Classification Metrics

CS109A Introduction to Data Science

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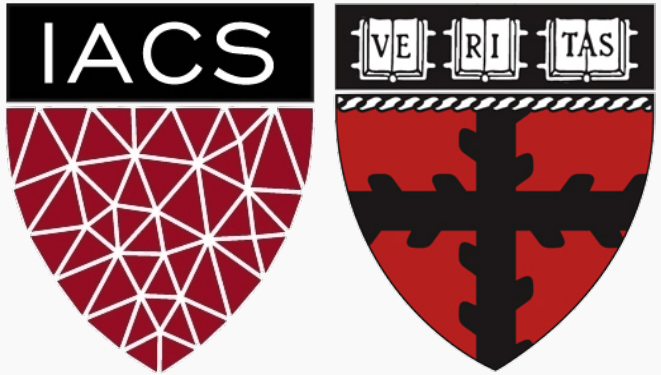


Approach #1: Dry definitions

Classification Metrics

$$P(D+|T+) = \frac{P(T+|D+)P(D+)}{P(T+|D+)P(D+) + P(T+|D-)P(D-)}$$

- *Sensitivity*: $P(T+|D+)$
- *Specificity*: $P(T-|D-)$
- *Prevalence*: $P(D+)$
- *Positive Predictive Value*: $P(D+|T+)$
- *Negative Predictive Value*: $P(D-|T-)$

D + - Disease
D - - Doesn't have disease

		predicted condition		
	total population	prediction positive	prediction negative	Sensitivity
true condition	condition positive	True Positive (TP)	False Negative (FN) (Type II error)	**Recall =** $\frac{\sum TP}{\sum \text{condition positive}}$
	condition negative	False Positive (FP) (Type I error)	True Negative (TN)	**Specificity =** $\sum TN / \sum \text{condition negative}$
	Accuracy = $\frac{\sum TP + \sum TN}{\sum \text{total population}}$	**Precision=** $\frac{\sum TP}{\sum \text{prediction positive}}$		**F1 Score =** $\frac{2}{\frac{1}{\text{Recall}} + \frac{1}{\text{Precision}}}$

THE END

Approach #2: Case Study

Covid Case Study

- At the peak of the pandemic, many nations with poor healthcare were running short of hospital beds to admit patients.
- Hospital authorities had to take a call on who to admit and who to send home.
- What if we could build a classifier that suggests whether the patient should be immediately admitted to the hospital or sent home ?

Pan-India-survey: 'Only 4% Covid patients who needed ICU bed able to get it through routine process'

LocalCircles, a community social media platform that enables people and small businesses to escalate issues for policy and enforcement interventions, decided to conduct a survey to get the pulse on the issue, and received over 17,000 responses from over 211 districts across India

Written by **Anuradha Mascarenhas** | Pune | September 21, 2020 4:34:22 am

Who should get medical attention first ?

Covid case study

ISSUES?

This analysis is for **educational** purpose only

- The data is sourced by online forms and thus is of questionable source.
- A lot of missing values in the original dataset are simply ignored for simpler analysis.
- The entire premise of predicting urgency `of admission` is false because some people had to wait longer to be admitted because of lack of hospital beds & resources.

Covid case-study

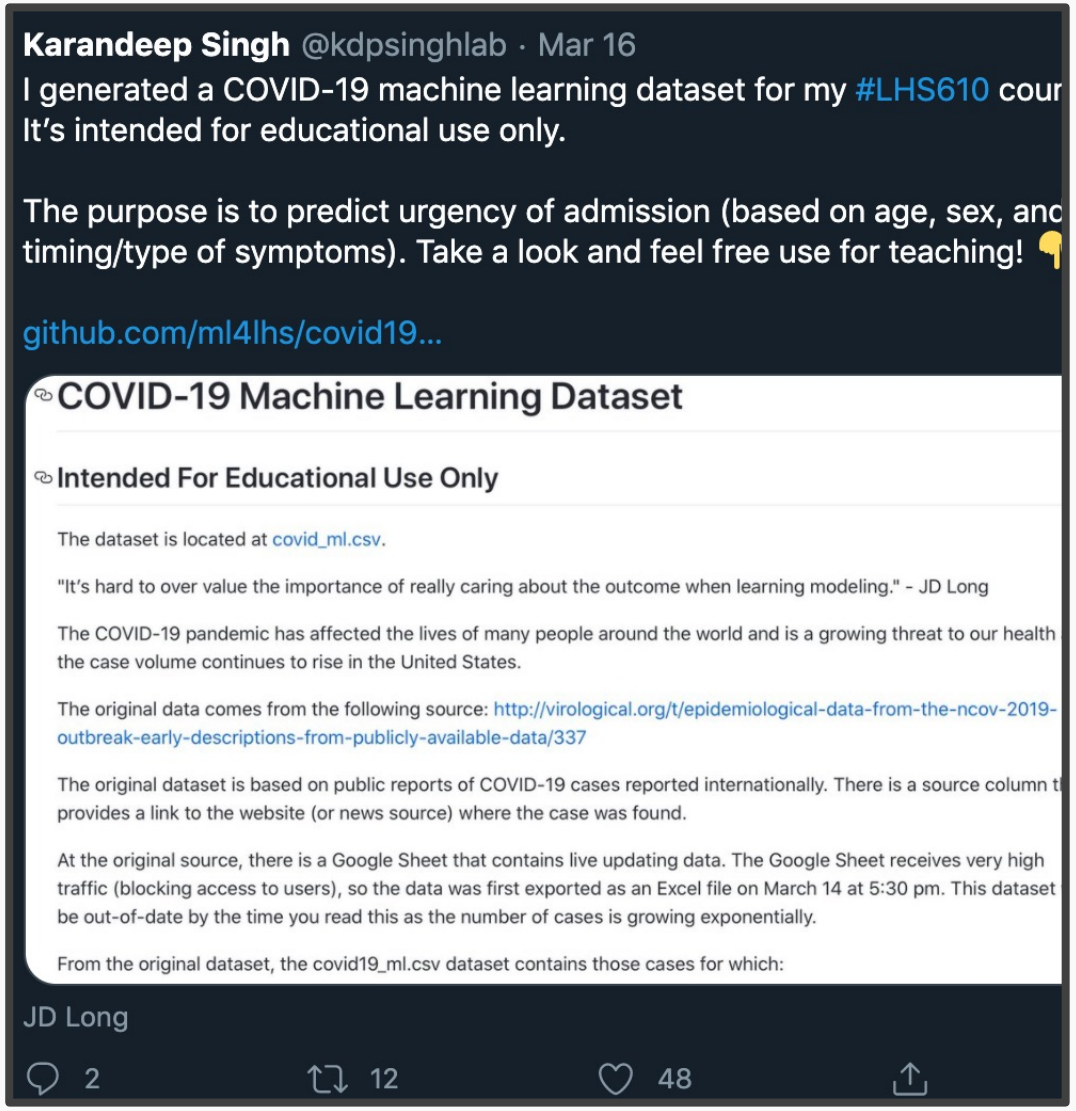
Primary predictors

- **age** (if an age range was provided in the source data, only the first number is used)
- **sex**
- **cough**, **fever**, **chills**, **sore throat**, **headache**, **fatigue**

Outcomes

Classification: `urgency_of_admission`

- 0-1 days from onset of symptoms to admission -> **High**
- 2+ days from onset of symptoms to admission *or* no admission -> **Low**



Scenario #1 - Brazil

BRAZIL

- The new covid variant is contagious and infecting many Brazilians.
- Brazilian officials however dictate that hospitals do not classify many people at 'high' risk to avoid bad press and subsequent political global backlash.
- In numbers we need the best classifier with the following restriction.

$$TPR + FPR \leq 0.5$$

Brazil accused of hiding data on coronavirus crisis

Bolsonaro government stops counting total cases and deaths as country becomes global pandemic hotspot

