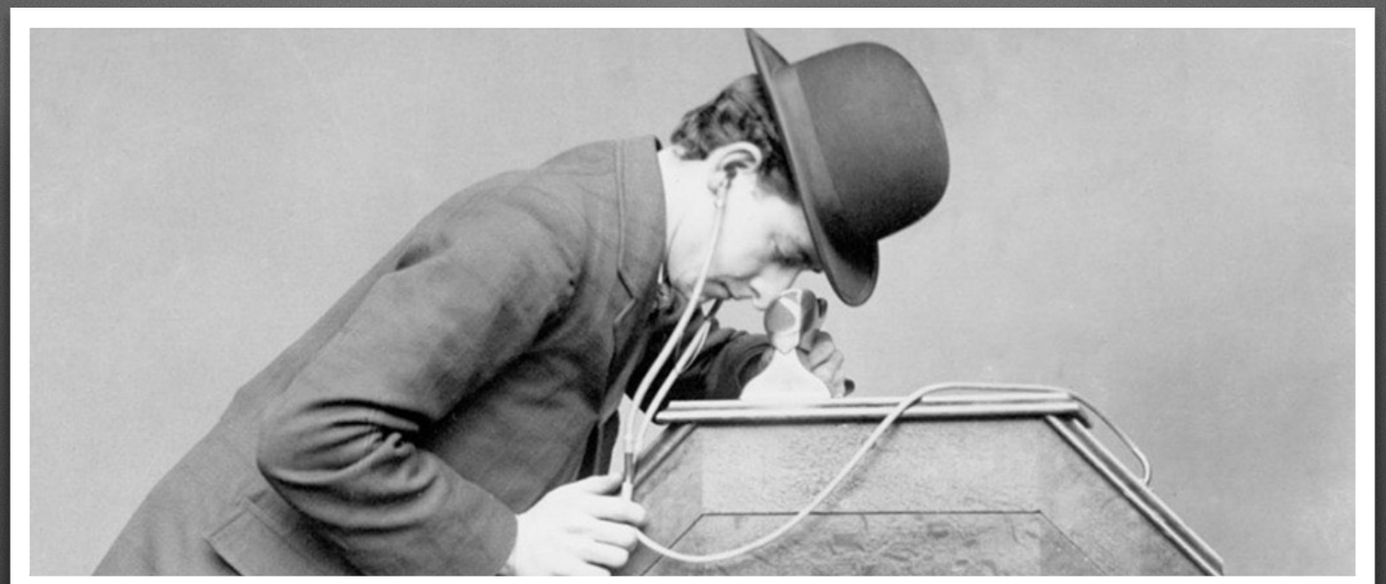


What is Data Science?

(a personal view)

Jordi Vitrià, PhD
Universitat de Barcelona

Data Science

Big Data

Taking (big)data-based decisions is **not new** but now it is **easier.**

Why now?

At the beginning

1 computer = 1 program = 1 user

Why now?

After a while

1 computer = N programs = M users

Why now?

Then

1 computer = N programs = 1 user

Why now?

Meanwhile

Internet & the Web

Why now?

A few years ago we reach the present situation.
From a user perspective:

M computers = N programs = 1 user

Why now?

From a “dev-ops” perspective we are implementing “the network is the computer” idea:

2^N computers = 2^M programs = 2^P users

Why now?

The “cloud” is a necessary condition to process big data, but not the main cause of the Big Data fever.

Big Data

What is Big Data?

- For some people, they have big data when its size > 65536 x 256.

- In general we have big data when its size does not allow its storage and analysis in a big computer.

More common

Fat Data

Big Data

Less common

Big Data

Wal-Mart handles over one million customer transaction per hour, the information is stored on a database sized in excess of 2.5 Petabytes ($2{,}0 \times 10^{16}$ bits).

By 2016 it is likely that a typical hospital will create 665 terabytes (5.32×10^{15} bits) of data a year.

