Data Science With Python

Mosky

Data Science

- = Extract knowledge or insights from data.
- Data Science ⊃
  - Visualization
  - Statistics
  - Machine Learning
  - Big Data
  - Etc.
- ≈ Data Mining

Statistics vs. Machine Learning

- Statistics constructs more solid **inferences**.
- Machine learning constructs more interesting **predictions**.
  - Machine Learning ⊃ Deep Learning
- The models may be the same, but the focuses are different.
- Good predictions usually needs good inferences on dataset.

Science, Analysis, Scientist, and Engineering

- Data Engineering / Data Engineer
  - Prepare the data infra to enable others to work with.
- Data Analysis / Data Analyst
  - Analyze to help the company's decisions.
- Data Scientist
  - Create software to optimize the company's operations.

Mosky

- Backend Lead at Pinkoi.
- Has spoken at: PyCons in TW, JP, SG, HK, KR, MY, COSCUPs, and TEDx, etc.
- Countless hours on teaching Python.
- Own Python packages: ZIPCodeTW, etc.
- http://mosky.tw/

Outline

1. **Exploratory** (EDA, Exploratory Data analysis)
   - ➤ Correlation Analysis, PCA, FA, etc.
2. **Inference** (Statistical Inference)
   - ➤ Hypothesis Testing, OLS, Logit, etc.
3. **Preprocessing**
   - ➤ By pandas, scikit-learn, etc.
4. **Prediction** (Machine Learning Prediction)
   - ➤ SVM, Trees, KNN, K-Means, etc.
5. **Models of Models**
   - ➤ Cross Validation & Pipeline, Model Development, etc.

PDF & Notebooks

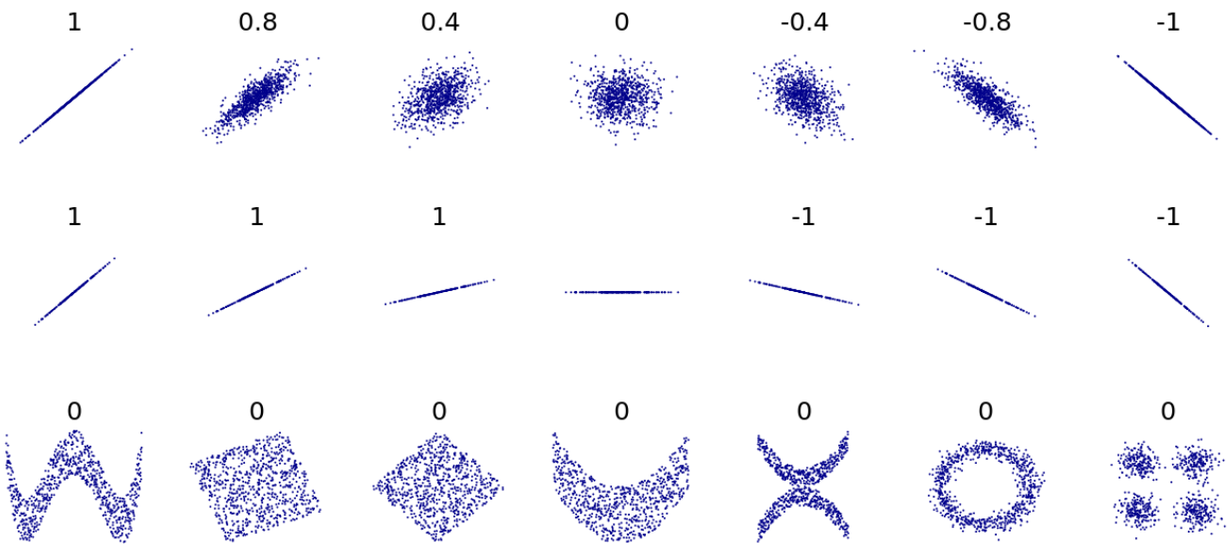
- The PDF and notebooks are available here:
  - https://github.com/moskytw/data-science-with-python
- A good notebook reader:
  - https://nbviewer.jupyter.org/
- Or run it on your own computer:
  - Prepare Python and Pipenv.
  - `$ pipenv sync`

Datasets

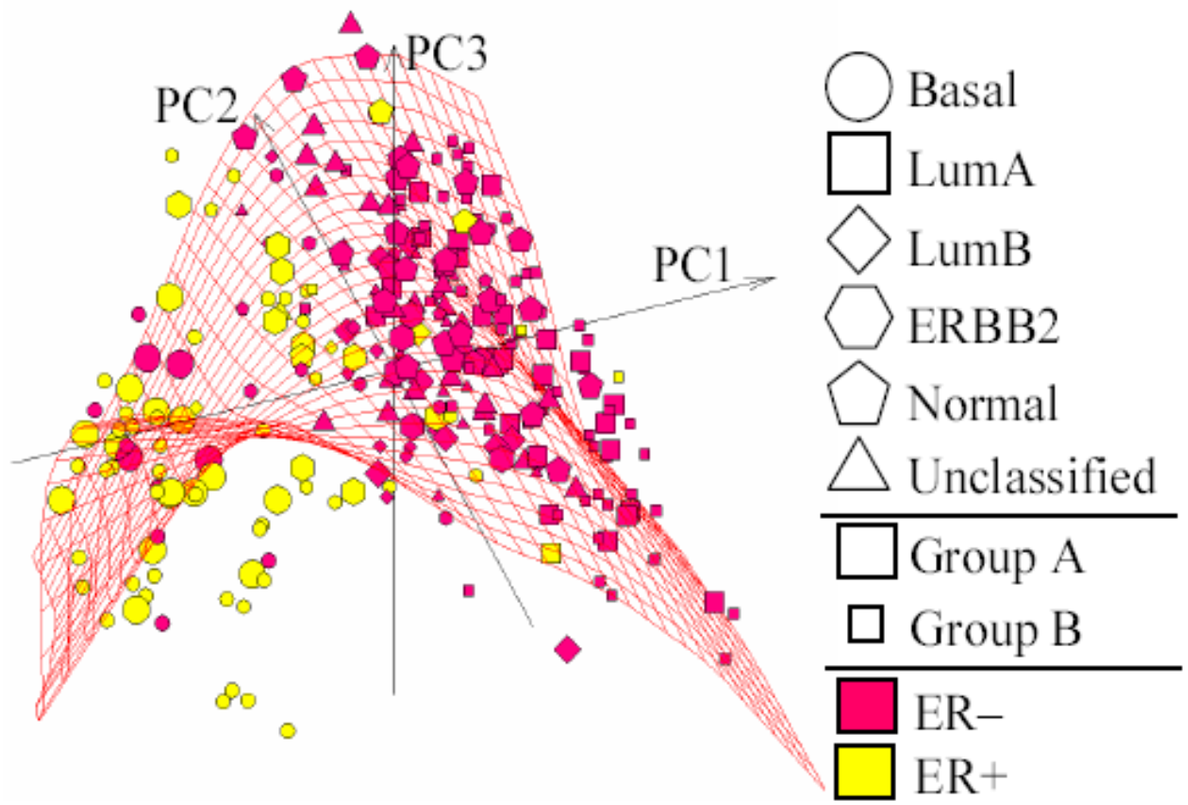
- The handouts are based on:
  - **American National Election Survey 1996** (944×10)
- You may play with:
  - **Extramarital Affairs Dataset** (1978; 6366×9)
  - **Star98 Educational Dataset** (1998; 303×13)
- **Handout:** datasets.ipynb
- The context matters:
  - 1970s – Wikipedia, 1990s – Wikipedia.
  - 1996 United States presidential election – Wikipedia.

