

Data Tidying and Cleaning

Preparing Data for Knowledge Extraction



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<https://softuni.bg>

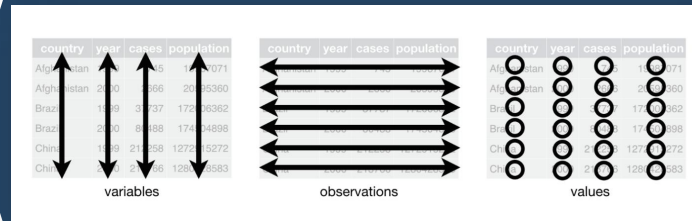
Have a Question?

sli.do

#DataScience

1. Messy and Tidy Data
 - Tidying up Messy Data
2. Operations on Datasets
3. Cleaning Data
 - Validation
 - Transformation
 - Error Correction
 - Features
4. Data Tidying and Cleaning as a Process





Data Tidying

Arranging Data in a Meaningful Manner

- Most important rules when creating (or using) datasets
 - Columns – attributes (features, variables)
 - Rows – observations
 - Cells – values (one observation of one feature)
 - All other data is called **messy data**
- Empirical rule for testing whether a dataset is tidy
 - Adding one more observation should create one new row
 - No new columns
 - No multiple rows
 - No partial rows, no changes to other rows
- pandas allows us to read, tidy up and transform datasets
 - Data modelling requires a tidy and clean dataset in order to work well (garbage in – garbage out)

- What we want

country	year	cases	population
Afghanistan	1999	1815	15467071
Afghanistan	2000	2666	20595360
Brazil	1999	31737	17210362
Brazil	2000	84488	174504898
China	1999	212258	1272015272
China	2000	213566	1280425883

variables

country	year	cases	population
Afghanistan	1999	1815	15467071
Afghanistan	2000	2666	20595360
Brazil	1999	31737	17210362
Brazil	2000	84488	174504898
China	1999	212258	1272015272
China	2000	213566	1280425883

observations

country	year	cases	population
Afghanistan	1999	1815	15467071
Afghanistan	2000	2666	20595360
Brazil	1999	31737	17210362
Brazil	2000	84488	174504898
China	1999	212258	1272015272
China	2000	213566	1280425883

values

- What we get instead

	A	B	C	D	E	F	G	H	I	J	
1	Company I	Website U	First Name	Last Name	Email	Street	Add	City	Postal / Zip	State / Prc	Country
2	Vandelay I	http://van	George	Costanza	g.costance	3661 Hinkl	Binghamtc	13901	New York	USA	
3	Thatherto	http://King	Heather	Hall	heather.h	1683 Jasper	Edmonton	T5J 3N6	Alberta	Canada	
4	Western E	http://ww	Erich	Thomson	eric.t@we	745 Stroof	Atlanta	30305	Georgia	USA	
5	Mammoth	http://tiny	Michael	Blake	michael.bl	4984 Clair	Morgan	76671	Texas	USA	
6	Powell M	http://ww	Harbert	Powell	harbert@f	1125 Cross	Michigan	48607	Detroit	USA	
7	Urban Son	http://ww	Garcia Est	Orosco	garcia@ur	16221 E 4C	Denver	80239	Colorado	USA	
8	Wayne Enl	http://way	Bruce	Wayne	b.wayne@	3881 Mich	Chicago	60631	Illinois	USA	
9	Kramerica	http://ww	Cosmo	Kramer	ckramer@	22 Marion	New York	66059	New York	America	
10	Bluth Com	http://thel	Bluth	George	george@b	36 Southw	Fairfield	60042	New Jerse	USA	
11	Flowers B	http://ww	Elliott	Irene	irene@irer	2197 Tatol	Buffalo Gr	60089	Illinois	USA	
12	Spacely Sp	http://spa	Spacely	Cosmo	cosmo@sj	89 Davidsc	New York	66412	New York	USA	
13	Dunder Mi	http://ww	Dudner	Bob	bob@dunc	25 Spring	C Waterloo	N3E 0R4	Ontario	Canada	
14	Sixty Seco	http://ww	Brown	Darren	darren@si	35 Brentw	San Franci	94210	California	USA	
15	Charles To	http://ww	Angel	Charles	c.angel@t	20 Dora Cr	The Bay	94212	California	USA	
16	Spade and	http://ww	Archer	Christoph	c.a@spade	68 Cambri	Waterloo	N2N 2J8	Ontario	Canada	
17	Atlantic N	http://ww	Thomas	Won	won@atla	94 Walter	Vancouver	K2C 4C3	BC	Canada	
18	Tessier-As	http://ww	Tessier	Marie	marie@te	2 Bourke	C Melbourne	3418		Australia	
19	Southern C	http://ww	Van Houte	Kirk	kirk@allie	67 Gadd A	Springfield	63012	Illinois	USA	
20	Initech	http://ww	Charles	Deborah	d.charles@	35 Quintin	Waterloo	N3E 0R4	Ontario	Canada	
21	McMahon	http://ww	Tate	Charles	tate@man	87 Wright	Palo Alto	94304	California	USA	
22	Widget Inc	http://ww	Wilbert	Gregg	gregg@wic	3094 Boul	Quebec	G1R 1B8	Quebec	Canada	
23	Acme Corp	http://ww	Harris	Mike	mike@acn	59 South	S London	N1 9EW		UK	
24	LexCorp	http://ww	Luthor	Lex	lex@lex.c	29 Fergus	Toronto	N2N 2K2	Ontario	Canada	