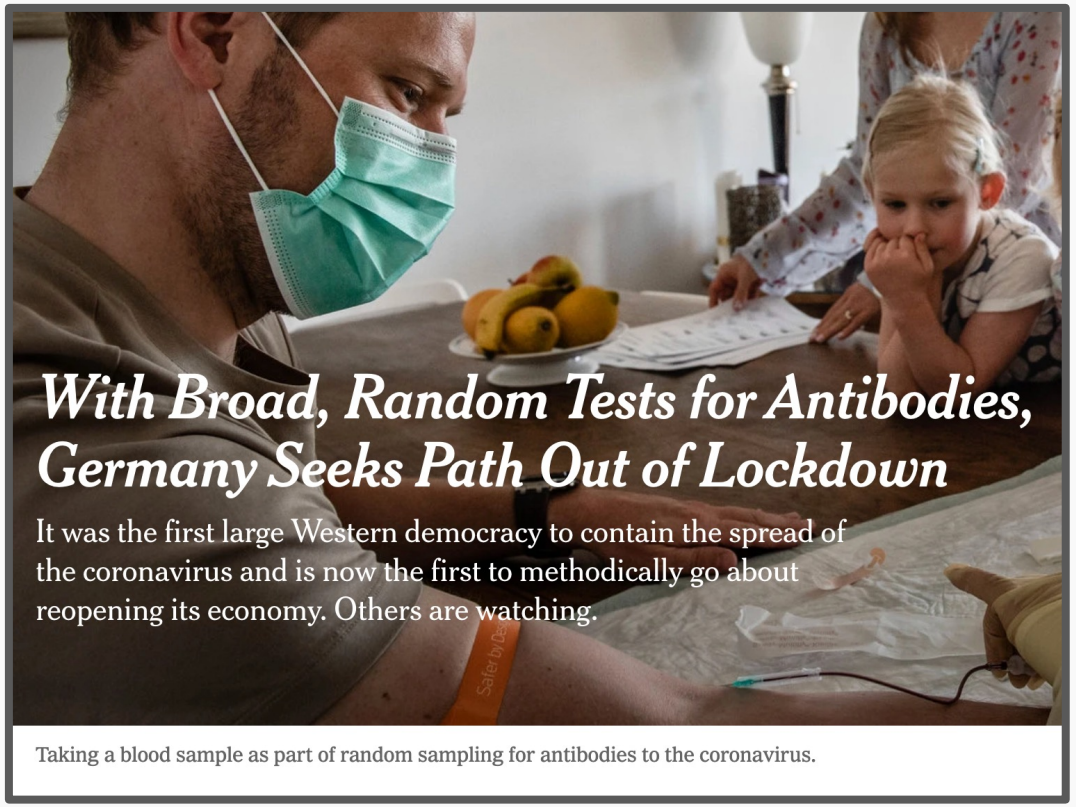
People in Brasília hold flares during a demonstration against president Jair Bolsonaro and racism, and in support of democracy, on Sunday © REUTERS

Scenario #2 - Germany

GERMANY

- German officials want the fatality ratio to be as less as possible.
- Thus, it is imperative to find cases in need of urgent attention and give them the best chance of survival.
- In numbers we need the best classifier with the following restriction.

$$TPR \geq 0.85$$



Scenario #3 - India

INDIA

- India has only 1 million beds left, and there are already 2 million people suspected of having the disease
- The officials need to work out a strategy to find the people at most need of urgent
- In numbers we need the best classifier with the following restriction

$$TPR + FPR \leq 1$$

Two models

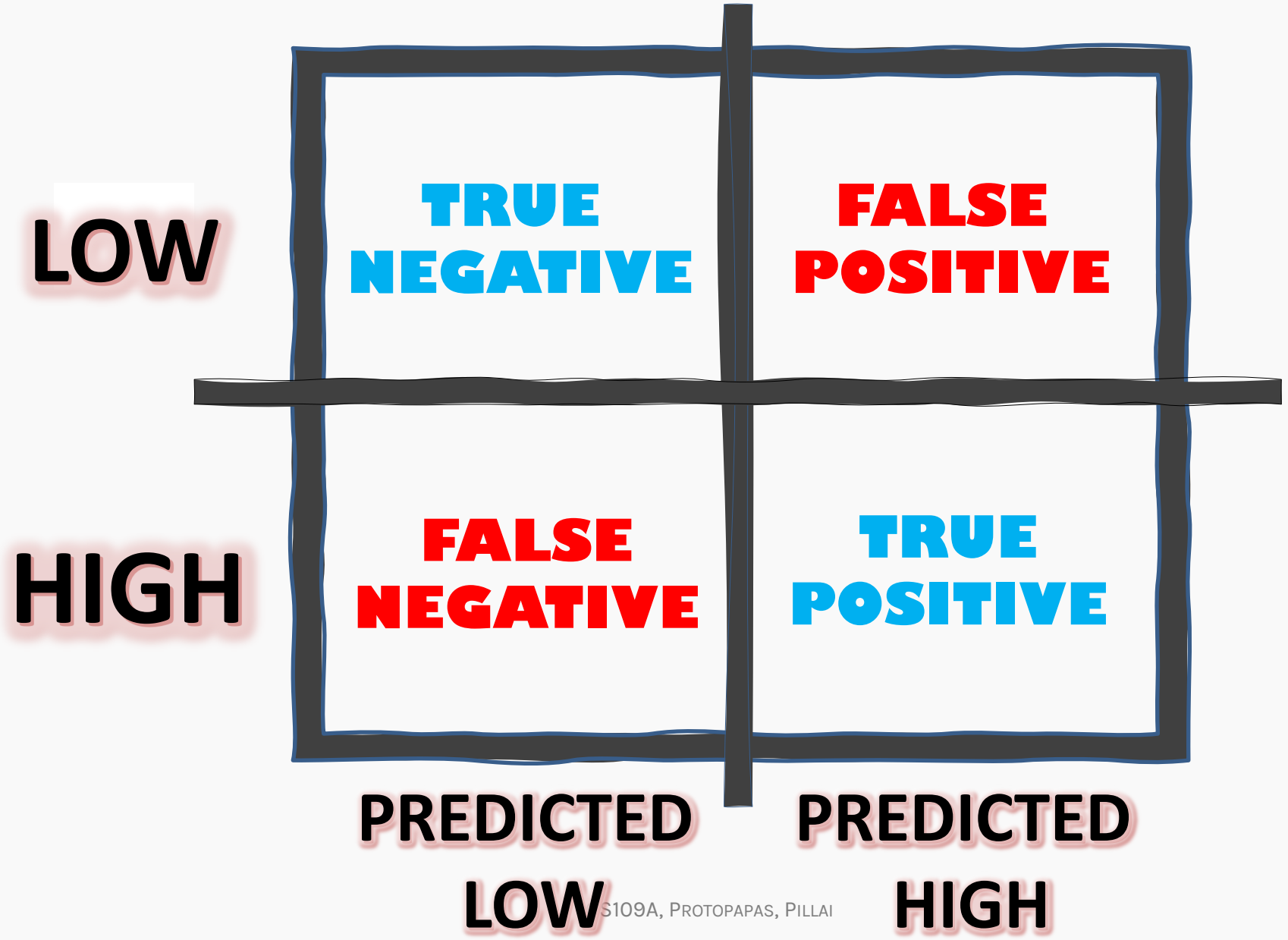
Logistic Regression

kNN Classification

Model Comparison – Logistic vs kNN

Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy			
Sensitivity (Recall)			
Specificity			
Precision			
F1 score			

