILLION
NETWORK CONNECTIONS**
– almost 2.5 connections
per person on earth



The FOUR V's of Big Data

From traffic patterns and music downloads to web history and medical records, data is recorded, stored, and analyzed to enable the technology and services that the world relies on every day. But what exactly is big data, and how can these massive amounts of data be used?

As a leader in the sector, IBM data scientists break big data into four dimensions: **Volume, Velocity, Variety and Veracity**

Depending on the industry and organization, big data encompasses information from multiple internal and external sources such as transactions, social media, enterprise content, sensors and mobile devices. Companies can leverage data to adapt their products and services to better meet customer needs, optimize operations and infrastructure, and find new sources of revenue.

By 2015
4.4 MILLION IT JOBS
will be created globally to support big data, with 1.9 million in the United States



As of 2011, the global size of
data in healthcare was
estimated to be

150 EXABYTES
[161 BILLION GIGABYTES]



Variety DIFFERENT FORMS OF DATA

**30 BILLION
PIECES OF CONTENT**

are shared on Facebook
every month



By 2014, it's anticipated
there will be
**420 MILLION
WEARABLE, WIRELESS
HEALTH MONITORS**

4 BILLION+
HOURS OF VIDEO

are watched on
YouTube each month



400 MILLION TWEETS
are sent per day by about 200
million monthly active users

Veracity UNCERTAINTY OF DATA

**1 IN 3 BUSINESS
LEADERS**

don't trust the information
they use to make decisions

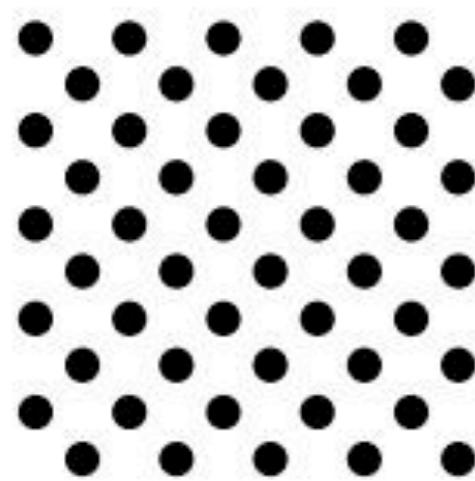


**27% OF
RESPONDENTS**

in one survey were unsure of
how much of their data was
inaccurate



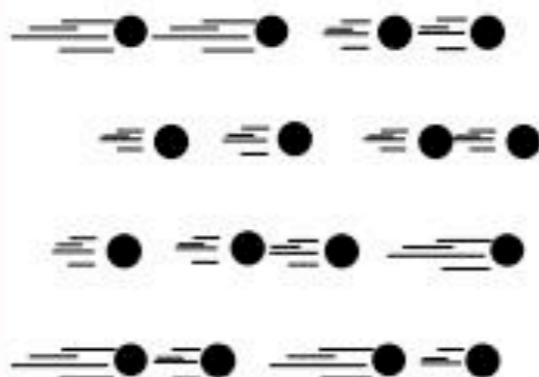
Volume



Data at Rest

Terabytes to exabytes of existing data to process

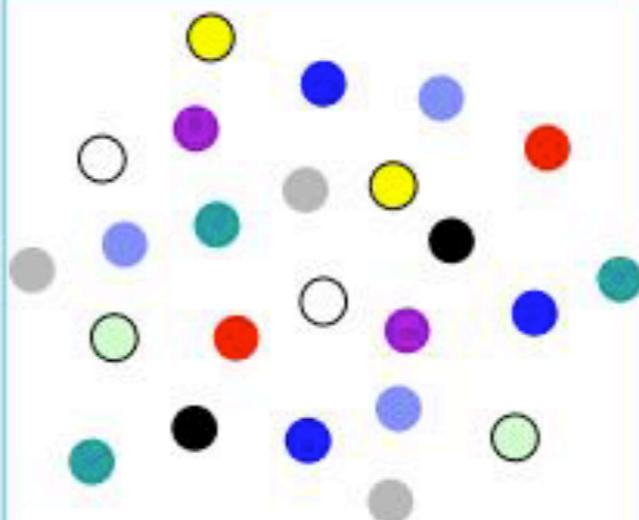
Velocity



Data in Motion

Streaming data, milliseconds to seconds to respond

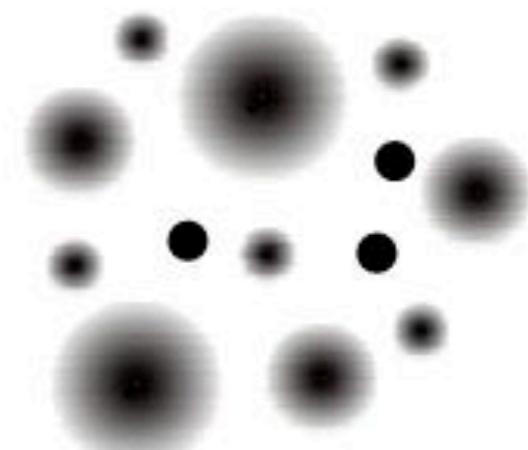
Variety



Data in Many Forms

Structured, unstructured, text, multimedia

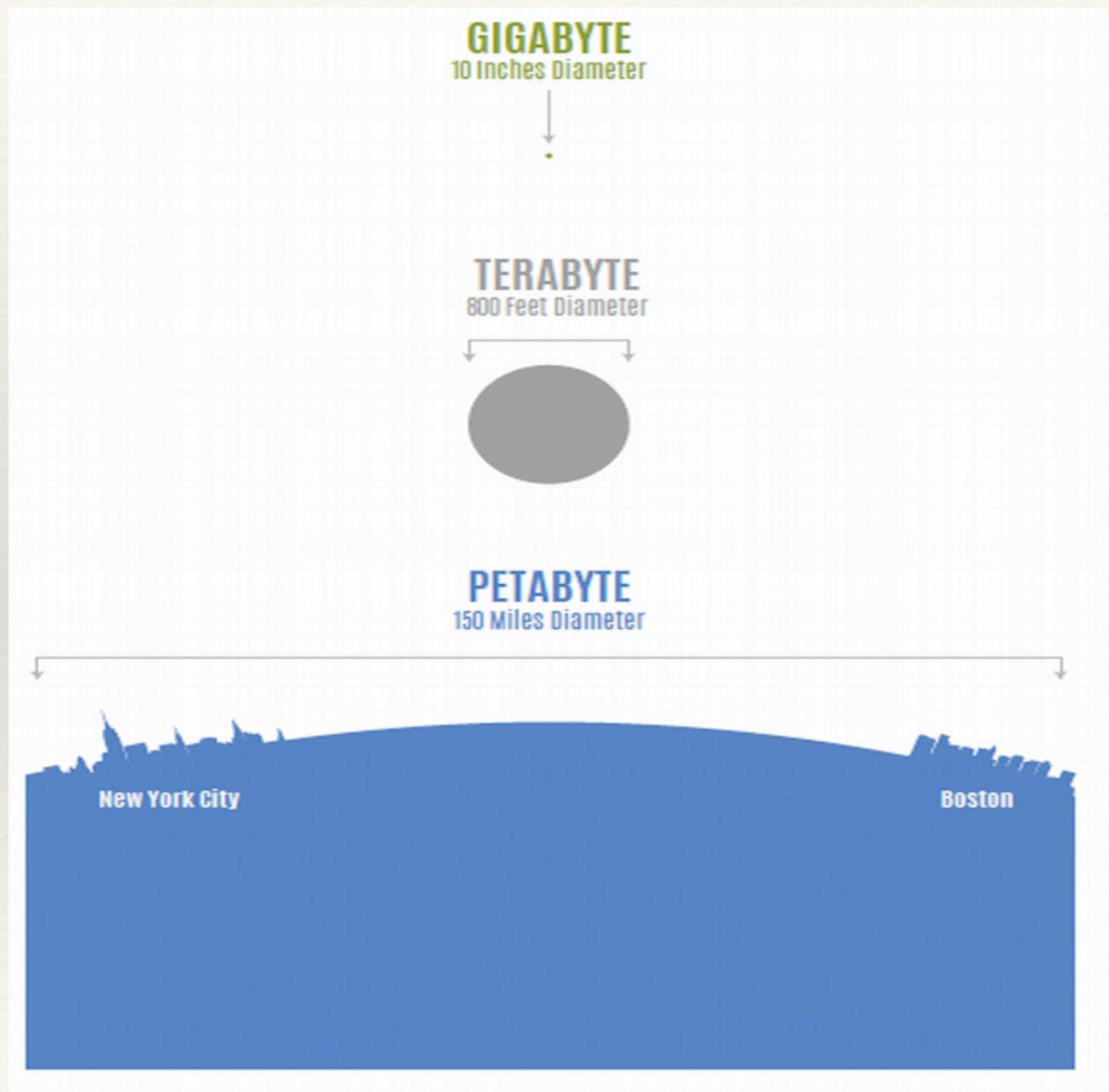
Veracity*



Data in Doubt

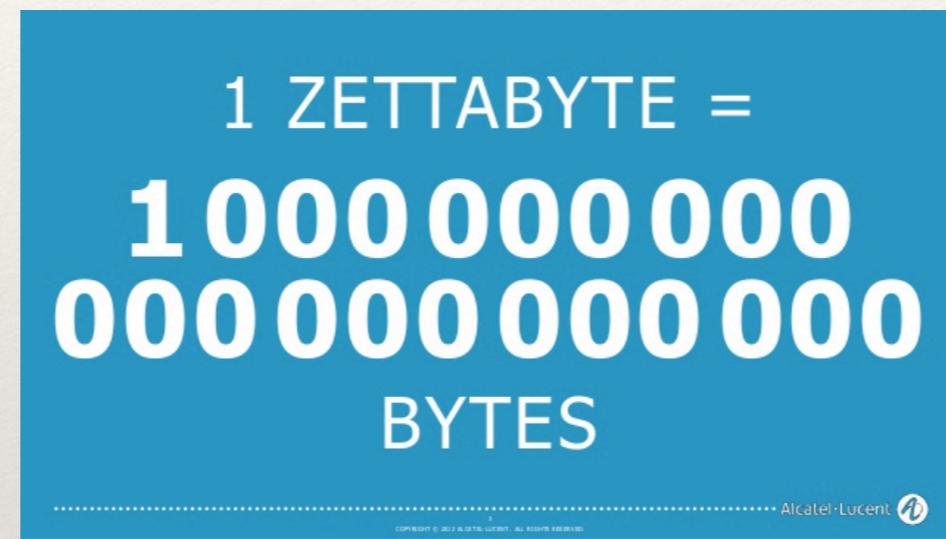
Uncertainty due to data inconsistency & incompleteness, ambiguities, latency, deception, model approximations

Volume



Volume

- ❖ In 2020, a total of 40 zettabytes of data on the web produced per year



- ❖ Scientific installations :
 - ❖ The radiotelescope Square Kilometre Array will generate 50 TB of *reduced* data per day ; with 7 000 TB of raw data per second
 - ❖ The LSST will produce 100 Petabyte of reduced data over a 10-year period starting in 2020.

Volume

- ❖ Today:
 - ❖ 150 millions emails every minute
 - ❖ Facebook : 4000 TB / day (i.e, 4 PB)
 - ❖ CERN, LHC : 15 PB / year (Source : Wikipedia)

