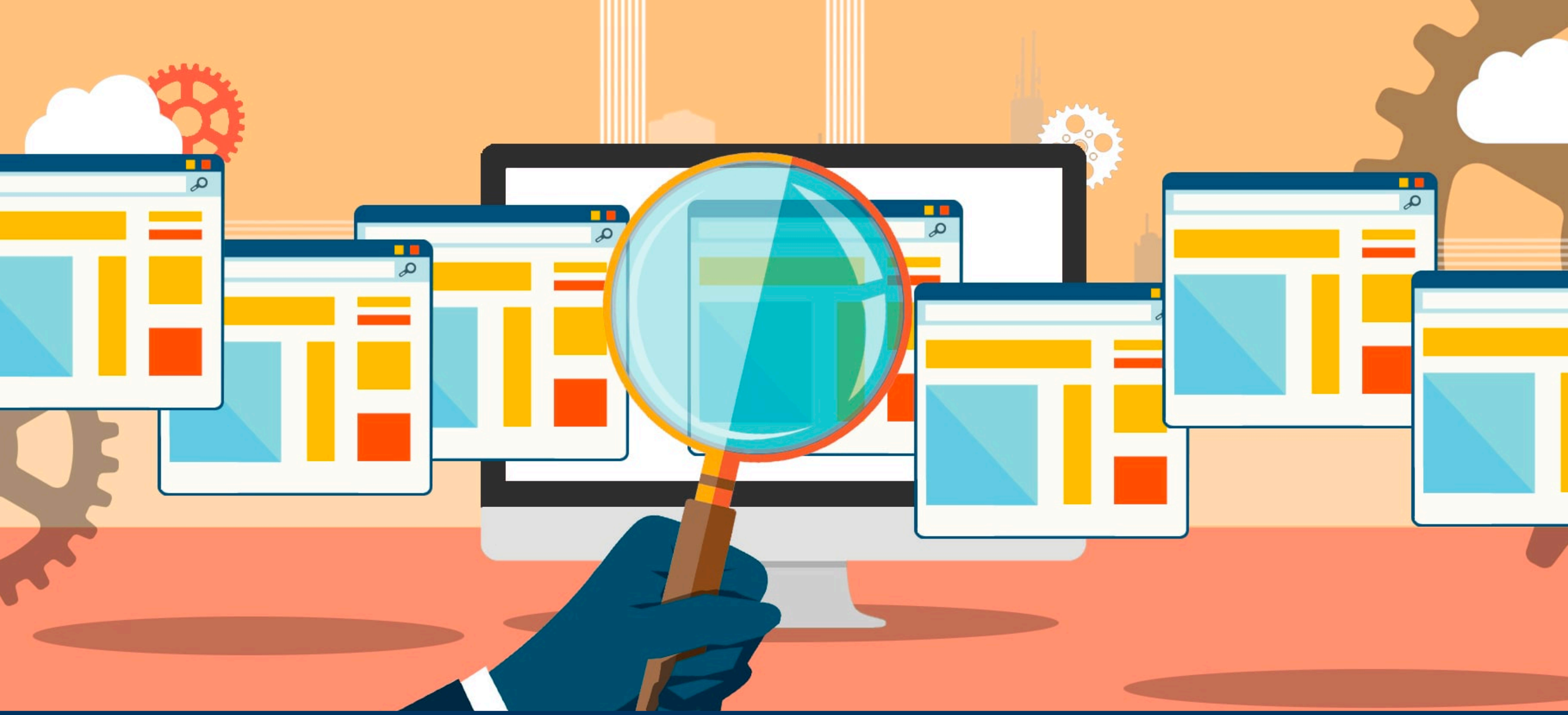
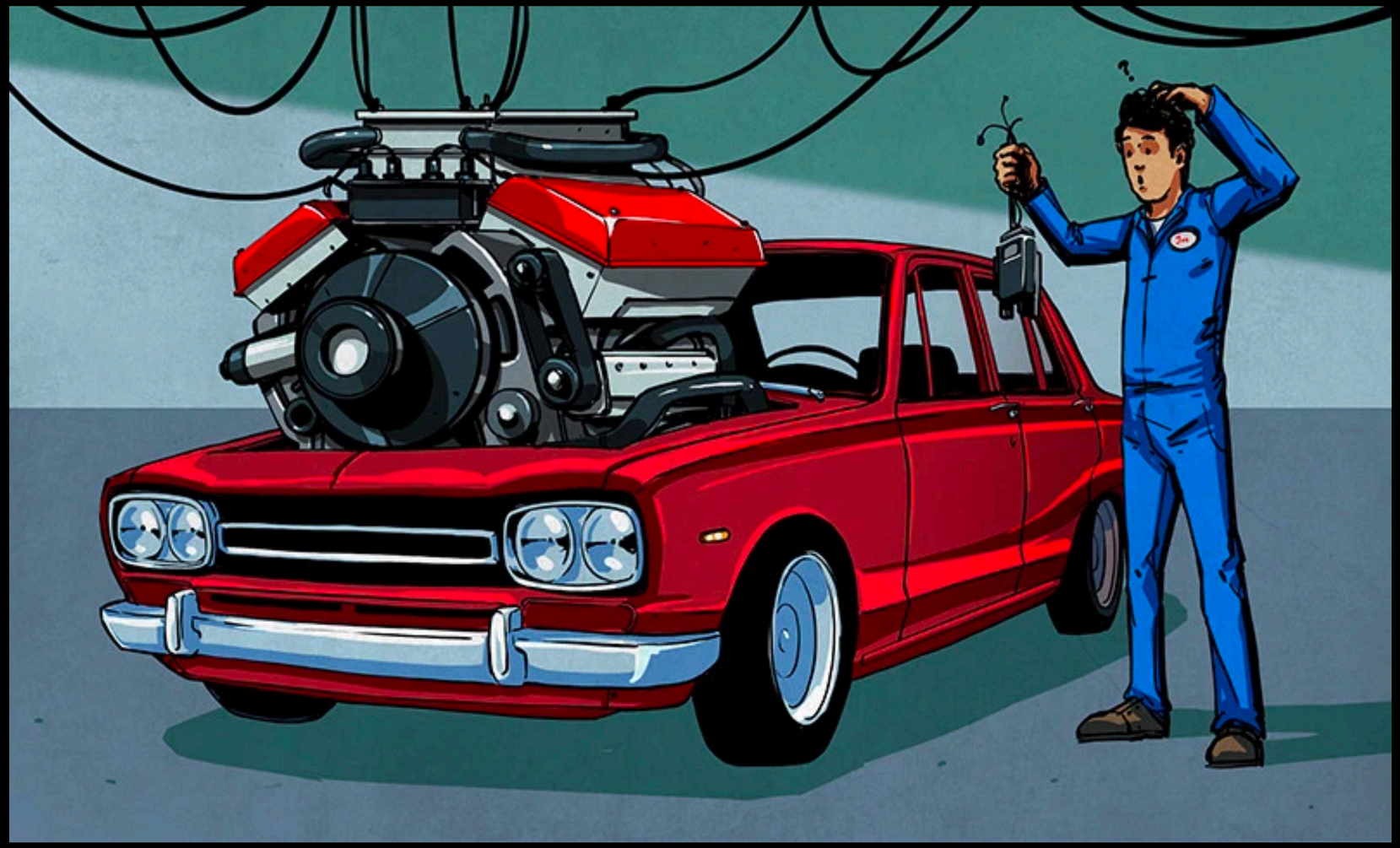