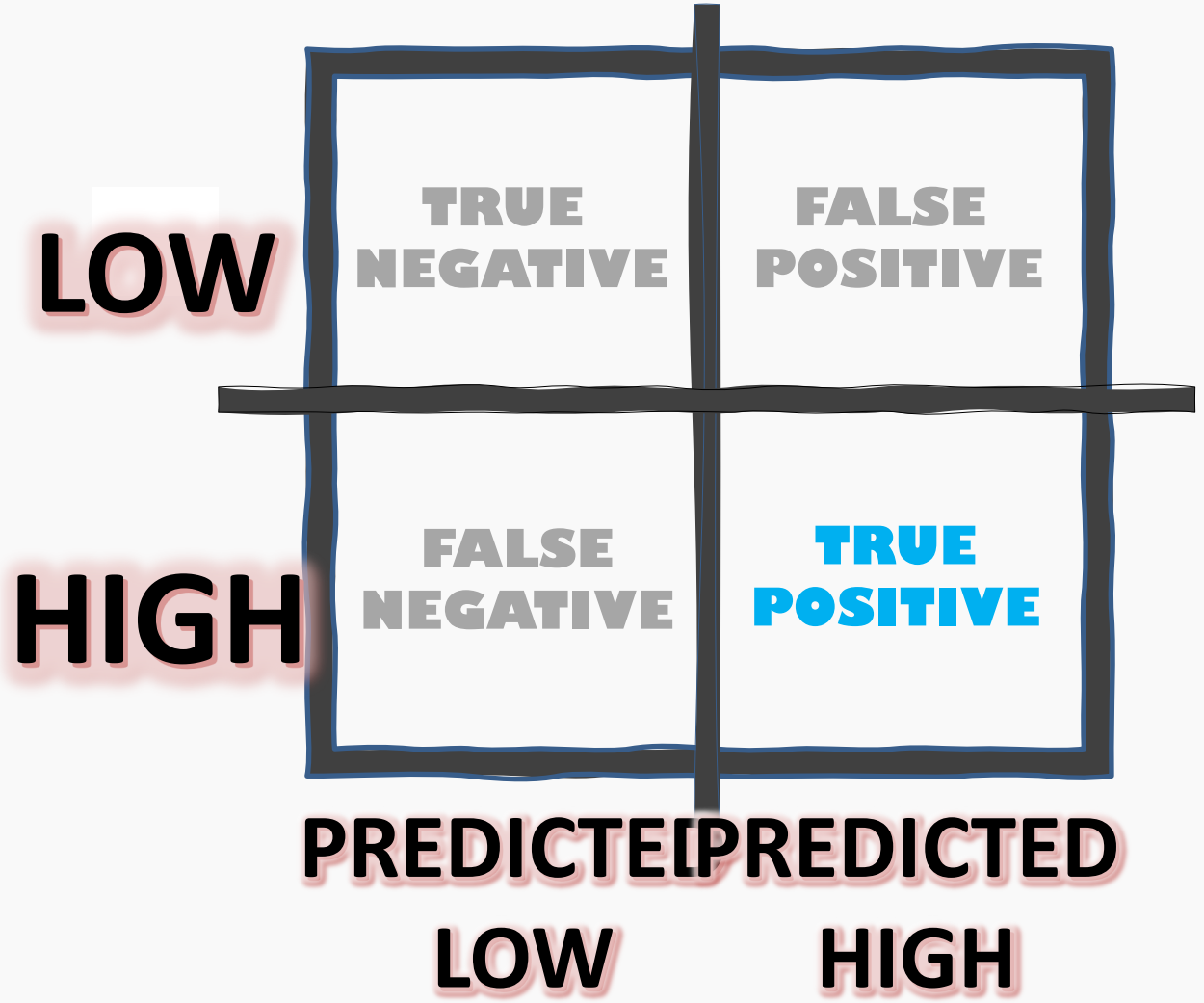
The 'Confusion' Matrix



The 'Confusion' Matrix

TRUE POSITIVE (TP)

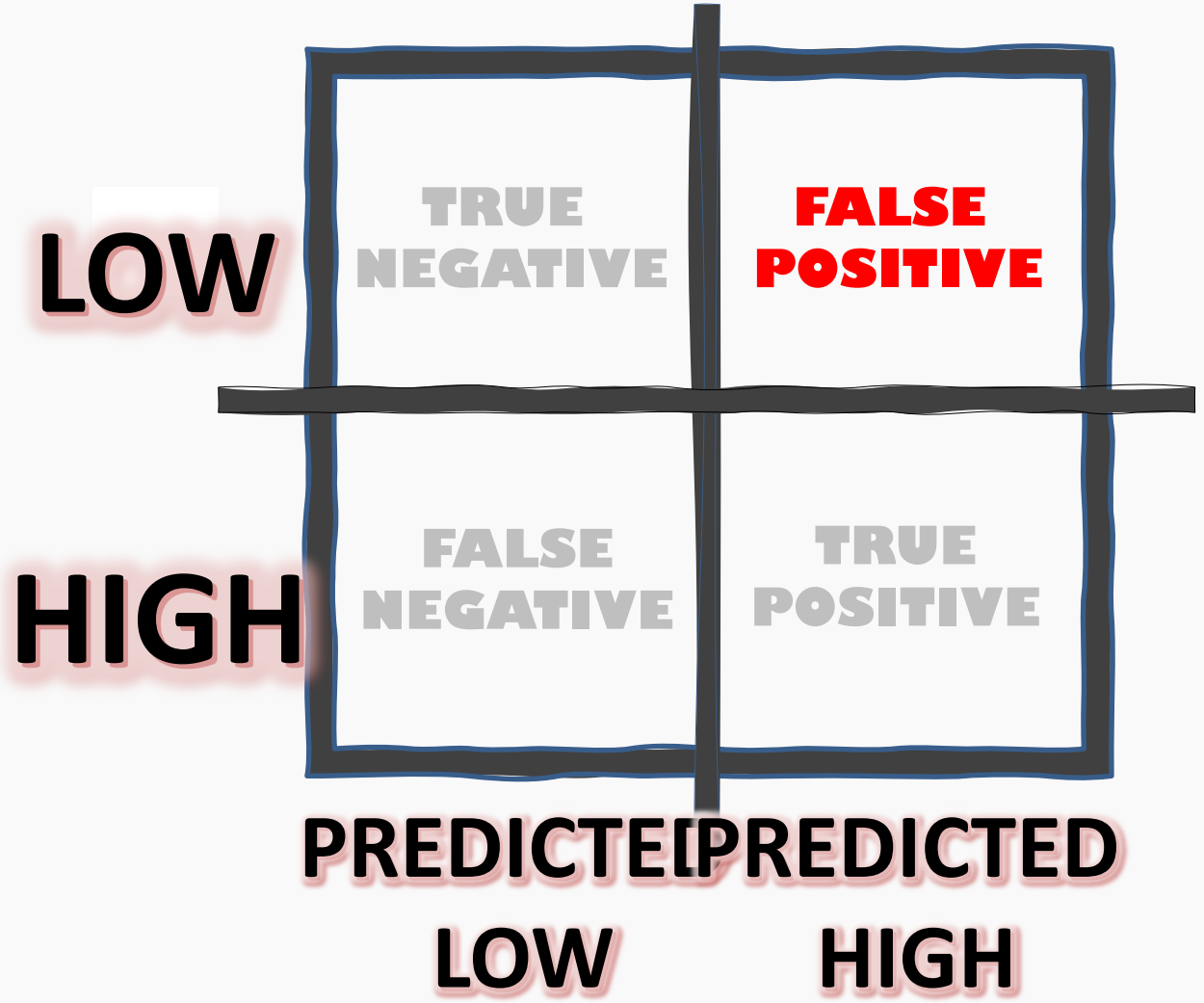
- Samples that are positive and the classifier predicts them as positive are called True Positives.
- For eg. a positive Covid test result would be a TRUE POSITIVE if you actually have Covid.



The 'Confusion' Matrix

FALSE POSITIVE (FP)

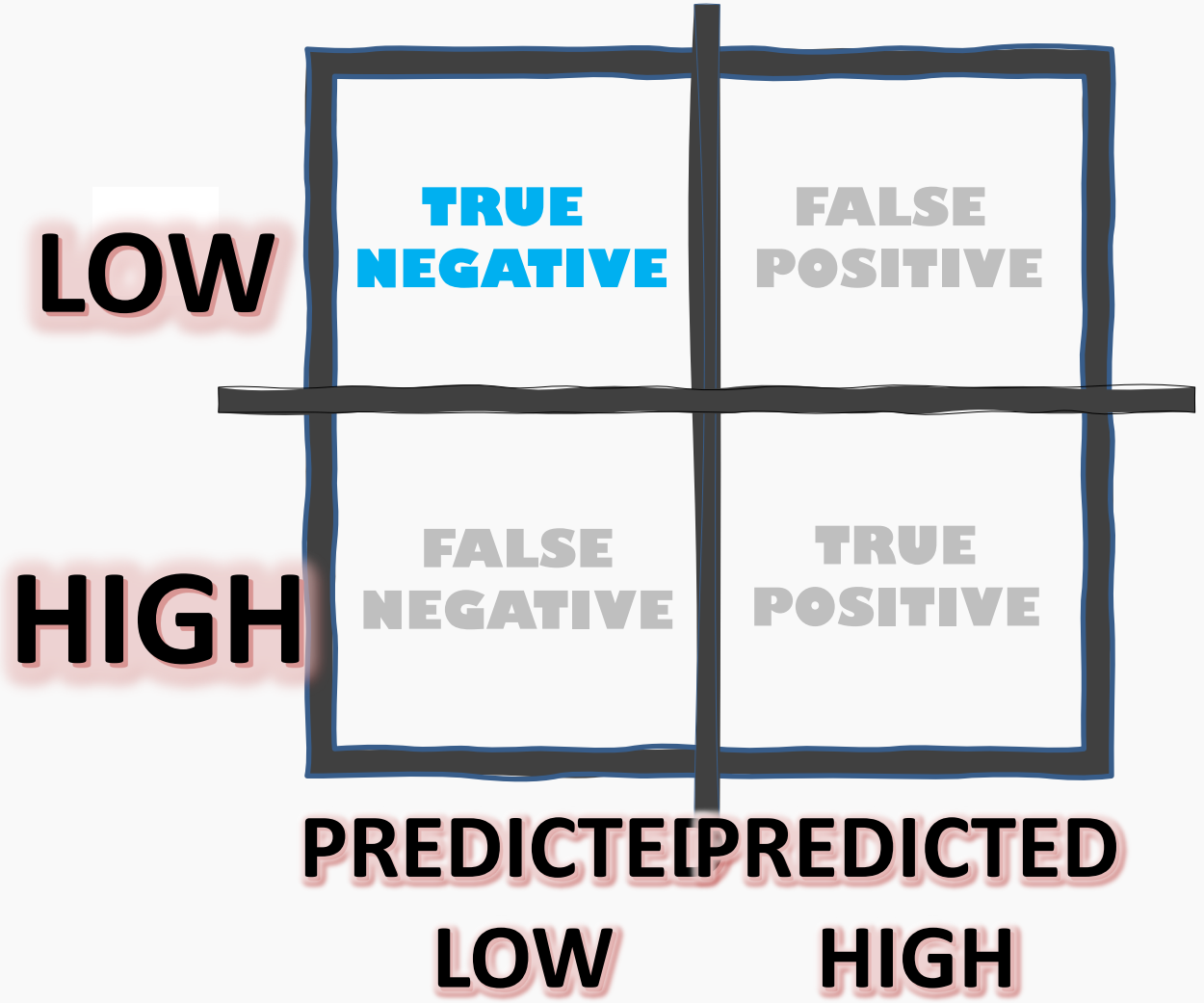
- Samples that are negative and the classifier predicts them as positive are called False Positives.
- For eg. a positive Covid test result would be a FALSE POSITIVE if you actually don't have Covid.



