Pengantar Data Analysis

Tim Penyusun Materi Pengenalan Komputasi

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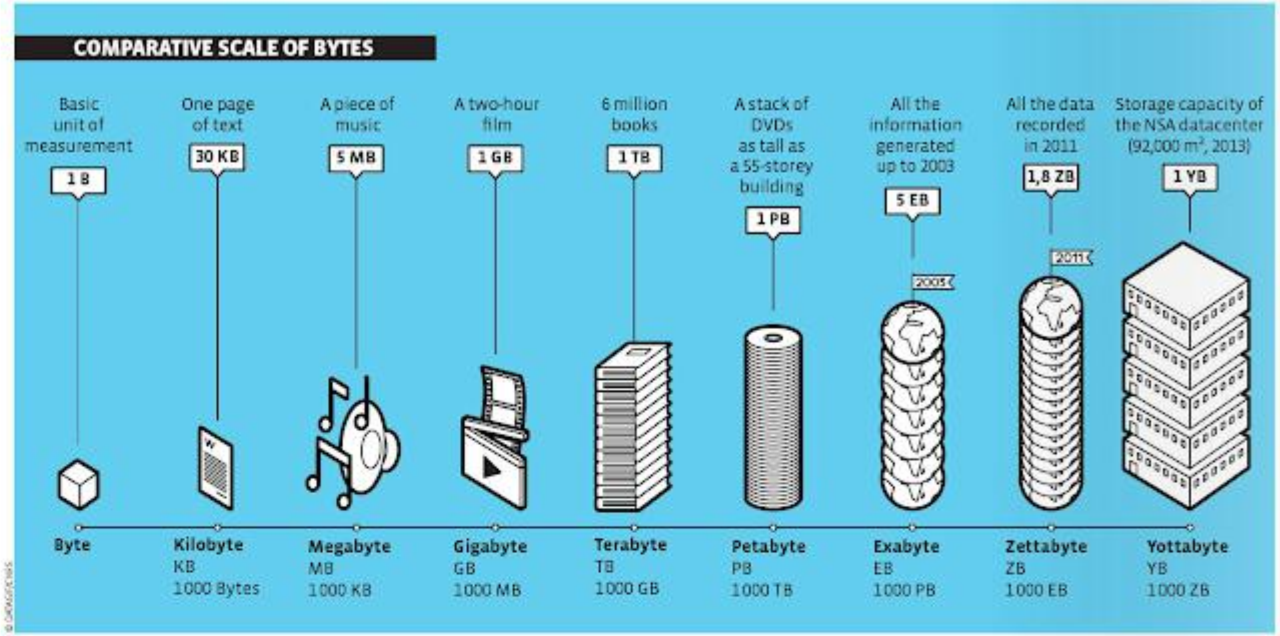
Objektif

- Mahasiswa memahami latar belakang dan pentingnya data analisis
- Mahasiswa dapat membedakan terminologi Data, Informasi, Knowledge, Wisdom (DIKW)
- Mahasiswa mengerti lingkup dan workflow Data Analisis

Motivasi

- Bigdata dan IoT
- Information Overload
- People are getting stupider?

Big Data



- “if all the data used in the world today where written to CD ROMs and the CD ROMs piled up in a single stack, the stack will stretch all the way from the Earth to the Moon and a quarter of the way back again”
  - *Hilbert, M & Lopez, P. (2011), “The world’s technological capacity to store, communicate and compute information”, Science 332, 1 April 2011, 60-65*
- “by 2020 the digital universe will reach 40 zettabytes (ZB), which is 40 trillion GB of data, or 5,200 GB of data for every person on Earth”
  - *IDC (2010), “IDC Digital Uiverse Study, sponsored by EMC”, May 2010*

Big Data, IoT

Google 24 PB/day (2009)

2.5 PB of user data + 15 TB/day (2009)

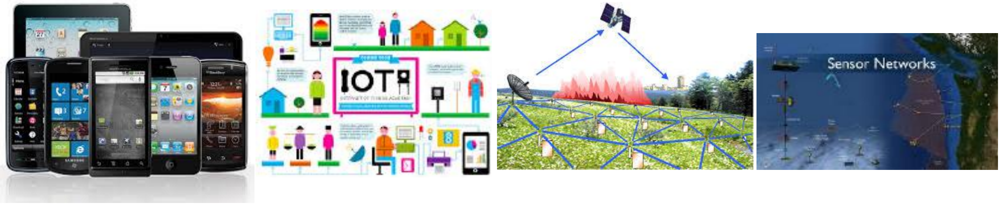
6.5 PB of user data + 50 TB/day (2009)

Web, Social Media & Network

10^{18} bytes/day (2024, est.)

22 PB (2012, the Large Hadron Collider)

Scientific Data, Scientific Instruments

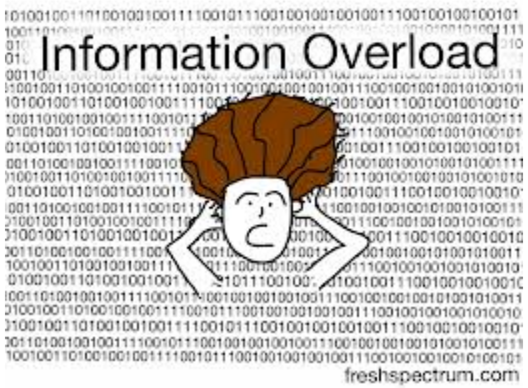


Mobile Devices, IoT, Sensor Technology & Networks

Information Overload

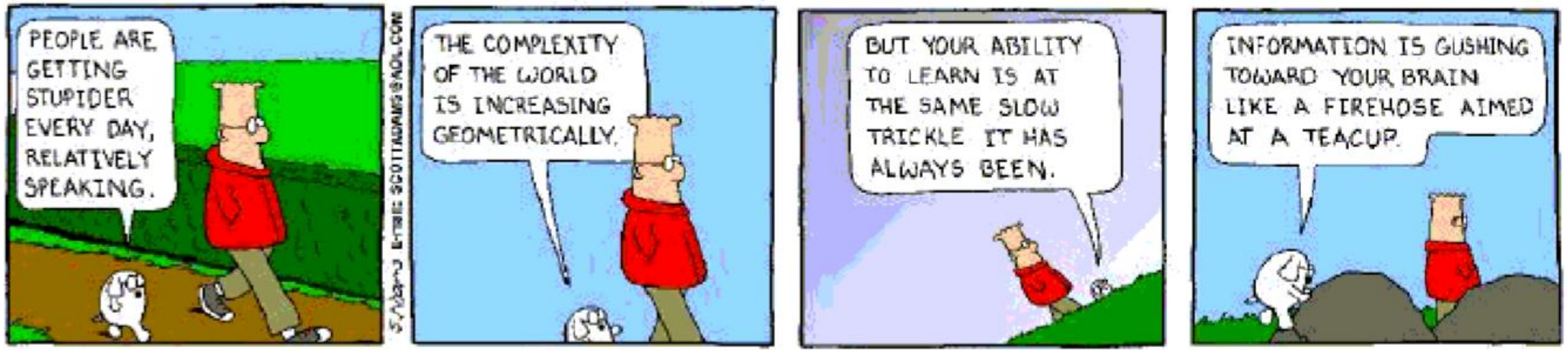
The difficulty in understanding an issue and effectively making decisions when one has too much information about that issue

(Yang et al, 2003)



Information overload occurs when the amount of input to a system exceeds its processing capacity. Decision makers have fairly limited cognitive processing capacity. Consequently, when information overload occurs, it is likely that a reduction in decision quality will occur. (Speier et al., 1999)

People are getting stupider?


PEOPLE ARE GETTING STUPIDER EVERY DAY, RELATIVELY SPEAKING.
S.Adams E-MAIL: SCOTTADAMS@AOL.COM
THE COMPLEXITY OF THE WORLD IS INCREASING GEOMETRICALLY.
BUT YOUR ABILITY TO LEARN IS AT THE SAME SLOW TRICKLE IT HAS ALWAYS BEEN.
INFORMATION IS GUSHING TOWARD YOUR BRAIN LIKE A FIREHOSE AIMED AT A TEACUP.