Evaluation in Supervised Learning

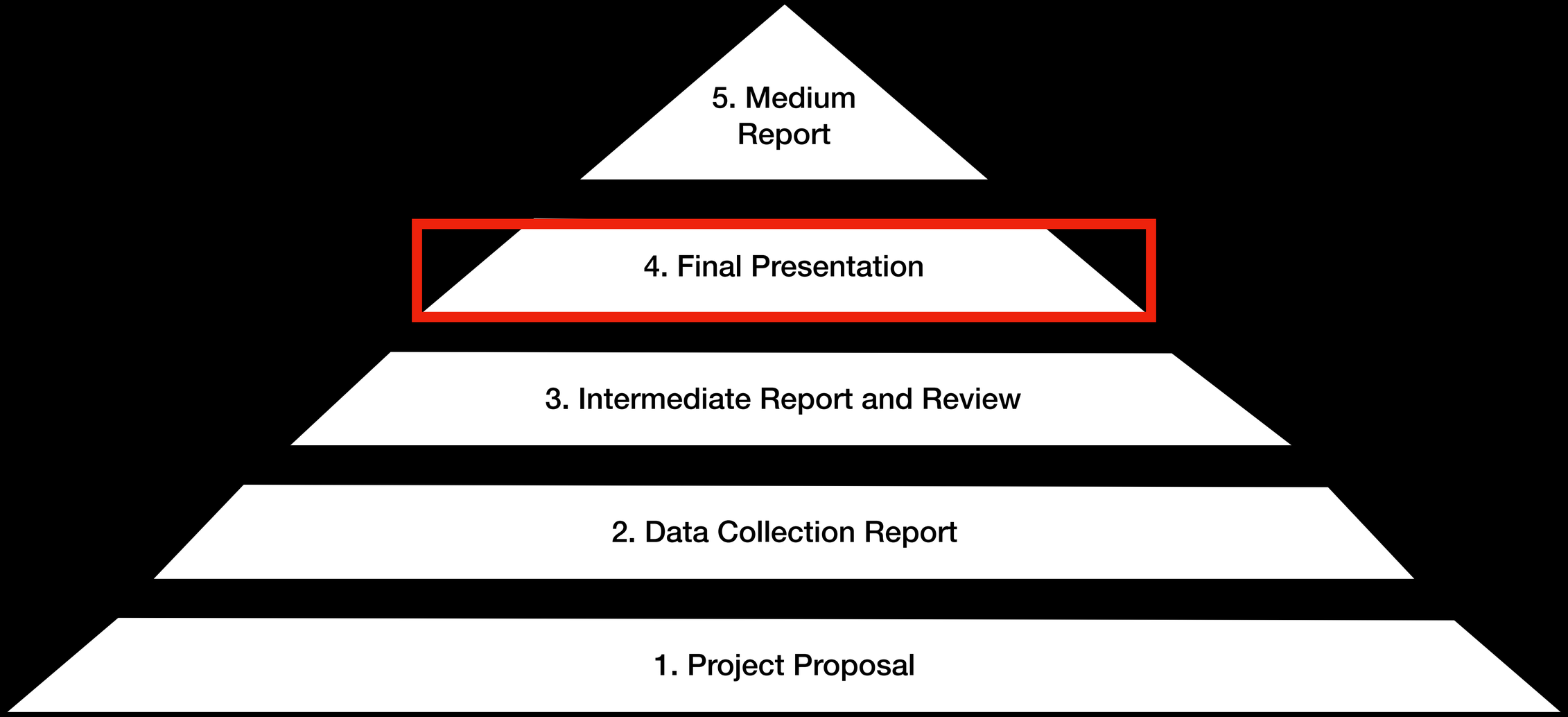
INST414 - Data Science Techniques

Medium Posts are **due no later than December 8**

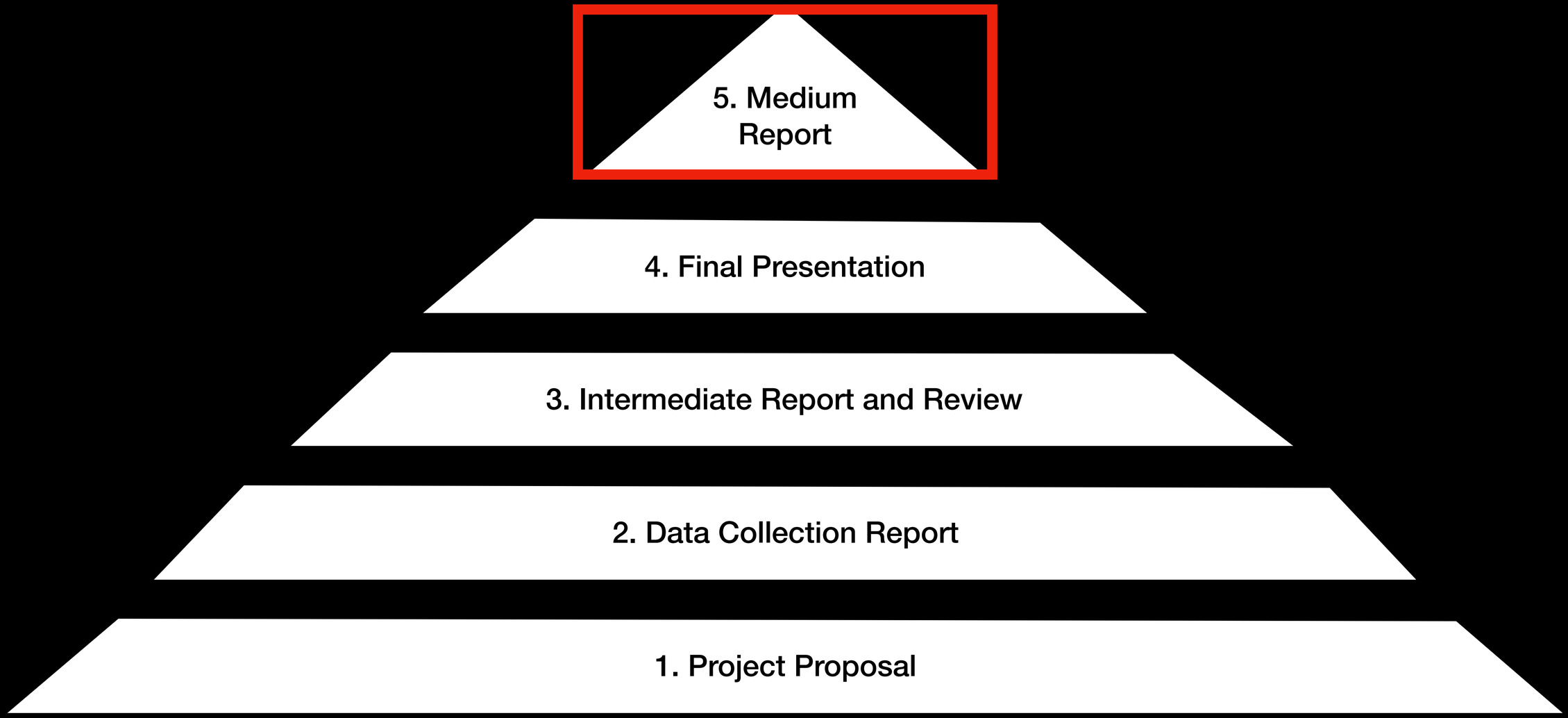
After this date, all unsubmitted assignments will get 0s



Semester Project



These are cancelled



We will discuss the final report next week

Semester Project - 5 - Final [Medium] Report

Published | Edit

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Related Items

SpeedGrader™

How to use UMD Canvas

Textbooks

Adopt Textbook

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Source Code Submission via GitHub

Beyond the report describing your work, you must also submit the associated code you developed for this analysis. To submit this code, you should create a GitHub repository, and include a link to that repository in your final report on Medium.

If you do not want to share your code publicly, you have the option of creating a private GitHub repository and adding me as a collaborator, so I can see your code. My username on GitHub is cbuntain. If you take this option, you must include the following line in your report:

- "Source code for this project is available on request."

GitHub has free tiers of service, and you are entitled to additional free resources on that platform as a student.

GitHub also has significant documentation for creating repositories of your code, which you can find here: https://docs.github.com/en/get-started/quickstart/create-a-repo

