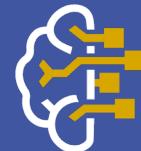


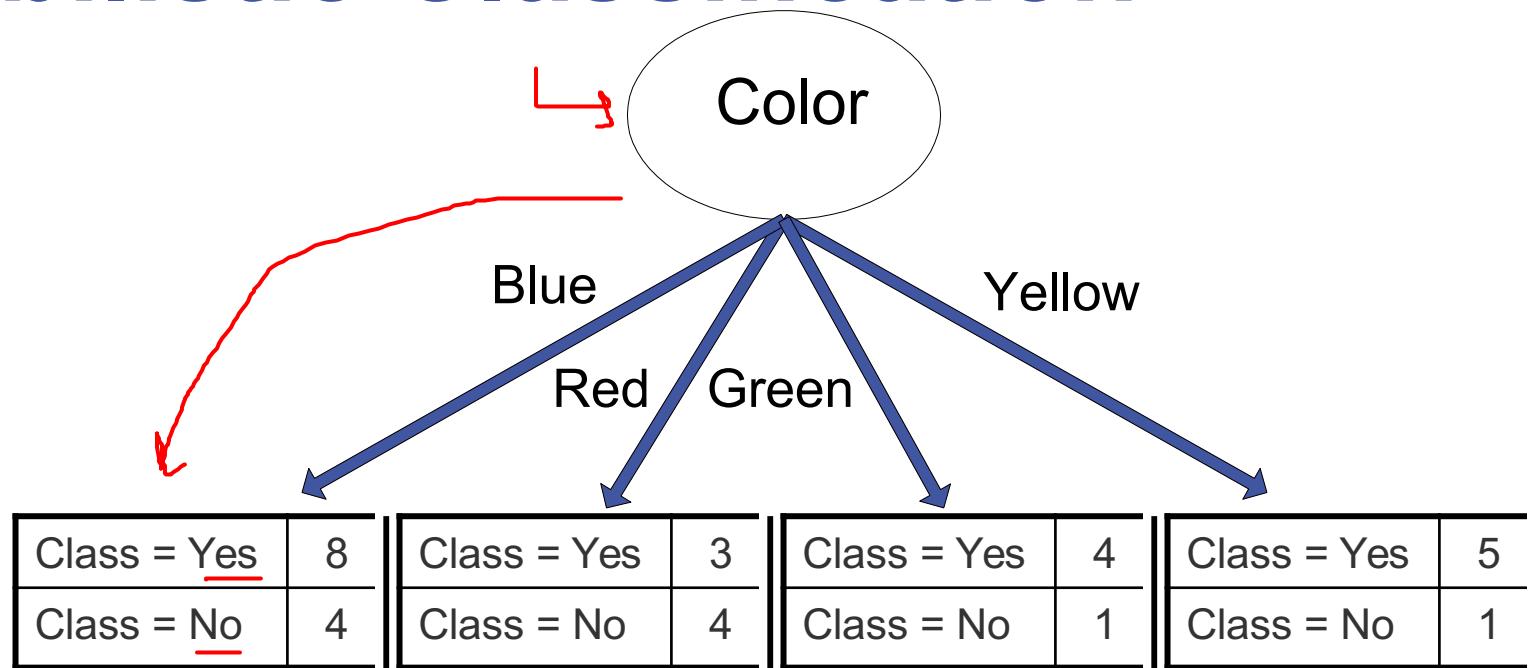
ROC Curves

Lesson



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Probabilistic Classification



What is the class of an instance with Color = Blue?

Discrete Output: since $8 > 4$, we predict "Yes"

Probabilistic Output: $P(\text{Yes}) = 8/12 = \underline{0.667}$

Probabilistic Classification

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What if our cost matrix looks like this?



Cost Matrix	PREDICTED CLASS		
ACTUAL CLASS	C(i j)	+	-
	+	0	<u>1</u>
	-	<u>100</u>	0

Should I accuse someone of stealing my lunch?

May be better to classify it as No, even though it is more likely to be yes.

Probabilistic Classification

What is the class of an instance with Color = Blue?

Discrete Output: since $8 > 4$, we predict "Yes"

Probabilistic Output: $P(\text{Yes}) = 8/12 = 0.667$

Select a threshold value T ,



Where $\underline{P(\text{Yes})} > \underline{T} \rightarrow (\text{Class} = \text{Yes})$.

We usually use $\underline{T=0.5}$, but this may not be optimal.

