Outline

1 Introduction

2 BigData Challenges

3 Analytical Workflow

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6 Summary
About DKRZ

German Climate Computing Center (DKRZ)

**Partner for Climate Research**
Maximum Compute Performance.
Sophisticated Data Management.
Competent Service.
Scientific Computing

- Research Group of Prof. Ludwig at the University of Hamburg
- Embedded into DKRZ

Research

- Analysis of parallel I/O
- I/O & energy tracing tools
- Middleware optimization
- Alternative I/O interfaces
- Data reduction techniques
- Cost & energy efficiency
Lecture

Concept of the lecture

- The lecture is focussing on applying technology and some theory

- Theory
  - Data models and processing concepts
  - Algorithms and data structures
  - System architectures
  - Statistics and machine learning

- Applying technology
  - Learning about various state-of-the-art technology
  - Hands-on for understanding the key concepts
  - Languages: Java, Python, R

- The domain of big data is overwhelming, especially in terms of technology

- It is a crash course for several topics such as statistics and databases

⇒ it is not the goal to learn and understand every aspect in this lecture
Lecture (2)

Slides

- Many openly accessable sources have been used
- Citation to them by a number
- The reference slide provides the link to the source
- For figures, a reference is indicated by Source: [Author]$^1$ [title] [ref]
- In the title, an [ref] means that this reference has been used for the slide, some text may be taken literally

Excercise

- Weekly delivery, processing time about 8 hours / per week estimated
- Teamwork of 2 or 3 people (groups are mandatory!)
- Supported by: Hans Ole Hatzel

$^1$If available
Idea of BigData

Methods of obtaining knowledge (Erkenntnisprozess)
Theory (model), hypothesis, experiment, analysis (repeat)
- Explorative: start theory with observations of phenomena
- Constructivism: starts with axioms and reason implications

The Fourth Paradigm
- (Big) Data + Analytics ⇒ Insight (prediction of the future)
  - For industry: insight = business advantage and money...
- Analytics: follow an explorative approach and study the data
  - To infer knowledge, use statistics / machine learning
- Construct a theory (model) and validate it with the data
Example Models

Similarity is a (very) simplistic model and predictor for the world

- Humans use this approach in their cognitive process
- Uses the advantage of BigData

Weather prediction

- You may develop and rely on complex models of physics
- Or use a simple model for a particular day; e.g. expect it to be similar to the weather of the day over the last X years
- Used by humans: rule of thumb for farmers

Preferences of Humans

- Identify a set of people which liked items you like
- Predict you like also the items those people like (items you haven’t rated so far)
Relevance of Big Data

- Big Data Analytics is emerging
- Relevance increases compared to supercomputing

Google Search Trends, relative searches
Introduction

BigData Challenges
- Volume
- Velocity
- Variety
- Veracity
- Value

Analytical Workflow

Use Cases

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Summary
BigData Challenges & Characteristics

Source: MarianVesper [4]
Volume: The size of the Data

What is Big Data
Terrabytes to 10s of petabytes

What is not Big Data
A few gigabytes

Examples

- Wikipedia corpus with history ca. 10 TByte
- Wikimedia commons ca. 23 TByte
- Google search index ca. 46 Gigawebpages\(^2\)
- YouTube per year 76 PByte (2012\(^3\))

\(^2\)http://www.worldwidewebsize.com/
\(^3\)https://sumanrs.wordpress.com/2012/04/14/youtube-yearly-costs-for-storagenetworking-estimate/
Velocity: Data Volume per Time

What is Big Data
30 KiB to 30 GiB per second
(902 GiB/year to 902 PiB/year)

What is not Big Data
A never changing data set

Examples

- LHC (Cern) with all experiments about 25 GB/s ⁴
- Square Kilometre Array 700 TB/s (in 2018) ⁵
- 50k Google searches per s ⁶
- Facebook 30 Billion content pieces shared per month ⁷

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⁴ [http://home.web.cern.ch/about/computing/processing-what-record](http://home.web.cern.ch/about/computing/processing-what-record)
⁷ [https://blog.kissmetrics.com/facebook-statistics/](https://blog.kissmetrics.com/facebook-statistics/)
Data Sources

