INFO 1998: Introduction to Machine Learning

Download lecture2data.csv and demo from the website – make sure they are in the same directory!

Lecture 2: Data Manipulation

INFO 1998: Introduction to Machine Learning

CDS Education

Logistics

- CDS Info Session right after this!

Ask yourself:

- Are you enrolled?
- Can you access the Ed Discussion?
- Can you access the course website?
- Can you access CSMx?
- Can you access the first assignment?
    - **Would you want the assignment to be ungraded?**
        - **Would not need to be submitted, but we expect you to be familiar with it.**
- A2 released! **Due Wednesday, October 1st at 11:59pm**

ATTENDANCE

Agenda

1. Define Good Question + Get Raw Data
2. Data Manipulation Techniques
3. Data Imputation
4. Other Techniques
5. Demo + Summary

Define Good Question + Get Raw Data

Creating A Good Question

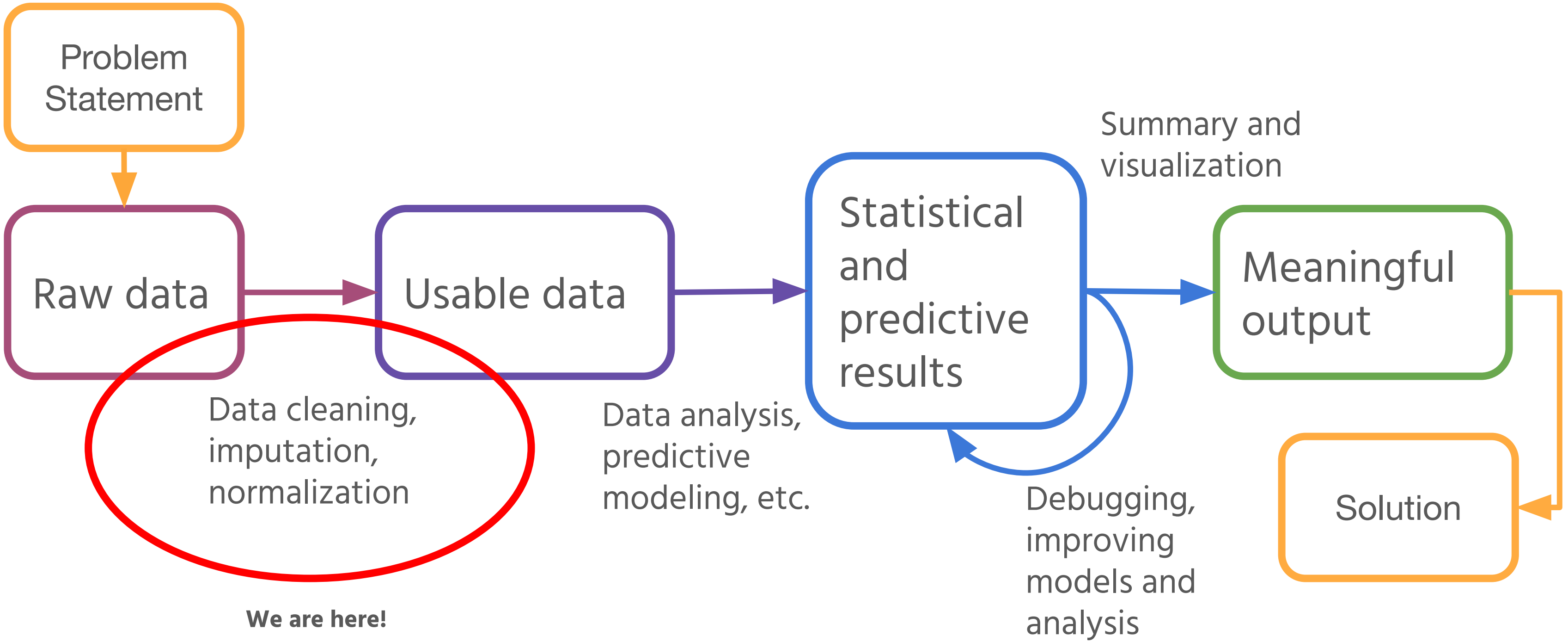
Good Examples:

- What work and lifestyle conditions greatly impact mental health, and in what way?
- Based on this data, what factors can be used to predict a candidate's success within a Canadian election?
- What features best predict the amount of solar radiation the Earth gets based on data collected by NASA?