The 'Confusion' Matrix

TRUE NEGATIVE (TN)

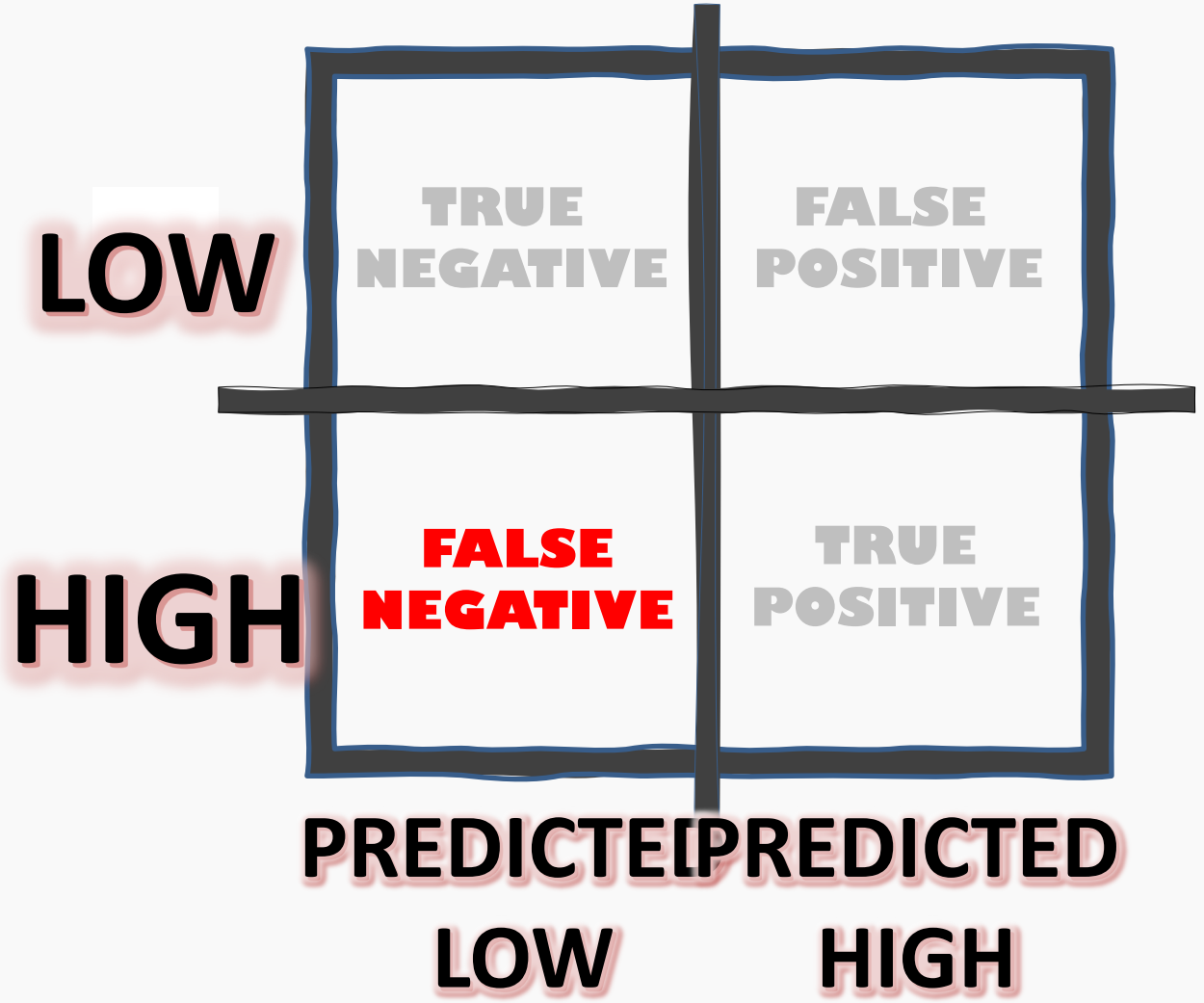
- Samples that are negative and the classifier predicts them as negative are called True Negatives.
- For eg. a negative Covid test result would be a TRUE NEGATIVE if you actually don't have Covid.



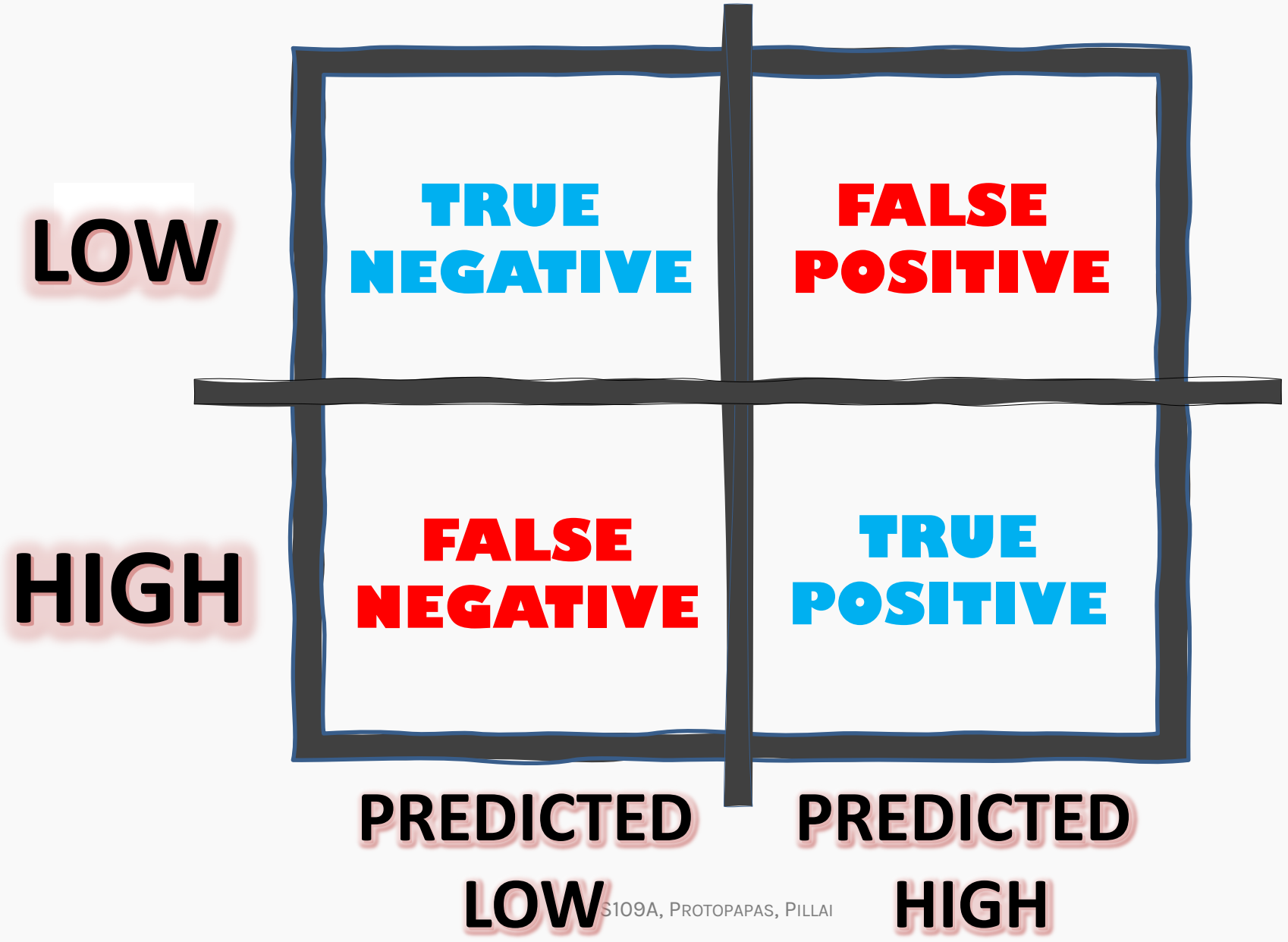
The 'Confusion' Matrix

FALSE NEGATIVE (FN)

- Samples that are negative and the classifier predicts them as positive are called False Negatives.
- For eg. a negative Covid test result would be a FALSE NEGATIVE if you actually have Covid.



