LECTURE 25

Conclusion

What you learned and didn't learn in this class. A farewell.

Agenda

- Logistics for the final.
- What did we teach you in this class?
- What’s next?
- Fun facts

Logistics

Final exam

The final exam is on **Friday, December 17th from 10:00-11:40**. It is worth 30% of your grade.

Important notes about the final:

- **Regex will not be on the final.**
- The exam is closed book closed note
- Please bring type two pencil with you
- No need for calculator

Feedback

Please fill out the course evaluation! (By 12/12)

As long as you submit proof that you filled out the evaluation on canvas, you will receive 1 bonus point!

What did you learn in this class?

What were we supposed to teach you?

Prepare

Prepare students for advanced courses in **data management**, **machine learning**, and **statistics**, by providing the necessary foundation and context.

Enable

Enable students to start careers as data scientists by providing experience working with **real-world data, tools, and techniques**.

Empower

Empower students to apply computational and inferential thinking to address **real-world problems**.

Note

- The following is a high-level overview of what we covered.
- You may find this useful in organizing your studying.
- But this is **not comprehensive!**

Data sampling and probability

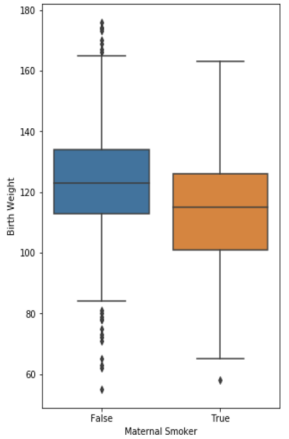
- Populations, samples, and sampling frames.
  - Sources of bias in sampling.
  - Types of samples (random samples vs. convenience samples, quota samples).
  - Benefits of random sampling.
    - Larger samples are not necessarily better.
    - Large biased samples can make things worse.
  - Sampling with and without replacement.
  - Binomial and multinomial probabilities.
- Random variables and distributions.
  - Expectation and its properties (e.g. linearity of expectation).
  - Variance and its properties.
  - Independence and correlation.
  - Sample means.

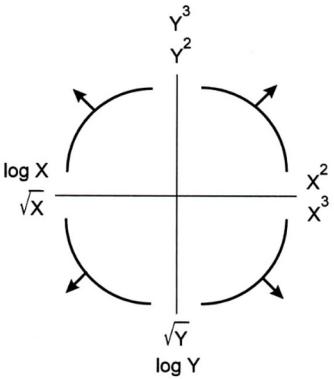
pandas, and data cleaning

- pandas as a means of working with tabular data in Python.
  - Series, DataFrames, and indexes.
  - .loc and .iloc.
  - Filtering, merging, grouping, pivoting, etc.
- Data cleaning and exploratory data analysis.
  - Structure, granularity, scope, temporality, faithfulness.
  - Handling missing values.

Regex and visualization

- Regular expressions as a means of identifying and extracting patterns in text.
  - Python string expressions.
  - regex101.com is your friend!
- Visualization.
  - Encodings and distributions.
  - When and how: bar plots, rug plots, histograms, density curves, box plots, violin plots, scatter plots, hex plots, contour plots.
  - Describing distributions in statistical terms (tails, skew, modes, outliers).
  - Principles of scale, conditioning, perception, and context.
  - Kernel density estimation.
  - Transformations.





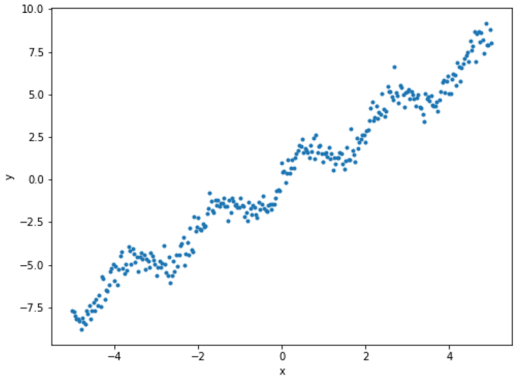
Modeling and linear regression

- The modeling “recipe”.
  - Choose a **model** (e.g. constant model, linear regression, logistic regression).
  - Choose a **loss function** (e.g. squared loss, absolute loss, cross-entropy loss).
  - Determine optimal parameters that **minimize** average loss (i.e. **empirical risk**) on training data.
- Simple linear regression.
  - Correlation coefficient r.
  - Finding optimal parameters by hand with calculus.
  - RMSE, Multiple R^2.