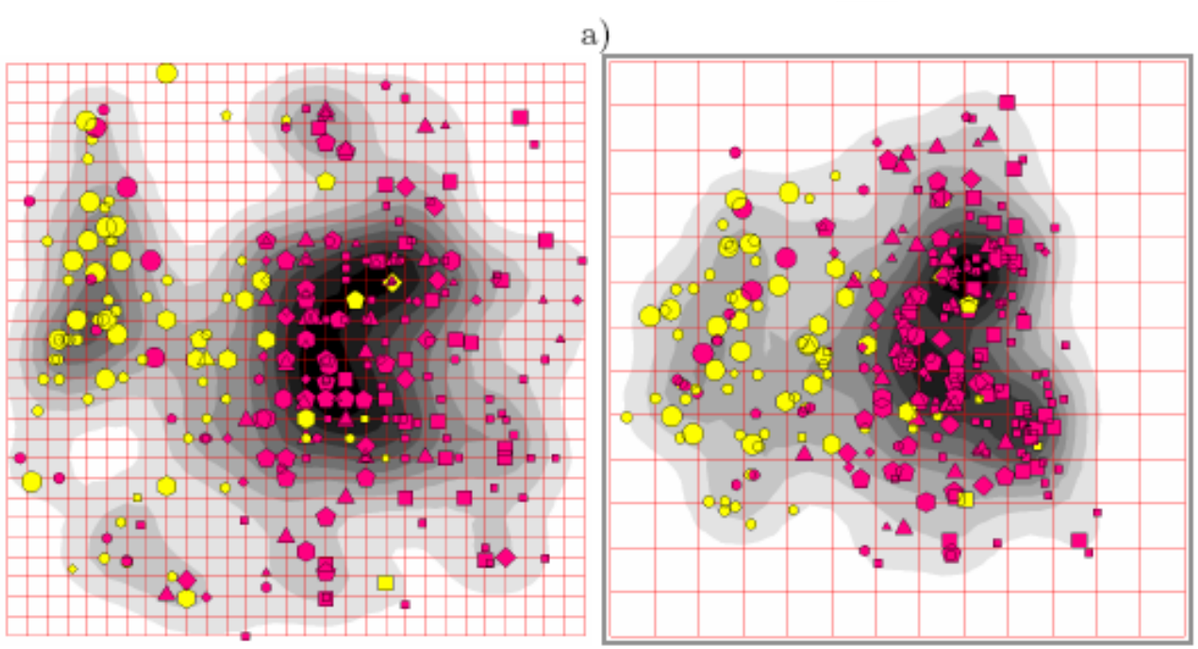
Exploration

Correlation Analysis



- Measures the bivariate linear “tightness”.
- ← **Pearson's** Correlation Coefficient (r)
- All pairs → correlation matrix.
- **Handout:** correlation_analysis.ipynb