Enterprise data
- Serves business objectives, well defined
- Customer information
- Transactions, e.g. Purchases

Experimental/Observational data (EOD)
- Created by machines from sensors/devices
- Trading systems, satellites
- Microscopes, video streams, Smart meters

Social media
- Created by humans
- Messages, posts, blogs, Wikis
Variety: Types of Data

- Structured data
  - Like tables with fixed attributes
  - Traditionally handled by relational databases

- Unstructured data
  - Usually generated by humans
  - E.g. natural language, voice, Wikipedia, Twitter posts
  - Must be processed into (semi-structured) data to gain value

- Semi-structured data
  - Has some structure in tags but it changes with documents
  - E.g. HTML, XML, JSON files, server logs

What is Big Data

- Use data from multiple sources and in multiple forms
- Involve unstructured and semi-structured data
Veracity: Trustworthiness of Data

What is Big Data

- Data involves some uncertainty and ambiguities
- Mistakes can be introduced by humans and machines
  - People sharing accounts
  - Like sth. today, dislike it tomorrow
  - Wrong system timestamps

Data Quality is vital!
Analytics and conclusions rely on good data quality

- Garbage data + perfect model => garbage results
- Perfect data + garbage model => garbage results

GIGO paradigm: Garbage In – Garbage Out
Value of Data

What is Big Data

- Raw data of Big Data is of low value
  - For example, single observations
- Analytics and theory about the data increases the value

Analytics transform big data into smart data!
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Types of Data Analytics and Value of Data

1. Descriptive analytics (Beschreiben)
   - “What happened?”

2. Diagnostic analytics
   - “Why did this happen, what went wrong?”

3. Predictive analytics (Vorhersagen)
   - “What will happen?”

4. Prescriptive analytics (Empfehlen)
   - “What should we do and why?”

The level of insight and value of data increases from step 1 to 4
The Value of Data (alternative view)

Source: Dursun Delen, Haluk Demirkan [9]
The Value of Data (alternative view 2)

Most BI remains backward-looking

Information about

NOW

Data volume (bytes)

Zetta

Exa

Peta

Tera

Unstructured external data

Unstructured internal data

Traditional reporting

Real-time reporting

Process automation

Ad hoc decision support

Operational planning

Strategic planning

Real-time

Predictive

Years

Months

Days

Hours

Mins

S

S

Mins

Hours

Days

Months

Years

Source: Forrester report. Understanding The Business Intelligence Growth Opportunity. 20-08-2011
1 Introduction

2 BigData Challenges

3 Analytical Workflow
   - Value Chain
   - Roles
   - Privacy

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Big Data Analytics Value Chain

There are many visualizations of the processing and value chain [8]

Source: Andrew Stein [8]
### Big Data Analytics Value Chain (2)

<table>
<thead>
<tr>
<th>Data discovery</th>
<th>Data integration</th>
<th>Data exploitation</th>
<th>Make decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collect and annotate</strong></td>
<td><strong>Prepare</strong></td>
<td><strong>Organize</strong></td>
<td><strong>Integrate</strong></td>
</tr>
<tr>
<td>Create an inventory of data sources and the metadata that describe them.</td>
<td>Enable access to sources and set up access-control rules.</td>
<td>Identify syntax, structure, and semantics for each data source.</td>
<td>Establish a common data representation of the data. Maintain data provenance.</td>
</tr>
<tr>
<td><strong>Analyze</strong></td>
<td><strong>Visualize</strong></td>
<td><strong>Make decisions</strong></td>
<td></td>
</tr>
<tr>
<td>Analyze integrated data.</td>
<td>Present analytic results to a decision maker as an interactive application that supports exploration and refinement.</td>
<td>Determine what actions (if any) to take on the basis of the interpreted results.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Miller and Mork [7]
Roles in the Big Data Business

**Data scientist**

*Data science is a systematic method dedicated to knowledge discovery via data analysis* [1]

- In business, optimize organizational processes for efficiency
- In science, analyze experimental/observational data to derive results

**Data engineer**

*Data engineering is the domain that develops and provides systems for managing and analyzing big data*