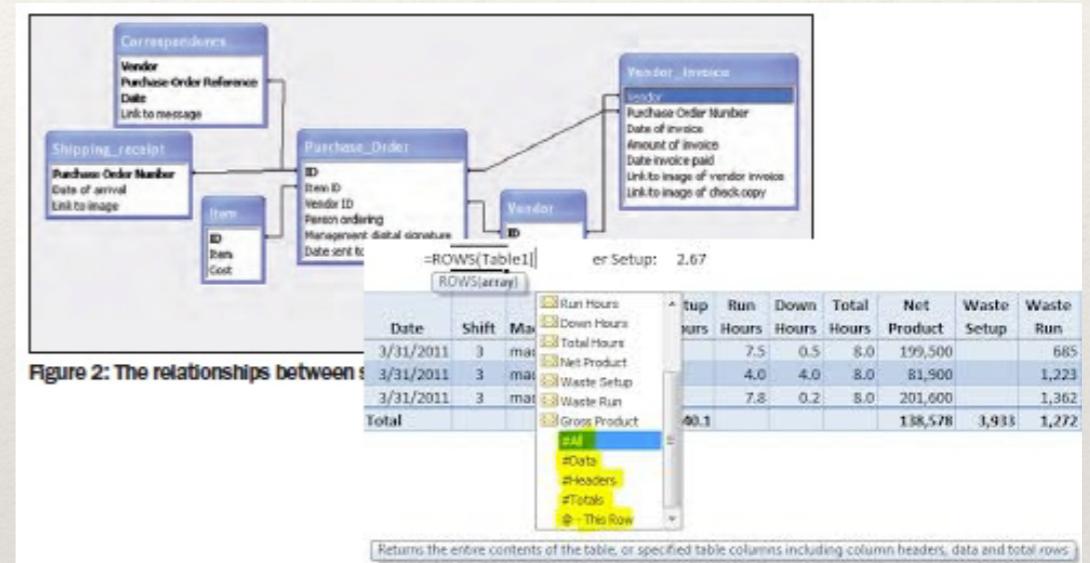
Dealing with volume

- ❖ Capacity of a big server
 - ❖ Memory : 256 GB
 - ❖ Disk storage : 24 TB
 - ❖ Disk speed : 100 MB / s