Grading Rubric

The rubric for this report is as follows: Rubric.doc

Points 100

Submitting a website url

This Module's Learning Objectives

Evaluation in Supervised Learning

Describe why accuracy may be a poor metric for imbalanced data

Calculate precision and recall for a supervised learning model

Differentiate macro- and micro-averaging for multi-class evaluation

Use k-fold cross-validation to estimate average performance

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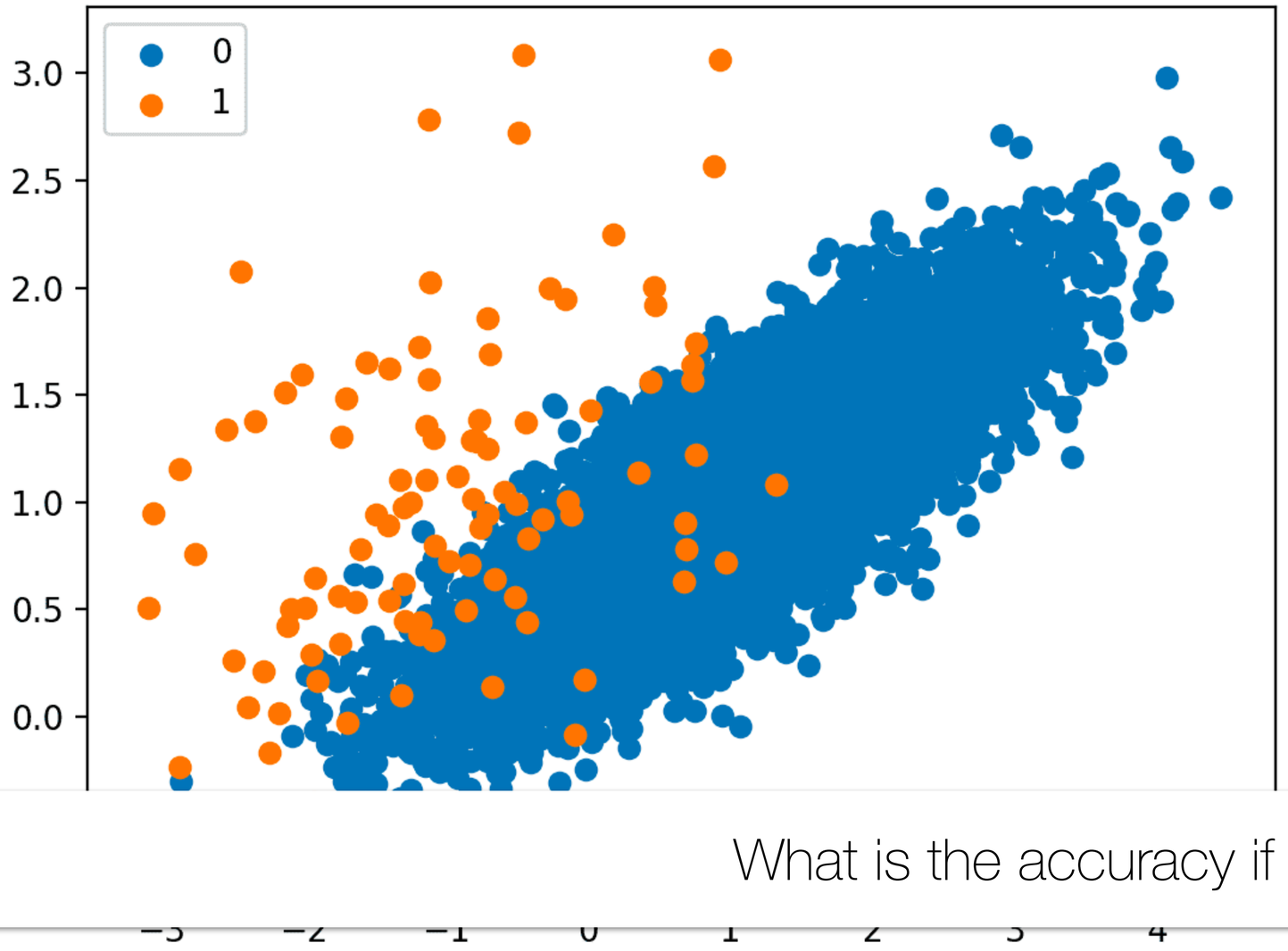

What is the accuracy if we always predict 0?

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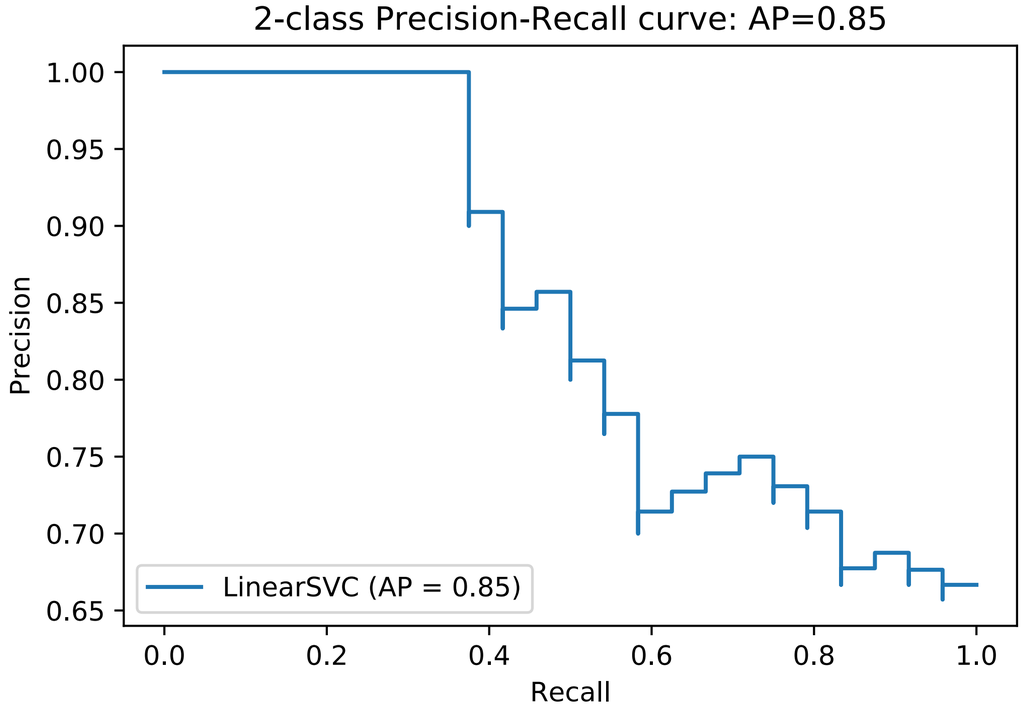
$$\text{Recall} = \frac{TP}{TP + FN}$$

What does *recall = 1.0* mean?

$$\text{Precision} = \frac{TP}{TP + FP}$$

What does *precision = 1.0* mean?

Precision-Recall Tradeoff



- Recall-oriented tasks:
  - Tumor detection
  - Legal discovery
  - (False Negatives are more costly.)
- Precision-oriented tasks:
  - Search engine ranking
  - Sentiment classification
  - Customer-facing tasks (users remember failures!)
  - (False Positives are more costly.)

Combining Precision and Recall with F-score

- $F_1 = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$
- $F_\beta = \frac{(1 + \beta^2) \times \text{Precision} \times \text{Recall}}{\beta^2 \times \text{Precision} + \text{Recall}}$
- β allows adjustment of the metric to control the emphasis on recall vs precision:
  - Precision-oriented: small β
  - Recall-oriented: large β

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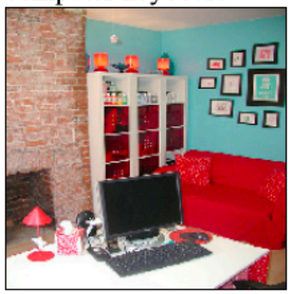
Old label: pier
ReaL: dock; pier; speedboat; sandbar; seashore

Old label: hammer
ReaL: screwdriver; hammer; power drill; carpenter's kit

Old label: monitor
ReaL: mouse; desk; desktop computer; lamp; studio couch; monitor; computer keyboard



Old label: zucchini
ReaL: broccoli; zucchini; cucumber; orange; lemon; banana

Old label: ant
ReaL: ant; ladybug

Old label: quill
ReaL: feather boa

Old label: water jug
ReaL: water bottle

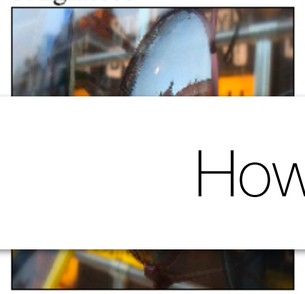
Old label: chain
ReaL: necklace

Old label: purse
ReaL: wallet

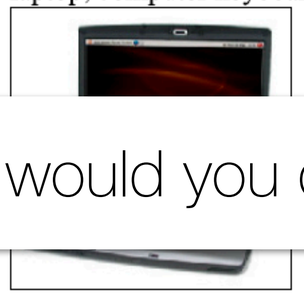
Old label: passenger car
ReaL: school bus

Old label: sunglass
ReaL: sunglass; sunglasses

Old label: sunglasses
ReaL: sunglass; sunglasses



Old label: laptop
ReaL: notebook; laptop; computer keyboard



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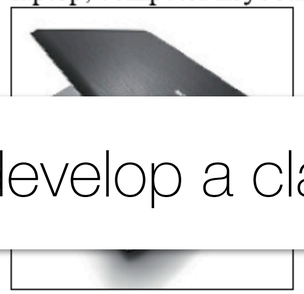
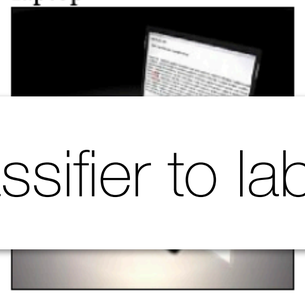
ReaL: notebook; laptop; computer keyboard