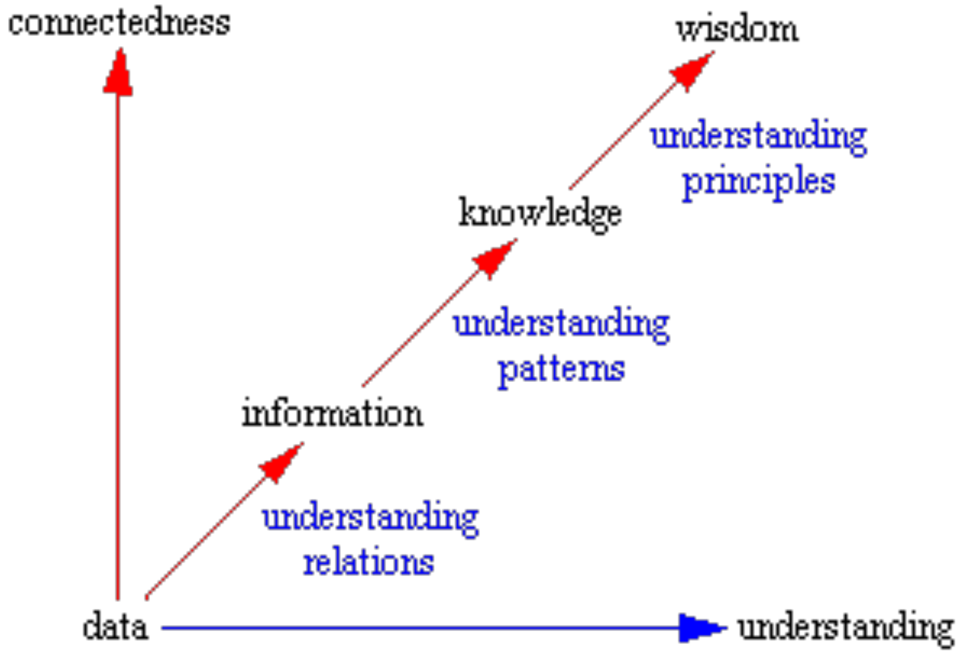
Adopted from: John Stasko http://www.cc.gatech.edu/~stasko/7450/Notes/overview.pdf

Data, Information, Knowledge, and Wisdom (1)

by Gene Bellinger, Durval Castro, Anthony Mills

According to Russell Ackoff, a systems theorist and professor of organizational change, the content of the human mind can be classified into five categories:

- **Data**: symbols
- **Information**: data that are processed to be useful; provides answers to "who", "what", "where", and "when" questions
- **Knowledge**: application of data and information; answers "how" questions
- **Understanding**: appreciation of "why“
- **Wisdom**: evaluated understanding.



Sumber: http://www.systems-thinking.org/dikw/dikw.htm

Data, Information, Knowledge, and Wisdom (2)

by Gene Bellinger, Durval Castro, Anthony Mills

- **Data** represents a fact or statement of event without relation to other things.
  - E.g.: It is raining.
- **Information** embodies the understanding of a relationship of some sort, possibly cause and effect.
  - E.g.: The temperature dropped 15 degrees and then it started raining.
- **Knowledge** represents a pattern that connects and generally provides a high level of predictability as to what is described or what will happen next.
  - E.g.: If the humidity is very high and the temperature drops substantially the atmospheres is often unlikely to be able to hold the moisture so it rains.
- **Wisdom** embodies more of an understanding of fundamental principles embodied within the knowledge that are essentially the basis for the knowledge being what it is. Wisdom is essentially systemic.
  - E.g.: It rains because it rains. And this encompasses an understanding of all the interactions that happen between raining, evaporation, air currents, temperature gradients, changes, and raining.

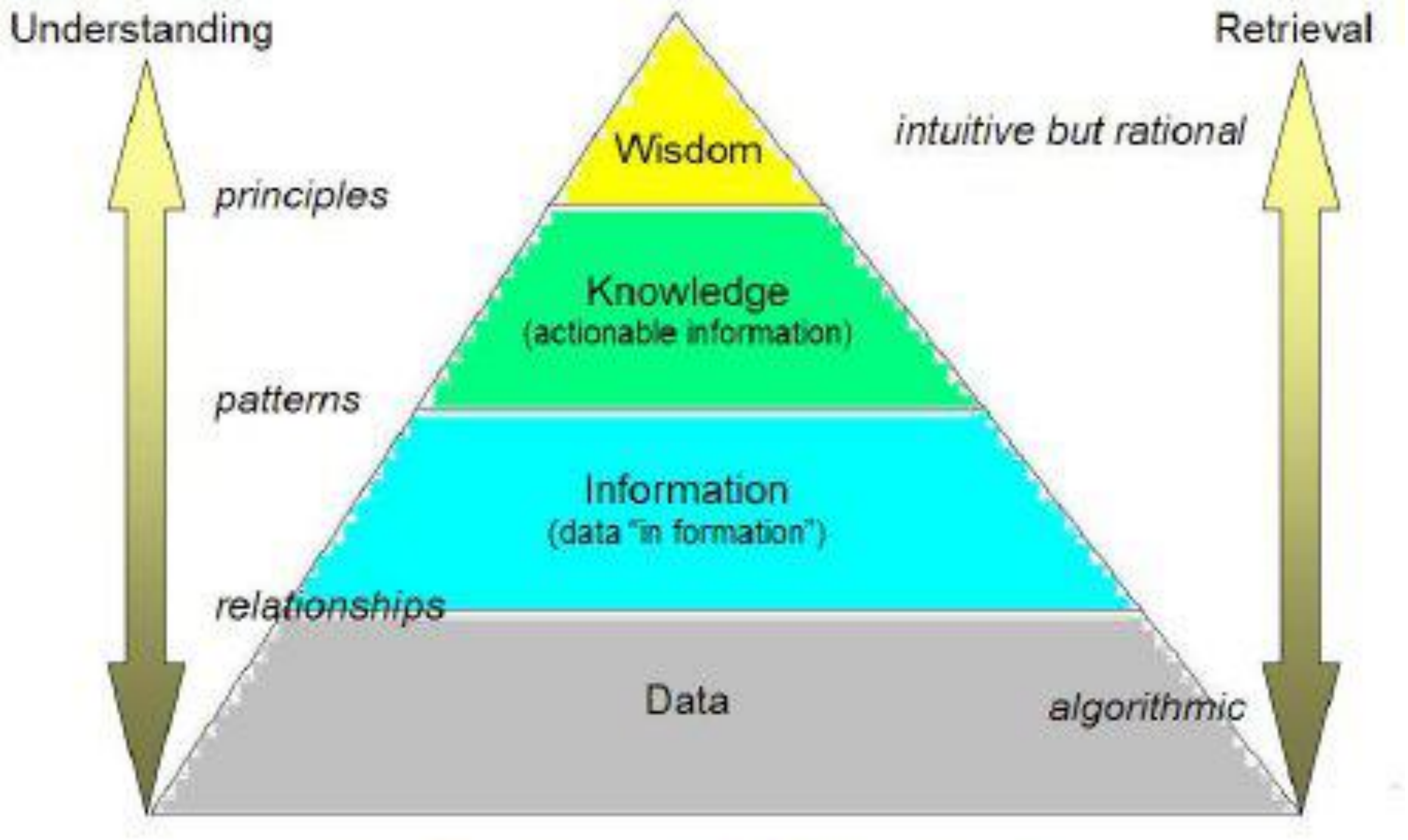
More on DIKW (1)

- **Data**: notice that they are raw and insignificant.
  - Ages of employees: 25; 29; 45; 23; 60; 51; 35 …
  - Names of employees: Ben; Anna: Mark; Kathy; Rose; Jack; Jane …
- **Information:** now we arrange the data to make sense and create information.
  - Ages of Employees: Ben is 25 yrs old; Anna is 29 yrs old; Mark is 45 yrs old; Kathy is 35 yrs old; Rose is 60 yrs old; while Jack is 51 yrs old…
- **Knowledge**:
  - so now we already have the knowledge of the ages of our employees, so now we can connect that with our other knowledge, so we may have wisdom on this situation.
- **Other knowledge**: (for examples sake lets assume that we conducted a survey and found out that:)
  - Young people have still a lot to learn, and are inexperienced, and are available for learning; and 35 yrs old is still young; And that older folks possess a lot of knowledge regarding work processes; and has a lot of experience; and that most of old folks today prefer to retire early; and say we would out that the usual retirement age is 60, yet some employees would retire early at the age of 55.