- Build modular and scalable data platforms for data scientists
- Deploy big data solutions
Typical Skills

Data scientist

- Statistics + (Mathematics)
- Computer science
  - Programming e.g.: Java, Python, R, (SAS, ...)
  - Machine learning
- Some domain knowledge for the problem to solve

Data engineer

- Computer science
  - Databases
  - Software engineering
  - Massively parallel processing
  - Real-time processing
- Languages: C++, Java, Python
- Understand performance factors and limitations of systems
Data Science vs. Business Intelligence (BI)

Characteristics of BI

- Provides pre-created dashboards for management
  - Repeated visualization of well known analysis steps
- Deals with structured data
- Typically data is generated within the organization
- Central data storage (vs. multiple data silos)
- Handeled well by specialized database techniques

Typical types of insight

- Customer service data: “what business causes the largest customer wait times”
- Sales and marketing data: “which marketing is most effective”
- Operational data: “efficiency of the help desk”
- Employee performance data: “who is most/least productive”
Privacy

Be aware of privacy issues if you deal with personal/private information. German privacy laws are more strict than those of other countries.

Ziel des Datenschutzes
Recht auf informationelle Selbstbestimmung

- Schutz des Einzelnen vor beeinträchtigung des Persönlichkeitsrechts durch den Umgang mit seinen personenbezogenen Daten
- Besonderer Schutz für Daten über Gesundheit, ethnische Herkunft, religiöse, gewerkschaftschliche oder sexuelle Orientierung

---

8§3 BDSG, Einzelangaben über persönliche oder sachliche Verhältnisse einer bestimmten oder bestimmmbaren natürlichen Person
Wichtige Grundsätze des Gesetzes [10]

- Verbotsprinzip mit Erlaubnisvorbehalt
  - Erhebung, Verarbeitung, Nutzung und Weitergabe von personenbezogenen Daten sind verboten
  - Nutzung nur mit Rechtsgrundlage oder mit Zustimmung der Person

- Unternehmen mit 10 Personen benötigen Datenschutzbeauftragten

- Verfahren zur automatischen Verarbeitung sind vom Datenschutzbeauftragten zu prüfen und anzeigepflichtig

- Sitz der verantwortlichen Stelle maßgeblich
  - Bei einer Niederlassung in D gilt BDSG

- Prinzipien: Datenvermeidung, -sparsamkeit

- Schutz vor Zugriffen, Änderungen und Weitergabe

- Betroffene haben Recht auf Auskunft, Löschung oder Sperrung

- Anonymisierung/Pseudonymisierung: Ist die Zuordnung zu Einzelpersonen (nahezu) ausgeschlossen, so können Daten verarbeitet werden
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THE BIG PICTURE ON HADOOP

Apache Hadoop is an open source software framework created in 2005. Engineered for Big Data and large-scale processing applications.

Most Commonly Used Hadoop Services

- 69% MapReduce
- 67% HDFS
- 61% Hive
- 54% HBase
- 50% Pig

Top Application Types that Benefit from Hadoop

- 71% Big Data Sourcing
- 68% Advanced Analytics
- 48% Discovery Analytics
- 33% Information Exploration
- 30% Data Warehouse Augmentation

Problem or Opportunity?

- 12% Problem: Because Hadoop and Skills For it Are Immature
- 88% Opportunity: Because Hadoop Enables New Application Types

The Future of Hadoop

- 61% of organizations plan to deploy Hadoop or have already deployed it
- $50.2B Worldwide sales based on Hadoop technology are forecasted to reach $50.2 billion by 2020

This infographic is brought to you by StackIQ (www.stackiq.com), makers of stacki - the fastest open source bare metal installer. Download it at www.stacki.com.