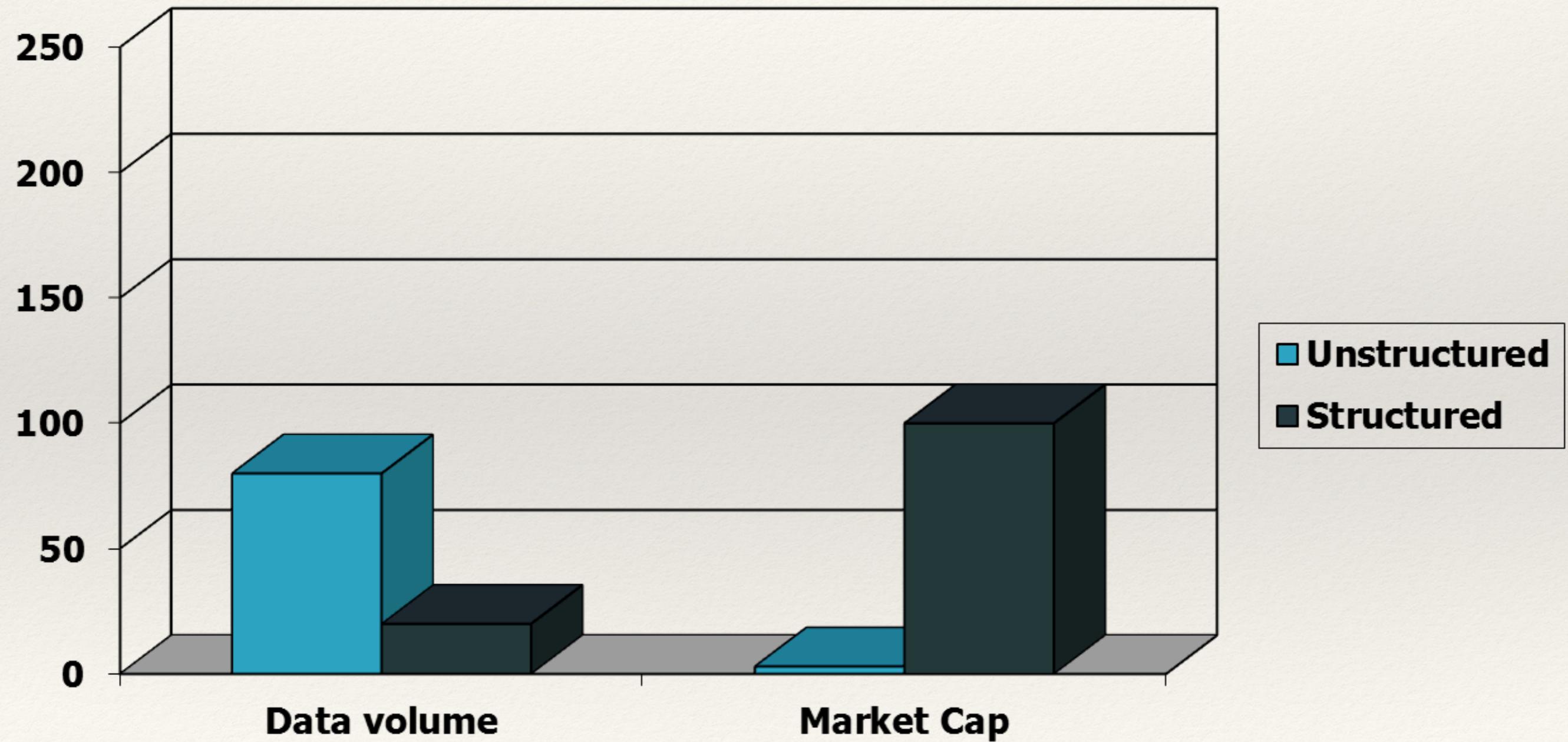


Variety

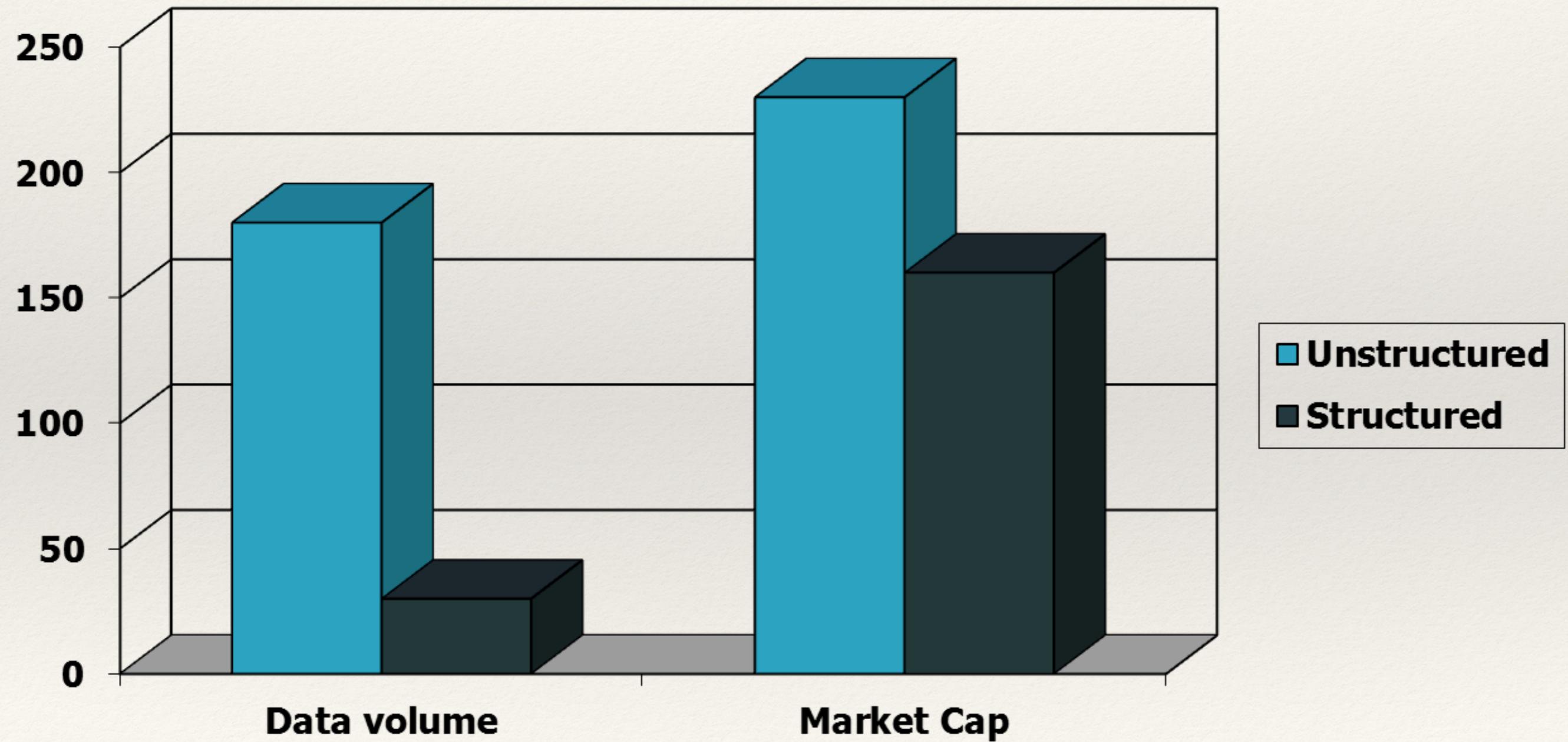
- ❖ The type and nature of the data : structured and unstructured data
- ❖ *Structured data*
 - ❖ Data with a level of organization.
 - ❖ e.g. : databases, excel sheets, ...
- ❖ *Unstructured data*
 - ❖ Without strong structuration
 - ❖ e.g. : emails, documents, images, social network data...