More on DIKW (2)

- So now we create **Wisdom:**
  - Our employees Ben, Anna, and Kathy are still young and they are prospective leaders of the firm.
  - They might want to earn a degree in a University and lets offer them promotion to encourage them.
  - We know that Rose is retiring this year, so we might as well train someone to replace her in her position. That might be either Ben, Anna or Kathy, or Mark since he has more experience and has more knowledge in our business processes already. And since Jack is 51 yrs old already, we might want to prepare for hist retirement. That will mean that we might loss one or two employees in at least 4 years now.
  - Shall we hire more employees? (further knowledge acquired) yes we might need more employees since our business is growing and we need more manpower.
- Sumber: https://www.quora.com/Can-someone-give-a-simple-example-for-data-information-knowledge-and-wisdom

The DIKW model



Adapted from: Awad & Ghaziri and Bellinger, Castro, & Mills

Sumber: https://www.researchgate.net/publication/221437134_Are_you_searching_for_ways_to_find_information/figures?lo=1

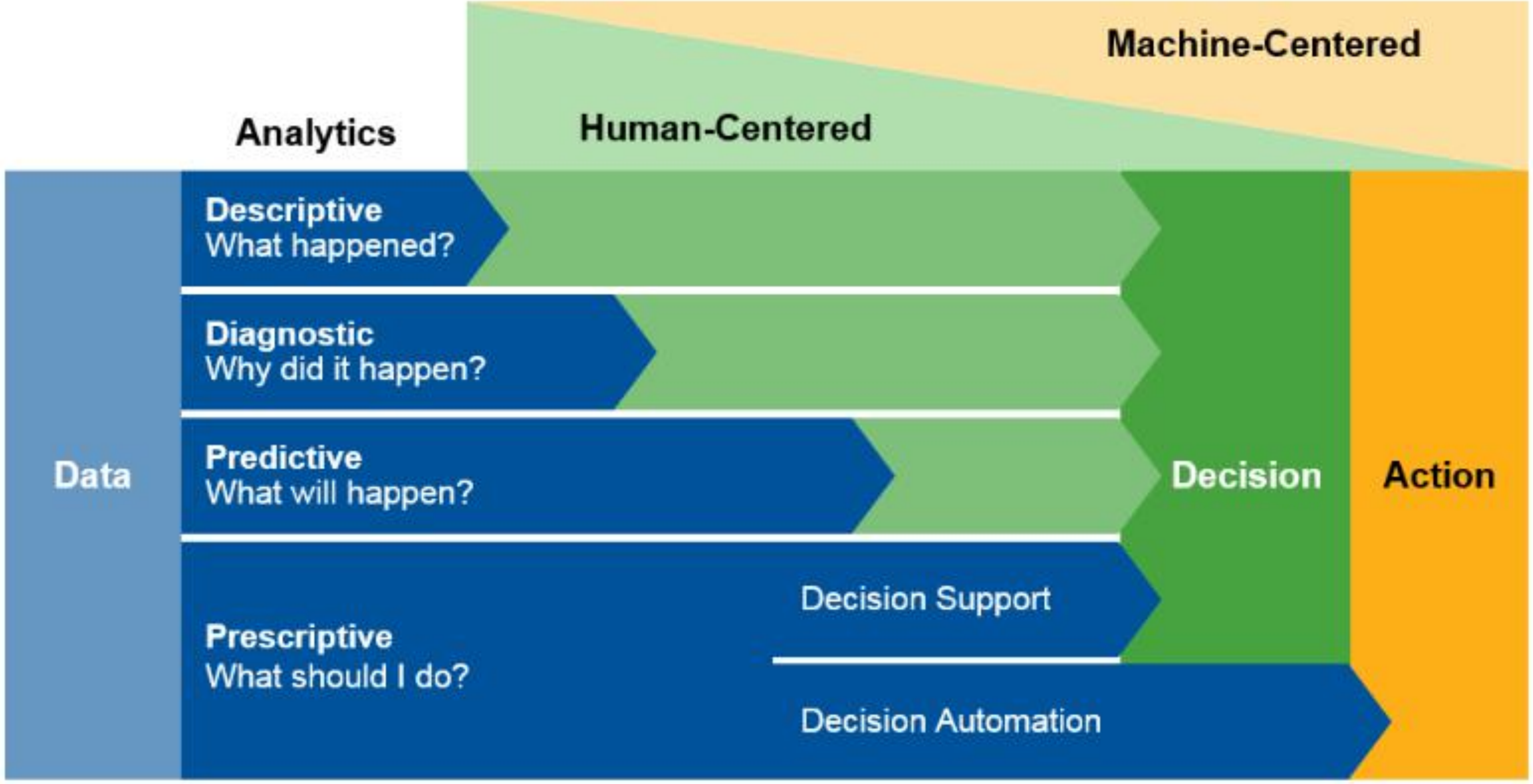
Data Analysis

- how to **break down** and **structure** complex problems and **data sets** to get right to **the heart** of the problems in their business. [1]
- a process of inspecting, cleansing, transforming, and modeling data with the goal of discovering useful information, informing conclusions, and supporting decision-making [2]

I detect ginger, garlic, paprika, and perhaps a hint of fish sauce...

1. Michael Milton, Head First Data Analysis, O'Reilly 2009
2. https://en.wikipedia.org/wiki/Data_analysis

Klasifikasi Data Analytics



Source: Gartner (October 2016)

Sumber:
2017 Planning Guide for Data and Analytics

Descriptive Analytics

- Jenis paling sederhana dari Data Analytics
- Analisis terhadap data history untuk mendapatkan profil umum dalam bentuk summary dari data atau hubungan antar data untuk menjelaskan situasi yang telah terjadi.
- Contoh hasil analisis:
  - Banyaknya friend, mention, followers, page views
  - Banyaknya page views
  - Perbandingan banyaknya mahasiswa antar prodi di ITB
  - Rata-rata nilai mahasiswa peserta PTIB
  - Hubungan antara banyaknya jam belajar dengan prestasi akademik
  - Ada kecenderungan bahwa orang beli **roti tawar** bersamaan dengan **butter/mentega**
  - dll

Predictive Analytics

- Analisis terhadap data history untuk mendapatkan hubungan dan trend yang ada (yang direpresentasikan dalam bentuk model prediksi) dalam rangka untuk memperkirakan apa yang akan terjadi di masa yang akan datang.
- Contoh:
  - Memperkirakan nilai saham atau mata uang tertentu berdasarkan data nilai saham atau mata uang pada periode waktu sebelumnya
  - Memperkirakan apakah seseorang dengan karakteristik tertentu (usia, penghasilan, jumlah tanggungan, frekwensi sakit berat) layak/tidak diberikan kredit bank, berdasarkan data history pengambilan keputusan oleh ahli keuangan.
  - dll

Prescriptive Analytics

- Analisis terhadap data history untuk dapat menghasilkan kesimpulan berupa rekomendasi bagaimana sesuatu harus dilakukan
- Contoh:
  - Menentukan rute terbaik dari satu tempat ke tempat lain, berdasarkan data yang ada
  - Analisis oleh travel agent terhadap berbagai faktor terkait travel (customer, tujuan, waktu, dll) untuk optimasi harga tiket
- Tidak dibahas detail di kuliah ini

Tipe Data

- Categorical-Nominal
  - Nama negara, warna kulit, nama program studi, dll
- Categorical-Ordinal
  - Likert scale (“sangat setuju” s.d. “sangat tidak setuju”)
  - Indeks nilai A, B, C, D, E
- Categorical-Binary
  - Jenis kelamin, status mahasiswa (aktif, tidak aktif), dll
- Quantitative-Discrete
  - Banyaknya anak, banyaknya mahasiswa, banyaknya sks lulus
- Quantitative-Continues
  - Usia, berat badan, tinggi, suhu