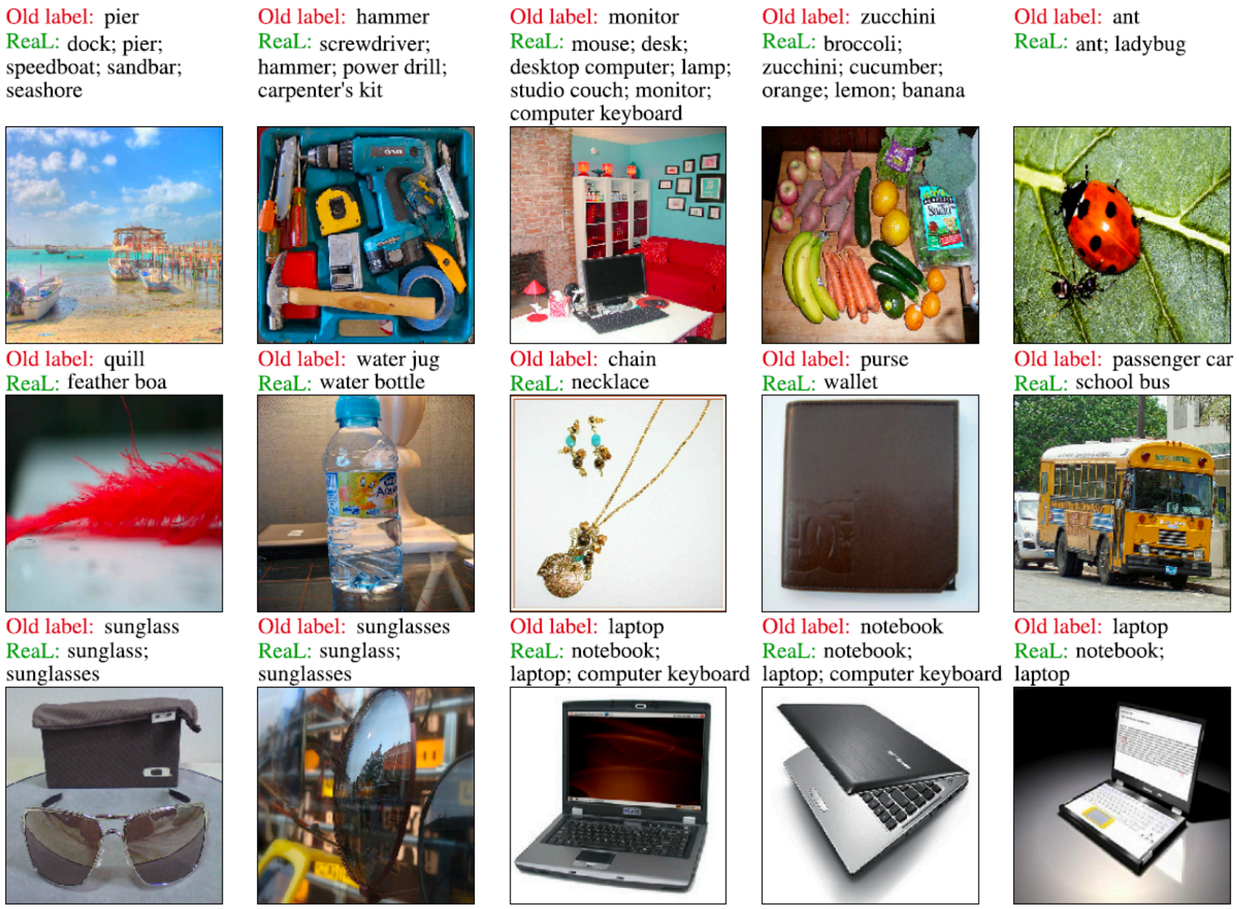
Old label: laptop
ReaL: notebook; laptop



How would you develop a classifier to label these images?

Multi-Class Classification

- An extension to binary classification
  - How are binary and multi-class different?
- Multiple ways to solve this problem:
  - Train a single classifier that supports different outcomes (e.g., decision tree)
  - Train many one-vs-rest classifiers
  - Train many more one-vs-one classifiers (for all pairs of labels)



Is this a pier (y=1) or not (y=0)?

Is this a drill (y=1) or not (y=0)?

One vs. rest strategy

Is this a monitor (y=1) or not (y=0)?

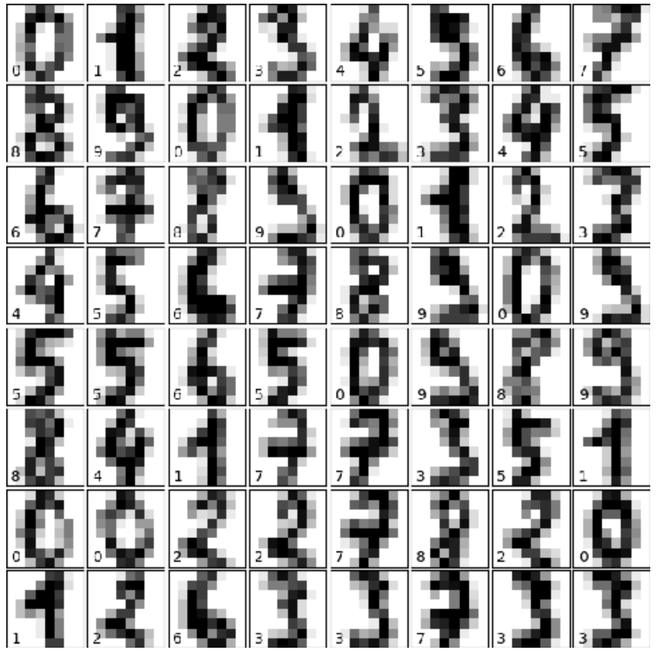
Is this a banana (y=1) or not (y=0)?

Is this a bus (y=1) or not (y=0)?

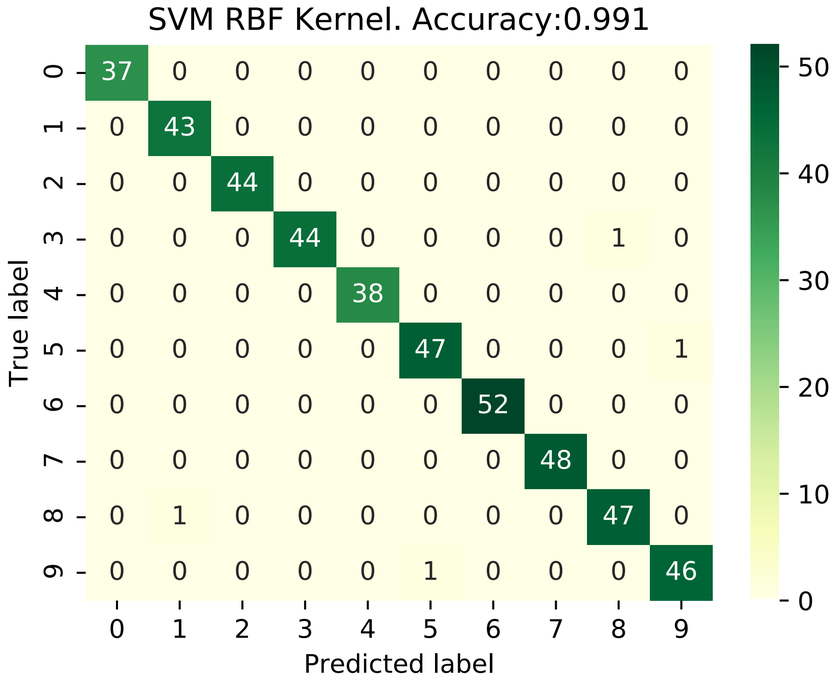
Evaluation in Multi-Class Classification

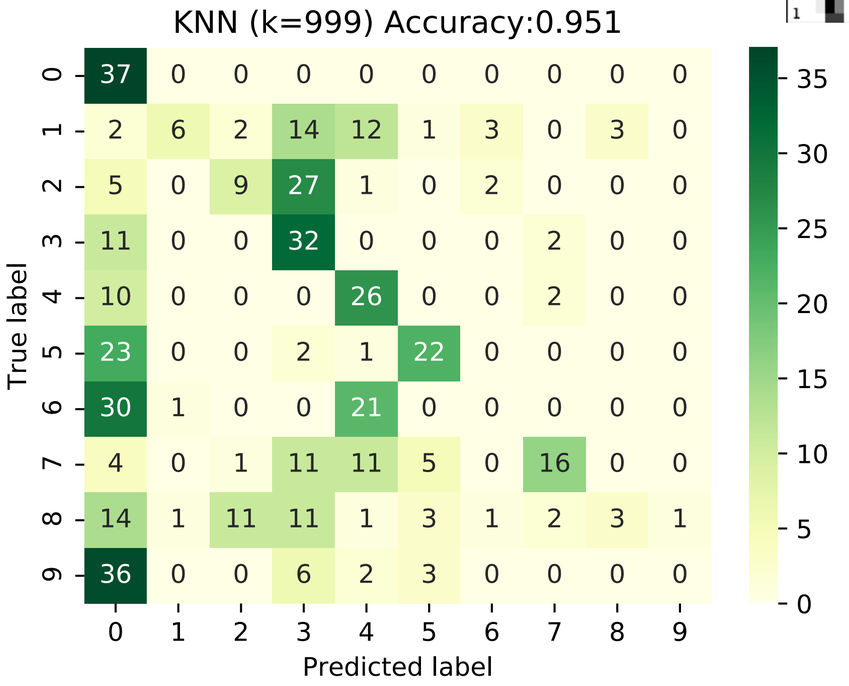
- Multi-class evaluation is an extension of the binary case
  - A collection of true vs. predicted binary outcomes, one per class
  - Confusion matrices are especially useful