Source: [21]
# Use Cases for BigData Analytics

## Increase efficiency of processes and systems

- Advertisement: Optimize for target audience
- Product: Acceptance (like/dislike) of buyer, dynamic pricing
- Decrease financial risks: fraud detection, account takeover
- Insurance policies: Modeling of catastrophes
- Recommendation engine: Stimulate purchase/consume
- Systems: Fault prediction and anomaly detection
- Supply chain management

## Science

- Epidemiology research: Google searches indicate Flu spread
- Personalized Healthcare: Recommend good treatment
- Physics: Finding the Higgs-Boson, analyze telescope data
- Enabler for social sciences: Analyze people’s mood
### Big Data in Industry

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>USE CASE</th>
<th>DATA TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sensor</td>
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<td>Server</td>
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<td>Logs</td>
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<td>Text</td>
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<td>Social</td>
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<td>Geographic</td>
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<td>Clickstream</td>
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<tr>
<td>Financial Services</td>
<td>New Account Risk Screens</td>
<td>✓  ✓</td>
</tr>
<tr>
<td></td>
<td>Trading Risk</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Insurance Underwriting</td>
<td>✓</td>
</tr>
<tr>
<td>Telecom</td>
<td>Call Detail Records (CDR)</td>
<td>✓  ✓</td>
</tr>
<tr>
<td></td>
<td>Infrastructure Investment</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Real-time Bandwidth Allocation</td>
<td>✓  ✓  ✓</td>
</tr>
<tr>
<td>Retail</td>
<td>360° View of the Customer</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Localized, Personalized Promotions</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Website Optimization</td>
<td>✓</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Supply Chain and Logistics</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Assembly Line Quality Assurance</td>
<td>✓</td>
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<tr>
<td></td>
<td>Crowd-sourced Quality Assurance</td>
<td>✓</td>
</tr>
<tr>
<td>Healthcare</td>
<td>Use Genomic Data in Medial Trials</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Monitor Patient Vitals in Real-Time</td>
<td>✓</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>Recruit and Retain Patients for Drug Trials</td>
<td>✓  ✓</td>
</tr>
<tr>
<td></td>
<td>Improve Prescription Adherence</td>
<td>✓  ✓</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>Unify Exploration &amp; Production Data</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Monitor Rig Safety in Real-Time</td>
<td>✓</td>
</tr>
<tr>
<td>Government</td>
<td>ETL Offloaded Response to Federal Budgetary Pressures</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Sentiment Analysis for Government Programs</td>
<td>✓</td>
</tr>
</tbody>
</table>

Source: [20]
Example Use Case: Deutschland Card [2]

Goals

- Customer bonus card which tracks purchases
- Increase scalability and flexibility
- Previous solution based on OLAP

Big Data Characteristics

- Volume: $O(10)$ TB
- Variety: mostly structured data, schemes are extended steadily
- Velocity: data growth rate $O(100)$ GB / month

Results

- Much better scalability of the solution
- From dashboards to ad-hoc analysis within minutes
Example Use Case: DM [2]

Goals

- Predict required employees per day and store
- Prevent staff changes on short-notice

Big Data Characteristics

- Input data: Opening hours, incoming goods, empl. preferences, holidays, weather ...
- Model: NeuroBayes (Bayes + neuronal networks)
- Predictions: Sales, employee planning
- 450,000 predictions per week

Results

- Daily updated sales per store
- Reliable predictions for staff planning
- Customer and employee satisfaction
Example Use Case: OTTO [2]

Goals
Optimize inventory and prevent out-of-stock situations

Big Data Characteristics
- Input data: product characteristics, advertisement
- Volume/Velocity: 135 GB/week, 300 million records
- Model: NeuroBayes (Bayes + neuronal networks)
- 1 billion predictions per year

Results
- Better prognostics of product sales (up to 40%)
- Real time data analytics
Example Use Case: Smarter Cities (by KTH) [2]

Goals

- Improve traffic management in Stockholm
- Prediction of alternative routes

Big Data Characteristics

- Input data: Traffic videos/sensors, weather, GPS
- Volume/Velocity: 250k GPS-data/s + other data sources

Results

- 20% less traffic
- 50% reduction in travel time
- 20% less emissions
## Example Facebook Studies

### Insight from [11] by exploring posts

- Young narcissists tweet more likely. Middle-aged narcissists update their status.
- US students post more problematic information than German students.
- US Government checks tweets/facebook messages for several reasons.
- Human communication graph has an average diameter of 4.74.