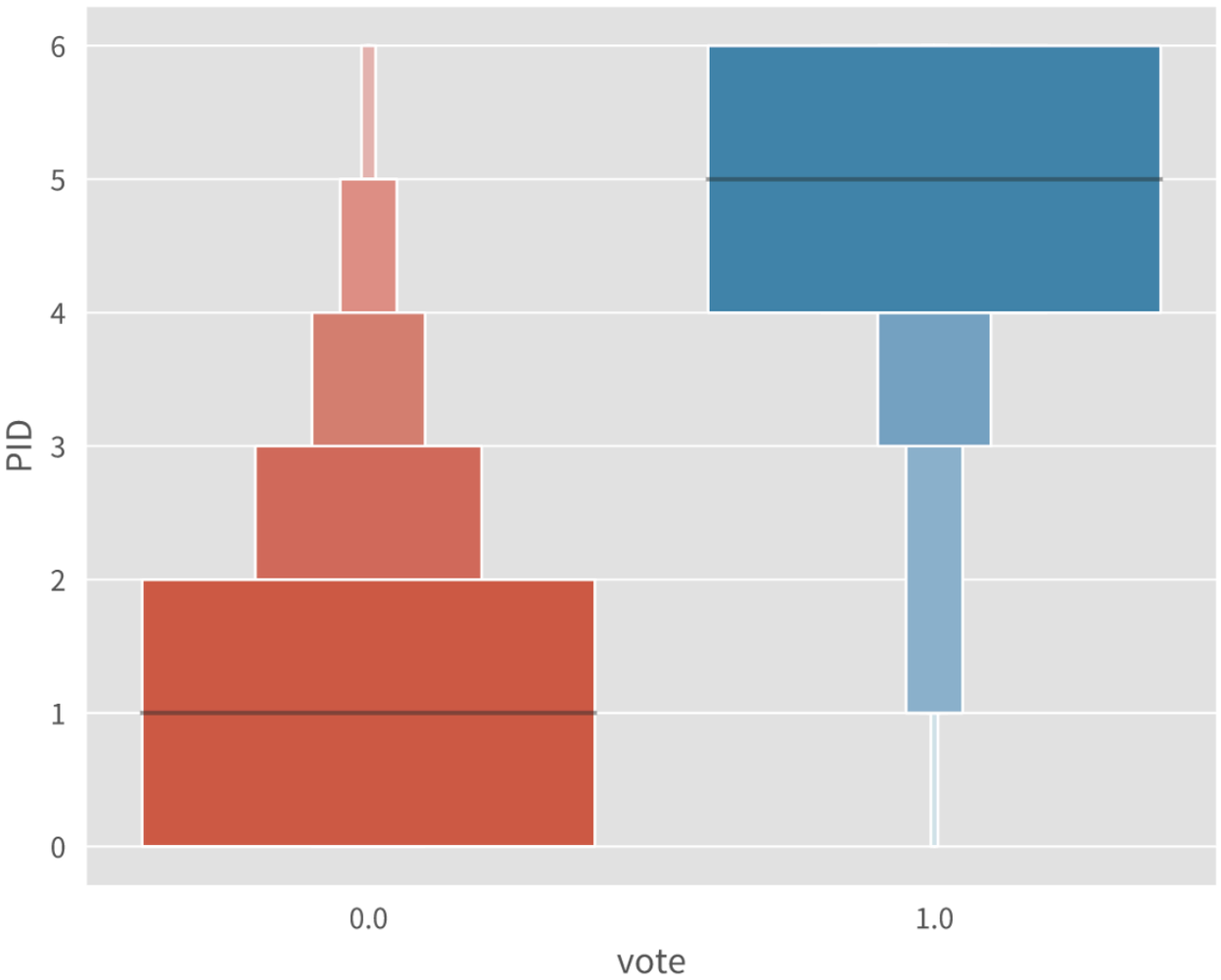
PCA & FA

- Maps into a lower-dim space.
- **Principal Component Analysis (PCA)**
  - Visualize quickly.
- **Factor Analysis (FA)**
  - Assume lower-number unobserved variables (factors) exist.
- **Handouts:**
  - pca.ipynb, pca_3d.ipynb, ipywidgets.ipynb, fa.ipynb

See Also

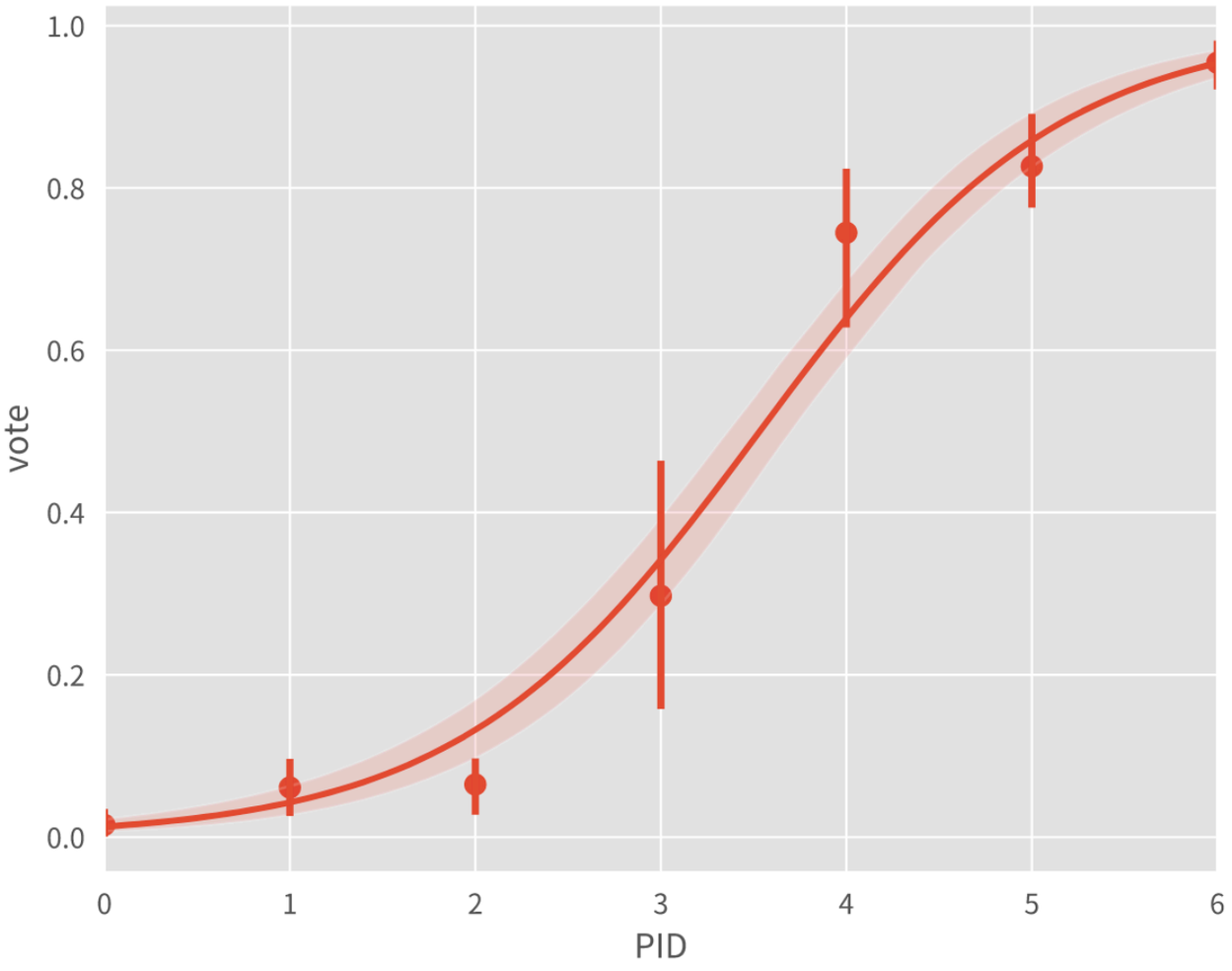
- seaborn
  - For drawing attractive and informative statistical graphics.
- Plotly
  - Makes interactive graphs.
- pandas.DataFrame.corr
  - Also has **Kendall's τ** (tau) and **Spearman's ρ** (rho).
- Isomap – scikit-learn
  - Seeks a lower-dimensional embedding which maintains geodesic distances between all points.
- Dimensionality reduction – scikit-learn

Inference



Hypothesis Testing

- Given a hypothesis, calculate the probability to observe the data.
- The hypothesis may be:
  - "the means are the same"
  - "the medians are the same"
  - "the prop. are the same, e.g., conversion rates", etc.
- Like testing the performances of the model A and the B.
- **Handout:** hypothesis_testing.ipynb



OLS & Logit

- Measures the "steepness".
- With various assumptions:
  - Linear: OLS
  - y is {0, 1}: Logit
  - y is {0, 1, ...}: Poisson, etc.