The 'Confusion' Matrix



Let's Begin

The 'Confusion' Matrix

Logistic Regression

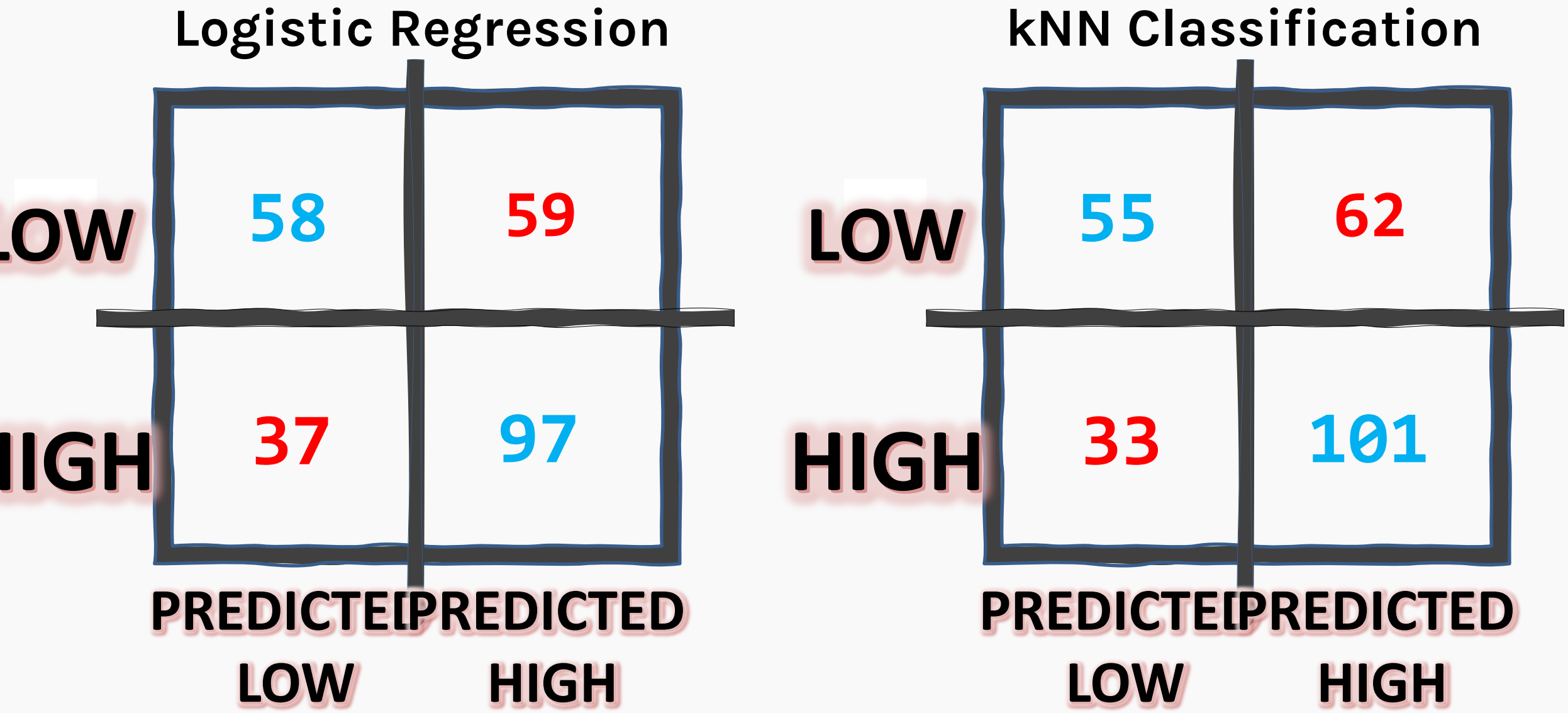
	PREDICTED LOW	PREDICTED HIGH
LOW	58	59
HIGH	37	97