Representasi Data berdasar Strukturnya

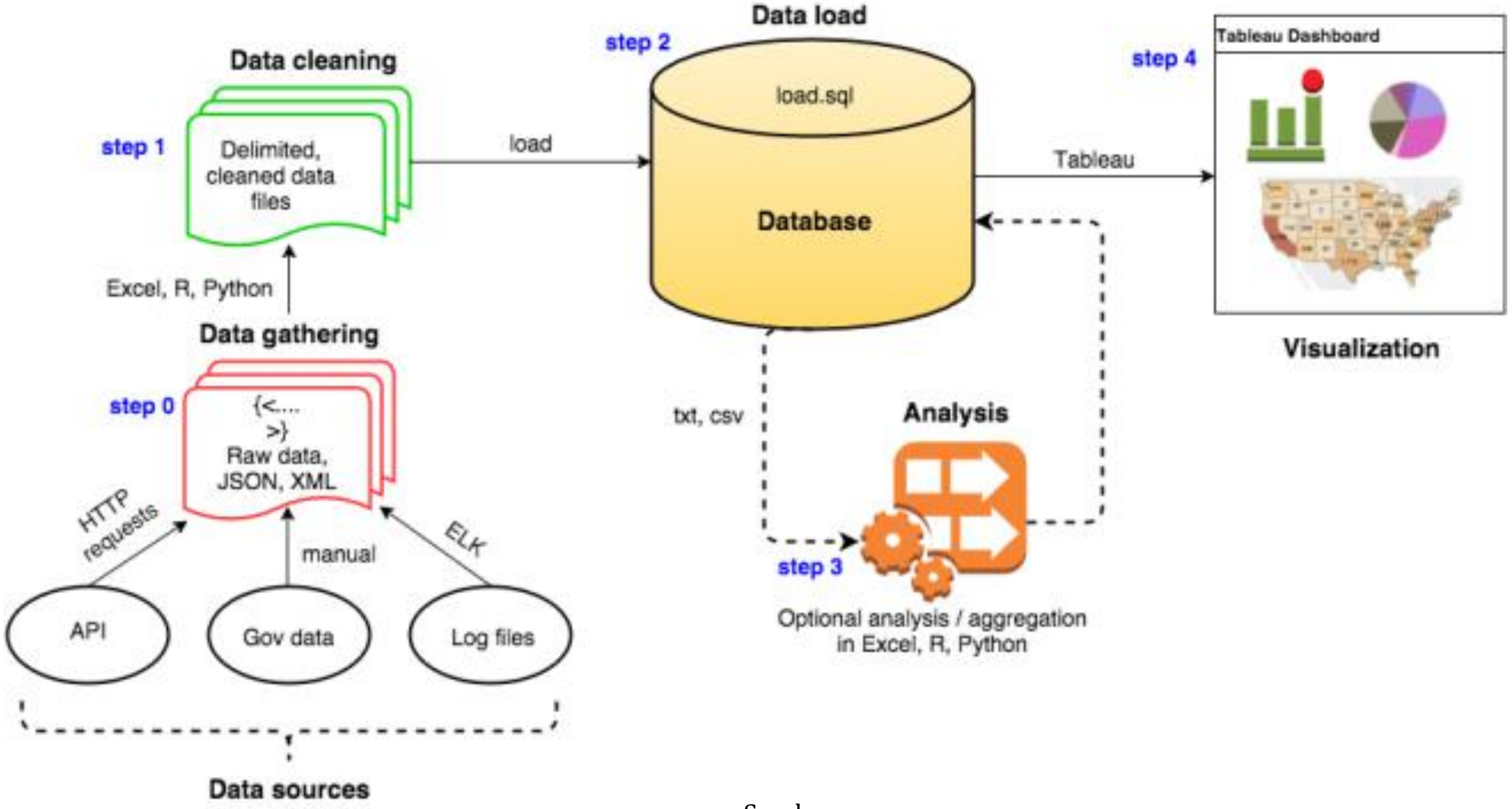
- Structured Data
    - Data dalam bentuk table/relational
    - Contoh: data dalam xls, data tersimpan dalam relational DBMS
- Semi-structured Data
    - Data yang tidak direpresentasikan dalam bentuk table, namun masih memiliki struktur/pengorganisasian yang memudahkan proses/analisis
    - Contoh: data dalam format xls, json, noSQL database
- Unstructured Data
    - Data yang tidak memiliki struktur yang memudahkan proses/analisis
    - Contoh: data teks, data video, data foto

Contoh-contoh kegiatan Data Analysis Descriptive Analytics dan Exploratory DA

- Retrieve Value (Selection)
- Filter
- Compute Derived Value
- Find Extremum
- Sort
- Determine Range
- Characterize Distribution
- Find Anomalies
- Correlation
- Clustering

https://en.wikipedia.org/wiki/Data_analysis

Data Analysis Workflow



Sumber:
https://ketakirk.wordpress.com/2016/04/03/an-end-to-end-data-analysis-workflow/

Data Store

- Adalah sebuah repository untuk secara persisten (bersifat tetap) menyimpan dan mengelola kumpulan data
- Bentuk-bentuk data store:
  - File, semacam csv file, spreadsheet
  - Email
  - Database
  - Distributed Data Store
  - Directory Services
  - dll

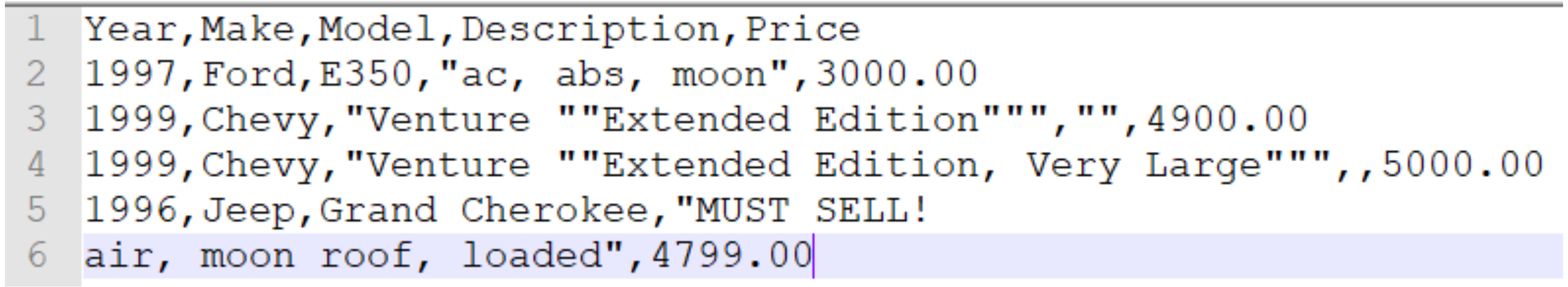
Data Gathering

- Data dapat dikumpulkan dari berbagai sumber:
  - **Transactional data**: data yang berasal dari transaksi sebuah organisasi
    - Tersimpan dalam database organisasi, membutuhkan cara akses khusus
  - **Log files**: data mengenai event yang terjadi dalam suatu sistem, misalnya banyaknya klik atau page-request pada suatu website
  - **API** (*Application Programming Interface*): aplikasi khusus yang disediakan website untuk *men-download* data
    - Format data yang umum: XML, JSON, XLS
  - **Online-datasets**: data tersedia secara online dari berbagai website baik pemerintah maupun swasta, dapat di-download secara manual
    - Format data yang umum: CSV, TXT, PDF, JSON, XML, HTML, XLS

  Data yang tersedia untuk publik dapat bersifat **gratis** (*free*) atau **berbayar** (*for-purchase*)

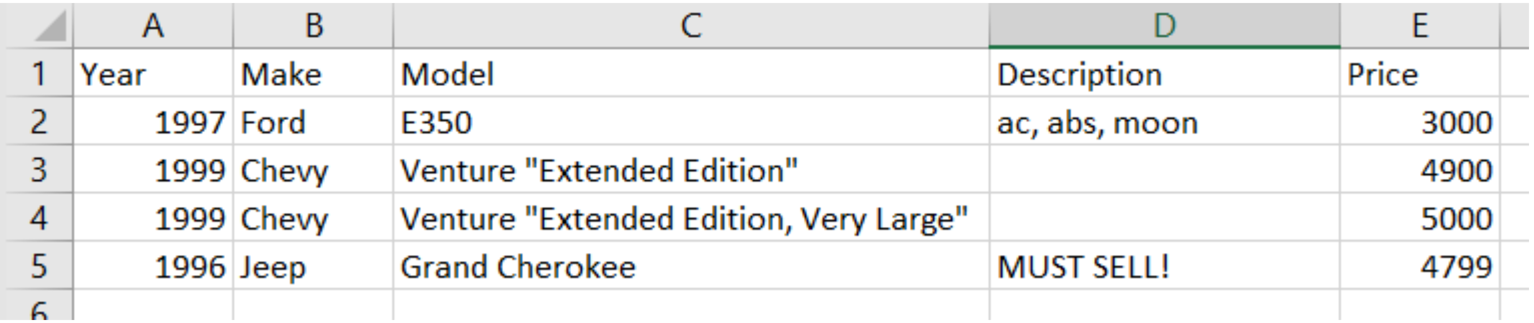
Mengenal berbagai format data (1)