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noise,20140423232745,3,3,COMMUNITY_NOISE,48.9 noise,20140423232745,6,6,COMMUNITY_NOISE,48.8 noise,20140423232745,61,61,COMMUNITY_NOISE,45.6 noise,20140423232745,2,2,COMMUNITY_NOISE,37.8
noise,20140423232746,4,4,COMMUNITY_NOISE,48.8 noise,20140423232746,60,60,COMMUNITY_NOISE,50.7 noise,20140423232746,3,3,COMMUNITY_NOISE,49.3 noise,20140423232746,6,6,COMMUNITY_NOISE,46.5
noise,20140423232746,61,61,COMMUNITY_NOISE,44.7 noise,20140423232746,2,2,COMMUNITY_NOISE,34.6 noise,20140423232747,4,4,COMMUNITY_NOISE,49.3 noise,20140423232747,60,60,COMMUNITY_NOISE,50.4
noise,20140423232747,3,3,COMMUNITY_NOISE,48.9 noise,20140423232747,6,6,COMMUNITY_NOISE,48.8 noise,20140423232747,61,61,COMMUNITY_NOISE,45.6 noise,20140423232747,2
```

Tidy and Messy Data

- A very good [paper](#) on tidy data
- Example: several datasets
 - Same information, different ease of use

	country	year	cases	population
1	Afghanistan	1999	745	19987071
2	Afghanistan	2000	2666	20595360
3	Brazil	1999	37737	172006362
4	Brazil	2000	80488	174504898
5	China	1999	212258	1272915272
6	China	2000	213766	1280428583

	country	year	rate
1	Afghanistan	1999	745/19987071
2	Afghanistan	2000	2666/20595360
3	Brazil	1999	37737/172006362
4	Brazil	2000	80488/174504898
5	China	1999	212258/1272915272
6	China	2000	213766/1280428583

Tidy dataset

	country	year	key	value
1	Afghanistan	1999	cases	745
2	Afghanistan	1999	population	19987071
3	Afghanistan	2000	cases	2666
4	Afghanistan	2000	population	20595360
5	Brazil	1999	cases	37737
6	Brazil	1999	population	172006362
7	Brazil	2000	cases	80488
8	Brazil	2000	population	174504898
9	China	1999	cases	212258
10	China	1999	population	1272915272
11	China	2000	cases	213766
12	China	2000	population	1280428583

1. The table header contains values
 - Identify the variables and distribute (unpivot) the values
 - Read the pew.csv dataset
 - Distribution of income by religion
 - Show the first 5 values (use the head() function)
 - Also see the number of variables and observations (shape)
 - This will also ensure that you've read the dataset correctly
 - **Variables:** religion, income, frequency
 - Transform the dataset to make it tidy (docs)

```
pew = pd.read_csv("pew.csv")
pew_tidy = pew.melt(
    id_vars = ["religion"], # Identifier variables (all others are "unpivoted")
    var_name = "income", # Variable
    value_name = "frequency" # Value
)
```


2. Multiple variables stored in one column

- Identify and split the variables into separate columns
- Read the tb.csv dataset
 - Tuberculosis cases
 - m04, m514, m1524, etc. contain two variables (gender and age)
 - male, 0-4 years old; male, 5-14 years old, etc.
 - There's also a problem with missing values (NaN)
- Tidying process
 - First, melt all columns (they are values and should not be)
 - Next, split the column names and extract the gender and age information
 - Add the new info to the dataset
 - Remove all missing values

Messy to Tidy Data