ROC (Receiver Operating Characteristic)

- Developed in the 1950s for signal detection theory.
- ROC curve plots TP-Rate (on the y-axis) against FP-Rate (on the x-axis).
- Performance of the classifier at each value of T is a point on the ROC curve.

TPR and FPR

		PREDICTED CLASS	
ACTUAL CLASS		Class=Yes	Class>No
	Class=Yes	a (TP)	b (FN)
	Class>No	c (FP)	d (TN)

*Of all the lunch-stealers,
how many did I catch?*

$$\underline{\text{TPR}} = \frac{TP}{TP + FN} = \underline{\text{Recall}} = \underline{\text{Sensitivity}}$$

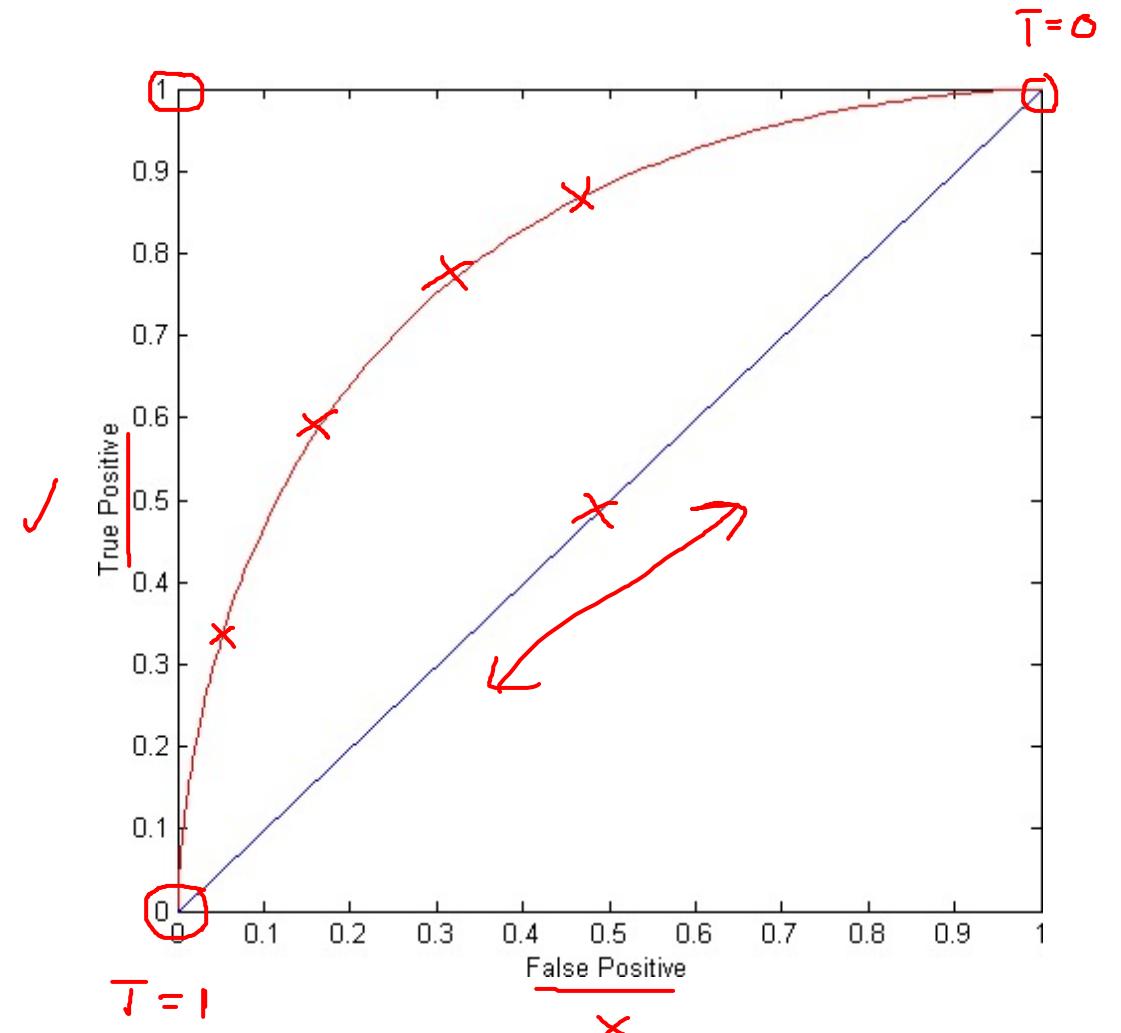
*Of all the innocent people,
how many did I wrongly
accuse?*