CSV (Comma-Separated Values):
Text file, data dipisahkan comma atau separator lain



```
Year,Make,Model,Description,Price
1997,Ford,E350,"ac, abs, moon",3000.00
1999,Chevy,"Venture ""Extended Edition""","",4900.00
1999,Chevy,"Venture ""Extended Edition, Very Large""",,5000.00
1996,Jeep,Grand Cherokee,"MUST SELL!
air, moon roof, loaded",4799.00
```

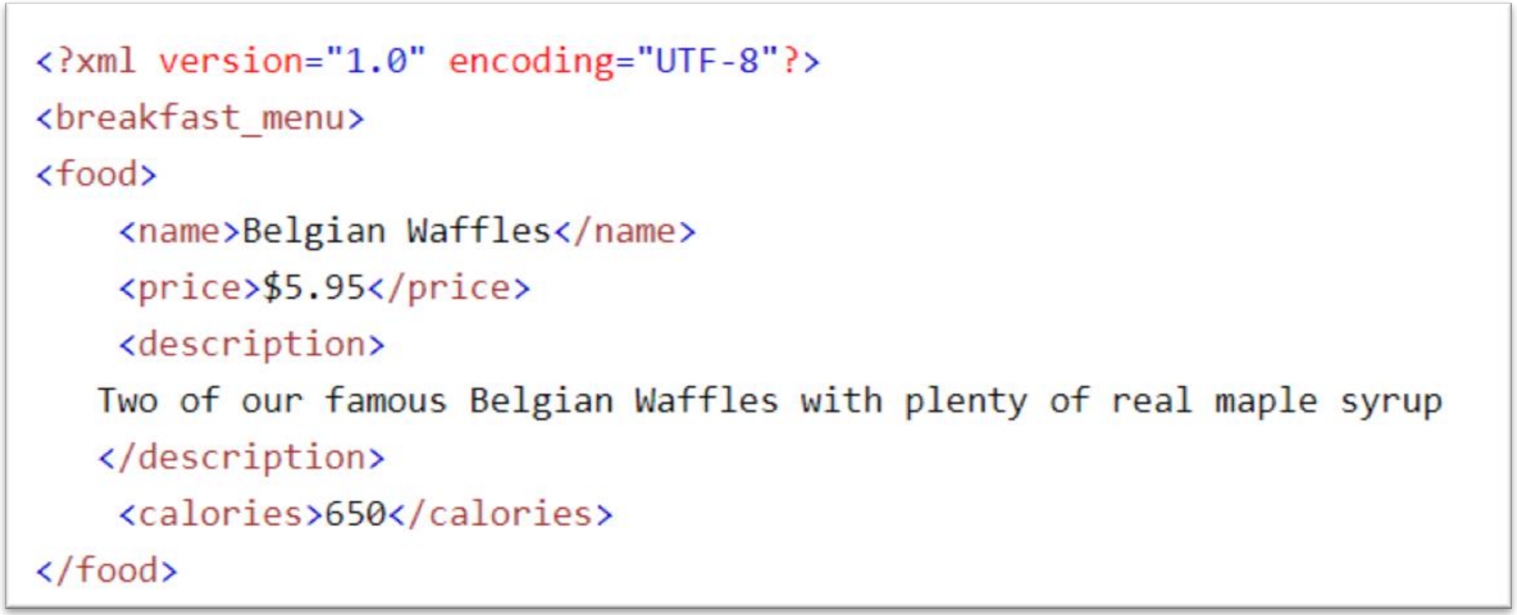
XLS (excel spreadsheet):
Format khusus MS Excel, menyimpan data, chart, macro, dll.



	A	B	C	D	E
1	Year	Make	Model	Description	Price
2	1997	Ford	E350	ac, abs, moon	3000
3	1999	Chevy	Venture "Extended Edition"		4900
4	1999	Chevy	Venture "Extended Edition, Very Large"		5000
5	1996	Jeep	Grand Cherokee	MUST SELL!	4799
6					

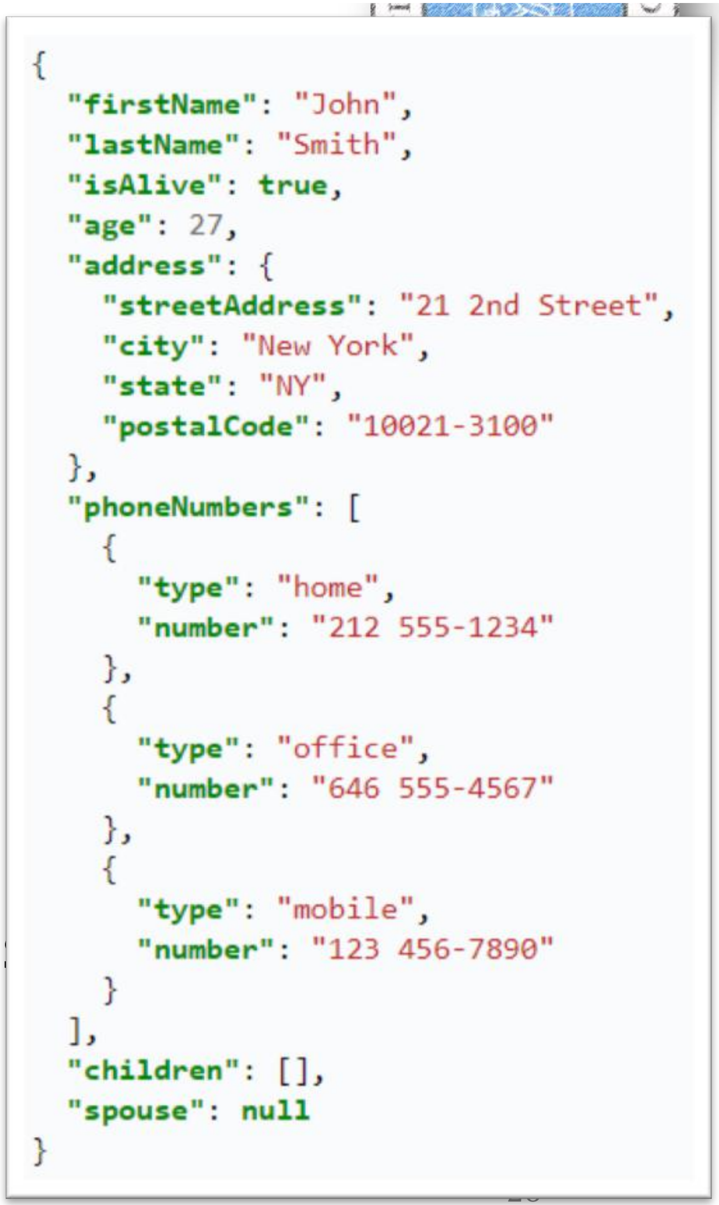
Mengenal berbagai format data (2)

XML (eXtensible Mark-up Language):
Data ditandai dengan menggunakan *tag*.