Poor Examples:

- What can the data tell me about mental health?
- Is there a relationship between the data and a candidate's success in a Canadian election?
- Can we predict amount of solar radiation the earth gets?

The Data Pipeline



https://towardsdatascience.com/5-steps-of-a-data-science-project-lifecycle-26c50372b492

Acquiring data

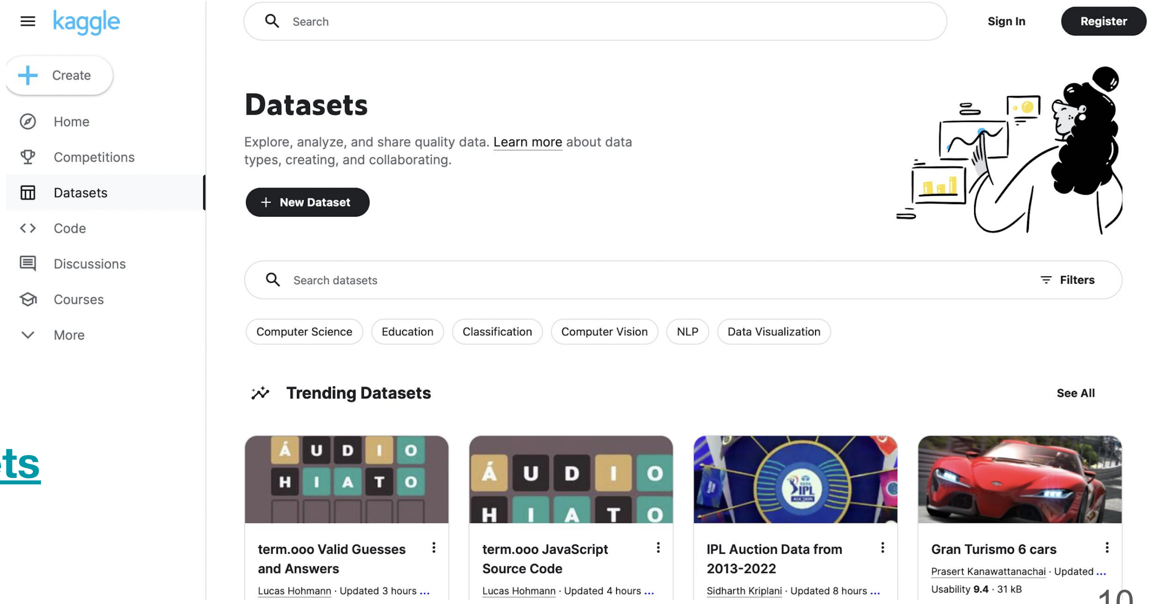
- **Option 1:** Web scraping directly from web with tools like [BeautifulSoup]
- **Option 2:** Querying from databases
- **Option 3:** Downloading data directly (ex. from Kaggle/Inter-governmental organizations/Govt./Corporate websites)

…and more!

Finding a Relevant Dataset

Questions to Ask Yourself…

- Does the data measure what you care about?
- Is your data connected/related?
- Do you have a lot of data?



https://www.kaggle.com/datasets

How does input data usually look?

```
Timestamp,Class Year:,Major:,"On a scale 1 to 5 (1=unfamiliar, 5=proficient) , how well do you know Python?",How did you hear about this class?,"We will hold some optional workshops to dive deeper into industry applications of advanced analytics, and any other topics that might be of interest to you (eg. Data Scraping). What are some workshops you would like to attend? Anything goes.",What is a data problem that interests you the most?
2/9/20 0:26,2020,MBA,1,Referral by Friend,Tensorflow,A/B testing and setting up experiments
2/10/20 16:33,2023,Computer Science,1,In-class advertisement,"Website Analytics, Sentiment Analysis, Cleaning Data",How can we design efficient metrics to gauge performance of any type of data?
2/11/20 8:26,2022,MechE,1,In-class advertisement,,I would like to know more about how computational methods are used in engineering or physics researches.
2/11/20 22:43,2023,ILR,1,Referral by Friend,,The ethics behind data sharing and privacy laws online
2/12/20 17:41,2023,Food Science,1,Referral by Friend,"artificial intelligence
human behavior
```