Big Data

With a personal computer:

- **You can find an element in a 1 MB file in less than a second.**
- **You can find an element in a 1 GB file in less than a minute.**
- **You can find an element in a 1 TB file in less than sixteen hours.**
- **You can find an element in a 1 PB file in less than two years.**
- **You can find an element in a 1 EB file in less than two thousand years.**

A PETABYTE IS A LOT OF DATA

1 PETABYTE = **20 MILLION** FOUR-DRAWER FILING CABINETS FILLED WITH TEXT

1 PETABYTE = **13.3 YEARS** OF HD-TV VIDEO

1.5 PETABYTES = SIZE OF THE 10 BILLION PHOTOS ON → **FACEBOOK**

20 PETABYTES = THE AMOUNT OF DATA PROCESSED BY **GOOGLE** **PER DAY**

20 PETABYTES = TOTAL HARD DRIVE SPACE **MANUFACTURED IN 1995**

50 PETABYTES = **THE ENTIRE WRITTEN WORKS OF MANKIND**, FROM THE BEGINNING OF RECORDED HISTORY, IN ALL LANGUAGES

(all approximate)

Big Data

Big data is more than size.

It is commonly characterized with four V:

- Volume
- Velocity
- Variety
- Veracity

Big Data

The cloud is key to deal with the three V, but the main phenomenon behind Big Data is **datification**.

Key enabler

The three V are a consequence of it.

Big Data

We are rendering into data many aspects of the world that have never been quantified before:

business networks

books I'm reading

location

physical activity

consumed food

purchases

physiological signals

straight thoughts

friendship

gaze

driving behavior

Big Data

Information comes from:

- Corporate Data Bases (structured information).
- Unstructured information in documents, Wikipedia, textbooks, journals, blogs, tweets, etc.
- Images in the web, public cameras, phones, TV, YouTube, etc.
- Public APIs: smart cities, government, search engines, etc.
- Sensor Data: GPS, accelerometer, physico-chemical sensors, sociometric sensors, super-colliders, telescopes, etc.

Big Data

There are several problems:

- ETL (Extract, Transform, Load)
- BI/Analytics (Think you can do in SQL)
- **Advanced Analytics.**
- **Machine Learning.**
- Visualization.

Artificial Intelligence and Machine Learning

Artificial intelligence is an academic discipline devoted to the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, language recognition, decision-making, planning, reasoning, etc.

Artificial intelligence is classified into two parts, General AI and Narrow AI. General AI refers to making machines intelligent in a wide array of activities that involve thinking and reasoning. Narrow AI, on the other hand, involves the use of artificial intelligence for a very specific task.

Machine learning is a subset of artificial intelligence that uses algorithms to learn from data (inductive behavior).