$$\underline{\text{FPR}} = \frac{FP}{FP + TN}$$



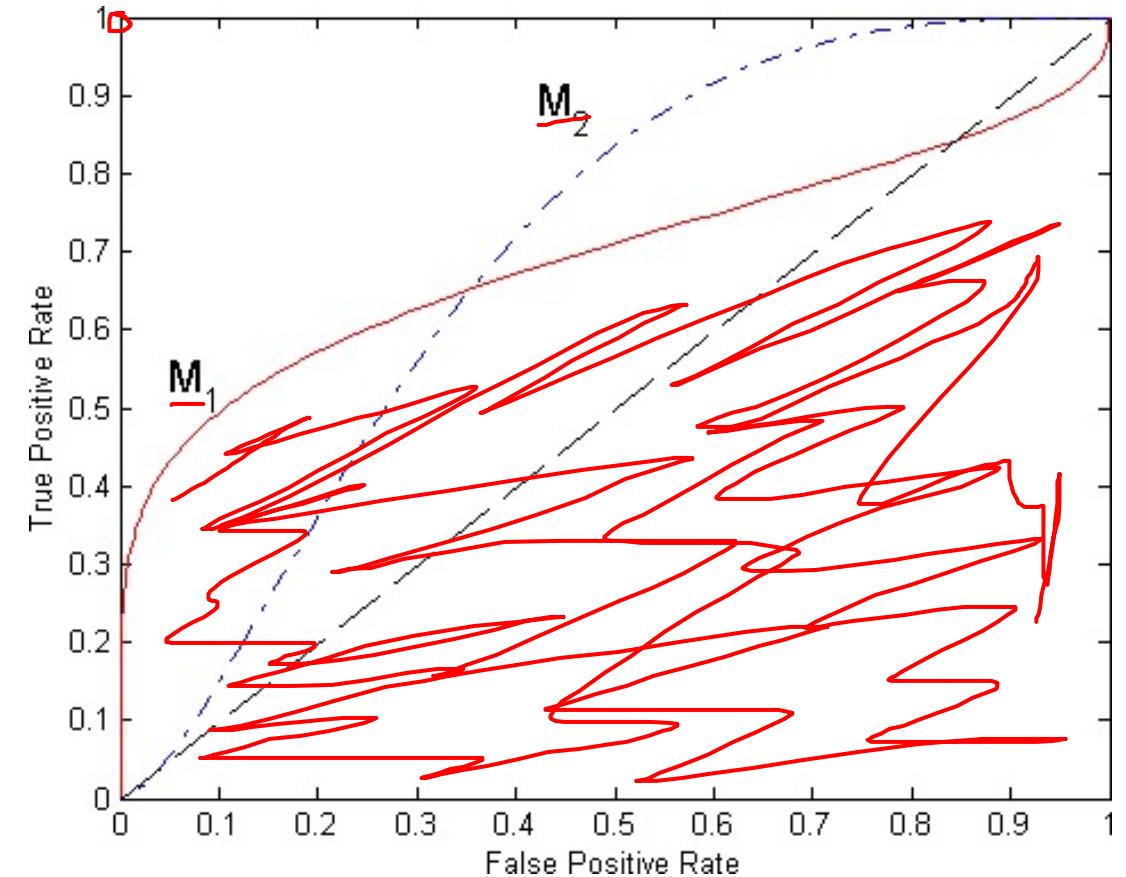
ROC Curve

- (0,0): Declare everything to be a negative class
- (1,1): Declare everything to be positive class
- (0,1): Ideal
- Diagonal line:
 - Random guessing
- Below diagonal line
 - Worse than random



Using ROC for Model Comparison

- Neither model consistently outperforms the other:
 - M_1 is better for small FPR (high T).
 - M_2 is better for large FPR (low T).
- Area Under the ROC Curve (AUC)
 - Compare any models.
 - Ideal: Area=1.
 - Random guess: Area=0.5.