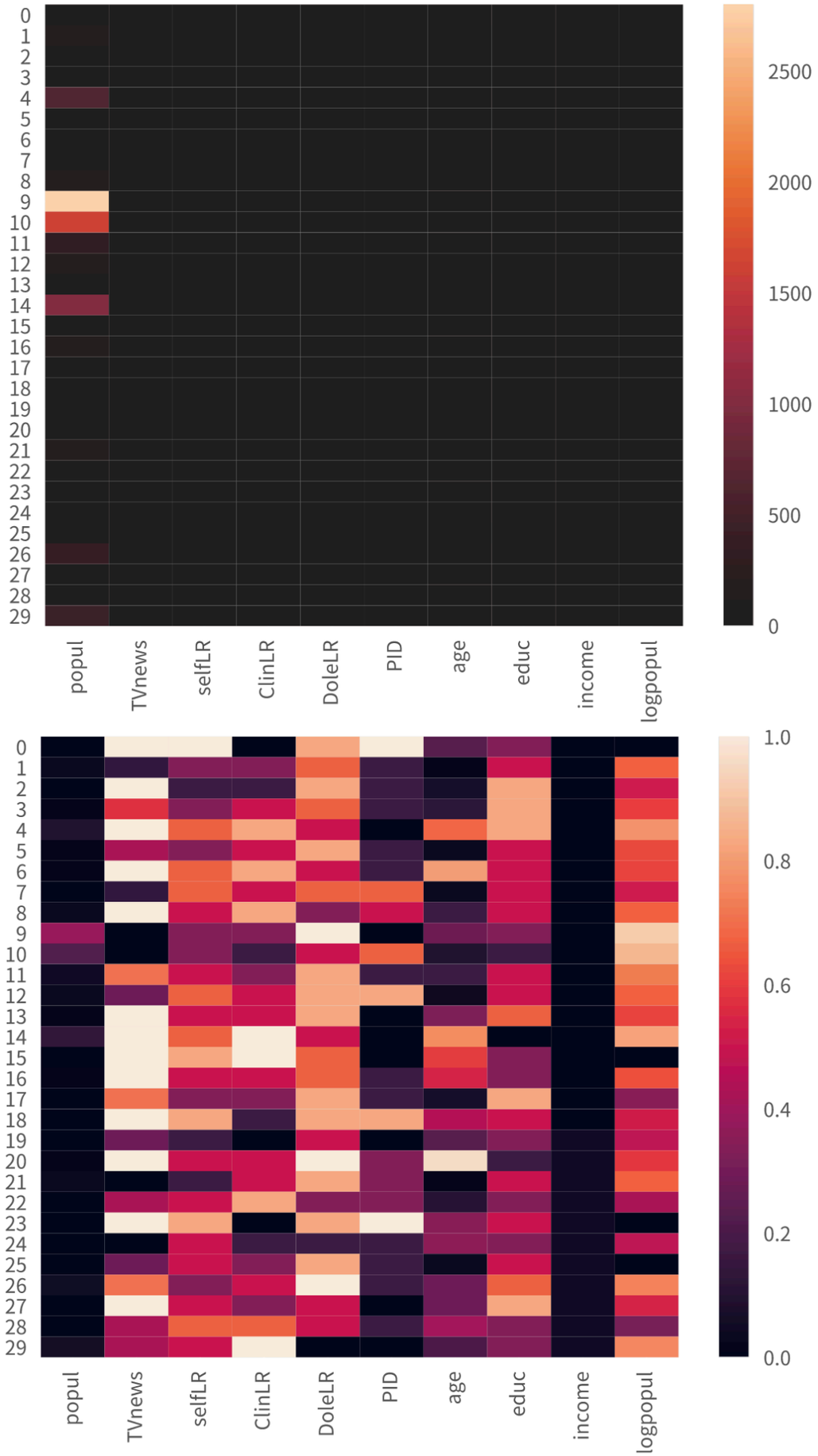
← **Logit Regression**

- Like understanding the dataset primarily, or even find the insights directly.
- **Handouts:**
  ols.ipynb, logit.ipynb

See Also

- Statistical functions – SciPy
  - Includes most of the hypothesis testing functions.
- User Guide – statsmodels
  - Includes much more models for statistical inference.
- Hypothesis Testing With Python
  - Answers like “how much sample is enough?”
- Statistical Regression With Python
  - Answers like “how to read a regression summary?”

Preprocessing



Preprocessing

- Make the models understand the data by various methods.

← **MixMinScaler**

- **Handouts:**
  pandas_preprocessing.ipynb,
  sqlite.ipynb,
  sklearn_preprocessing.ipynb,