Multi-Class Confusion Matrix



MNIST Dataset

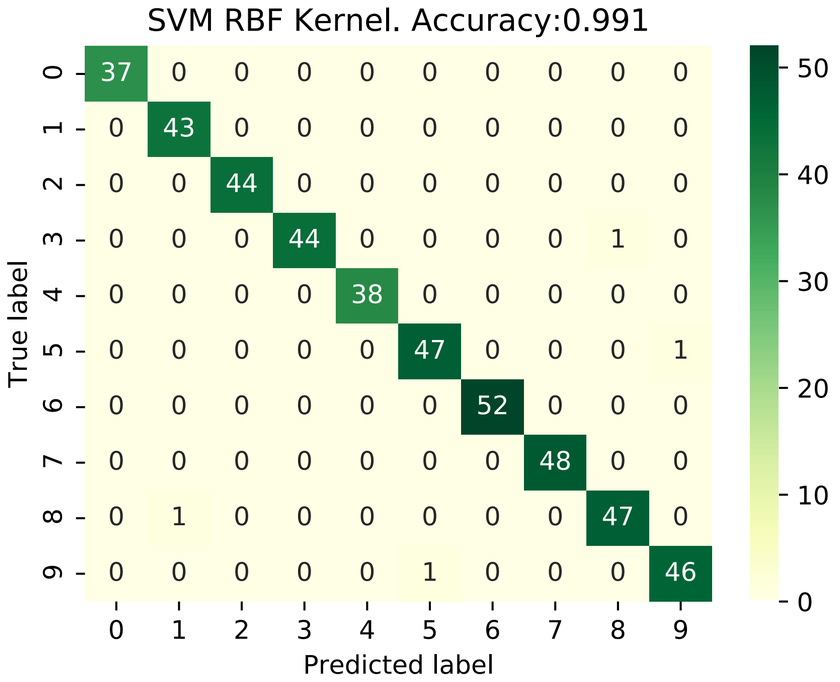




Multi-Class Classification

- Overall evaluation metrics are average across classes
  - But there are different ways to average

Average across this matrix



Micro-Average

- Each element has equal weights
  - Aggregate outcomes across all classes (count correct labels in each class)
  - Compute metric with aggregated outcomes (count correct / total count)

Class	Predicted Class	Correct?
Orange	Lemon	0
Orange	Lemon	0
Orange	Apple	0
Orange	Orange	1
Orange	Apple	0
Lemon	Lemon	1
Lemon	Apple	0
Apple	Apple	1
Apple	Apple	1

Micro Average Recall:
4 / 9 = 0.44

Largest classes have the most influence!

jupyter prediction_model_01.c /2023

Logout

File Edit View Language current mode

```
imdb_id,predicted,actual genres,correct?
tt10880158,Sci-Fi,['Comedy'],0
tt0462573,Documentary,"['Drama', 'Romance']",0
tt2160413,Adventure,['Drama'],0
tt6032704,Action,['Horror'],0
tt2198235,Documentary,"['Action', 'Crime', 'Drama']",0
tt0319829,History,"['Comedy', 'Drama', 'Music']",0
tt0206917,Reality-TV,"['Drama', 'Music', 'Romance']",0
tt6048930,Animation,"['Comedy', 'Fantasy', 'Romance']",0
tt4913966,Music,"['Horror', 'Mystery', 'Thriller']",0
tt7090140,Biography,"['Drama', 'Music']",0
tt12709774,Comedy,['Action'],0
tt1885299,Short,"['Comedy', 'Drama']",0
tt12458678,Music,"['Comedy', 'Horror']",0
tt3416742,News,"['Comedy', 'Horror']",0
tt4842646,Animation,"['Biography', 'Drama', 'History']",0
tt1374990,Reality-TV,"['Action', 'Animation', 'Drama']",0
tt0762114,Comedy,"['Comedy', 'Romance']",1
tt0251075,Western,"['Comedy', 'Sci-Fi']",0
tt15053518,War,"['Drama', 'Horror', 'Music']",0
tt14010416,Crime,['Action'],0
tt5300736,Crime,['Horror'],0
tt0396171,Musical,"['Crime', 'Drama', 'Fantasy']",0
tt4591226,Horror,['Horror'],1
tt0881913,Family,"['Drama', 'Family']",1
tt5741008,History,['Comedy'],0
tt1837569,Sport,"['Drama', 'Thriller']",0
tt1188113,Short,"['Drama', 'Thriller']",0
tt11197858,Biography,['Documentary'],0
tt1462901,Crime,"['Comedy', 'Drama']",0
tt10840042,Animation,"['Drama', 'Thriller']",0
tt10350922,Family,"['Action', 'Comedy', 'Horror']",0
tt0760329,Comedy,"['Adventure', 'Family', 'Fantasy']",0
tt0309593,Biography,"['Horror', 'Thriller']",0
tt0369436,Short,"['Comedy', 'Drama', 'Romance']",0
tt3344694,Comedy,"['Drama', 'Romance']",0
tt8589474,Adventure,"['Drama', 'Thriller']",0
tt1684558,Adventure,"['Comedy', 'Drama', 'Romance']",0
tt6405208,Romance,"['Action', 'Drama', 'Thriller']",0
tt0304912,Comedy,['Comedy'],1
tt0156376,Romance,"['Comedy', 'Romance']",1
tt0420740,Short,"['Drama', 'Thriller']",0
tt1105740,Western,['Drama'],0
tt3678656,Mystery,"['Comedy', 'Drama']",0
```

Micro-averaged accuracy: Sum“correct?” column / rows in the dataset

Why might this micro-averaging be problematic?

What happens when the classes are imbalanced?

Macro-Average

- Each class has equal weights
  - First compute metric within each class
  - Then average resulting metrics across classes

Class	Predicted Class	Correct?
Orange	Lemon	0
Orange	Lemon	0
Orange	Apple	0
Orange	Orange	1
Orange	Apple	0
Lemon	Lemon	1
Lemon	Apple	0
Apple	Apple	1
Apple	Apple	1

Class	Recall
Orange	1/5 = 0.2
Apple	2/2 = 1.0
Lemon	1/2 = 0.5

Macro Average Recall:
(0.2 + 0.5 + 1.0) / 3 = 0.57

All classes have the same influence!

Imbalance and Macro- vs. Micro-Averaging

- If each class has about the same number of instances, what happens?
  - micro-average < macro-average?
  - micro-average > macro-average?
  - micro-average ≈ macro-average?
- Why?

Imbalance and Macro- vs. Micro-Averaging

- If your data is imbalanced, and…
- You want to weight your metric toward the largest ones
  - Use micro-averaging
  - Where might you want this weighting?
- You want to weight your metric toward the smallest ones
  - Use macro-averaging
  - Where might you want this weighting?

Imbalance and Macro- vs. Micro-Averaging

- Rules of Thumb:
  - If micro-average << macro-average, then examine the larger classes.
  - If micro-average >> macro-average, then examine the smaller classes.

This Module's Learning Objectives

Evaluation in Supervised Learning

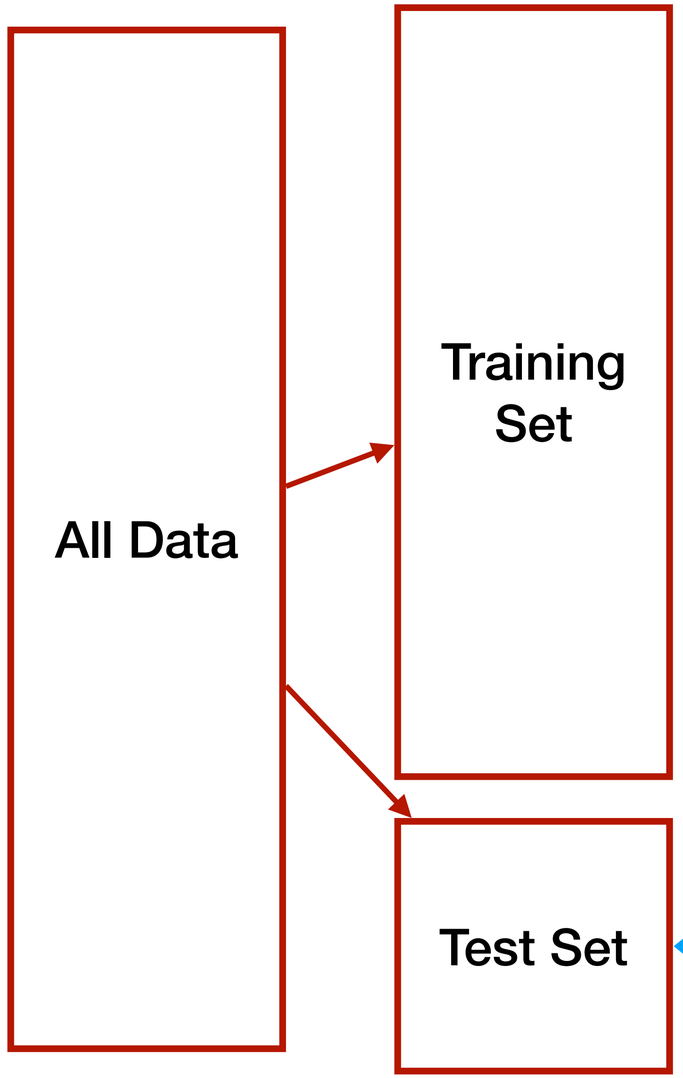
Describe why accuracy may be a poor metric for imbalanced data