How to Construct an ROC curve

Instance	$P(+ A)$	True Class
1	0.95	+
2	0.93	+
3	0.87	-
4	0.85	-
5	0.85	-
6	0.85	+
7	0.76	-
8	0.53	+
9	0.43	-
10	0.25	+

- Use a classifier that produces probability $P(+|A_i)$ for each test instance i .
- Sort the instances according to $P(+| A_i)$ in decreasing order.
- Create a point for each unique value of $P(+| A_i)$
- Count the number of TP, FP, TN, FN at $T = P(+| A_i)$
- TP rate, $TPR = TP/(TP+FN)$
- FP rate, $FPR = FP/(FP + TN)$
- Plot a point at (TP, FP)

	P(+ A)	
1	0.95	+
2	0.93	+
3	0.87	-
4	0.85	-
5	0.85	-
6	0.85	+
7	0.76	-
8	0.53	+
9	0.43	-
10	0.25	+

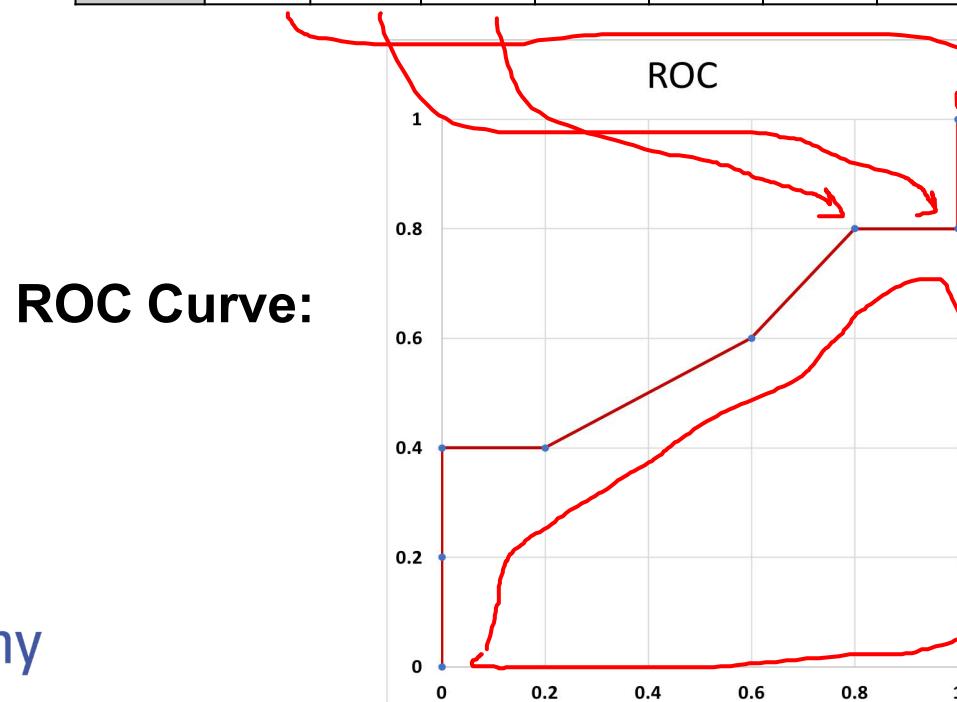
	+	-	+	-	+	-	+	+	
↳	0.25	0.43	0.53	0.76	0.85	0.87	0.93	0.95	1.00
TP	5	4	4	3	3	2	2	1	0
FP	5	5	4	4	3	1	0	0	0
TN	0	0	1	1	2	4	5	5	5
FN	0	1	1	2	2	3	3	4	5
TPR	1	0.8	0.8	0.6	0.6	0.4	0.4	0.2	0
FPR	1	1	0.8	0.8	0.6	0.2	0	0	0

$$TPR = \frac{TP}{TP + FN}$$

$$FPR = \frac{FP}{FP + TN}$$

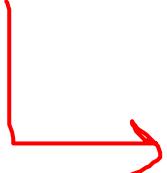
How to construct an ROC curve

Class	+	-	+	-	+	-	+	+	
Threshold >=	0.25	0.43	0.53	0.76	0.85	0.87	0.93	0.95	1.00
TP	5	4	4	3	3	2	2	1	0
FP	5	5	4	4	3	1	0	0	0
TN	0	0	1	1	2	4	5	5	5
FN	0	1	1	2	2	3	3	4	5
TPR	1	0.8	0.8	0.6	0.6	0.4	0.4	0.2	0
FPR	1	1	0.8	0.8	0.6	0.2	0	0	0



Which Metrics to Report?

Table 1: Grading accuracy, precision, recall, area under ROC curve (AUC), F-1 Score for code2vec.



Metric	Majority	SVM	NN	code2vec
Accuracy	63.95%	69.67%	71.71%	75.66%
Precision	0	61.68%	62.74%	67.06%
Recall	0	42.21%	58.30%	72.66%
AUC	0.5	0.650	0.689	0.814
F1	0	0.460	0.593	0.6895

All of them (or most of them)!