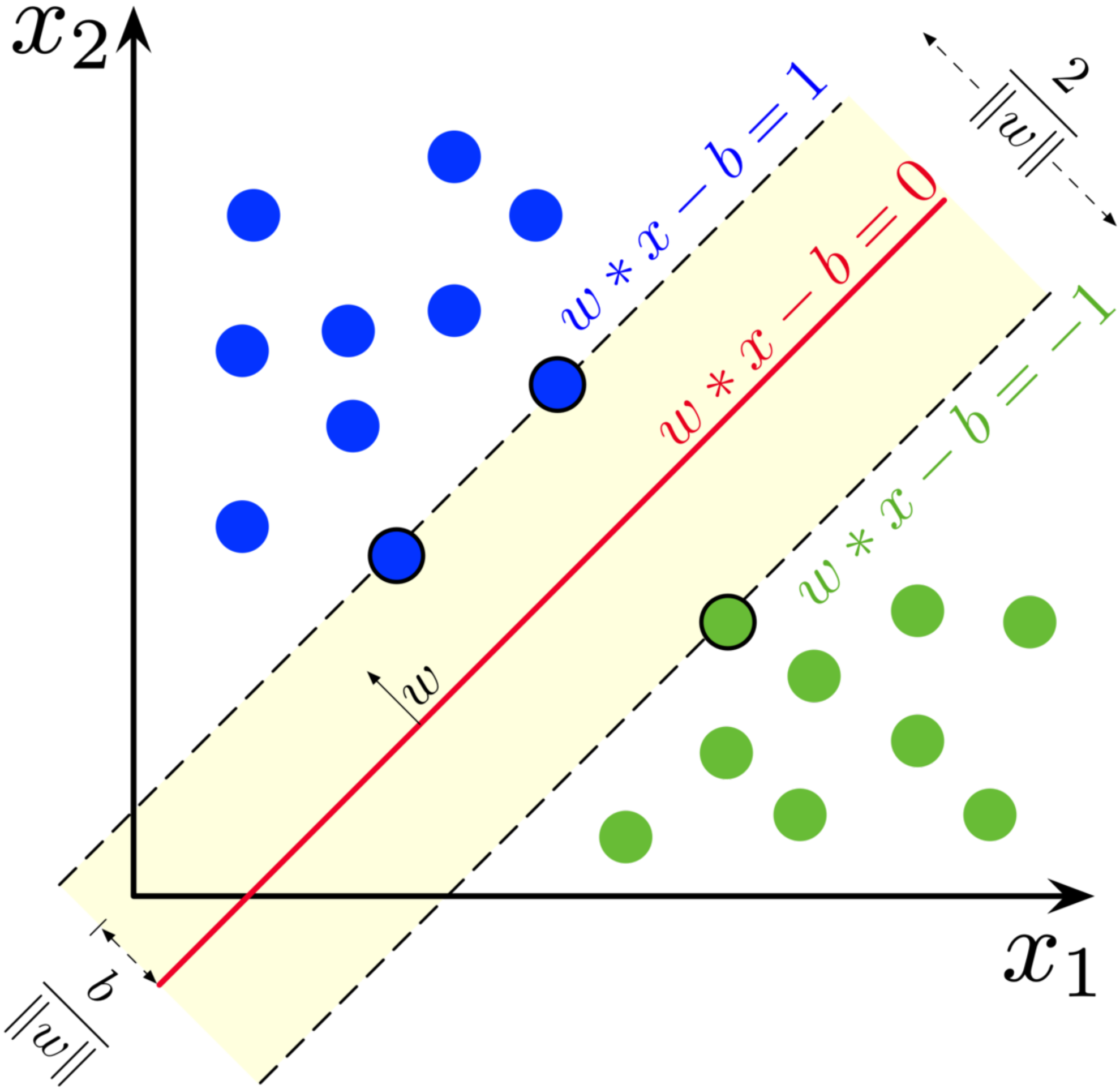
See Also

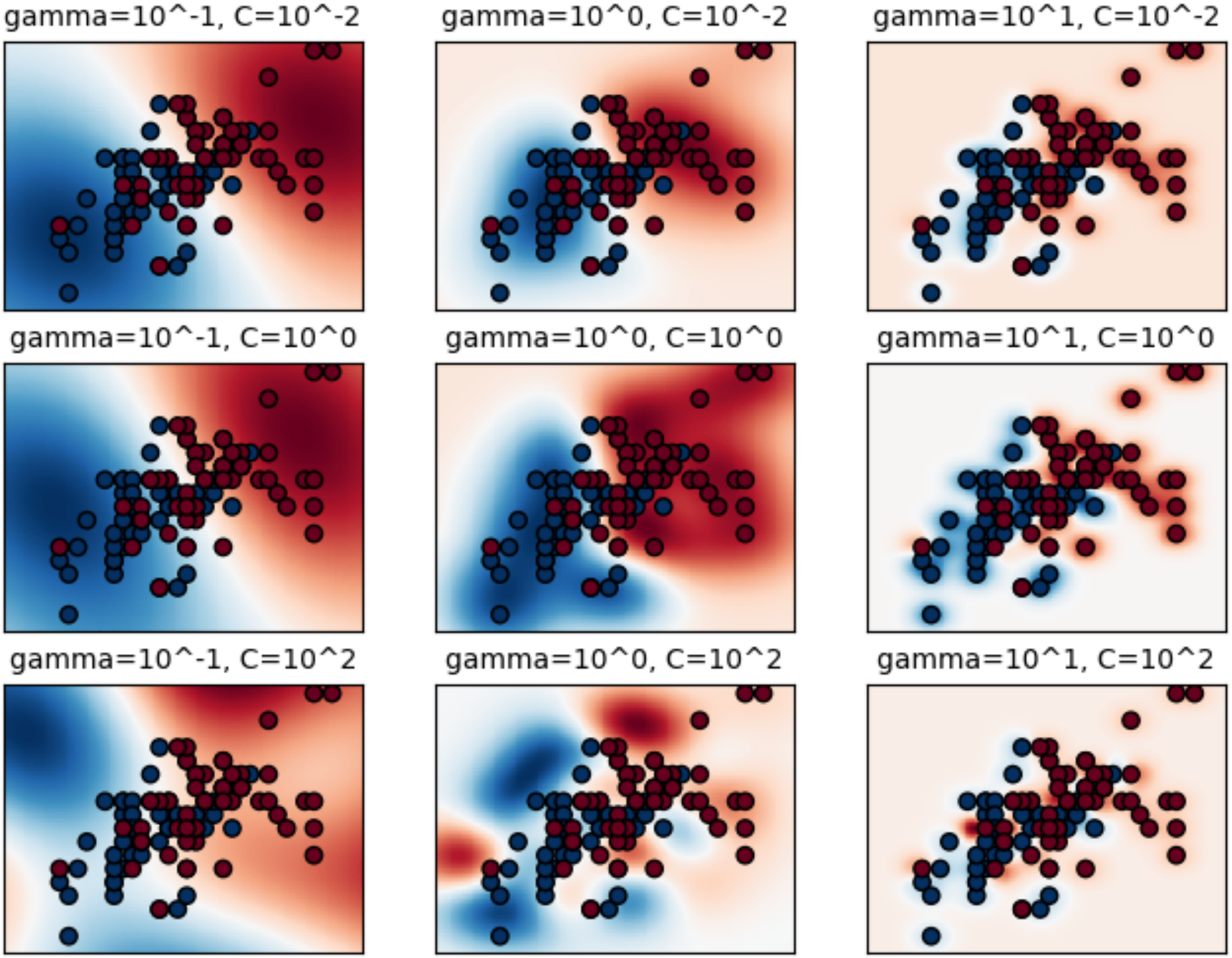
- Text feature extraction & Image feature extraction – scikit-learn
- Column Transformer with Mixed Types – scikit-learn
- patsy: describe models by formulas, e.g., $y \sim age + C(gender)$.
- imbalanced-learn: balance the classes more carefully.
  - The *class_weight='balanced'* in scikit-learn may be also useful.
    - Since we may not want the model to be partial to the majority.
- Rather than pandas:
  - dfply: Some consider cleaner.
  - datatable: Faster.
  - Spark: More scalable.
  - Database-like ops benchmark – H2O.ai
- Feature Engineering: create features by domain knowledge.