	Timestamp	Class Year:	Major:	On a scale 1 to 5 (1=unfamiliar, 5=proficient) , how well do you know Python?	How did you hear about this class?	We will hold some optional workshops to dive deeper into industry applications of advanced analytics, and any other topics that might be of interest to you (eg. Data Scraping). What are some workshops you would like to attend? Anything goes.	What is a data problem that interests you the most?
0	2/9/20 0:26	2020	MBA	1	Referral by Friend	Tensorflow	A/B testing and setting up experiments
1	2/10/20 16:33	2023	Computer Science	1	In-class advertisement	Website Analytics, Sentiment Analysis, Cleanin...	How can we design efficient metrics to gauge p...
2	2/11/20 8:26	2022	MechE	1	In-class advertisement	NaN	I would like to know more about how computatio...
3	2/11/20 22:43	2023	ILR	1	Referral by Friend	NaN	The ethics behind data sharing and privacy law...
4	2/12/20 17:41	2023	Food Science	1	Referral by Friend	artificial intelligence \nhuman behavior\necon...	how to predict human behavior using internet d...
...	...	...	...	...	...	...	...

However…

Most datasets are **messy**.

Datasets can be **huge**.

Datasets **may not make sense**.

Question

What are some ways in which data can be “*messy*”?

Examples of Weird Data

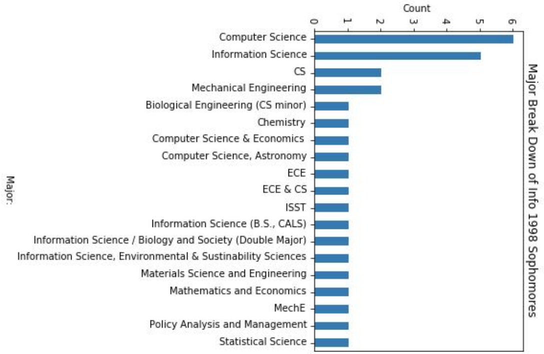
From the onboarding form!

Example 1: Let's find CS majors in INFO 1998.

Different cases:

- Computer Science
- CS
- Cs
- computer science
- CS and Math
- OR/CS

…goes on



Example 2: From INFO 1998

Example answers for 'What Year Are You?'

- 2002
- 1st
- Junor
- INFO SCI 2026

…goes on

Data Manipulation Techniques

Why should we manipulate data?

Ease of Use

Prevent calculation errors

Capture True Intentions

DataFrames

- **Pandas** (a Python library) offers **DataFrame** objects to help manage data in an orderly way
- Similar to Excel spreadsheets or SQL tables
- DataFrames provides functions for selecting & manipulating data

```
import pandas as pd
```

Data Manipulation Techniques (with Pandas)

- Filtering & Subsetting
- Concatenating
- Joining
- *Bonus*: Summarizing

Filtering vs. Subsetting

- Filters **rows**
- Focusing on data entries

Name	Year	Major
Sri	2025	CS
Deniz	2026	CS
Mahi	2025	ORIE
Mericel	2025	CS

Filtering

- Subsets **columns**
- Focusing on characteristics

Name	Year	Major
Sri	2027	CS
Deniz	2026	CS
Mahi	2025	ORIE
Eric	2024	Math

Subsetting

Joining

Joins together two data frames on any specified key (fills in NaN = Not a Number otherwise). The index is the key here.

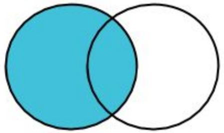
	Name
0	Sri
1	Deniz
2	Mahi
3	Eric
4	Mericel

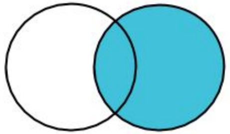
	Name	Age	Major
0	Sri	20	CS
1	Deniz	21	CS
2	Mahi	21	CS

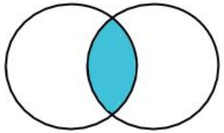
	Name	Age	Major
0	Sri	20	CS
1	Deniz	21	CS
2	Mahi	21	CS
3	Eric	NaN	NaN
4	Mericel	NaN	NaN

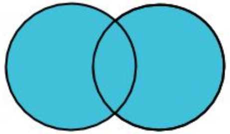
```
DataFrame.join(other, on=None, how='left', lsuffix='', rsuffix='', sort=False)
```