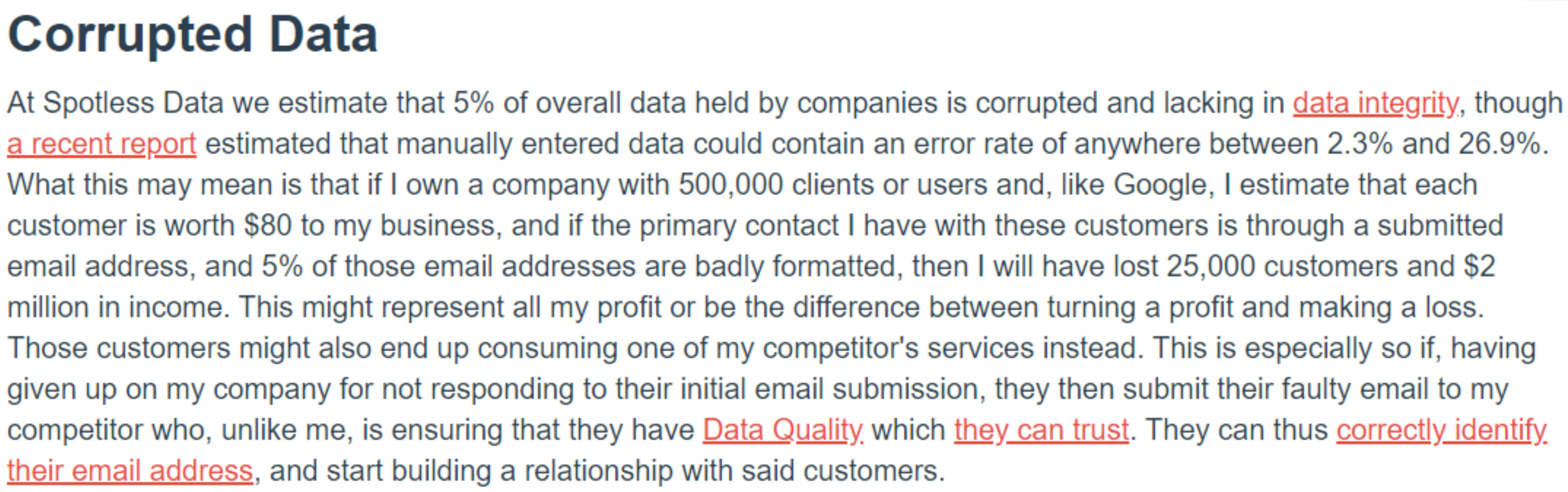
```
<?xml version="1.0" encoding="UTF-8"?>
<breakfast_menu>
<food>
    <name>Belgian Waffles</name>
    <price>$5.95</price>
    <description>
   Two of our famous Belgian Waffles with plenty of real maple syrup
   </description>
    <calories>650</calories>
</food>
```

JSON (JavaScript Object Notation):



```
{
  "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "office",
      "number": "646 555-4567"
    },
    {
      "type": "mobile",
      "number": "123 456-7890"
    }
  ],
  "children": [],
  "spouse": null
}
```

Data Cleansing (1)



Corrupted Data

At Spotless Data we estimate that 5% of overall data held by companies is corrupted and lacking in data integrity, though a recent report estimated that manually entered data could contain an error rate of anywhere between 2.3% and 26.9%. What this may mean is that if I own a company with 500,000 clients or users and, like Google, I estimate that each customer is worth $80 to my business, and if the primary contact I have with these customers is through a submitted email address, and 5% of those email addresses are badly formatted, then I will have lost 25,000 customers and $2 million in income. This might represent all my profit or be the difference between turning a profit and making a loss. Those customers might also end up consuming one of my competitor's services instead. This is especially so if, having given up on my company for not responding to their initial email submission, they then submit their faulty email to my competitor who, unlike me, is ensuring that they have Data Quality which they can trust. They can thus correctly identify their email address, and start building a relationship with said customers.

Sumber: https://web.archive.org/web/20171205042031/https://spotlessdata.com/blog/importance-data-cleaning-user-generated-content

Data Cleansing

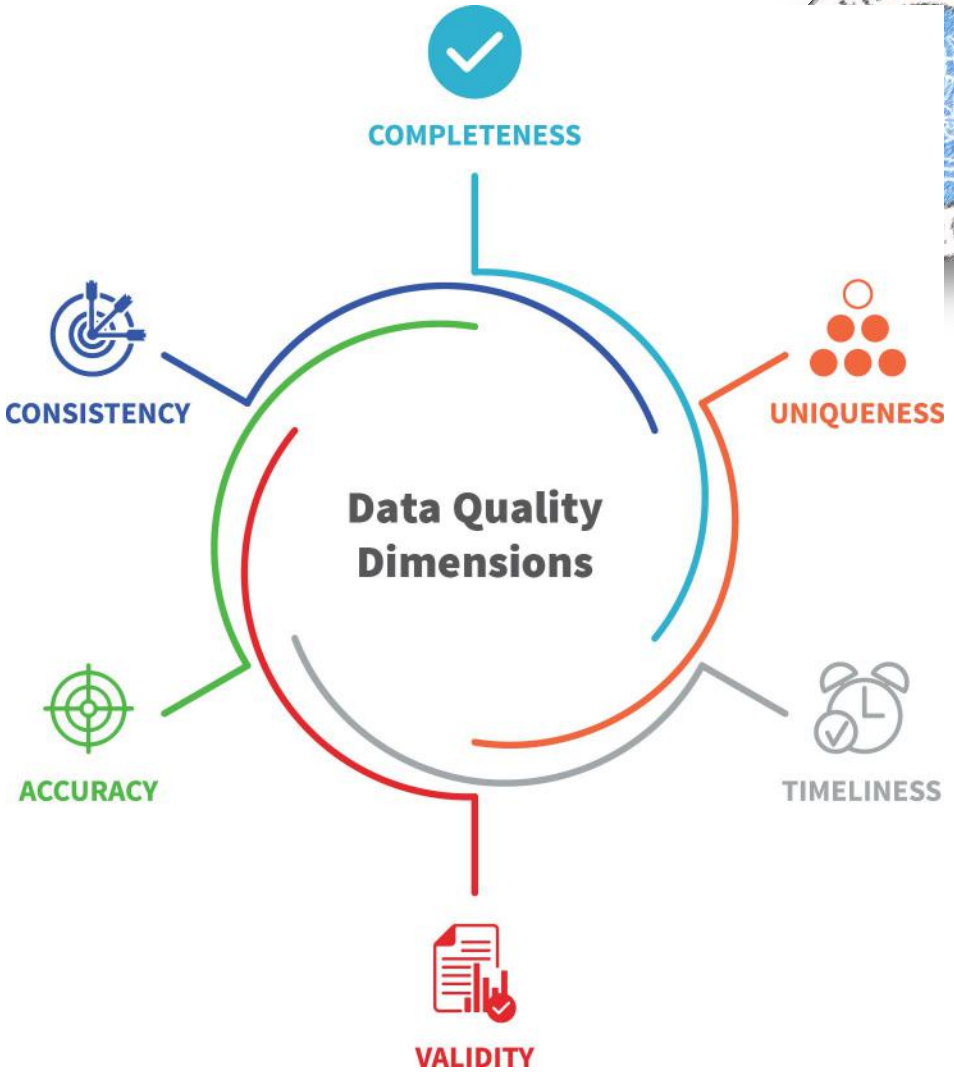
process of detecting and correcting (or removing) corrupt or inaccurate records from a record set, table, or database and refers to identifying incomplete, incorrect, inaccurate or irrelevant parts of the data and then replacing, modifying, or deleting the dirty or coarse data

Wu, S. (2013), "A review on coarse warranty data and analysis“

incorrect or inconsistent data can lead to false conclusions and misdirected investments

Kualitas Data

- Hasil analisis sangat dipengaruhi oleh kualitas data
- Ada banyak dimensi kualitas data



Sumber:
https://www.whitepapers.em360tech.com/wp-content/files_mf/1407250286DAMAUKDQDimensionsWhitePaperR37.pdf
https://www.cdc.gov/ncbddd/hearingloss/documents/dataqualityworksheet.pdf
https://www.rfigroup.com/rfi-group/news/rfi-group-opinion-australia-why-business-leaders-need-own-data-quality

Problems with Data (1)

- Duplicate entries
    - Data yang sama tercatat lebih dari 1 kali
    - Bisa jadi yang dibutuhkan sebenarnya hanya 1 data, tetapi dalam beberapa kasus entry lebih dari 1 kali menjadi penting
- Multiple entries of single entity
    - Data yang berhubungan dengan objek yang sama dientri lebih dari 1 kali, bisa dengan nilai yang berbeda. Contoh: Mahasiswa A, di satu data tercatat tingginya 150cm, di data lain tercatat tingginya 148cm
- Missing entries
    - Data yang seharusnya ada, tidak ditemukan. Data lengkap penting untuk analisis yang menyeluruh.
- Null values
    - Sebagian data terdefinisi nilainya, sebagian lagi *null* (*unknown*/tidak terdefinisi)

Problems with Data (2)