Data Science

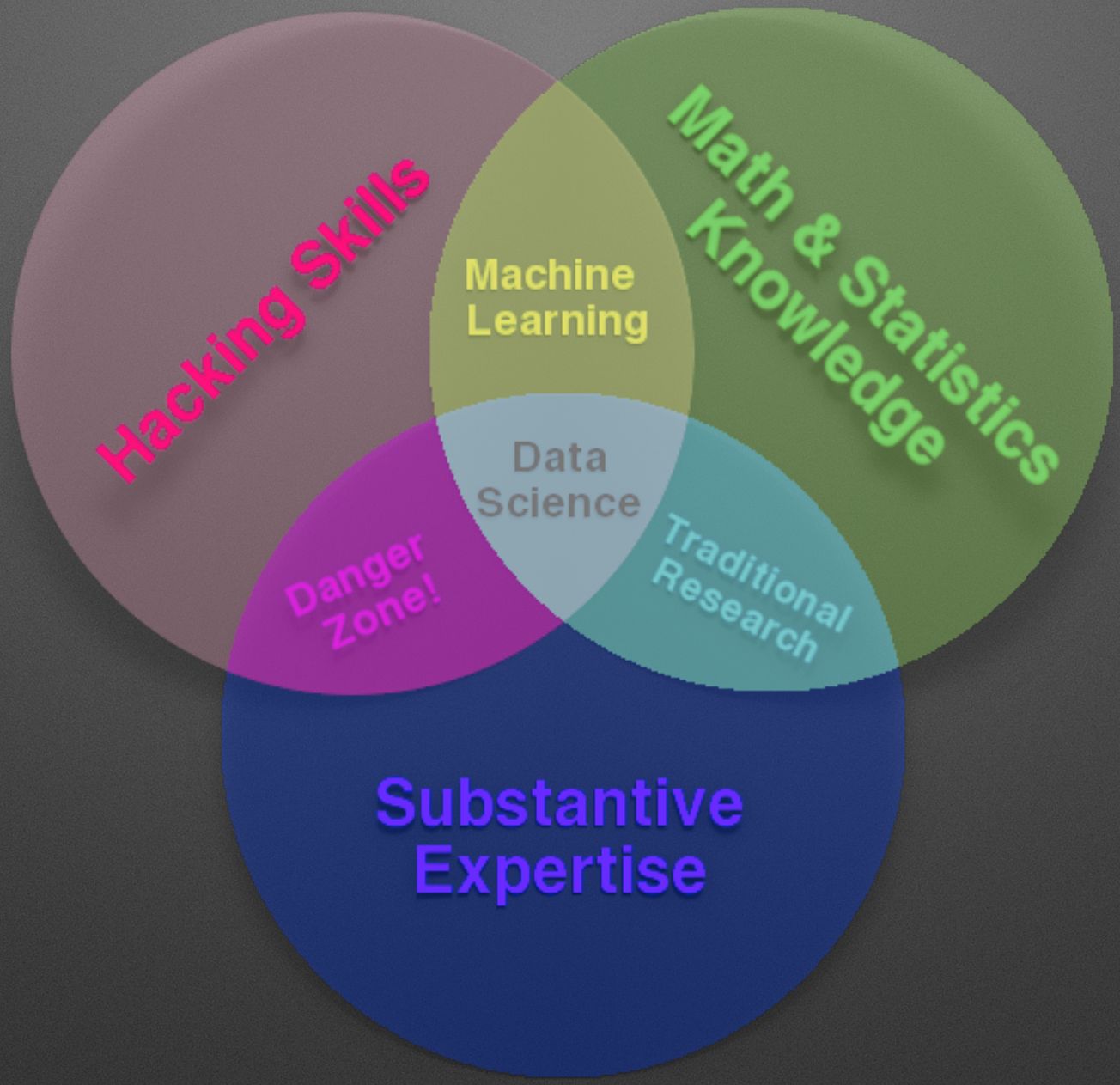
Data Science

Technology is the collection of tools, including machinery, modifications, arrangements and procedures used by humans.

Big Data is a key **technology** to process massive amounts of data (f.e. to count items).

Methodology is the systematic, theoretical analysis of the methods applied to a field of study.

Data Science is a **methodology** to define what we want to do with data, how do we evaluate our actions, what decisions can be grounded on data, how do we combine evidences from several sources, etc.



Drew Conway's Data Science Venn Diagram

Data Science Tasks

Background

Output

Domain Knowledge, Causality, Decision Making, Human Behavior

Data Insights: realistic models.

Prescriptive Decisions: Why? What is best?

Knowledge

Domain Knowledge, Statistics, Machine Learning, Complex Systems, etc.

Data Analytics/Data Processing/ Visualization

Data Analysis: experiment design, simple models.

Predictive Decisions: How to? When to?

Data Processing: aggregation, segmentation, labeling, metrics, etc.

Data Descriptions.

Data Processing/ Data Engineering

Data Preparation: cleaning, anomaly detection, imputation, etc.

Datasets

Information

Data Engineering

Data Storing from reliable data flow, using good infrastructure pipelines.

Databases

Data Engineering

Data Collection from instruments, logging, sensors, external data, etc.

Raw Data

Data

Data Science

Data Science is **not** a **science** but a methodology based on multidisciplinar knowledge.

Currently, most company decisions are based on intuition and best practices. The alternative is to integrate data-based knowledge in the decision process.

Data Science is a new data processing model focused on turning data into actions.

Data Science

Steps:

- Ask a **question**.
- Get the (available) data. They can be heterogeneous and non structured.
- Process the data (cleaning, munging, etc.).
- Analyze the data (description, simulation, prediction, prescription).
- Take a decision and **act**.

Questions…

- **Description** is using data to provide a quantitative summary of certain features of the world. → What is the mean value of X?

- **Prediction** (or **association**) is using data to map some features of the world (the inputs) to other features of the world (the outputs). → How would seeing X change my belief in Y?

Observational data

- **Causation**: Measuring the causal influence of a variable X in another variable Y, while excluding any influences on Y not actually due to the causal effect of X, and being able to guess what the effect will be if one performs an action. → How would expected lifespan change if more people become vegetarian?