Types of Joins


Left Join


Right Join


Inner Join


Full Outer Join

ID	X1
1	a1
2	a2

ID	X2
2	b1
3	b2

Inner Join

ID	X1	X2
2	a2	b1

Outer Join

ID	X1	X2
1	a1	NA
2	a2	b1
3	NA	b2

Left Join

ID	X1	X2
1	a1	NA
2	a2	b1

Right Join

ID	X1	X2
2	a2	b1
3	NA	b2

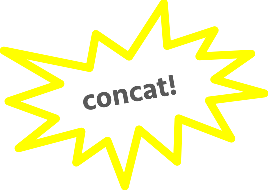
https://statisticsglobe.com/wp-content/uploads/2021/12/join-types-python-merge-programming.png

Concatenating

Combines together two data frames, either row-wise or column-wise

Name	Sex	Major
Sri	M	CS
Eric	M	Math

Name	Sex	Major
Mahi	F	ORIE
Deniz	F	CS



Name	Sex	Major
Sri	M	CS
Eric	M	Math
Mahi	F	ORIE
Deniz	F	CS

```
pandas.concat(objs, axis=0, join='outer', ignore_index=False, keys=None,
levels=None, names=None, verify_integrity=False, sort=False, copy=True)
```

Bonus: Summarizing

- Gives a quantitative overview of the dataset
- Useful for understanding and exploring the dataset!

```
>>> s = pd.Series([1, 2, 3])
>>> s.describe()
count     3.0
mean      2.0
std       1.0
min       1.0
25%       1.5
50%       2.0
75%       2.5
max       3.0
dtype: float64
```

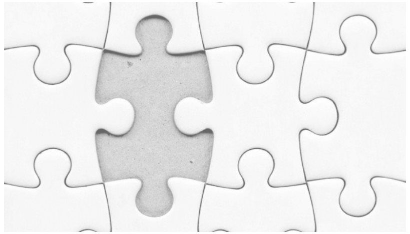
```
>>> s = pd.Series(['a', 'a', 'b', 'c'])
>>> s.describe()
count      4
unique     3
top        a
freq       2
dtype: object
```

Above: stats made easy

Data Imputation

Dealing with missing data

Datasets are usually incomplete. We can solve this by:



Leaving out samples with missing data

Data imputation

- Randomly Replacing NaNs
- Using summary statistics
- Using predictive models

1: Leaving out samples with missing values

- Option: Remove NaN values by removing specific samples or features
- **Beware** not to remove too many samples or features!
    - Information about the dataset is lost each time you do this

2: Data Imputation

3 main techniques to impute data:

1. Randomly replacing NaNs
2. Using summary statistics
3. Using regression, clustering, and other advanced techniques

2.1: Randomly replacing NaNs

- **This is not good - don't do it**
- Replacing NaNs with random values adds unwanted and unstructured noise

2.2: Using summary statistics

non-categorical data

- Works well with small datasets
- Fast and simple
- Does not account for correlations & uncertainties
- e.g. mean vs. median, average

categorical data

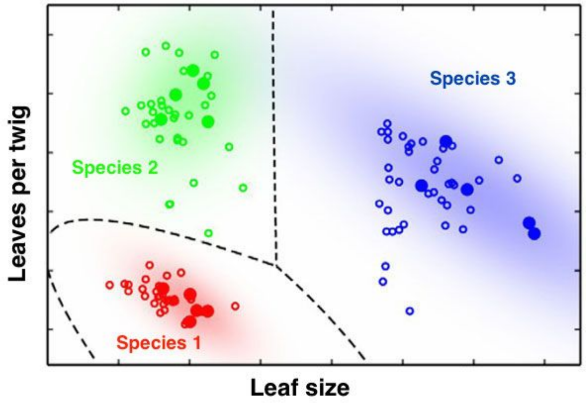
- Using mode works with categorical data (only theoretical)
- But it introduces **bias** in the dataset

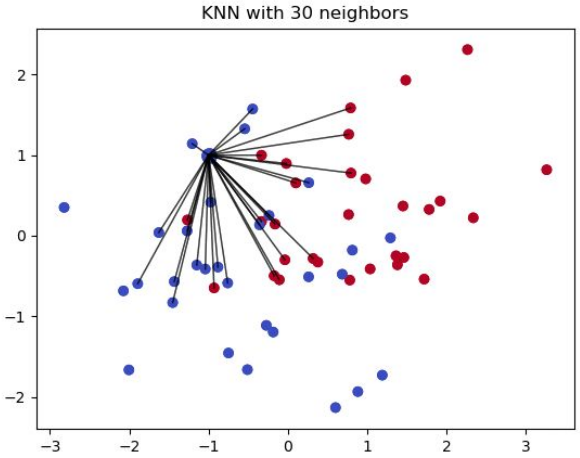
```
>> an_array.mean(axis=1) # computes means for each row
```

```
>> an_array.median() # default is axis=0
```