- Ordinary least squares.
  - **Regression**: given features, compute a real-valued prediction for each observation.
  - Design matrices, residuals, orthogonality.
  - Normal equation.

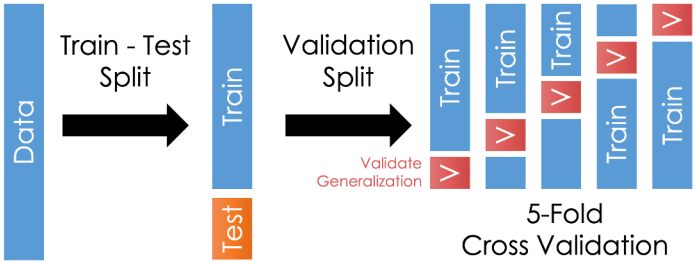
Feature engineering, bias-variance tradeoff

- Feature engineering: how do we model non-numeric and non-linear relationships, using linear models?
  - Categorical: one-hot encoding, bag-of-words, n-gram.
  - Polynomial features.
  - Overfitting to training data.
- Bias-Variance tradeoff
  - What are the underlying assumptions of randomness when modeling? (true model, random noise, etc.)
  - As we increase complexity, what happens to model bias? Model variance?
  - Model risk and its decomposition.

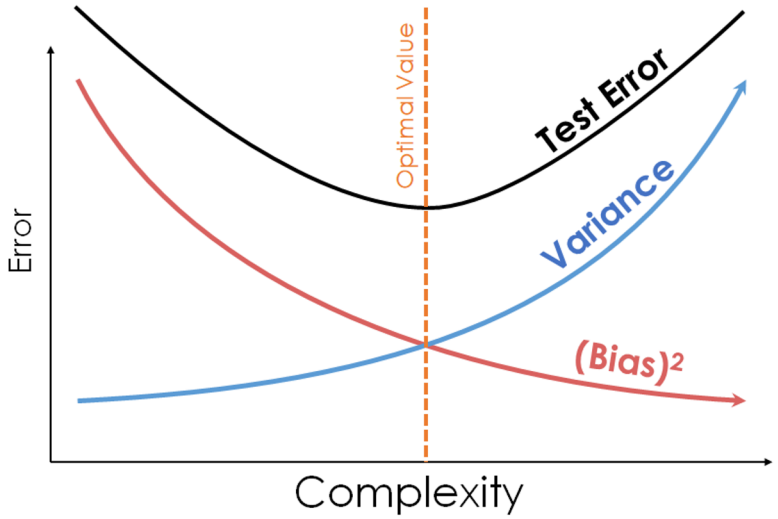


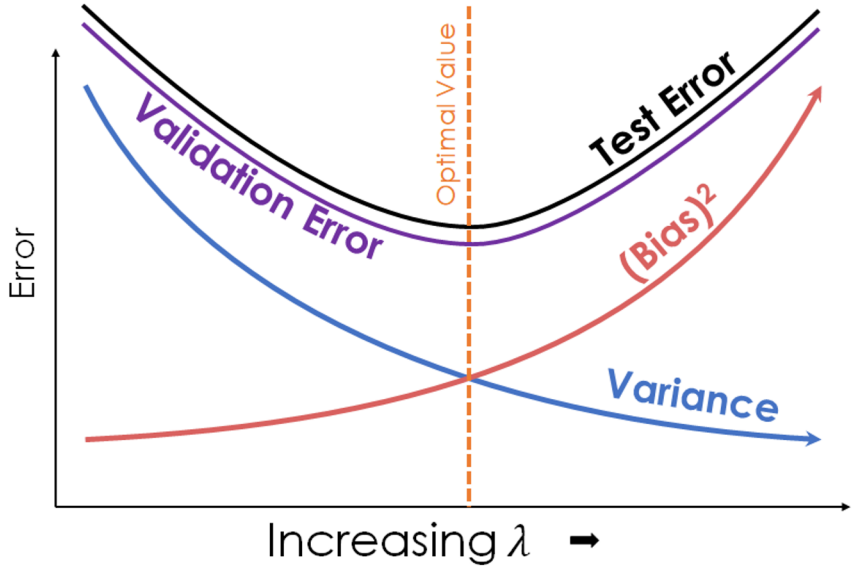
Regularization and cross-validation

- Regularization as a means of controlling model complexity.
  - Penalties on the norm of parameter vectors.
  - Ridge and LASSO.
  - Effects of the regularization hyperparameter on model complexity.
- Cross-validation as a means of selecting hyperparameters and/or sets of features.
  - Train-test splits, and why they're necessary.
  - Cross-validation as a means of estimating model performance on testing data using just training data.