```
def process_age_group(age_group):
    ages = {"04": "0-4", "65": "65+", "u": "unknown"}
    if age_group in ages:
        return ages[age_group]
    else:
        # Put a dash before the last two digits
        return f"{age_group[:-2]}-{age_group[-2:]}"

tb = tb.melt(
    id_vars = ["iso2", "year"], var_name = "sex_and_age", value_name = "cases")

tb["sex"] = tb.sex_and_age.str.get(0)
tb["age_group"] = tb.sex_and_age.str.slice(1)
tb = tb.drop(columns = "sex_and_age")

tb.age_group = tb.age_group.apply(process_age_group)

# Tidy up the column and row order
tb = tb[["iso2", "year", "sex", "age_group", "cases"]]
tb = tb.sort_values(["iso2", "year"])
```

3. Variables are stored in both rows and columns
 - Identify and split the variables
 - Read the weather.csv dataset
 - Daily weather records in Mexico in 2010
 - d1, d2, etc. are the days of a month; tmin and tmax should be columns
 - Make a new column with the date: [date, tmin, tmax]
 - Tidying process
 - Melt all days
 - Create days based on date, month and year
 - Pivot the tmin and tmax columns

Messy to Tidy Data

```
weather_data = weather_data.melt(  
    id_vars = ["id", "year", "month", "element"], var_name = "day")  
weather_data.day = weather_data.day.str.slice(1).astype(int)  
  
# Remove missing / invalid days (e.g., 31st April) and dates with no records  
weather_data = weather_data.dropna()  
weather_data["date"] = pd.to_datetime(weather_data[["year", "month", "day"]])  
weather_data = weather_data.drop(columns = ["year", "month", "day"])  
  
# Pivot the elements back to their own columns  
weather_data = weather_data.pivot_table(  
    index = ["id", "date"], columns = "element", values = "value")  
  
# Pivoting returns a multi-indexed element, go back to a flat DataFrame  
weather_data = weather_data.reset_index()  
weather_data.columns.name = ""  
weather_data = weather_data[["id", "date", "tmin", "tmax"]]
```

4. One type in multiple tables

- Merge the tables into one
 - Read all tables, add the new columns
 - Often the filename should be in its own column (if it's important)
 - Melt and tidy if necessary

5. Multiple types in one table

- Split into more tables
 - If necessary, introduce relations (similar to a relational database)
- Each table should be responsible for one type of measurement
- * Read the billboard.csv dataset and apply those transformations



Operations on Datasets

Basic Tools to Get Started Working with Messy Data

- Selecting only some rows (aka **selection**)
- First / last n records (observations)

```
weather_data.head(10)  
weather_data.tail() # 5 by default
```

- Random n records

```
weather_data.sample(n = 10)  
weather_data.sample() # 1 random record by default
```

- Smallest / largest n records in each column

```
weather_data.nsmallest(3, "tmax")  
weather_data.nlargest(3, "tmax")
```

- Subsetting by a Boolean expression (predicate)
 - Returns only rows where the expression returns True

```
weather_data[weather_data.tmax > 30]
```


- Selecting only some columns (aka **projection**)

- Single column (returns a Series object)

```
weather_data["tmax"]  
weather_data.tmax # Possible in most cases
```

- More than one column (returns a DataFrame object)

```
weather_data[["tmin", "tmax"]]
```

- Combining filters

```
weather_data[weather_data.date > "2010-08-01"][["date", "tmax"]]  
weather_data.loc[weather_data.date > "2010-08-01", ["date", "tmax"]]
```

- A note on Boolean expressions

- and, or, not are &, |, ~
- **Always** put parentheses around the individual expressions

```
weather_data[  
    (weather_data.date > "2010-08-01") & (weather_data.date < "2010-09-01")]
```

- These methods work by columns
 - If multiple columns are passed, they are applied to each column individually

```
print("Count:", weather_data.tmin.count()) # number of non-null values
print("Min:", weather_data.tmin.min())
print("Max:", weather_data.tmin.max())
print("Mean:", weather_data.tmin.mean())
print("Median:", weather_data.tmin.median())
print("Standard deviation:", weather_data.tmin.std())
```

- Grouping
 - Splits the data into several groups based on the values of a column
 - We have to apply a method after grouping
 - Or iterate over the groups (using a for-loop)
 - Example: Average number of people for each income group