2.3: Using Regression / Clustering

- Use other variables to predict the missing values
  - Through regression, clustering, KNN…
- Doesn't include an error term, so it's not clear how confident the prediction is

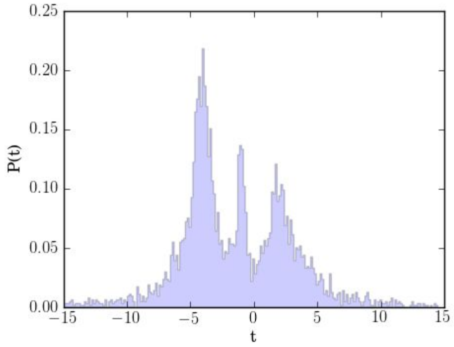


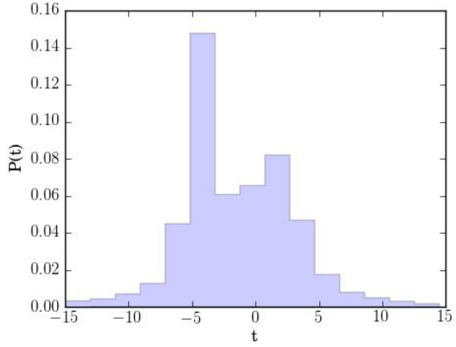


Other Techniques

Technique 1: Binning

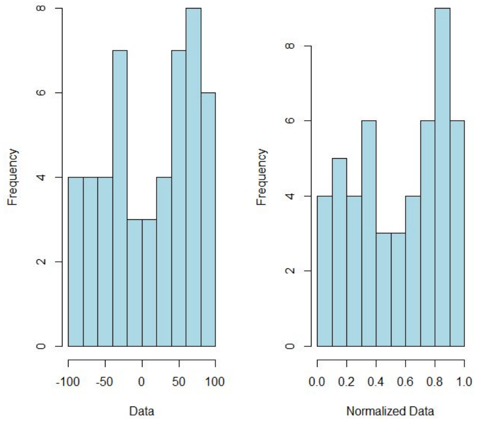
What?	Makes continuous data categorical by lumping ranges of data into discrete “levels”
Why?	Applicable to problems like (third-degree) price discrimination





Technique 2: Normalizing

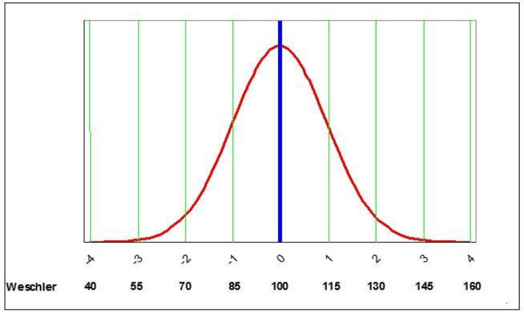
What?	Turns the data into values between 0 and 1
Why?	Easy comparison between different features that may have different scales. Necessary for models with distance metrics.



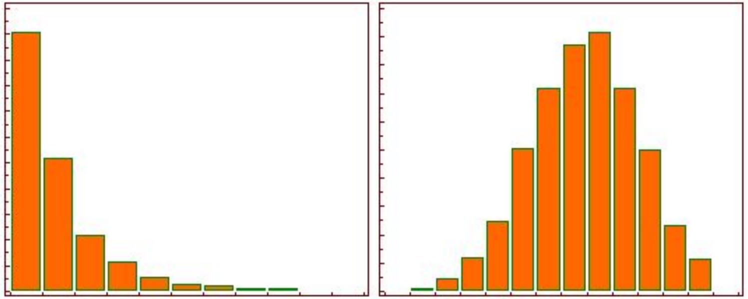
Technique 3: Standardizing

What?	Turns the data into a normal distribution with mean = 0 and SD = 1
Why?	Meet model assumptions of normal data; act as a benchmark since the majority of data is normal; curving grades.