### Manipulation of news feeds [13]

- News feeds have been changed to analysis people’s behavior in subsequent posts.
- Paper: “Experimental evidence of massive-scale emotional contagion through social networks”
From Big Data to the Data Lake [20]

- With cheap storage costs, people promote the concept of the data lake
- Combines data from many sources and of any type
- Allows for conducting future analysis and not miss any opportunity

Attributes of the data lake

- Collect everything: all data, both raw sources over extended periods of time as well as any processed data
  - Decide during analysis which data is important, e.g. no “schema” until read
- Dive in anywhere: enable users across multiple business units to refine, explore and enrich data on their terms
- Flexible access: enable multiple data access patterns across a shared infrastructure: batch, interactive, online, search, and others
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   - Java
   - Python
   - R

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Programming BigData Analytics

High-level concepts

- SQL and derivatives
- Domain-specific languages (Cypher, PigLatin)

Programming languages

- Java interfaces are widely available but low-level
- Python and R have connectors to popular BigData solutions

In the exercises, we’ll learn and use basics of those languages/interfaces
Introduction to Java

- Developed by Sun Microsystems in 1995
- Object oriented programming language
- OpenJDK implementation is open source
- Source code $\Rightarrow$ byte code $\Rightarrow$ just-in-time compiler
  - Byte code is portable & platform independent
  - Virtual machine abstracts from systems
- Strong and static type system
- Popular language for Enterprise & Big Data applications
  - Most popular programming language (Pos. 1 on the TIOBE index)
- Development tools: Eclipse

Specialties

- Good runtime and compile time error reporting
- Generic data types (vs. templates of C++)
- Introspection via. Reflection
Example Java Program

```java
import java.util.Scanner;
import java.io.FileReader;
import java.io.FileNotFoundException;

// compile with javac program.java
// run with java program
public class program{
    // the main method is part of a class
    public static void main(String [ ] args) throws FileNotFoundException{
        try{
            // read from file "program.java" and create simple tokens
            Scanner data = new Scanner(new FileReader("program.java"));
            while(data.hasNext()){
                System.out.println(data.next());
            }
        }catch(Exception e){
            // handle error here, we'll just rethrow the error
            throw(e);
        }
    }
}
```
Example Java Classes

```java
// Run: javac classes1.java and java Rabbit
// An abstract class is not completely implemented
abstract class Animal{
    // instance member
    private float weight;
    // not-implemented instance function
    public abstract String name();
    // constructor
    public Animal(float weight){ this.weight = weight; }
    public String toString(){ return "I’m a " + name() + " with " +
                                weight + " kg"; }
}

class Rabbit extends Animal{
    // invoke the constructor of the parent
    public String name(){ return "Rabbit"; }
    public Rabbit(){ super(2.5f); }

    // the main method is part of a class
    public static void main(String [ ] args){
        Animal a = new Rabbit();
        System.out.println(a); // I’m a Rabbit with 2.5 kg
    }
}
```

Introduction to Python

- Open source
- Position 5 on TIOBE index
- Interpreted language
- Weak type system (errors at runtime)
- Development tools: any editor, interactive shell
- Note: Use and learn python3 explicitly
- Recommended plotting library: matplotlib

Specialties

- Strong text processing
- Simple to use
- Support for object oriented programming
- Indentation is relevant for code blocks

---

9http://matplotlib.org/gallery.html
Example Python Program

```python
#!/bin/env python
import re # use the module 're'

# function reading a file
def readFile(filename):
    with open(filename, 'r') as f:
        data = f.readlines()
        f.close()
    return data

return [] # return an empty array/list

# the main function
if __name__ == '__main__':
    data = readFile('intro.py')
    # iterate over the array
    for x in data:
        # extract imports from a python file using a regex
        m = re.match("import[ \t]+(?P<WHAT>[^# \t]*)", x)
        if m:
            print(m.group("WHAT"))
            # dictionary (key value pair)
            dic = m.groupdict()
            dic.update( {"FILE" : 'intro.py'}) # append a new dict. with one key
            # use format string with dictionary
            print("Found import '%(WHAT)s' in file %(FILE)s" % dic )
            # Prints: Found import 're' in file intro.py
```
Example Python Classes

```python
from abc import abstractmethod

class Animal:
    # constructor, self are instance methods, else class methods
    def __init__(self, weight):
        self.__weight = weight # private variables start with __

    # decorator
    @abstractmethod
    def name(self):
        return self.__class__.__name__ # reflection like

    def __str__(self):
        return "I'm a %s with weight %f" % (self.name(), self.__weight)

class Rabbit(Animal):
    def __init__(self):
        super().__init__(2.5)

    def name(self):
        return "Small Rabbit" # override name

if __name__ == '__main__':
    r = Rabbit()
    print(r) # print: I'm a Small Rabbit with weight 2.500000
```
Introduction to R