- Huge outliers
  - Outlier: data point that differs significantly from other observations.
  - Outlier mungkin terjadi karena kesalahan pada proses pengambilan data atau eksperimen
  - Outlier dapat menyebabkan masalah pada data analysis → menyebabkan akurasi analysis menjadi rendah
- Out-of-date data
  - Data yang sudah tidak akurat pada saat analysis dilakukan
- Artificial entries
  - Banyak data buatan ditambahkan ke data asli dalam rangka kebutuhan testing (misalnya)
- Irregular Spacings
  - Pengukuran data sering dilakukan dalam jarak/jangka yang regular. Misalnya: lalu lintas suatu website diambil per jam, data temperature wilayah diambil per meter persegi
  - Jarak/jangka yang tidak regular akan menyebabkan masalah pada pemrosesan

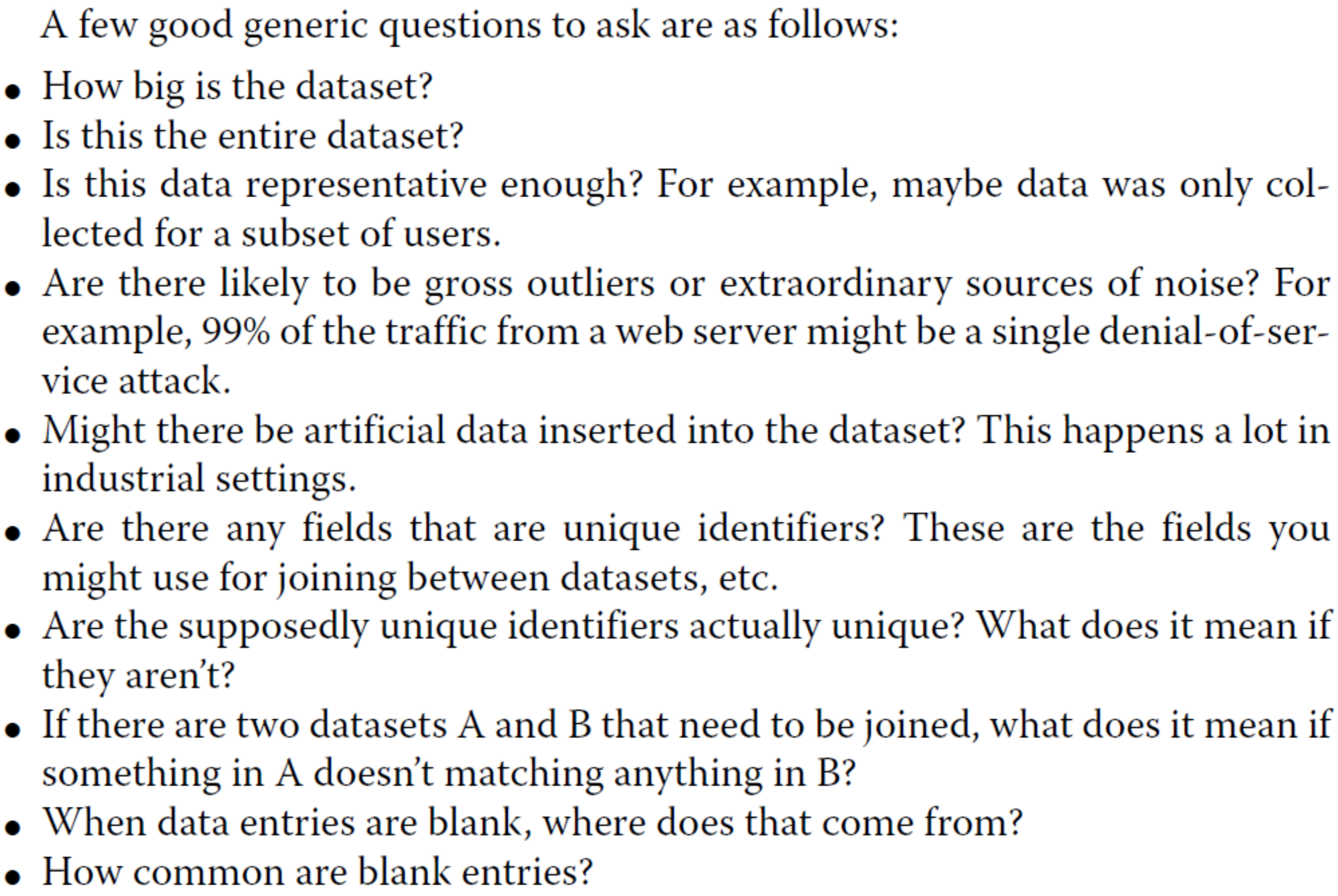
Problems with Data (3)
Formatting Issues

- Data berasal dari tabel-tabel dengan kolom-kolom yang berbeda
  - Kolom yang sama bisa memiliki data yang berbeda. Contoh: Jenis Kelamin bisa bernilai {“laki-laki”, “perempuan”}, bisa {“M”,”F”}, bisa {0,1}
- *Extra whitespace*: jumlah spasi yang berbeda dalam teks untuk data yang sama
  - Contoh: “ABC” dengan “A B C”
- *Irregular capitalization*: penggunaan huruf kapital (dan huruf kecil) yang berbda
  - Contoh: “Bandung” atau “bandung”
- *Inconsistent delimiter*
  - Contoh: pada data CSV, digunakan semicolon atau comma atau tab untuk file data yang sama

Problems with Data (3)
Formatting Issues

- Format data null (unknown) yang berbeda-beda
  - Bisa digunakan: null, N/A, atau hanya sekedar kosong
- *Invalid characters*: karakter-karakter tidak valid yang tidak dapat diproses oleh tools
- Data tanggal yang tidak *compatible*:
  - Perbedaan format: August 1, 2013 atau AUG 1, 2013 atau 2013-8-13
  - Perbedaan format berdasarkan negara: 10/9/2019 dalam format US adalah 9 Oktober 2019, sedangkan dalam format Indonesia adalah 10 September 2019

Data Exploration: Understanding the Data



A few good generic questions to ask are as follows:

- How big is the dataset?
- Is this the entire dataset?
- Is this data representative enough? For example, maybe data was only collected for a subset of users.
- Are there likely to be gross outliers or extraordinary sources of noise? For example, 99% of the traffic from a web server might be a single denial-of-service attack.
- Might there be artificial data inserted into the dataset? This happens a lot in industrial settings.
- Are there any fields that are unique identifiers? These are the fields you might use for joining between datasets, etc.
- Are the supposedly unique identifiers actually unique? What does it mean if they aren't?
- If there are two datasets A and B that need to be joined, what does it mean if something in A doesn't matching anything in B?
- When data entries are blank, where does that come from?
- How common are blank entries?

Sumber:
Cady (2017),
"The Data Science Handbook"

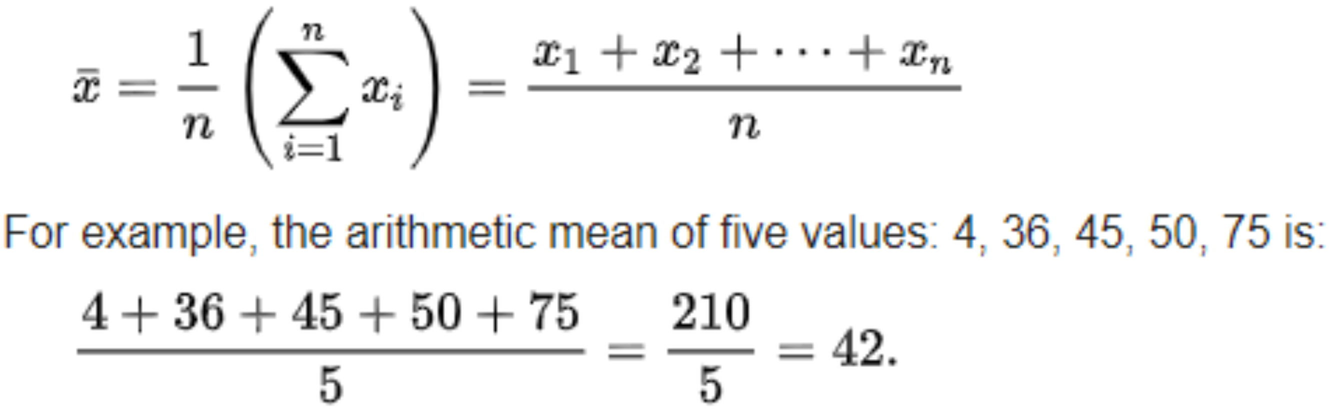
Useful Statistics for Data Exploration

- *Mean* (rata-rata)
- *Extreme values* (nilai ekstrim): Minimum, maximum
- *Standard Deviation* (simpangan baku)
- *Percentiles*
- *Correlation*

Mean (1)

[Population] **mean**:

- measure of the central tendency either of a probability distribution or of the random variable characterized by that distribution



$$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

For example, the arithmetic mean of five values: 4, 36, 45, 50, 75 is:

$$\frac{4 + 36 + 45 + 50 + 75}{5} = \frac{210}{5} = 42.$$

Mean (2)

- When to use **mean**:
  - Is a good measure of the average when a dataset contains values that are relatively evenly spread with no exceptionally high or low values
- When not to use **mean**:
  - If a dataset contains one or two very high or very low values, the mean will be less typical as it will be adversely influenced by these exceptional value(s)
  - generally an inappropriate measure of average for data that are measured on ordinal scales
- **Median** and **mode** are other alternatives of central tendency measure → what are they?