The 'Confusion' Matrix

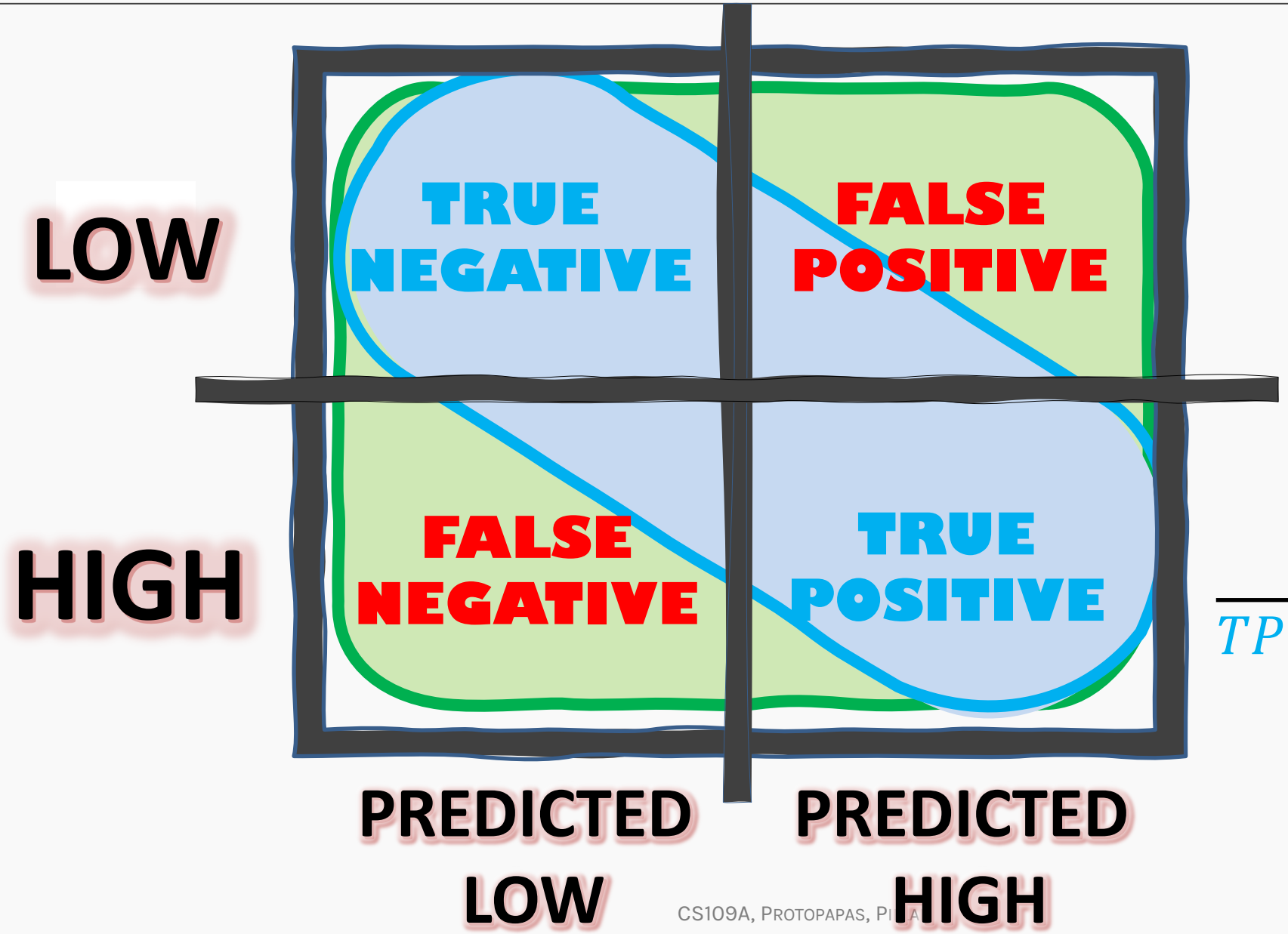
kNN Classification

	PREDICTED LOW	PREDICTED HIGH
LOW	55	62
HIGH	33	101

The 'Confusion' Matrix



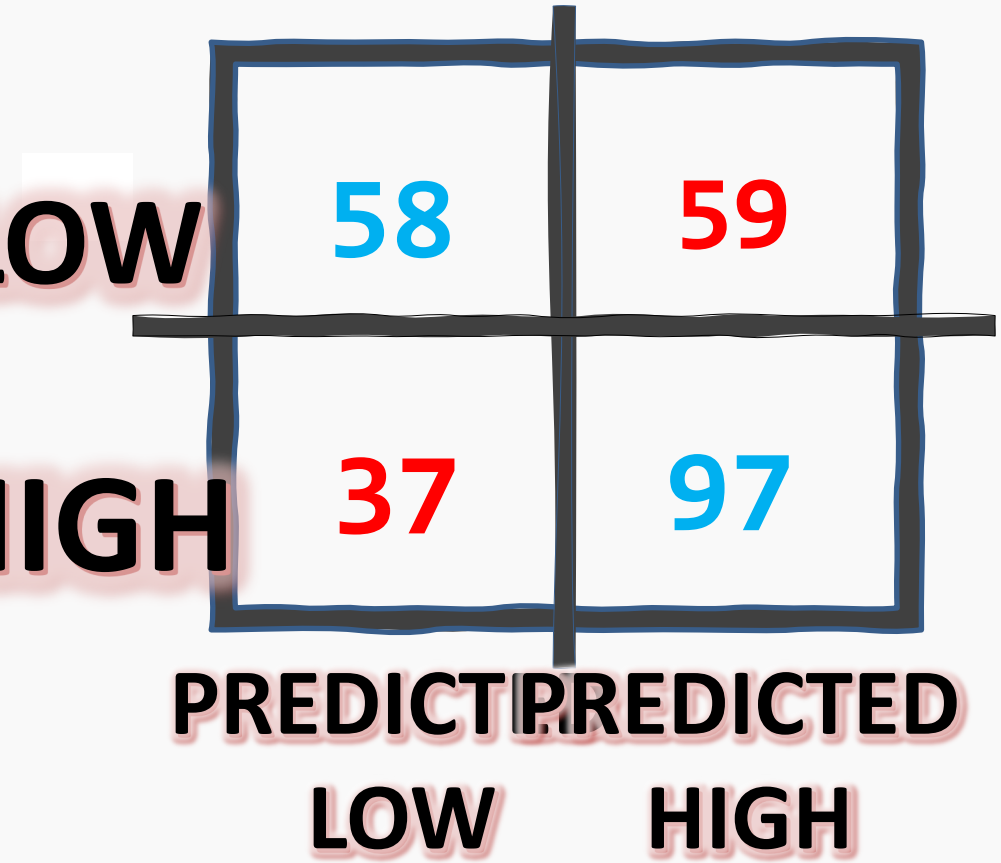
Accuracy



$$\frac{TN + TP}{TP + TN + FP + FN}$$

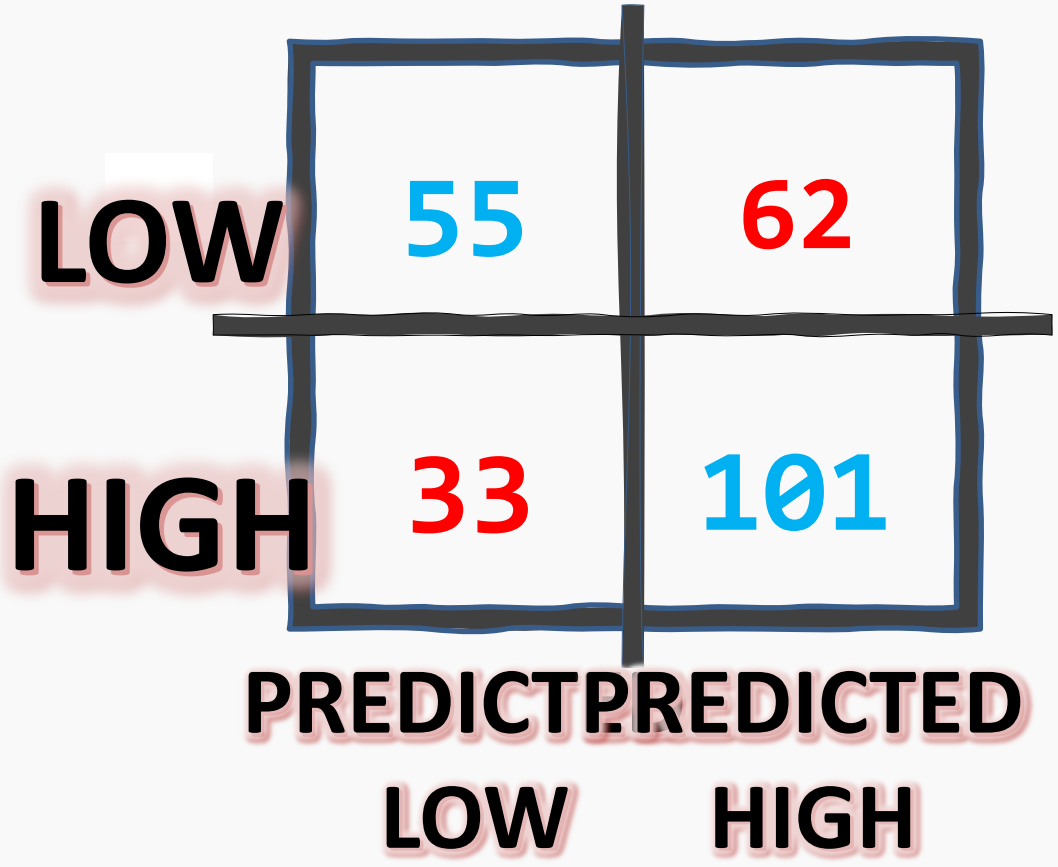
Accuracy

Logistic Regression



$$\text{Accuracy} = \frac{58+97}{58+97+37+59} = 0.62$$

kNN Classification

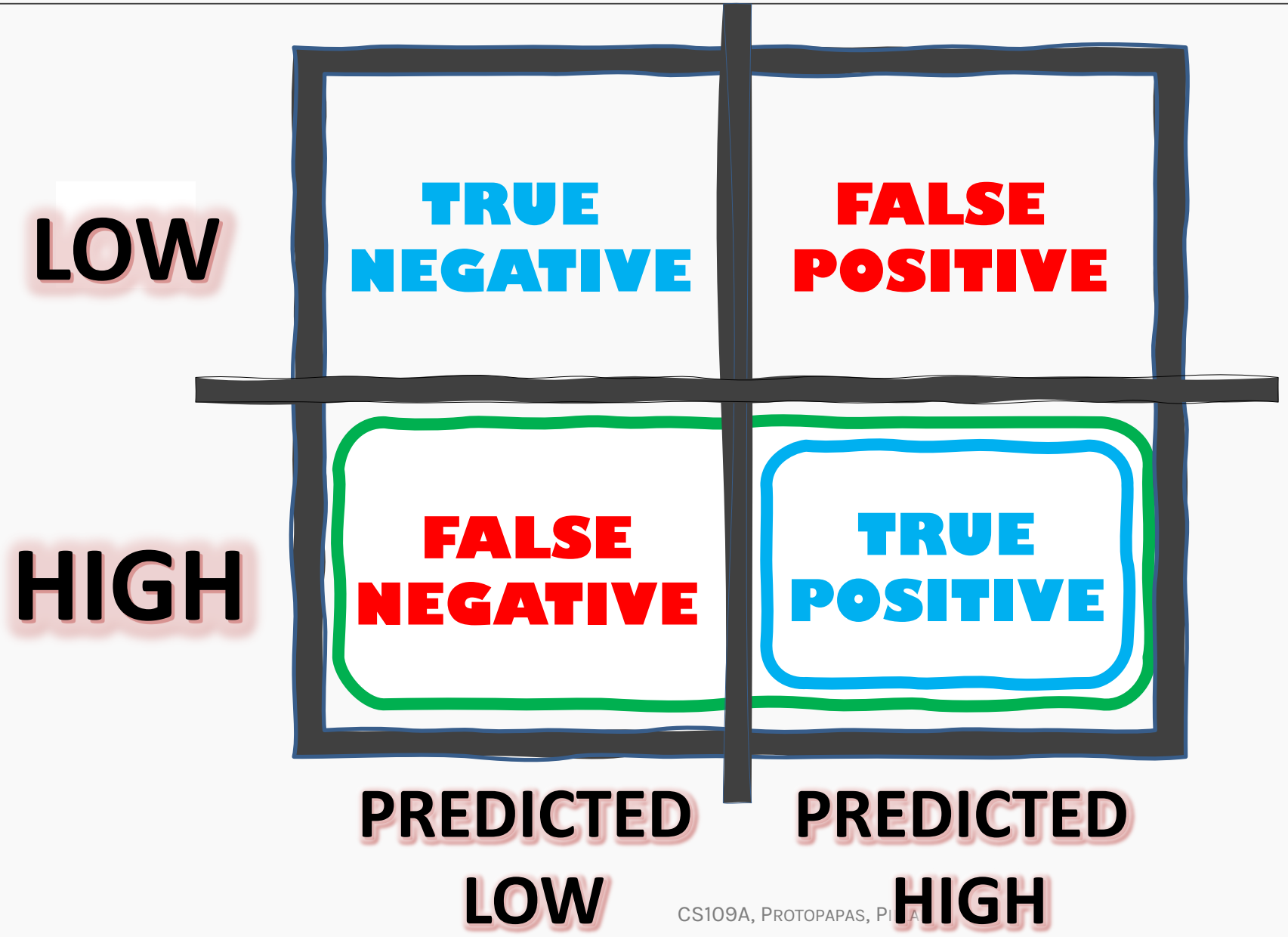


$$\text{Accuracy} = \frac{55+101}{55+101+33+62} = 0.62$$

Model Comparison – Logistic vs kNN

Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy	$\frac{TN + TP}{TP + TN + FP + FN}$		
Sensitivity (Recall)			
Specificity			
Precision			
F1 score			