```
pew_tidy.groupby("income").mean()
```



Data Cleaning

Cleaning Data

You've Got the Data... Now What?

- No common way of doing this
- We need to rely on intuition and some common patterns
 - Tidy up the dataset
 - You must know the dataset documentation first
 - Treat nulls / NaNs: either remove them or replace them
 - Replacing values might be **dangerous**
 - If done properly, it will affect the data in a positive way
 - Identify and fix errors (also **dangerous**)
 - Melt and pivot datasets
 - Merge (join) and separate datasets
 - Subset variables and / or observations
 - Summarize and group variables
 - *Pandas Cheat Sheet*

Example: Weather Data

- Since there's no common way of cleaning, we'll explore and clean a dataset, showing steps and examples as we go
- Dataset (weather data, courtesy of [synesthesiam@github](#))
- Read the dataset (you don't need to download it)
 - See how many variables and observations are there
 - Display the first and last few rows to get a sense of the data
 - Check the data types (to see if something's wrong with the reading)
 - E.g., numbers recognized as strings
 - See a subset of the columns
 - Summarize (describe) the dataset

Example: Weather Data

- The column names don't look good
 - Make them "pythonic" (lowercase_with_underscores)
 - This will make selecting them easier (weather.mean_temp)
- ```
weather.columns = ["date", "max_temp", "mean_temp", "min_temp", "max_dew",
 "mean_dew", "min_dew", "max_humidity", "mean_humidity",
 "min_humidity", "max_pressure", "mean_pressure",
 "min_pressure", "max_visibility", "mean_visibility",
 "min_visibility", "max_wind", "mean_wind", "max_gusts",
 "precipitation", "cloud_cover", "events", "wind_dir"]
```
- What are the ranges of data?
    - E. g. temperature, pressure, humidity
    - Use the min() and max() methods
  - \* Try to explore the data a bit
    - Plot a few histograms and / or boxplots to see the distributions

# Example: Weather Data

- Convert the dates to a datetime object

- To make performing time-dependent analysis easier

```
weather.date = pd.to_datetime(weather.date)
```

- If needed, use `apply()` to perform a function on every row

```
from datetime import datetime
def string_to_date(date_string):
 return datetime.strptime(date_string, "%Y-%m-%d")
```

```
weather.date = weather.date.apply(string_to_date)
```

- It's even better to use dates as indices (when we need to subset date ranges or perform other time-dependent tasks)

```
weather = weather.set_index("date") # or use inplace = True
```

```
print(weather.loc[pd.to_datetime("2012-08-19")])
or weather.loc["2012-08-19"], or any other formatting
```

- Also see why precipitation is not a float and edit it



# Example: Weather Data

- Remove or replace missing values
  - In this case, replacing is better because removing takes away an entire row

```
weather_with_events = weather.dropna(subset = ["events"])
weather.events = weather.events.fillna("") # Better
```

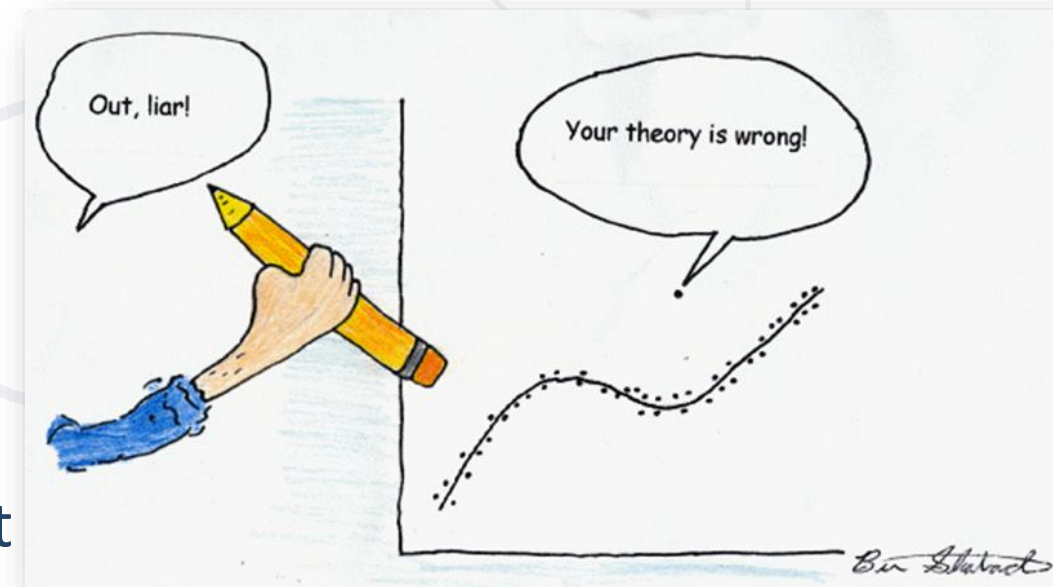
- Try to see how variables interact – group the data
  - E.g., by cloud cover and events
  - Print the number of days when each combination of {cover, events} occurred