Experimental data

Causal Model | Intervention | Observational data

- **Counterfactuals**: Being able to reason about hypothetical situations, things that *could* happen. → Would my grandfather still be alive if he did not smoke?

It cannot be estimated from interventional experiments

Counterfactuals: David Blei's election example

Given that Hilary Clinton did not win the 2016 presidential election, and given that she did not visit Michigan 3 days before the election, and given everything else we know about the circumstances of the election, what can we say about the probability of Hilary Clinton winning the election, had she visited Michigan 3 days before the election?

Let's try to unpack this. We are are interested in the probability that:

- she hypothetically wins the election

conditioned on four sets of things:

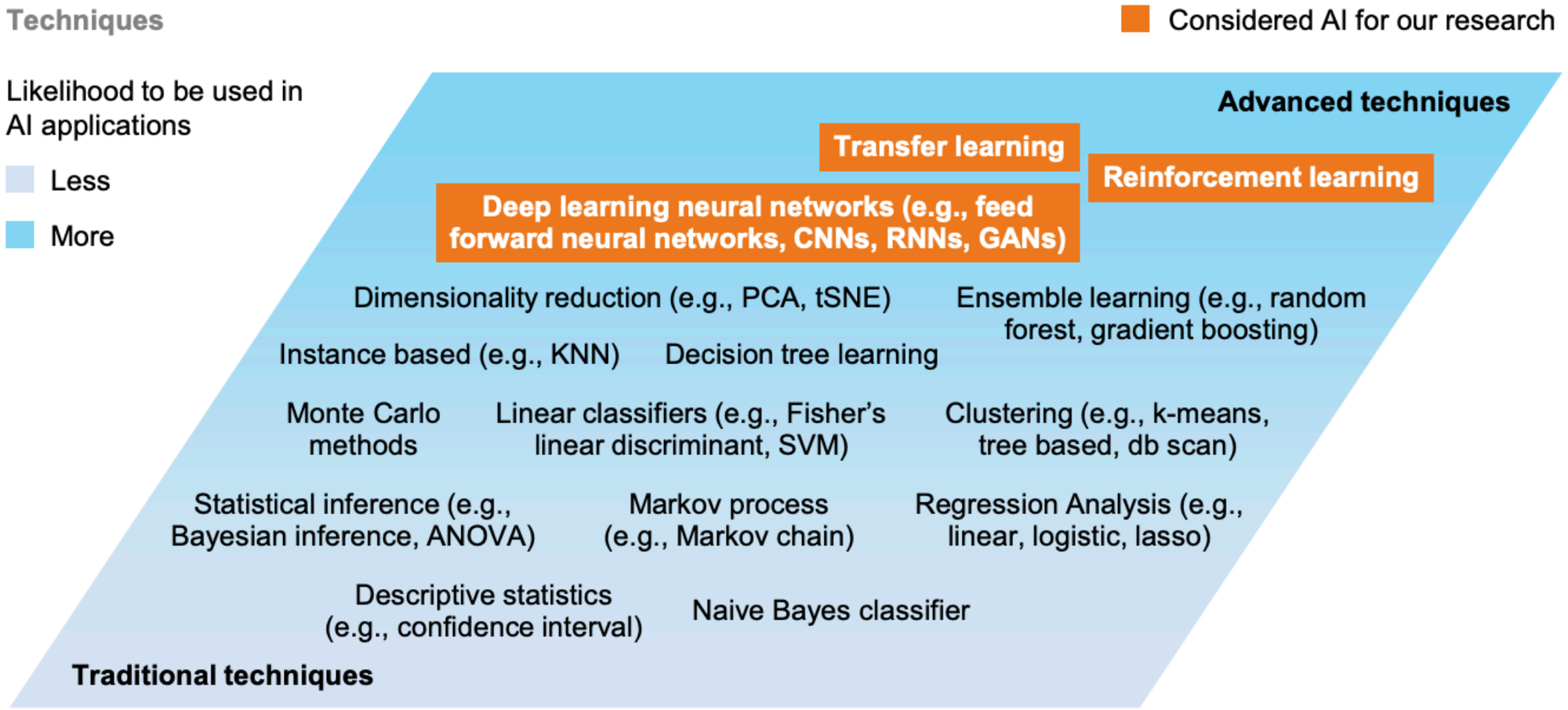
- she lost the election
- she did not visit Michigan
- any other relevant an observable facts
- she hypothetically visits Michigan

Why would quantifying this probability be useful? Mainly for credit assignment.