Generalization

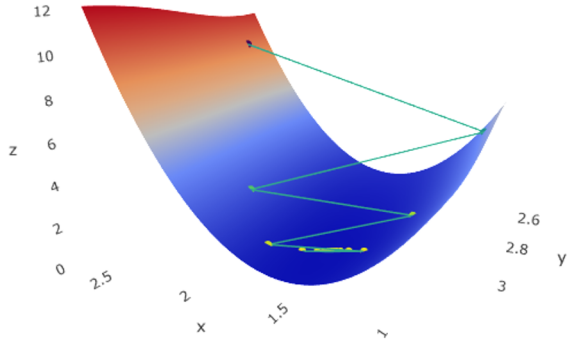


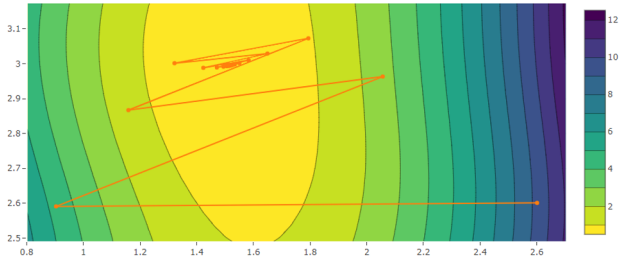


Our ultimate goal is to build models that generalize well to unseen data. The bias-variance tradeoff, training error, testing error, and cross-validation error all describe how well our model generalizes.

Gradient descent

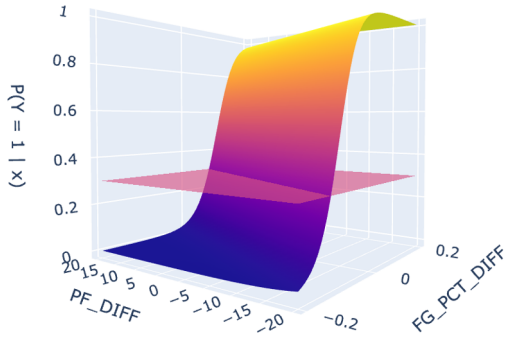
- Gradient descent as a means of numerically minimizing functions.
  - For our purposes, used to minimize average loss across a dataset.
  - Convexity.
    - If our loss function is not convex for our model, gradient descent may get stuck in a local minima.
  - Learning rates.
    - The size of the steps we take can affect whether or not we converge.
  - Stochastic gradient descent.

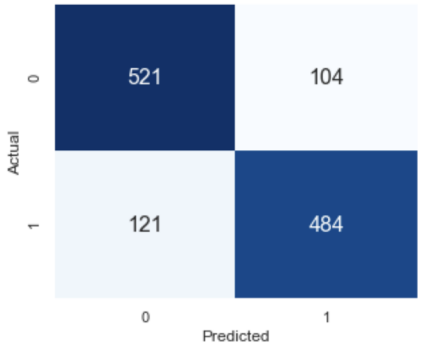




Logistic regression and classification

- Classification: given features, compute a discrete label for each observation.
- Logistic regression as a model of probabilities.
  - Linearity of log-odds.
  - The logistic function and its properties.
  - Cross-entropy loss vs. squared loss for logistic regression.
- Classification and classifier evaluation.
  - Thresholding and decision boundaries.
  - Linear separability, and the need for regularization.
  - Accuracy, precision, and recall. Confusion matrices.
  - PR curves, ROC curves, and AUC.