```
for (cover, events), group_data in weather.groupby(["cloud_cover", "events"]):
 print(f"Cover: {cover}, Events: {events}, Count: {len(group_data)}")
Or: weather.groupby(["cloud_cover", "events"]).size()
```

- Plot data
  - Next time

- If needed, perform transformations
  - Math operations: log, square root, addition, multiplication, etc.
    - Be careful as you'll get results in different dimensions
  - Normalizing scores (such as using Z-scores) is recommended in most cases
    - It's much better for ML algorithms to have data of similar scales
    - You can do that manually or use a library (such as [\*sklearn.preprocessing\*](#))
  - By convention, calculated columns are added to the dataset
- **Describe all operations as you're doing them**
  - Describe what you're doing and why
    - Useful to check your work later (or allow others to do that)
  - If needed, save the resulting dataset into a file
    - Supply your data transformation log with it
    - Provide a dataset description

- **Outliers** – values which are far from their expected range
  - Or having a very low probability of happening (assuming a model)
- Many possible cases
  - Wrong data entry (e.g. an adult weighing 5kg might be 50kg or something else)
  - Wrong assumptions (the data is correct, our view isn't)
- What to do?
  - Inspect the data point
  - Try to figure out what happened
    - If needed, remove the row or try to replace the value
  - Try a transformation
  - If possible, perform analysis with and without the outlier(s) and compare your results



- The quality of our results depends strongly on the features we use
  - "Garbage in – garbage out"
- **Dimensionality reduction**
  - Reducing the number of variables (features)
  - We can do this manually or use algorithms
  - **Feature selection**
    - Selecting only columns that are useful
  - **Feature extraction**
    - Transforming non-structured to structured data
      - Examples: images, audio, text
    - Getting meaningful features
- **Feature engineering**
  - Using our knowledge of the data to create meaningful features
    - Involves a lot of brainstorming and testing

# Next Steps (Optional)

- Have a look at scikit-learn's "Dataset Transformations" module
  - It describes the most common operations
    - Data cleaning
    - Dimensionality reduction
    - Feature extraction
- There are many algorithms based on
  - Data types (e.g., text or numerical data, labelled vs. not labelled)
  - Model types (how we want to present our data, e.g., linear model)
  - Algorithm types (e.g., finding similar news articles, recommending movies to users, classifying, etc.)
- No "hard and fast rule", use your intuition
  - Knowing more tools / models / algorithms -> better performance

# Summary

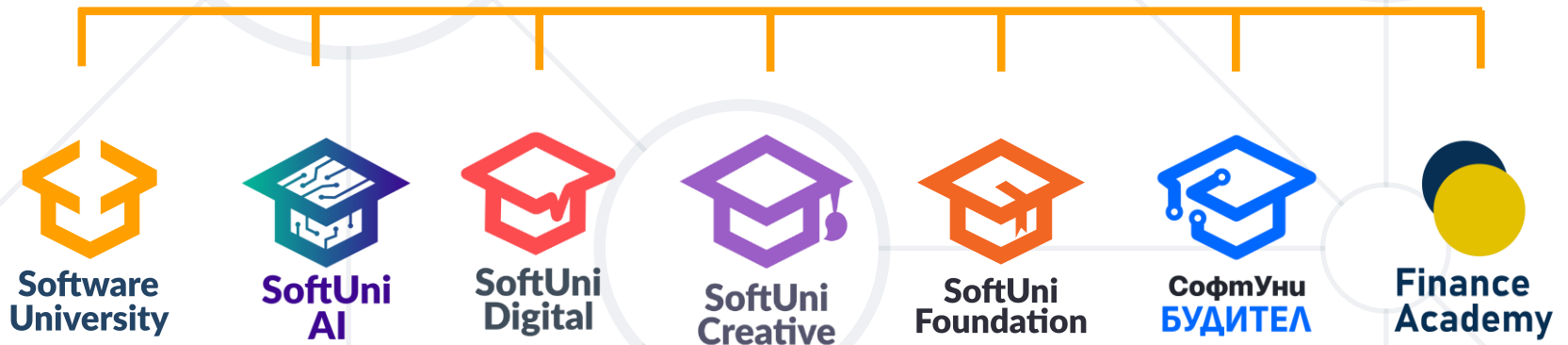
- Messy and Tidy Data
  - Tidying up Messy Data
- Operations on Datasets
- Cleaning Data
  - Validation
  - Transformation
  - Error Correction
  - Features
- Data Tidying and Cleaning as a Process



# Questions?



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