Calculate precision and recall for a supervised learning model

Differentiate macro- and micro-averaging for multi-class evaluation

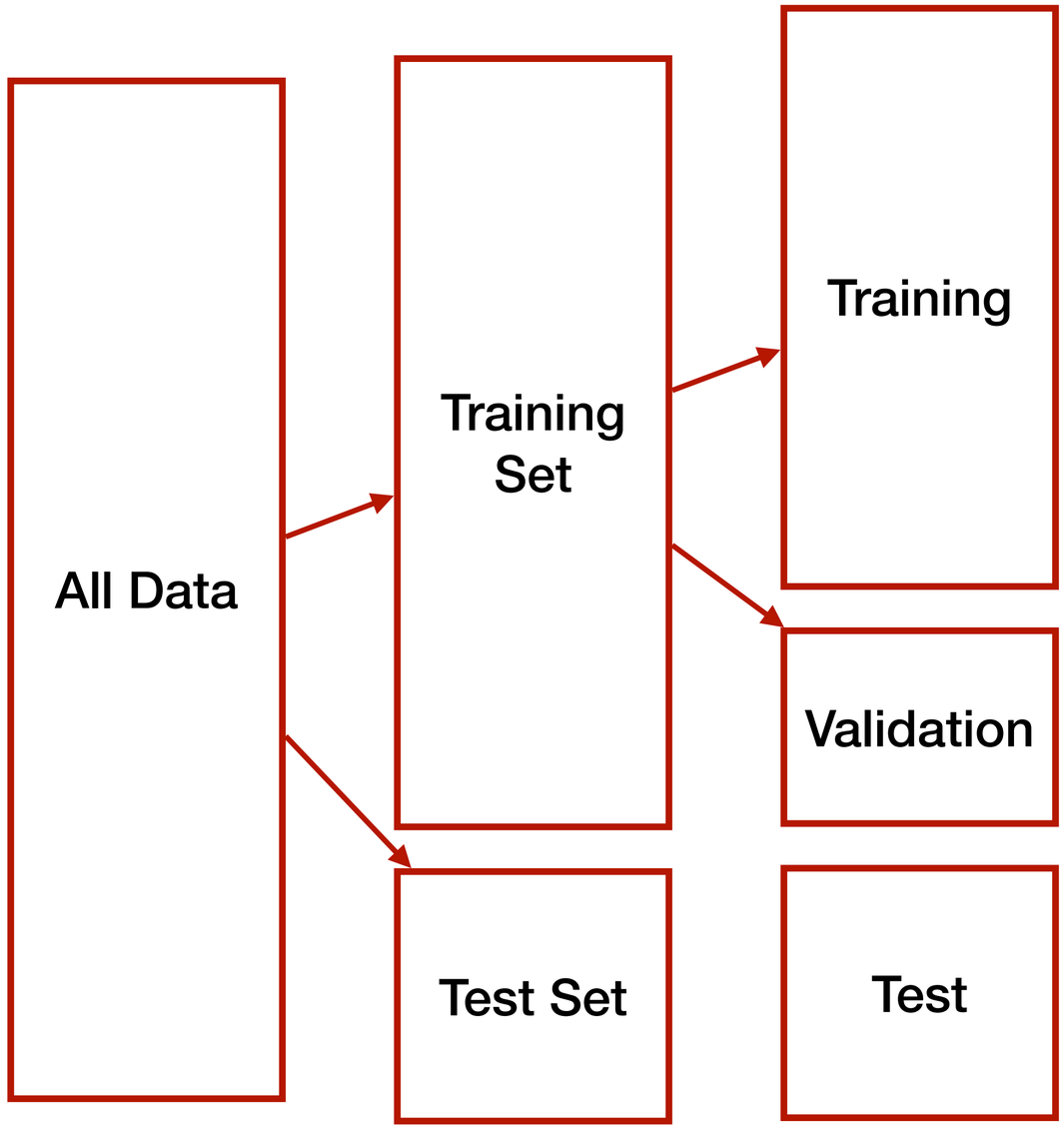
Use k-fold cross-validation to estimate average performance

Model Selection: Training-Test Split



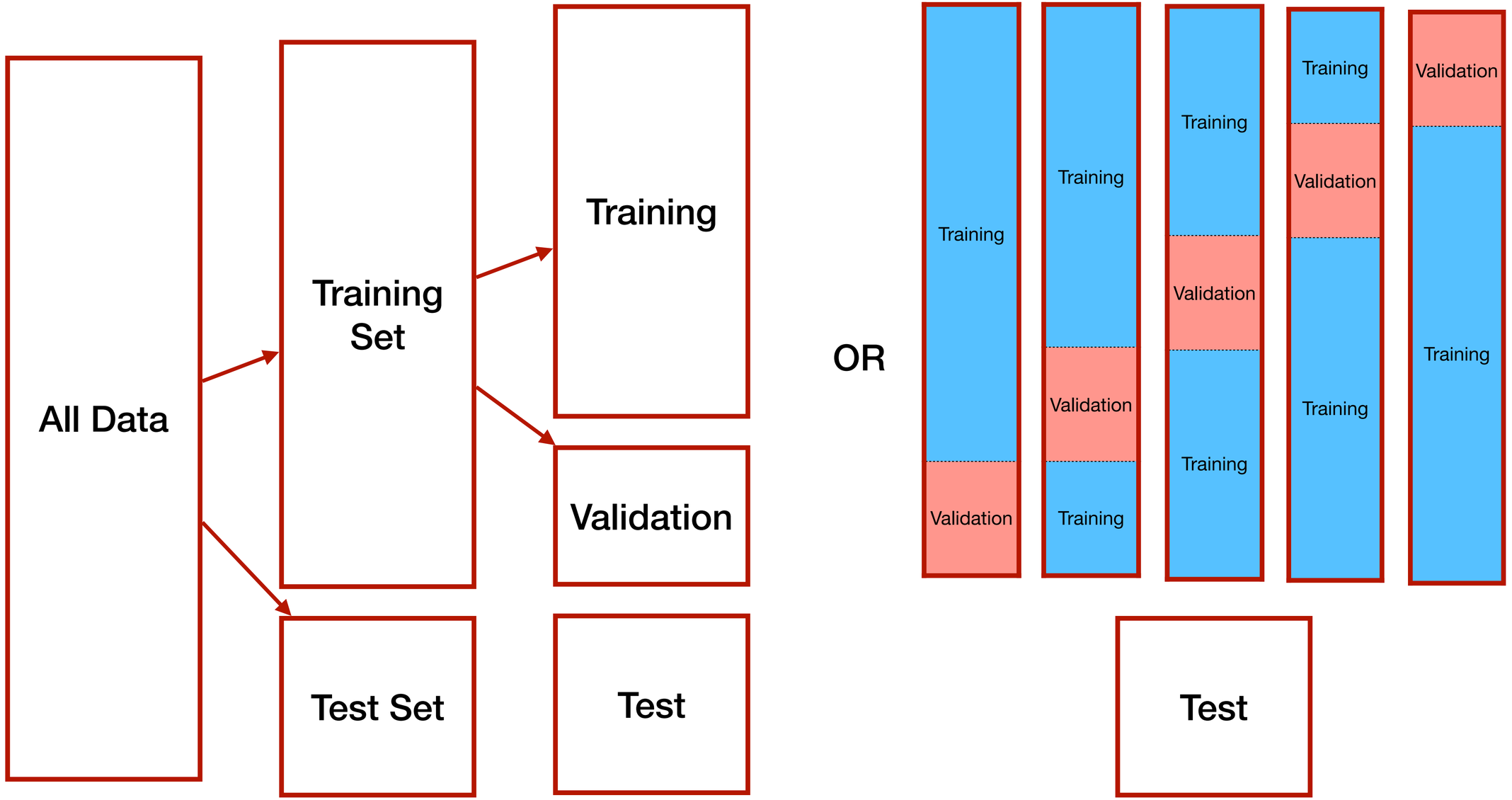
Now we lose this data from our training set… 👎