Prediction

Prediction

Support-Vector Machines (SVM)

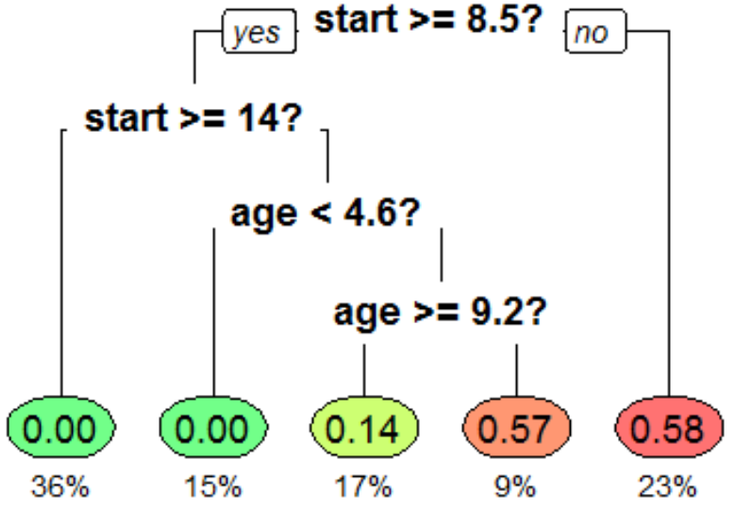

x_2
$w * x - b = 1$
$w * x - b = 0$
$w * x - b = -1$
$\frac{2}{\|w\|}$
w
$\frac{b}{\|w\|}$
x_1

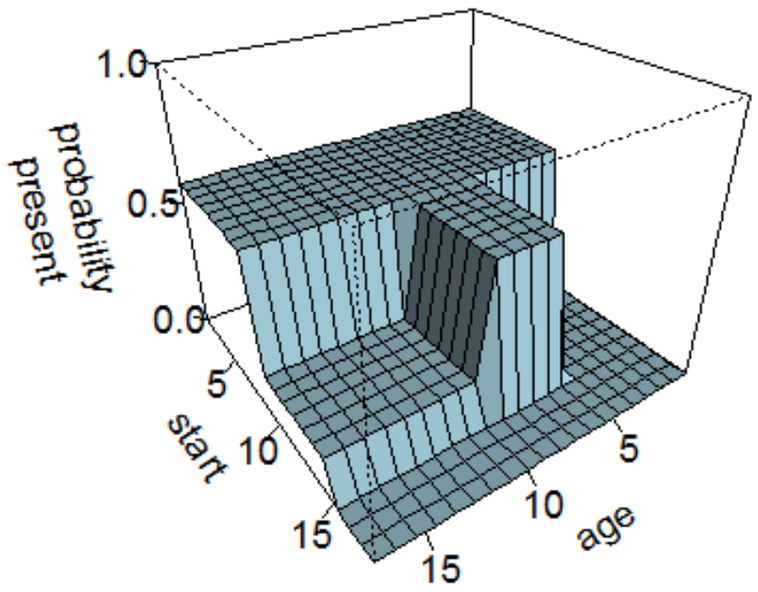


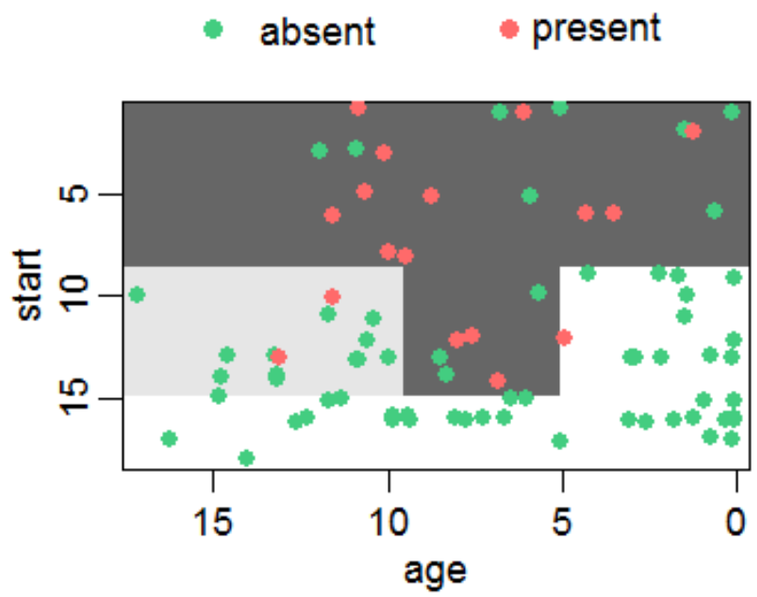
SVM With Radial Basis Function (RBF) Kernel

Prediction

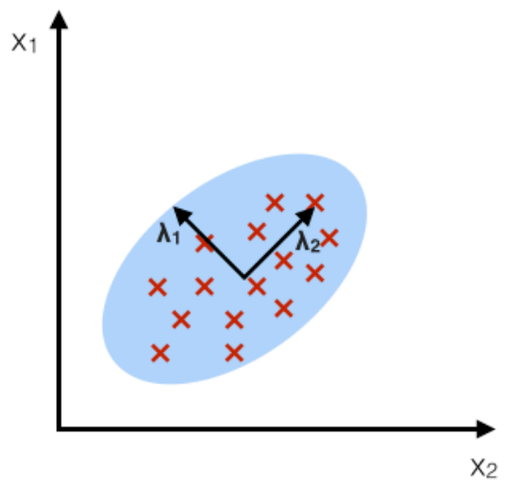
Decision Tree


yes
start >= 8.5?
no
start >= 14?
age < 4.6?
age >= 9.2?
0.00
0.00
0.14
0.57
0.58
36%
15%
17%
9%
23%