Data Science

Classification	To which category does this data point belong?	Medical diagnosis: does this tissue show signs of disease? Banking: is this transaction fraudulent? Computer vision: what type of object is in this picture? Is it a person? Is it a building?
Regression	Given this input from a dataset, what is the likely value of a particular quantity?	Finance: what is the value of this stock going to be tomorrow? Housing: what would the price of this house be if it were sold today? Food quality: how many days before this strawberry is ripe? Image processing: how old is the person in this photo?
Clustering	Which data points are similar to each other?	E-commerce: which customers are exhibiting similar behaviour to each other, how do they group together? Video Streaming: what are the different types of video genres in our catalogue, and which videos are in the same genre?

Canonical Problems and Tools



SOURCE: McKinsey Global Institute analysis

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4 See Jacques Bughin, Brian McCarthy, and Michael Chui, "A survey of 3,000 executives reveals how businesses succeed with AI," *Harvard Business Review*, August 28, 2017.

5 Michael Chui, James Manyika, and Mehdi Miremadi, "What AI can and can't do (yet) for your business," *McKinsey Quarterly*, January 2018.

6 For a detailed look at AI techniques, see *An executive's guide to AI*, McKinsey Analytics, January 2018. https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/an-executives-guide-to-ai

What are the limits of Data Science

- Data science is <u>nowadays</u> a tool to inform, not to explain.
- Data science cannot substitute intuition or creativity.

> If I had asked people what they wanted, they would have said faster horses.
>
> Henry Ford.

What are the limits of Data Science

- Current data science models reproduce what we do and how we do it (including bad things and wrong strategies).

Rich Caruana gives the example of a **pneumonia risk prediction** model on which he had worked. The purpose of the model was to evaluate whether a patient with pneumonia was at high or low risk, to help decide whether or not the patient should be admitted to the hospital. "On the basis of the patient data," says Caruana, "the model had found that patients with a history of asthma have a lower risk of dying from pneumonia. In reality, everybody knows that asthma is a very high risk factor for pneumonia. What the model found is the result of the fact that asthma patients get healthcare faster, which lowers their chance of dying compared to the general population."

https://cacm.acm.org/news/214618-in-black-box-algorithms-we-trust-or-do-we/fulltext

Ethical Data Science

If a data science system is making automatic decisions, someone has the **responsibility** of those decisions.

Problems:

- Choosing the wrong model.
- Building a model with inadvertently discriminatory rules.
- Not providing explanations about decisions.
- Not respecting privacy.
- Etc.

Ethical Data Science

Responsible data science challenges:

- Data science **without prejudice** – How to avoid unfair conclusions even if they are true?
- Data science **without guesswork** – How to answer questions with a guaranteed level of accuracy?
- Data science that **ensures confidentiality** – How to answer questions without revealing secrets?
- Data science that **provides transparency** – How to clarify answers such that they become indisputable?

Data Science

COMPANY
Mastercard

INDUSTRY
Finance

EMPLOYEES
67,000

TYPE
Behavioral Analytics

PURPOSE:

With 1.8 billion customers, MasterCard is in the unique position of being able to analyze the behavior of customers in not only their own stores, but also thousands of other retailers. The company teamed up with Mu Sigma to collect and analyze data on shoppers' behavior, and provide the insights it finds to other retailers in benchmarking reports.

Data Science

COMPANY
Starbucks Coffee

INDUSTRY
Food & Beverage

EMPLOYEES
160,000

TYPE
Behavioral Analytics

PURPOSE:

Starbucks collects data on its customers' purchasing habits in order to send personalized ads and coupon offers to the consumers' mobile phones. The company also identifies trends indicating whether customers are losing interest in their product and directs offers specifically to those customers in order to regenerate interest.

Data Science

Spotify®

COMPANY
Spotify

INDUSTRY
Entertainment

EMPLOYEES
5,000

TYPE
Customer Segmentation & Behavioral Analytics

PURPOSE:

Spotify uses data from user profiles and users' playlists, and historical data on music played to provide recommendations for each user. By combining data from millions of users, Spotify is able to make recommendations even if a particular user doesn't have an extensive history with the site.