Model Selection: Training-Validation-Test Split

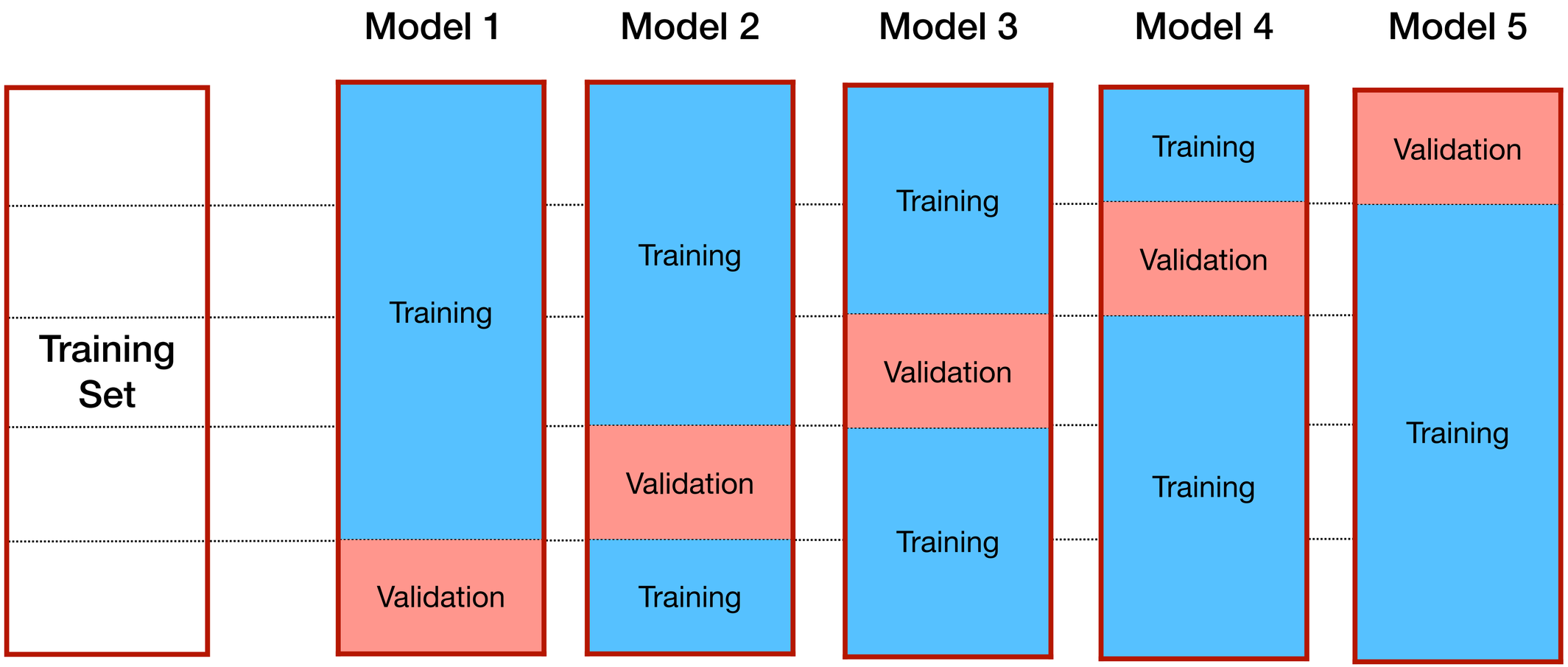


Now we lose this data from our training set… 👎

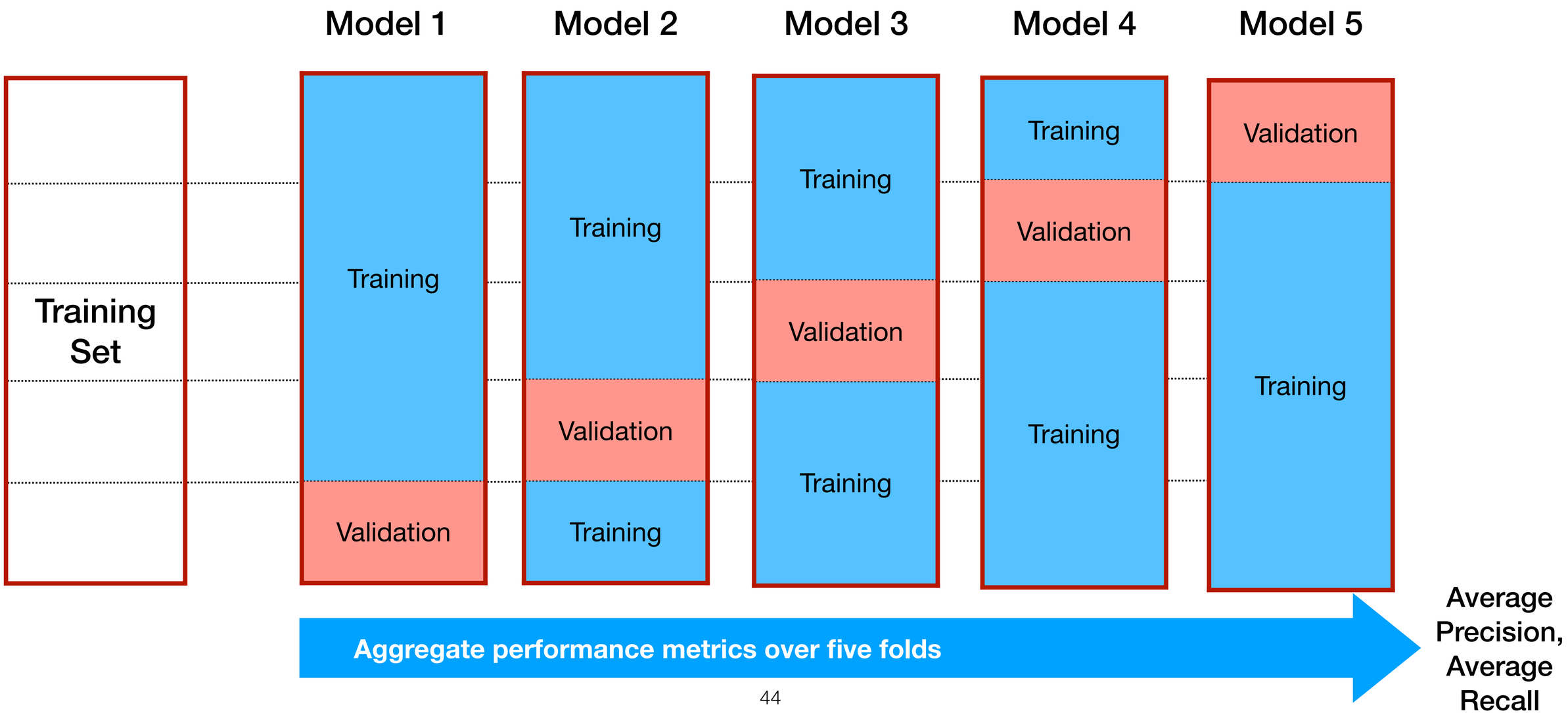
Model Selection: Training-Validation-Test Split