Sensitivity/True Positive Rate/Recall

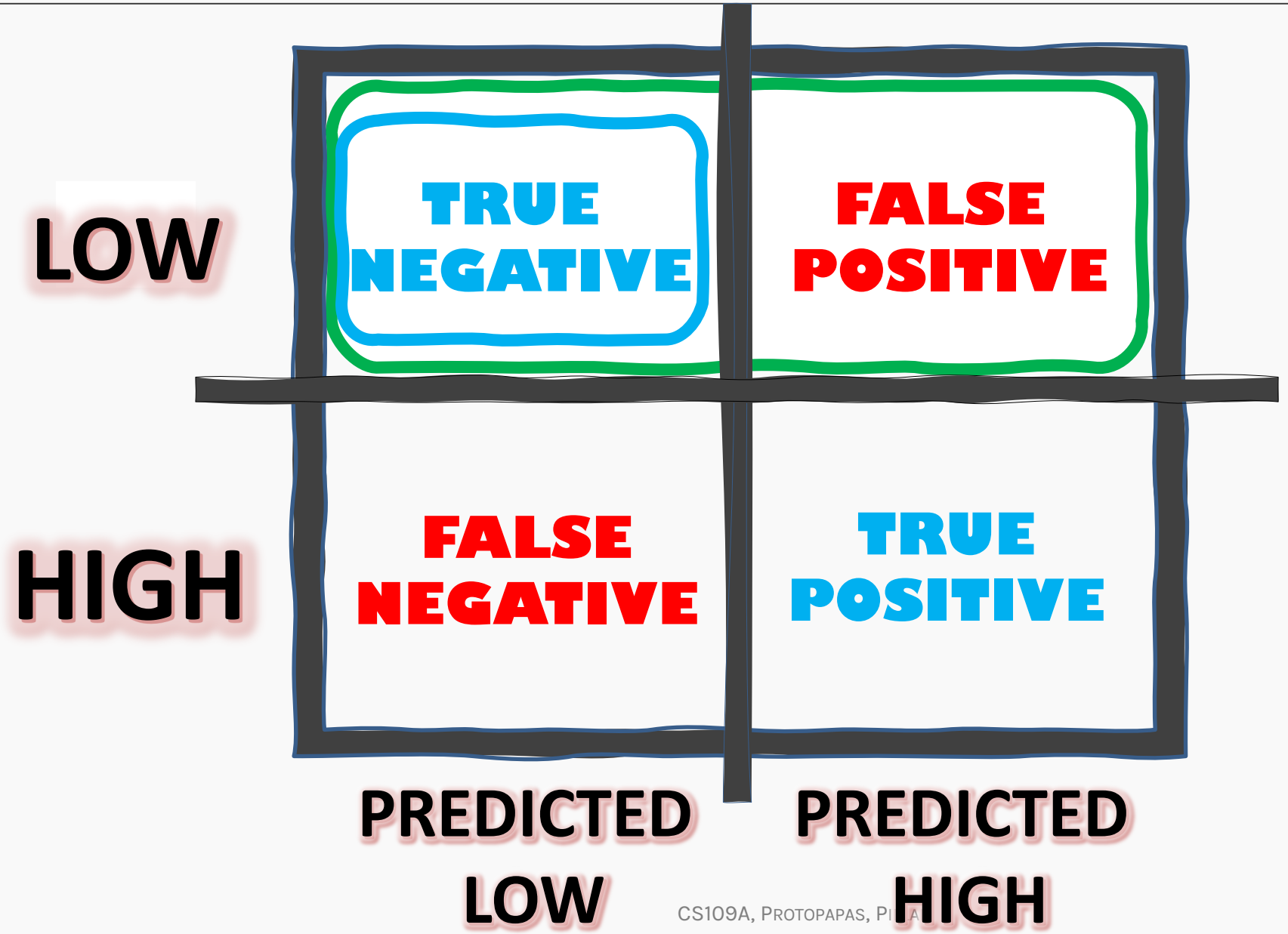


$$\frac{TP}{TP + FN}$$

Model Comparison – Logistic vs kNN

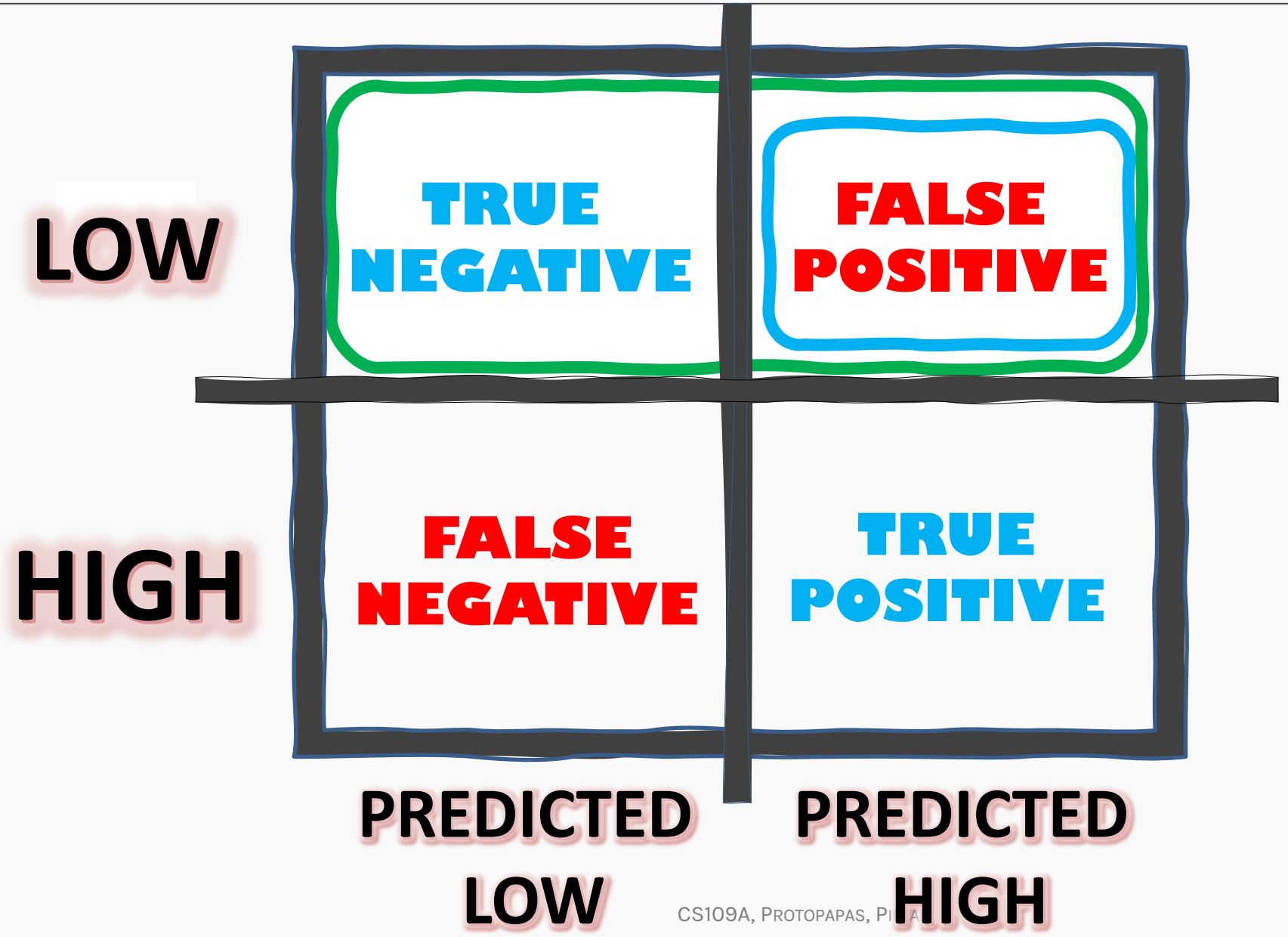
Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy	$\frac{TN + TP}{TP + TN + FP + FN}$		
Sensitivity (Recall)	$\frac{TP}{TP + FN}$		
Specificity			
Precision			
F1 score			