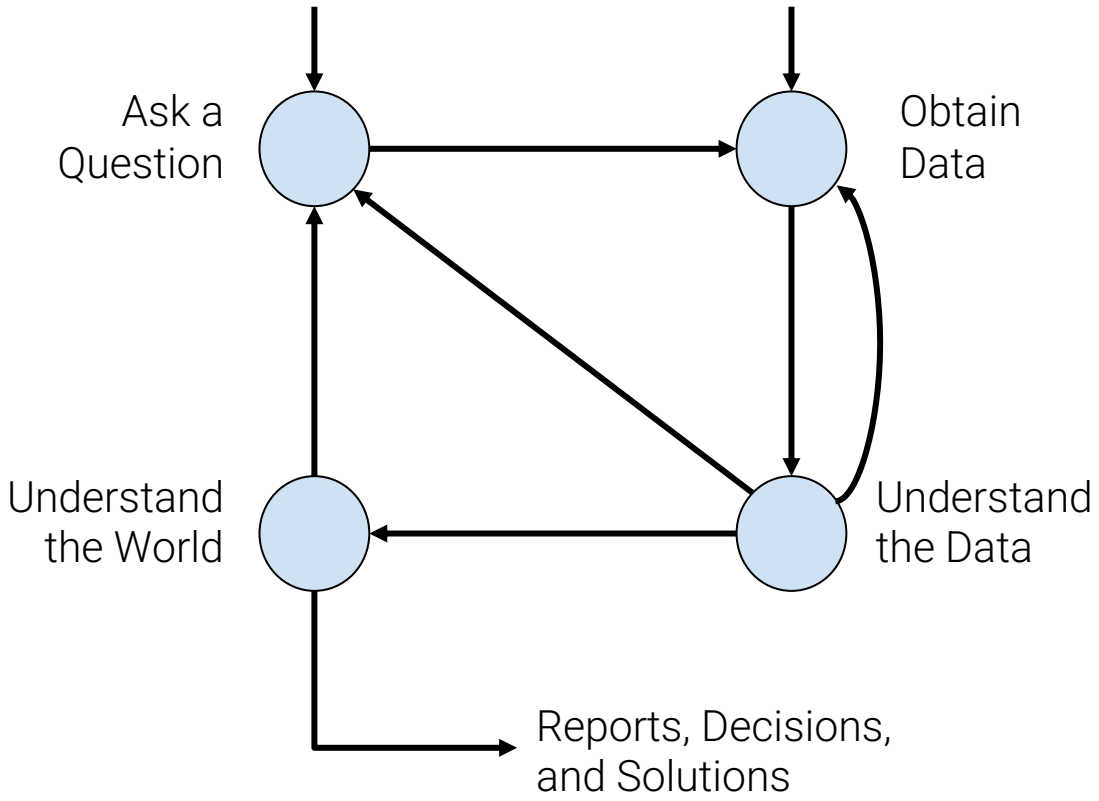




More models, model inference, PCA, clustering

- Other alternatives to regression and classification
  - Decision trees and random forests
  - Boosting: Adaboost, Realboos, Logitboost, XGBoost
  - SVM and SVR
- Model inference: using statistical tools to interpret our model's parameters.
  - Parameters, estimators, the bootstrap, and confidence intervals.
  - Multicollinearity.
- Unsupervised learning: instead of trying to learn the relationship between features and a response variable, we instead try and learn the pattern amongst the data itself.
  - Dimensionality reduction and PCA : How can we extract meaningful combinations of features from our high-dimensional data? What are "orthogonal basis vectors"?
  - Clustering: How can we segment our data into "groups" that are similar to one another?

Data science lifecycle



The data science lifecycle is a **high-level description** of the data science workflow.

Note the two distinct entry points!

Useful libraries and programming tools

What’s next

What didn’t we focus on this class?

- Causal inference.
  - How do we establish causality when we identify a correlation observed during EDA?
- Deep learning.
  - How can the machine do the hard work of picking the right features instead of requiring humans to pick them in advance?
- Decision making.
  - After we build our fancy regression/classification/clustering algorithms, what do we do next?
  - How do we avoid false discoveries?
- Time series analysis.
- Other flavors of machine learning (e.g. reinforcement learning).
- Open-ended exploration of problems and datasets picked by you.
- Non-tabular data (e.g. images/video, sensor-generated/spatial data, natural language...).

Real-world applications

A great way to strengthen your knowledge of the ideas you learned in this class (and to build a portfolio to help you find jobs!) is to use your new skills to analyze real-world data.

- There are countless sources of data available on the internet.
- Find one, load it into a notebook, and get to work!