In 1990



In 2005



Variety

- ❖ Non-structured data
 - ❖ 175 millions tweets per day.
 - ❖ 571 new websites every minute.
 - ❖ 2.5 exabytes of data per day.
 - ❖ Source

How big is a Yottabyte?

TERABYTE

Will fit 200,000 photos or mp3 songs on a single 1 terabyte hard drive.



PETABYTE

Will fit on 16 Backblaze storage pods racked in two datacenter cabinets.



EXABYTE

Will fit in 2,000 cabinets and fill a 4 story datacenter that takes up a city block.



ZETTABYTE

Will fill 1,000 datacenters or about 20% of Manhattan, New York.



YOTTABYTE

Will fill the states of Delaware and Rhode Island with a million datacenters.



The Cost

The cost of buying a 1 terabyte hard drive today is \$100. It would cost \$100 Trillion dollars to buy a yottabyte of storage for just the hard drives.



Velocity

- ❖ Speed at which data is generated and processed.

Comparing High-Velocity Data & Big Data

High-Velocity Data

- Real-Time
- Performance & Volume Challenges
- Use Cases: Operations & Analytics

Big Data

- Batch Process
- Volume Challenge
- Use Case: Analytics



Cost of velocity

- ❖ The measure of the eye blink (User experience)
 - ❖ Amazon : increase of more than 100 ms of the latency => -1 % in sales
 - ❖ Google : more than 500 ms at the loading => 20 % loss in traffic
 - ❖ Yahoo : more than 400 ms at the loading => + 5 to 9 % of cancelations (rebound)
 - ❖ Bing :more than 1 second at the loading => -2,8 % of ad revenue.

LIMITES TECHNOLOGIQUES

Au-delà de 10 To en ligne, les architectures « classiques » nécessitent des adaptations logiques et matérielles très importantes.

Application
orientée
Stockage

Stockage
distribué
Share
nothing

Au-delà de 1 000 transactions/seconde, les architectures « classiques » nécessitent des adaptations logiques et matérielles très importantes

Application
orientée
Flux évènementiel

Event Stream
Processing

XTP

Application
orientée
Transaction

Univers
« standard »
SGBDR,
Serveur d'application,
ETL, ESB

Au-delà de 1 000 événements/seconde, les architectures « classiques » nécessitent des adaptations logiques et matérielles très importantes.

Programmation
parallèle

Au-delà de 10 threads/Core CPU, la programmation séquentielle classique atteint ses limites (I/O).

Application
orientée
Calculs



Processing big data

- ❖ Solution : parallelism
 - ❖ 1 server
 - ❖ 8 disks
 - ❖ Read the web : 230 days
 - ❖ Cluster Hadoop Yahoo
 - ❖ 4000 servers with 8 disks
 - ❖ Read the web : 1h20

Problems with this approach:

- ❖ Some problems
 - ❖ Synchronization.
 - ❖ Programming models (share memory, message passing (MPI))
 - ❖ Scalability and elasticity (arbitrary numbers of nodes)
 - ❖ Fault Tolerance.

Solutions:

- ❖ How do we get data for computation ?
 - ❖ Solution 1 : Move data to computation ?
 - ❖ Solution 2 : Move computation to the data ?
- ❖ Solution 2 : not enough RAM to hold all the data in memory and prevent slow disk access
 - ❖ Data is stored on the local disks of nodes in the cluster.
 - ❖ The programs are started up on the node that has the data local.
- ❖ Distributed File Systems : GFS, HDFS.

Distributed computing models

- ❖ How do we design algorithms for distributed computing ?
 - ❖ Generic programming models : design patterns.
 - ❖ MapReduce