Standardizing



Log transformation



Others include square root, cubic root, reciprocal, square, cube…

Technique 4: Ordering

What?	Why?	Example
Converts categorical data that is inherently ordered into a numerical scale	Numerical inputs often facilitate analysis	January → 1 February → 2 March → 3 …

Technique 5: Dummy Variables

What?

Creates a binary variable for each category in a categorical variable

plant	is a tree
aspen	1
poison ivy	0
grass	0
oak	1
corn	0

Technique 6: Feature Engineering

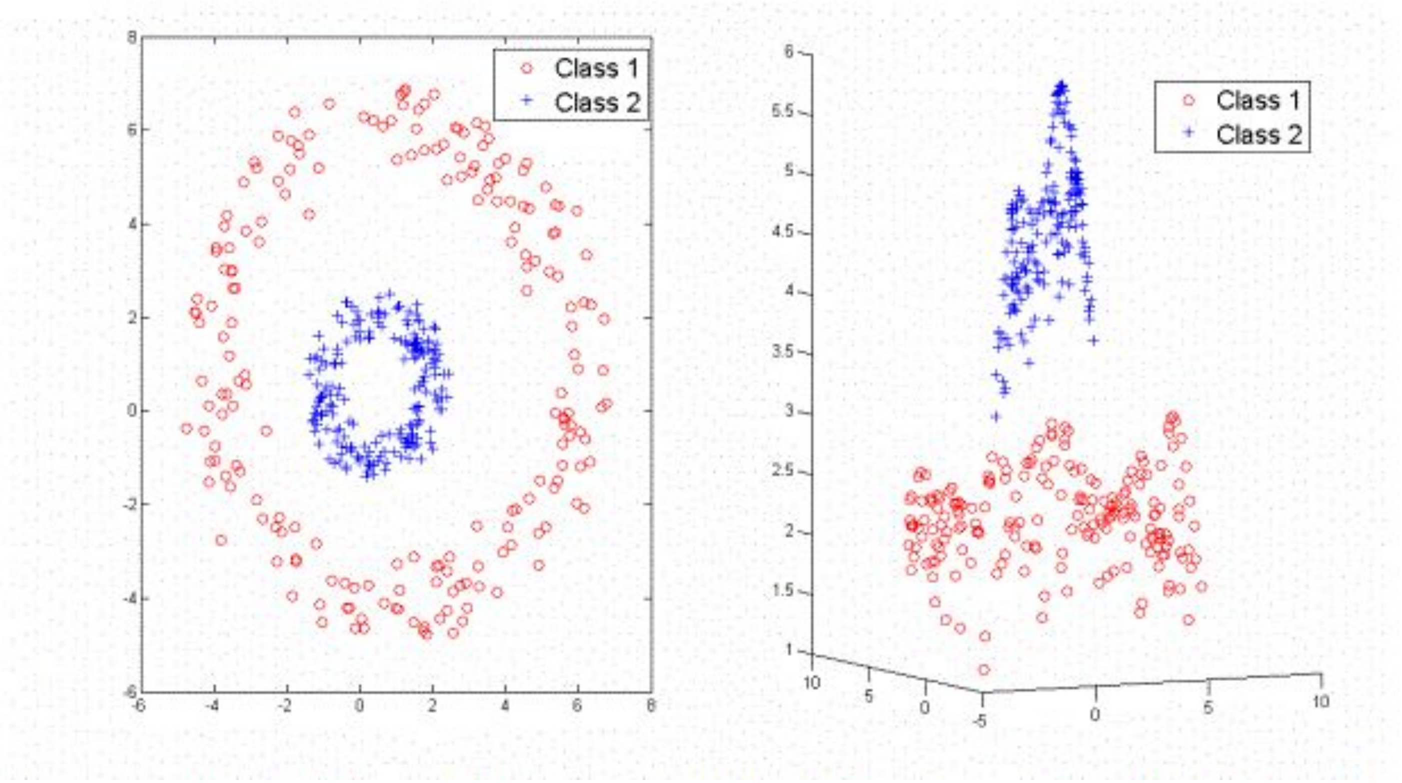
What?	Generates new features which may provide additional information to the user and to the model
Why?	You may add new columns/dimensions of your own design to derive more meaningful relationships in your analysis!