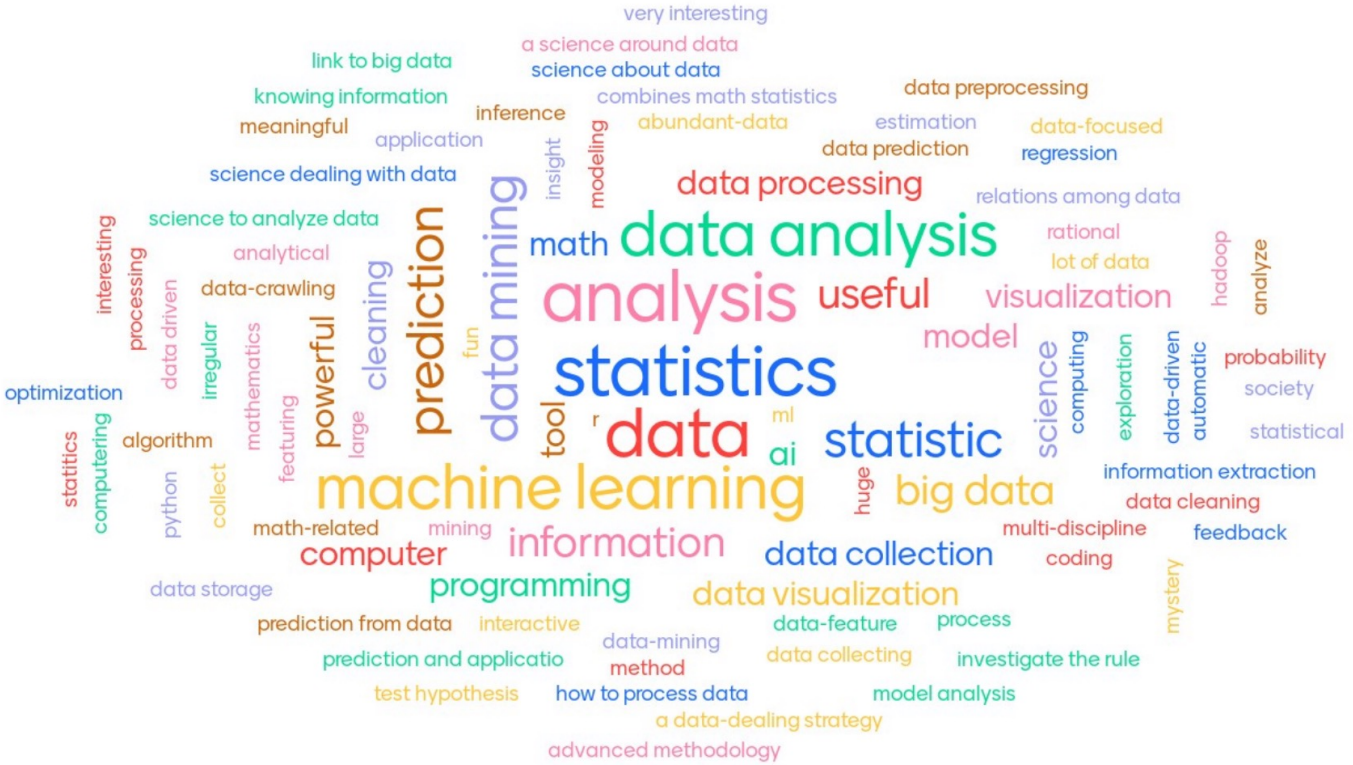
Places to look for data and applications of data science:

- Awesome Public Datasets GitHub repo.
- Kaggle.
- Towards Data Science.
- Five Thirty Eight.
- and so on!

Real-world applications

- Even though you're new to data science, you are also among the most skilled people in the world at data science. **Use your power wisely!**
- Let us know what you do next!

End (with some fun facts!)


very interesting
a science around data
link to big data
science about data
knowing information
combines math statistics
data preprocessing
meaningful
inference
abundant-data
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data-focused
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data prediction
regression
science dealing with data
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processing
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programming
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mystery
data storage
prediction from data
interactive
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process
data-mining
prediction and applicatio
data collecting
investigate the rule
method
test hypothesis
how to process data
model analysis
a data-dealing strategy
advanced methodology

Learning is about trial and error

Part 1

In [1790]:
```
ins['bid'] = ins['iid'].str.split("_").str[0]
ins['bid'] = ins['bid'].astype("int")
ins.head()
```

Out[1790]:

	iid	date	score	type	bid
0	100010_20190329	03/29/2019 12:00:00 AM	-1	New Construction	100010
1	100010_20190403	04/03/2019 12:00:00 AM	100	Routine - Unscheduled	100010
2	100017_20190417	04/17/2019 12:00:00 AM	-1	New Ownership	100017
3	100017_20190816	08/16/2019 12:00:00 AM	91	Routine - Unscheduled	100017
4	100017_20190826	08/26/2019 12:00:00 AM	-1	Reinspection/Followup	100017

Data Science is not only about understanding the world, but also understanding yourself!

Student	Dec 9 at 5:57am	07:15:14
TA	Dec 9 at 9:46pm	14:55:11
Student	Dec 9 at 12:22pm	03:09:33
Student	Dec 9 at 4:47pm	01:52:44
Student	Dec 9 at 7:28pm	05:14:23

Recruiting TA for 22 Spring!