Learning Objectives:

ROC/AUC

You now should be able to:

- Use an ROC curve to compare and evaluate classifiers, and identify when to use ROC curves.



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ROC Curves

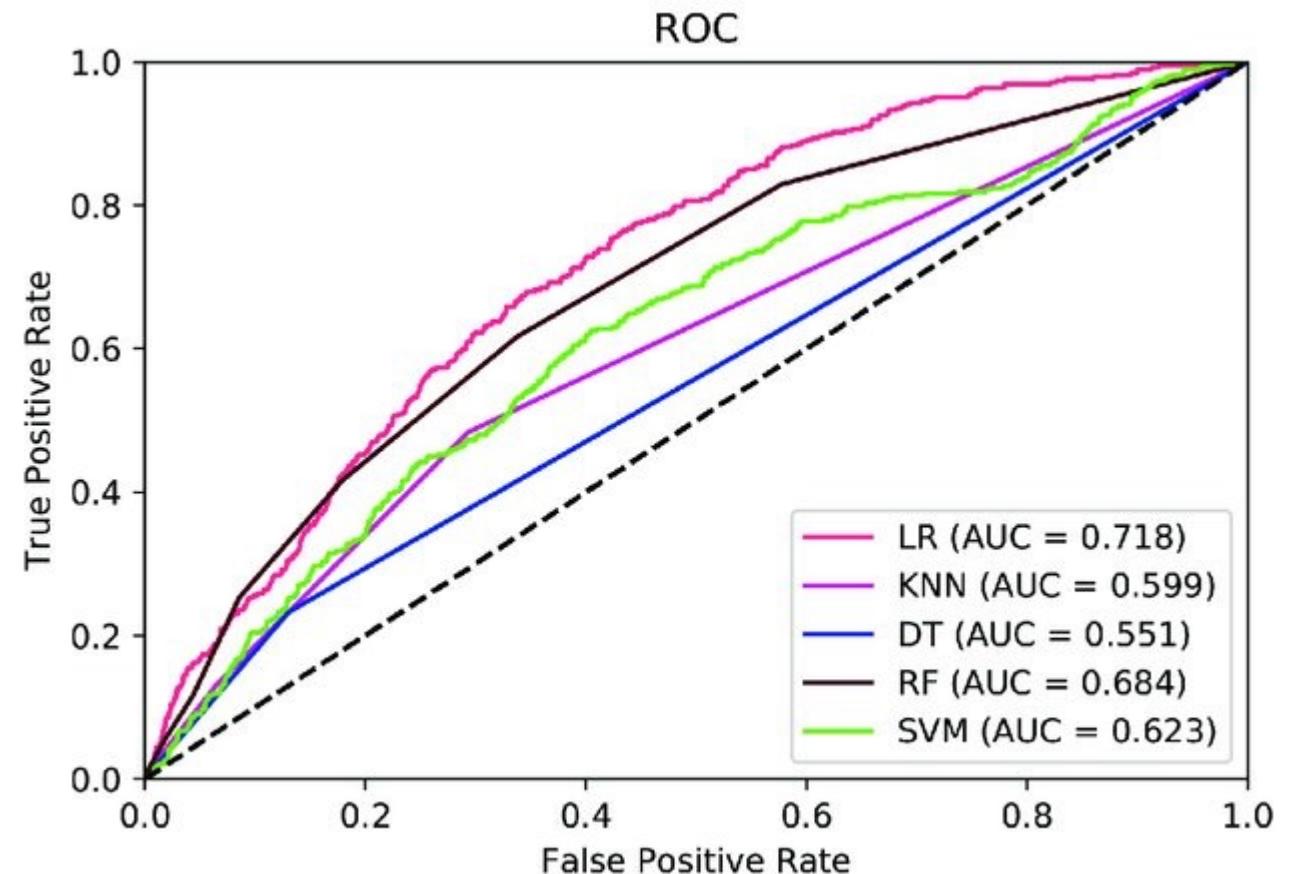
Exercises

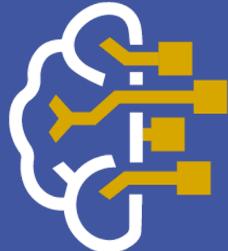


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ROC Exercise

- The following figure compares 5 models by plotting their ROC curves: Logistic Regression (LR), K-nearest-neighbor (KNN), Decision Tree (DT), Random Forest (RF) and Support Vector Machine (SVM). It also shows the AUC for each one. Which of the following can we conclude? **Select all the apply.**





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