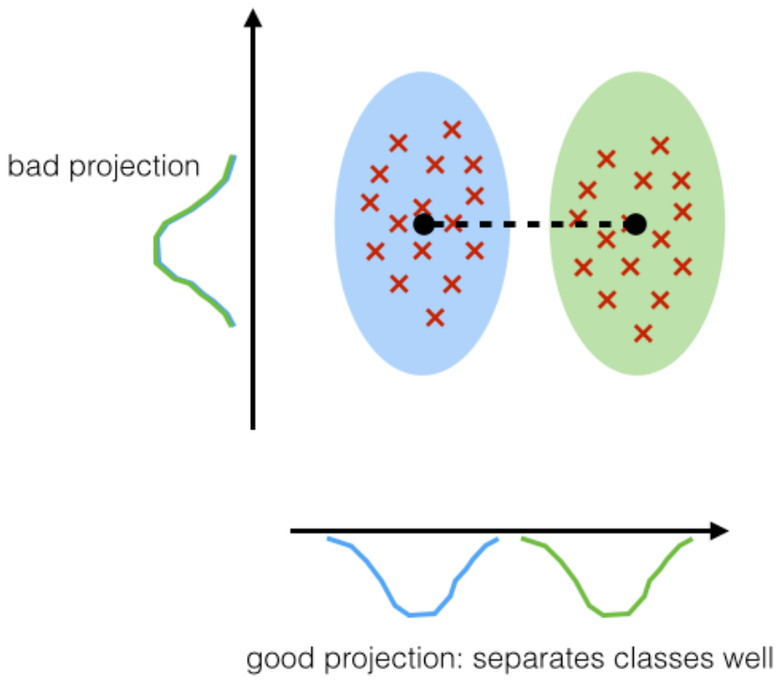

probability present
1.0
0.5
0.0
start
5
10
15
age
5
10
15


absent
present
start
5
10
15
age
15
10
5
0

PCA:
component axes that maximize the variance



LDA:
maximizing the component axes for class-separation



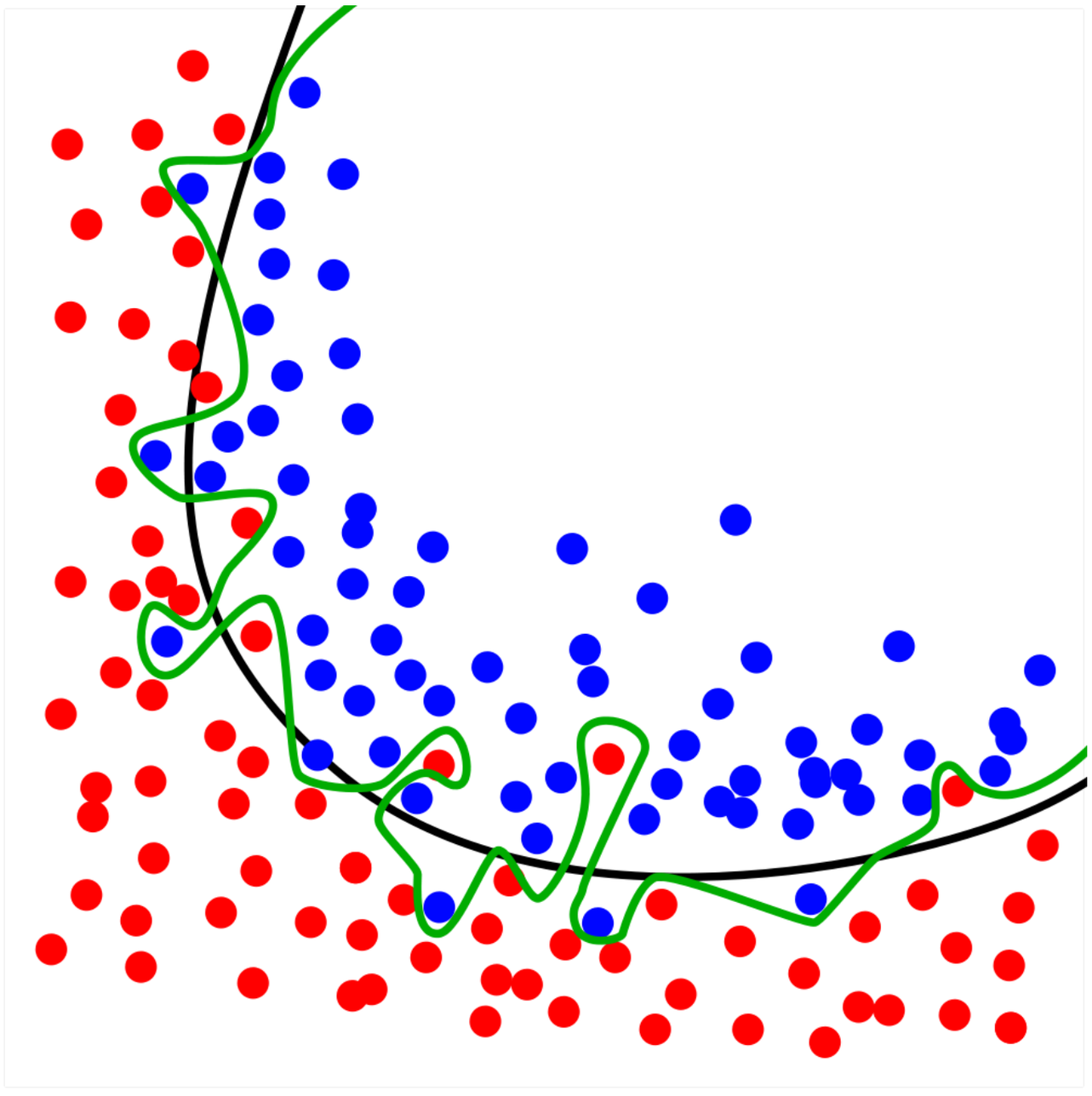
Prediction

- Predict the category or continuous value.
- By various models:
  - ↑ **SVM**
  - ↑ **Tree**
  - ← **Linear Discriminant Analysis (LDA)**
  - **KNN & K-Means**
- **Handouts:** svm.ipynb, trees.ipynb, logistic_and_lda.ipynb, knn.ipynb, kmeans.ipynb

See Also

- LightGBM: the most popular choice in Kaggle in 2019 [ref].
- Approximate Nearest Neighbor (ANN) Benchmark
- Recommender Systems in Practice – Towards Data Science
- Association Rules – mlxtend
- Voting & Stacking – scikit-learn

Models of Models



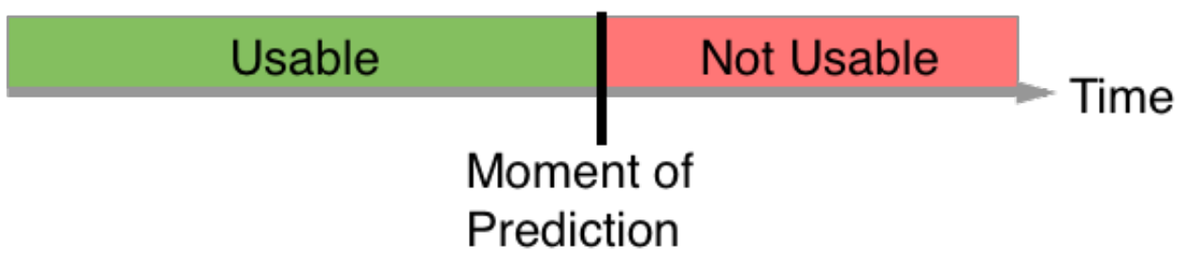
Overfitting

- A model fits the training data too well, and then fails to predict.
- Happens when the natural of the models, like trees, or over-tuning the hyperparameters.

← Green may be an **overfit**.