Data Science

COMPANY
Union Pacific Railroad

INDUSTRY
Transportation

EMPLOYEES
44,000

TYPE
Predictive Support

PURPOSE:
With predictive analytics and tools such as visual sensors and thermometers, Union Pacific can detect imminent problems with railway tracks in order to predict potential derailments days before they would likely occur. So far the sensors have reduced derailments by 75 percent.

Data Science

COMPANY
Coca-Cola Co.

INDUSTRY
Food

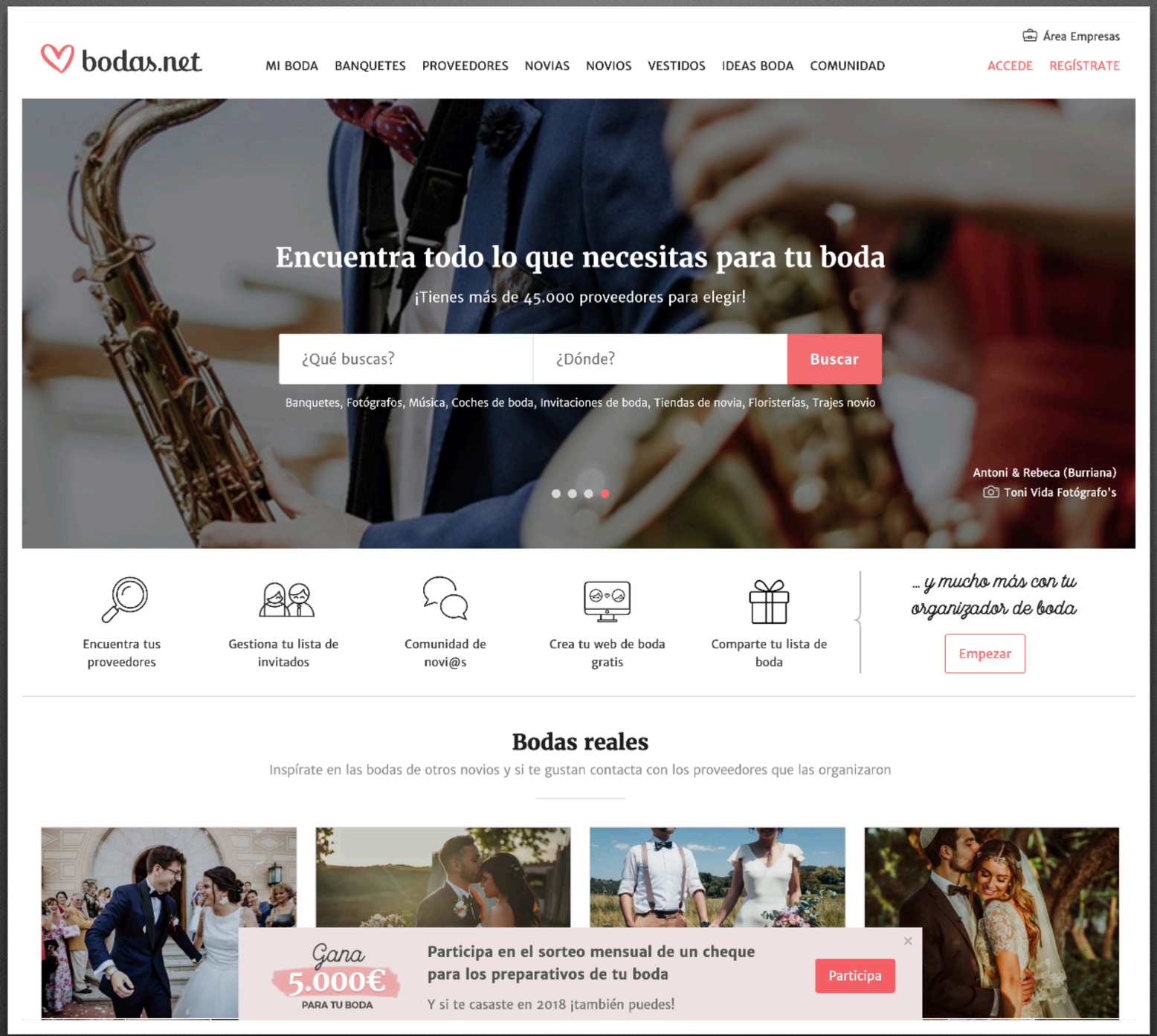
EMPLOYEES
146,200

TYPE
Market Basket Analysis

PURPOSE:

Coca-Cola uses an algorithm to ensure that its orange juice has a consistent taste throughout the year. The algorithm incorporates satellite imagery, crop yields, consumer preferences and details about the flavours that make up a particular fruit in order to determine how the juice should be blended.