- Based on S language for statisticians
- Open source
- Position 19 on TIOBE index
- Interpreter with C modules (packages)
  - Easy installation of packages via CRAN\(^\text{10}\)
- Popular language for data analytics
- Development tools: RStudio (or any editor), interactive shell
- Recommended plotting library: ggplot2\(^\text{11}\)

Specialties

- Vector/matrix operations. Note: Loops are slow, so avoid them
- Table data structure (data frames)

---

\(^{10}\) Comprehensive R Archive Network
\(^{11}\) http://docs.ggplot2.org/current/
# Run with "Rscript intro.R" or run "R" and copy&paste into interactive shell
# Installing a new package is as easy as:
install.packages("swirl")
# Note: sometimes packages are not available on all mirrors!
library(swirl) # load the package

help(swirl) # read help about the function swirl

swirl() # start an interactive course to learn R

# a simple for loop
for (x in 1:10){
  if (x < 5){
    print(x)
  }else{
    print(x * 2)
  }
}

Example R Program

```r
# create an array
x = c(1, 2, 10:12)

# apply an operator on the full vector and output it
print( x*2 ) # prints: 2 4 20 22 24

# slice arrays
print( x[3:5] ) # prints: 10 11 12
print( x[c(1,4,8)] ) # prints: 1 11 NA

r = runif(100, min=0, max=100) # create array with random numbers
m = matrix(r, ncol=4, byrow = TRUE) # create a matrix

# slice matrix rows "m[row(s), column(s)]"
print( m[10:12, ] ) # Output:
[1,] 85.46609 60.749703 10.5062183 7.449173
[2,] 79.76042 52.199321 96.9699856 97.877946
[3,] 37.34286 8.266282 0.3398741 1.957607

# slice rows & columns
print ( m[10, c(1,4)] ) # Output: [1] 85.466085 7.449173

# subset the table based on a mask
set = m[ (m[,1] < 20 & m[,2] > 2) , ]
```
Accessing CSV Files with R

```r
# function to create a table (data frame) and fill it with random data
createTable = function (size){
  tbl = read.table(text="", col.names = c("Type", "Time"))
  tbl[1:size, ] = 0  # initialize size times a full rows
  tbl$Time = runif(size, min=0, max=100)  # address by column name
  # create random types, factor() for nominal data and
  # ordered() for ordinal data
  tbl$Type = factor(round(runif(size, min=0.5, max=3.49)),
        levels=1:3,  # three categories
        labels=c("unknown", "good", "bad"))
  tbl$Type[size] = "bad"  # assign last element to be bad
  return (tbl)
}
# change columnnames
colnames(tbl) = c("Typ", "Duration")

d = createTable(5)
# Assign the column with the name
print( d )
print( summary (d) )  # some statistics about d
# Write CSV incl. header
write.table(d, file = "mydata.csv", sep="","", row.names=FALSE)
# reread table
d = read.table("mydata.csv", header = TRUE, sep = ",")
```
Summary

- Big data analytics
  - Explore data and model causalities to gain knowledge & value
- Challenges: 5 Vs – Volume, velocity, variety, veracity, value
- Data sources: Enterprise, humans, Exp./Observational data (EOD)
- Types of data: Structured, unstructured and semi-structured
- Levels of analytics: Descriptive, predictive and prescriptive
- Roles in big data business: Data scientist and engineer
- Data science != business “intelligence”
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