Extreme Values

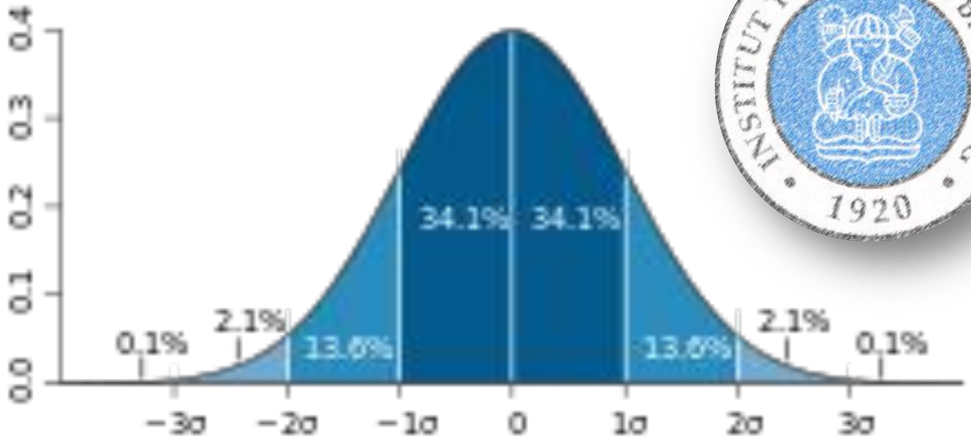
- **Minimum**: the lowest value of data
- **Maximum**: the highest value of data

- Extreme values are used to define the **range** of data [min..max]

Standard Deviation

Standard deviation:

- measure of the amount of variation or dispersion of a set of values
  - A low standard deviation means that most of the numbers are close to the mean
  - A high standard deviation means that the numbers are more spread out



A plot of normal distribution (or bell-shaped curve) where each band has a width of 1 standard deviation

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2},$$

s is sample standard deviation
$\{x_1, x_2, \ldots, x_N\}$ are the observed values of the sample items
$\bar{x}$: is the mean value of these observations
N is the number of observations in the sample

Percentiles

Percentile (or **centile**)

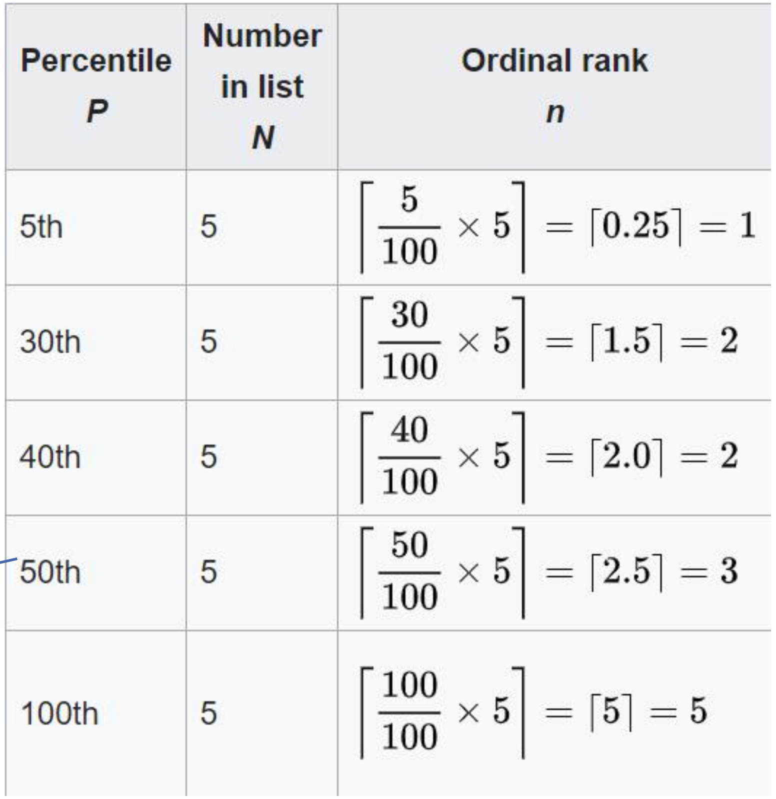
- is a measure used in statistics indicating the value below which a given percentage of observations in a group of observations falls.
  - For example, the 20th percentile is the value (or score) below which 20% of the observations may be found.

The near-est rank method:

$$n = \left\lceil \frac{P}{100} \times N \right\rceil$$

n: ordinal rank
P(-th): percentile (0<=P<=100)
N: number of ordered values

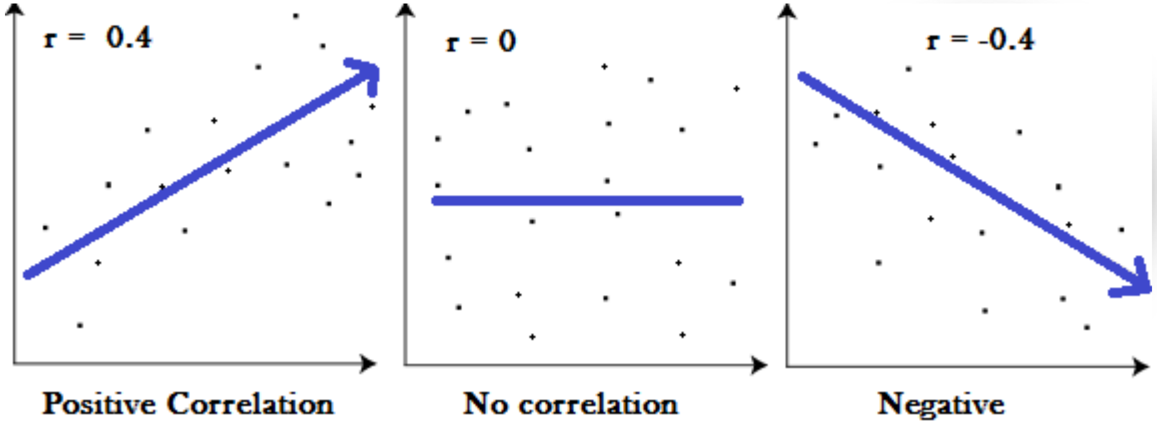
Example: Consider the ordered list {15, 20, 35, 40, 50}, which contains 5 values.



Percentile *P*	Number in list *N*	Ordinal rank *n*
5th	5	$\left\lceil \frac{5}{100} \times 5 \right\rceil = \lceil 0.25 \rceil = 1$
30th	5	$\left\lceil \frac{30}{100} \times 5 \right\rceil = \lceil 1.5 \rceil = 2$
40th	5	$\left\lceil \frac{40}{100} \times 5 \right\rceil = \lceil 2.0 \rceil = 2$
50th	5	$\left\lceil \frac{50}{100} \times 5 \right\rceil = \lceil 2.5 \rceil = 3$
100th	5	$\left\lceil \frac{100}{100} \times 5 \right\rceil = \lceil 5 \rceil = 5$

E.g.: The **50**th percentile of the data is **35** (from the ordered data, it ranks n = **3**)

Correlation



Correlation

- a statistical technique that can show whether and how strongly pairs of variables are related.
  - For example: height and weight are related: taller people tend to be heavier than shorter people
- The main result of a correlation is called the **correlation coefficient** (r): ranges from -1.0 to +1.0
  - If r is **close to 0**, it means there is no relationship between the variables.
  - If r is **positive**, it means that as one variable gets larger the other gets larger.
  - If r is **negative** it means that as one gets larger, the other gets smaller (often called an "inverse" correlation).