Data Science



Data Science

Telecom

Medical

Services

Retail

Health

Finances

e-commerce

Entertainment

Games

Cartography

Data Science is for all,

small and big, old and new, etc.

Swimming companies

Walking companies

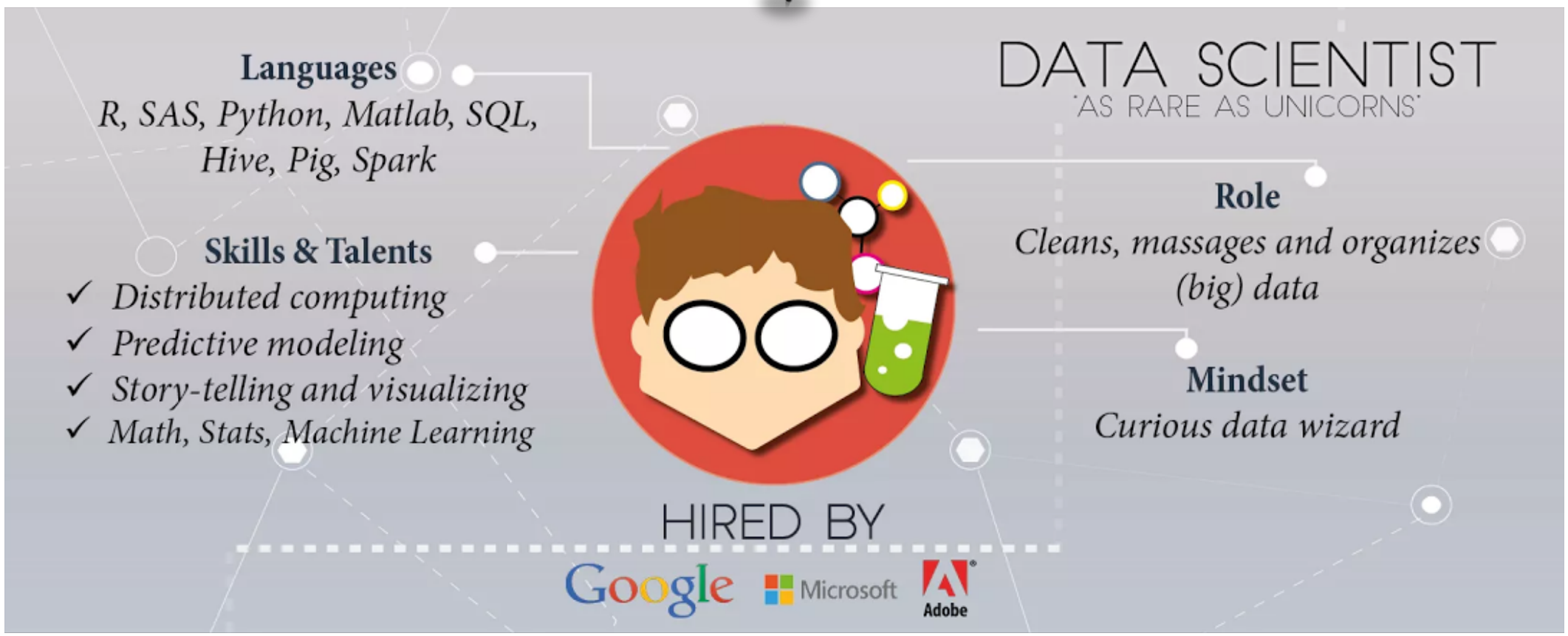
Running companies

Data Science is for all,

small and big, old and new, etc.

All these companies can be better by knowing better their customers, improving by their operational processes and even by creating new business models with data products.