- Solutions:
  - *train_score / test_score* should be around 1.
  - **Train-Test Split**
  - **Cross Validation**

Data Leakage



- The training data which leads a high performance is not available when prediction. Not the "leakage" in the security area.
- Two major types: [ref]
  - **Target Leakage:** like *disease_bool* is *y*, and *treated* in *X*.
  - **Train-Test Contamination:** like backfilling train by test.
- Solutions:
  - **Pipeline**
  - **Explanation** (+ Domain Knowledge)

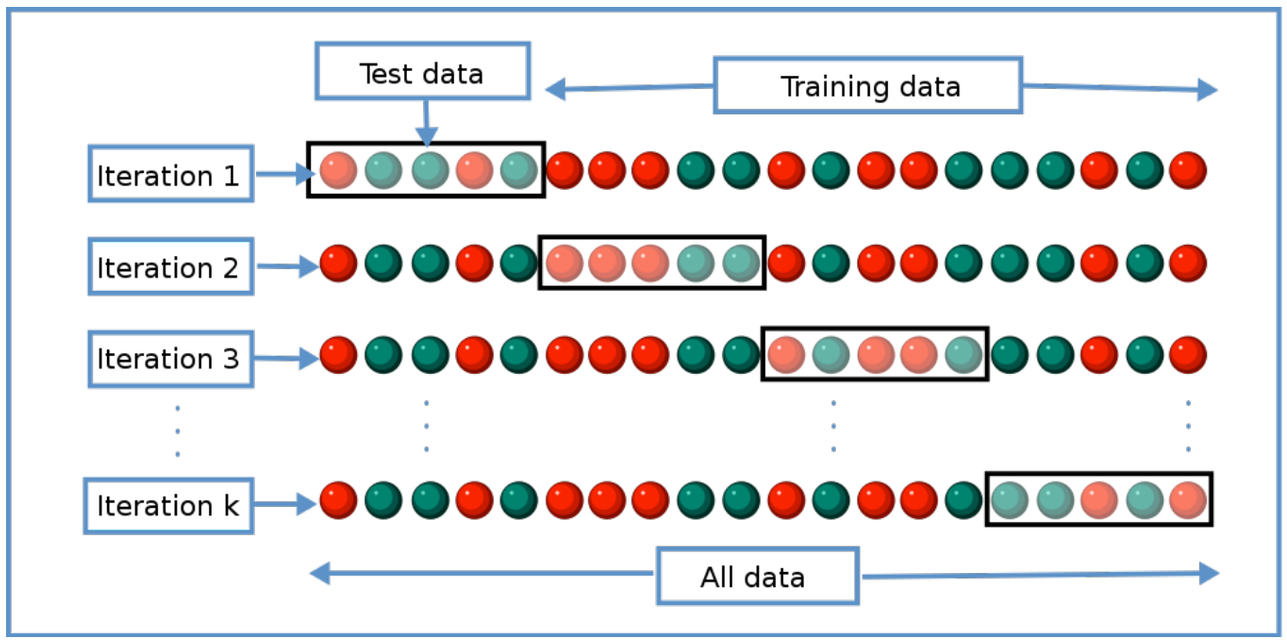
Spurious Relationship

- The model uses a false relationship to predict.
- ← Get the 90% accuracy by "the background is snowy, so the animal is Husky." [ref]
- Solution:
  - **Explanation**
    (+ Domain Knowledge)

Model–Market Fit

- “Product-Market Fit”.
- ← “Hey, this house is super similar to the one you just bought, buy one more?”
- ➤ “I build this model by ten years, please buy one!”
- ➤ Solution:
  - ➤ **Model Development**

Cross Validation



- Train-Test Split is simple, but can't use the data fully.
- Use the data fully by various strategies.

← K-Fold Cross Validation (K-Fold CV)

Pipeline

- A preprocessing step may operate on a whole matrix, e.g., backfilling.
- Split, preprocess, and then fit to ensure testing data is clean.
- Pipeline helps us to achieve it.
- **Handout:** pipe_and_cv.ipynb.

See Also

- Cross validation iterators – scikit-learn
  - Choose by the data generating process.
- Exhaustive Grid Search – scikit-learn
  - Search the best hyperparameters automatically.
- AWS Data Pipeline
  - Another common definition of “pipeline”.

Model Development

- ~~"Software Development"~~
- How to "model-market fit"?
- Delight people with fast release!
- People must like your model:
  - Users.
  - Domain experts.
- Release faster; then learn faster, ideally 1–2 weeks.

See Also

- The Analysis Steps
  - A suggested method to make an analysis, may be an analysis for building models or reviewing models.
- The Study Designs
  - Besides the A/B testing, some not costly methods.
- The Mini-Scrum
  - How to work with a team efficiently.

Temporal Data

- A **Spurious Relationship** happens between independent non-stationary variables naturally, like the mean varies respect to time.
- It can be modeled with a *time* variable.
- Some methods for temporal data:
  - tsa & statespace – statsmodels
    - ADF test – statsmodels
  - Cross validation of time series data – scikit-learn

Recap

- Exploratory like PCA helps to understand the data.
- Inference like statistical regressions finds the insights out.
- Preprocessing is for feeding easy-to-digest data to models.
- Inference helps prediction.
- Delight people with fast release! 😊

Image Credits

- “Linear PCA vs. Nonlinear Principal Manifolds”: https://en.wikipedia.org/wiki/Principal_component_analysis#/media/File:Elmap_breastcancer_wiki.png
- “SVM”: https://en.wikipedia.org/wiki/Support_vector_machine#/media/File:SVM_margin.png
- “SVM With RBF Kernel”: https://scikit-learn.org/stable/auto_examples/svm/plot_rbf_parameters.html
- “Tree”: https://en.wikipedia.org/wiki/Decision_tree_learning#/media/File:Cart_tree_kyphosis.png
- “PCA vs. LDA”: https://sebastianraschka.com/Articles/2014_python_lda.html
- “Overfitting”: https://en.wikipedia.org/wiki/Overfitting#/media/File:Overfitting.svg
- “Data Leakage”: https://www.kaggle.com/dansbecker/data-leakage
- “Husky”: https://en.wikipedia.org/wiki/Husky
- “Wolf”: https://en.wikipedia.org/wiki/Wolf#/media/File:Front_view_of_a_resting_Canis_lupus_ssp.jpg
- “Houses”: https://unsplash.com/photos/vZEPXDQHR4s
- “K-Fold Cross-Validation”: https://en.wikipedia.org/wiki/Cross-validation_(statistics)#/media/File:K-fold_cross_validation_EN.svg
- “Pipeline”: https://unsplash.com/photos/KP6XQIEjjPA
- “Smile”: https://unsplash.com/photos/g1Kr4Ozfoac