ID	Num
0001	2
0002	4
0003	6

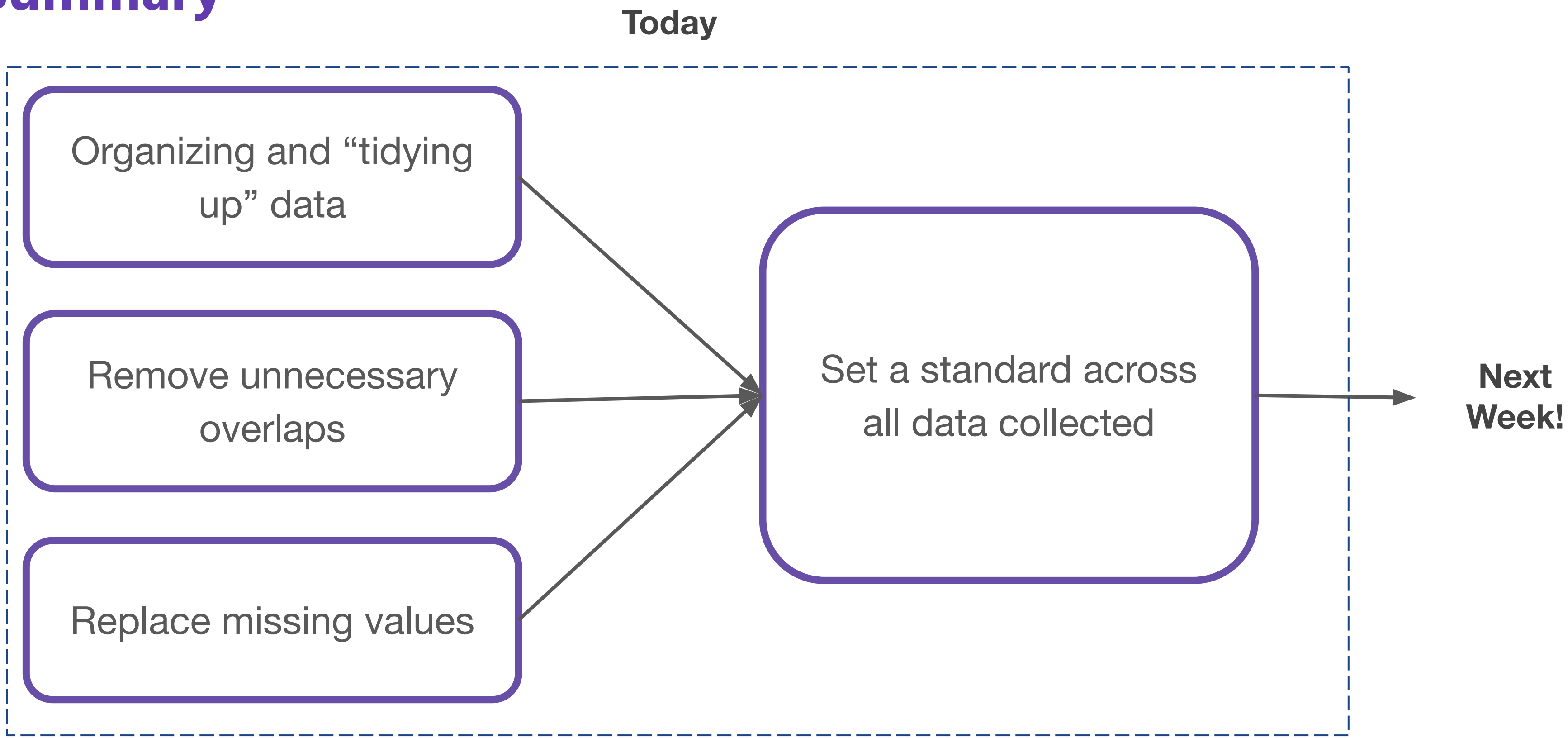
→

ID	Num	Half	SQ
0001	2	1	4
0002	4	2	16
0003	6	3	36

Example: Feature Engineering



Summary


Today
Organizing and "tidying up" data
Remove unnecessary overlaps
Replace missing values
Set a standard across all data collected
Next Week!

Demo

Coming Up

- **Assignment 2**: Due at 11:59pm on Wednesday, October 1st
- Submit **Assignment 1** by tonight!
- **Next Lecture**: Data Visualization
- Start thinking about project groups! Feel free to group up after class or send out potential project ideas on Ed.

CDS Education