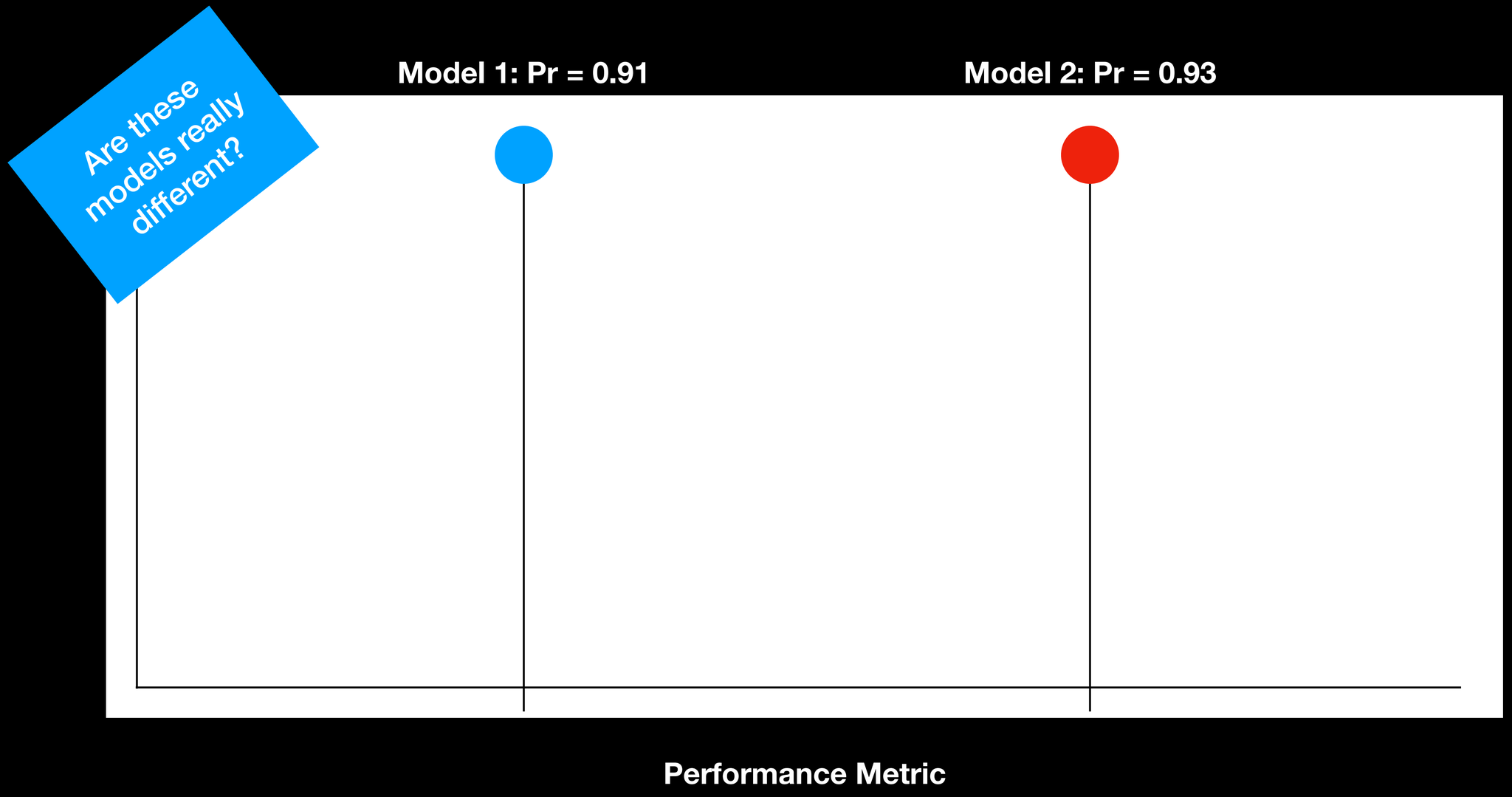


Five-fold Cross Validation

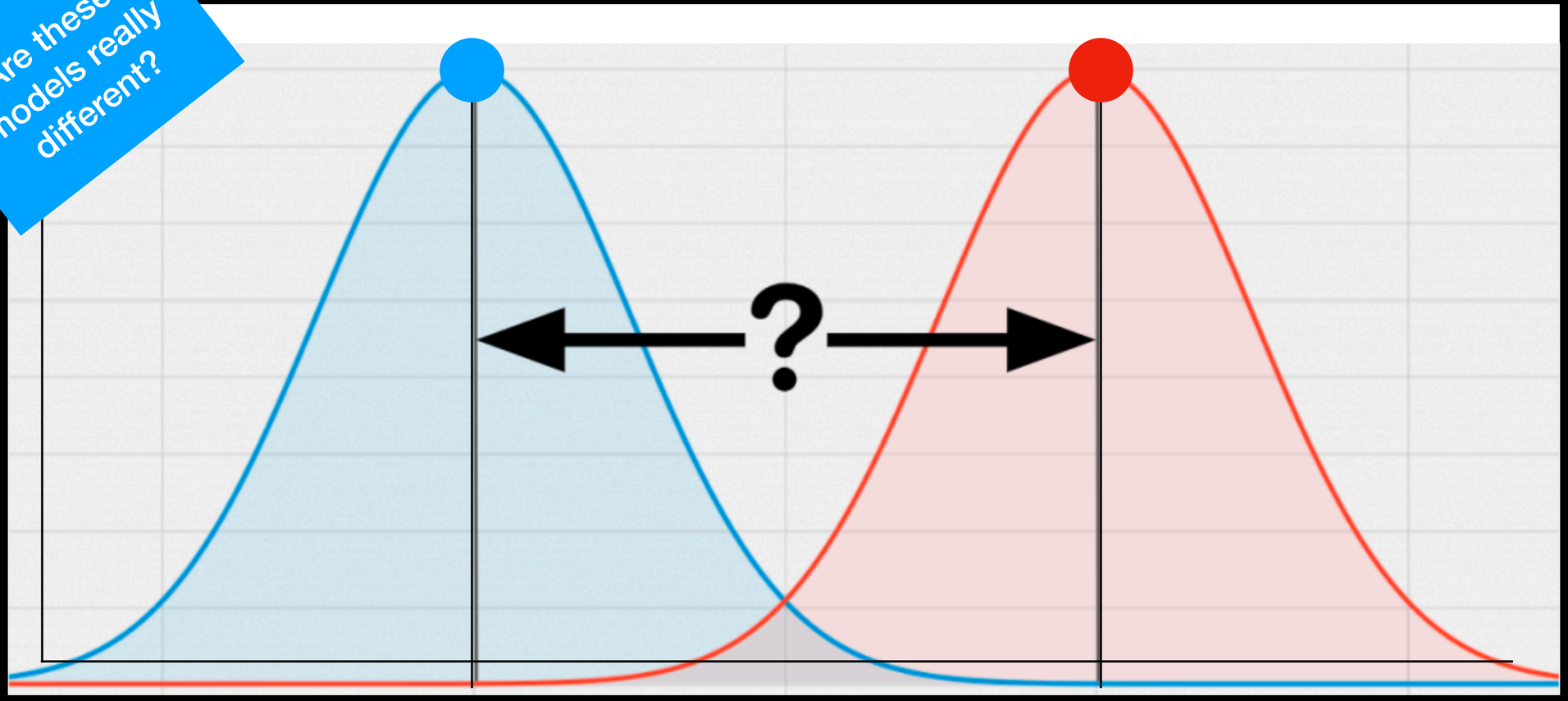


Five-fold Cross Validation

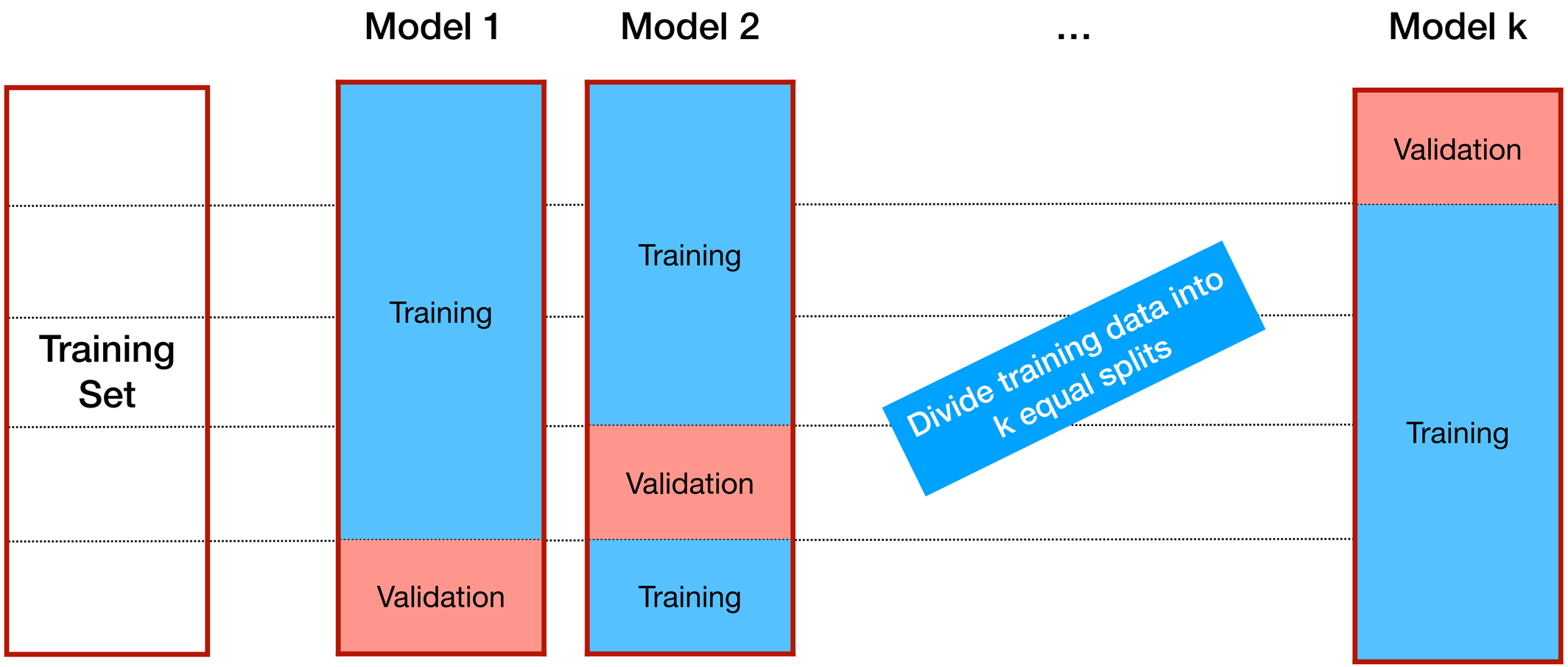



Are these models really different?
Model 1: Pr = 0.91
Model 2: Pr = 0.93
Performance Metric

Are these models really different?



k-fold Cross Validation



Concluding Notes on Model Evaluation and Selection

- Accuracy is often not the right evaluation metric for many real-world data science tasks
  - False positives and false negatives may need to be treated very differently
  - Make sure you understand the needs of your application and choose an evaluation metric that matches your application, user, or business goals

Concluding Notes on Model Evaluation and Selection

- Examples of additional evaluation methods include:
  - Learning curve: how much does accuracy (or other metric) change as a function of the amount of training data?
  - Sensitivity analysis: How much does accuracy (or other metric) change as a function of key learning parameter values?

What questions do you have?

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