Data Science Jobs



Data Science Jobs

DATA ENGINEER

'SOFTWARE ENGINEERS BY TRADE'

Role

Develops, constructs, tests and maintains architectures (such as databases and large-scale processing systems)

Mindset

All-purpose everyman

HIRED BY

Spotify

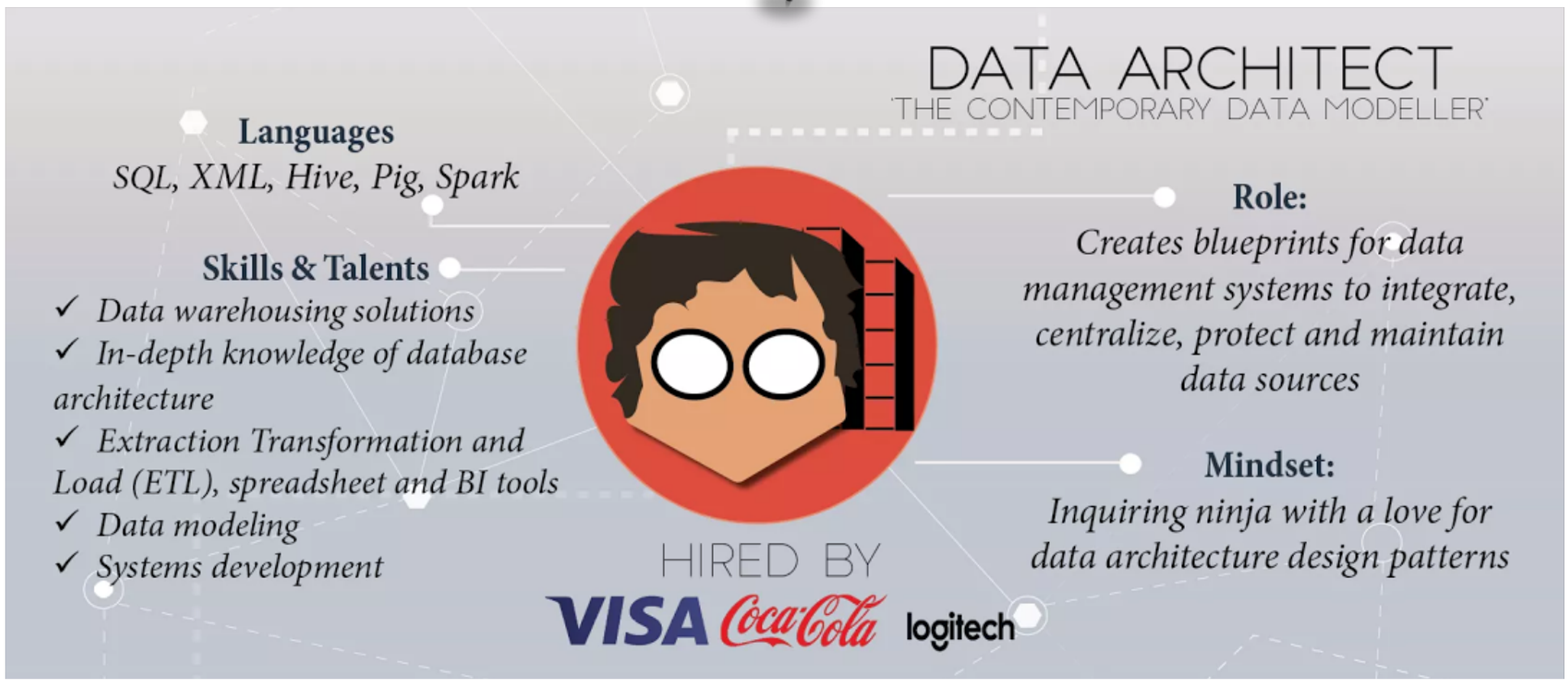
Languages

SQL, Hive, Pig, R, Matlab, SAS, SPSS, Python, Java, Ruby, C++, Perl

Skills & Talents

- ✓ *Database systems (SQL & NO SQL based)*
- ✓ *Data modeling & ETL tools*
- ✓ *Data APIs*
- ✓ *Data warehousing solutions*

Data Science Jobs



Conclusions

- Big Data will be soon a commodity that will be used mainly for data munging and counting at scale.
- The most difficult part of **Big Data** is **getting insight.**
- Data Science is a new job with a bright future.