Specificity/True Negative Rate



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

False Positive Rate

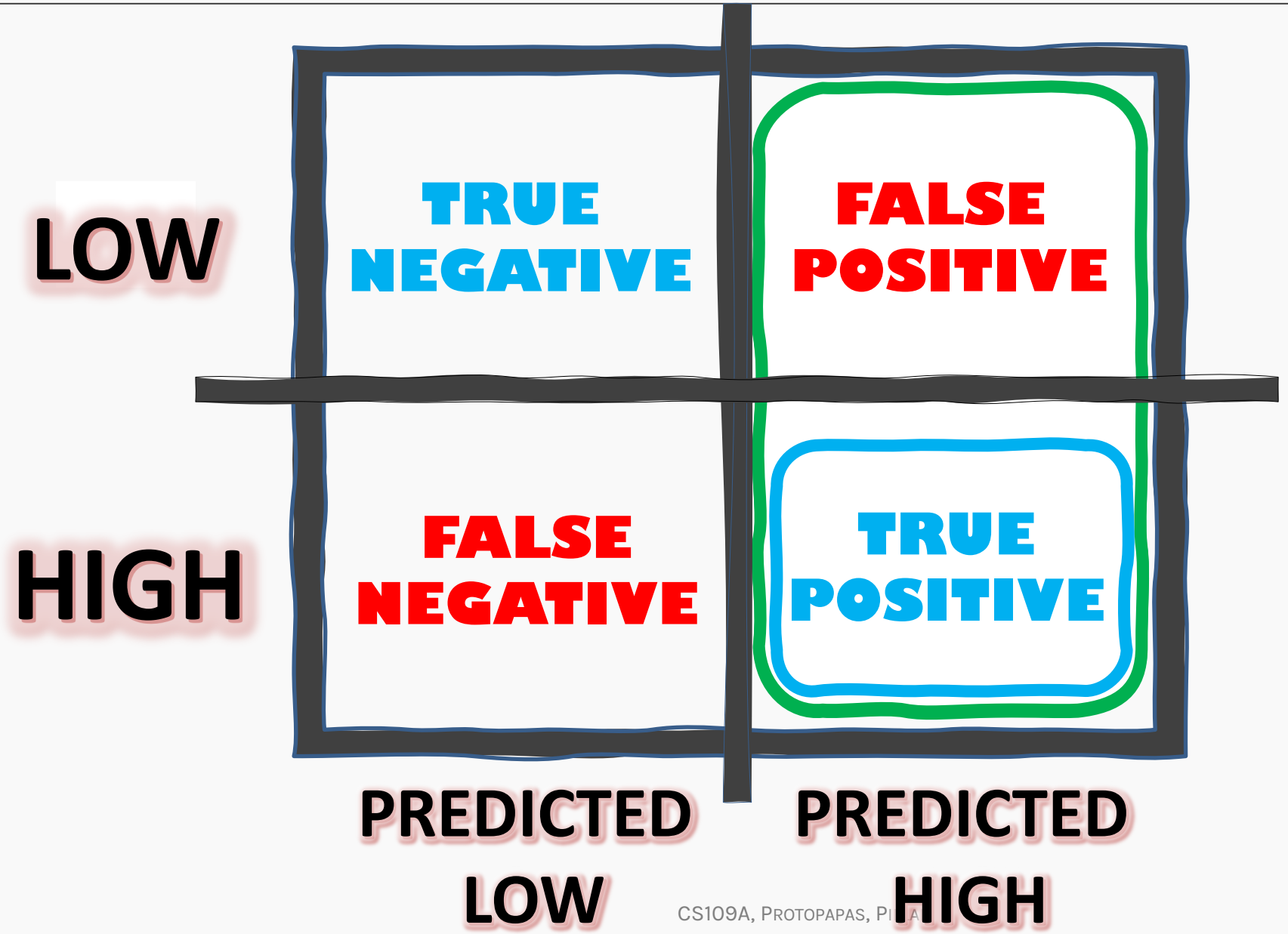


$$\frac{FP}{TN + FP}$$

Model Comparison – Logistic vs kNN

Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy	$\frac{TN + TP}{TP + TN + FP + FN}$		
Sensitivity (Recall)	$\frac{TP}{TP + FN}$		
Specificity	$\frac{TN}{TN + FP}$		
Precision			
F1 score			

Precision

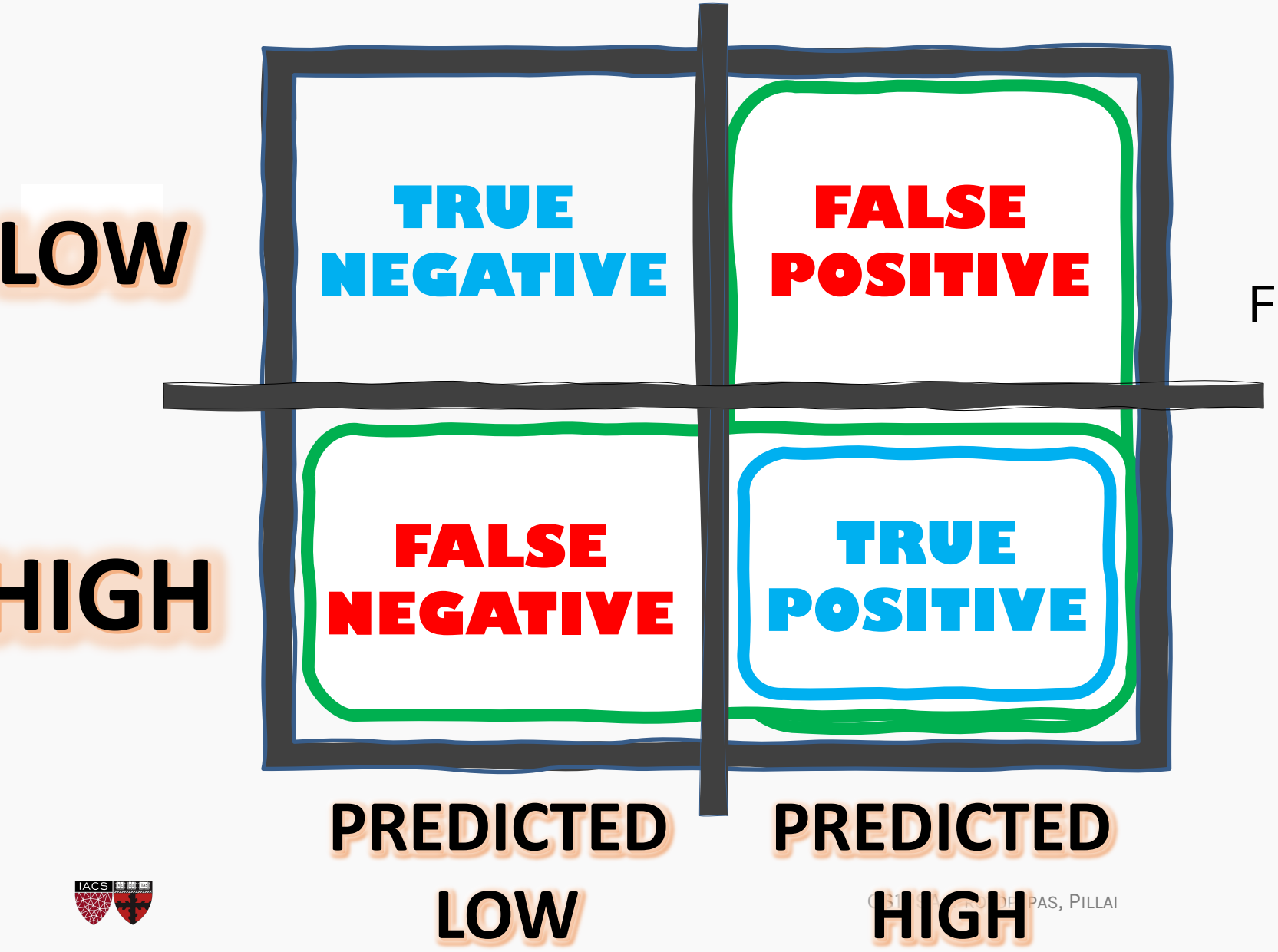


$$\frac{TP}{TP + FP}$$

Model Comparison – Logistic vs kNN

Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy	$\frac{TN + TP}{TP + TN + FP + FN}$		
Sensitivity (Recall)	$\frac{TP}{TP + FN}$		
Specificity	$\frac{TN}{TN + FP}$		
Precision	$\frac{TP}{TP + FP}$		
F1 score			

F1-score



$$\text{F1 score} = \frac{(2 * Precision * Recall)}{Precision + Recall}$$

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

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

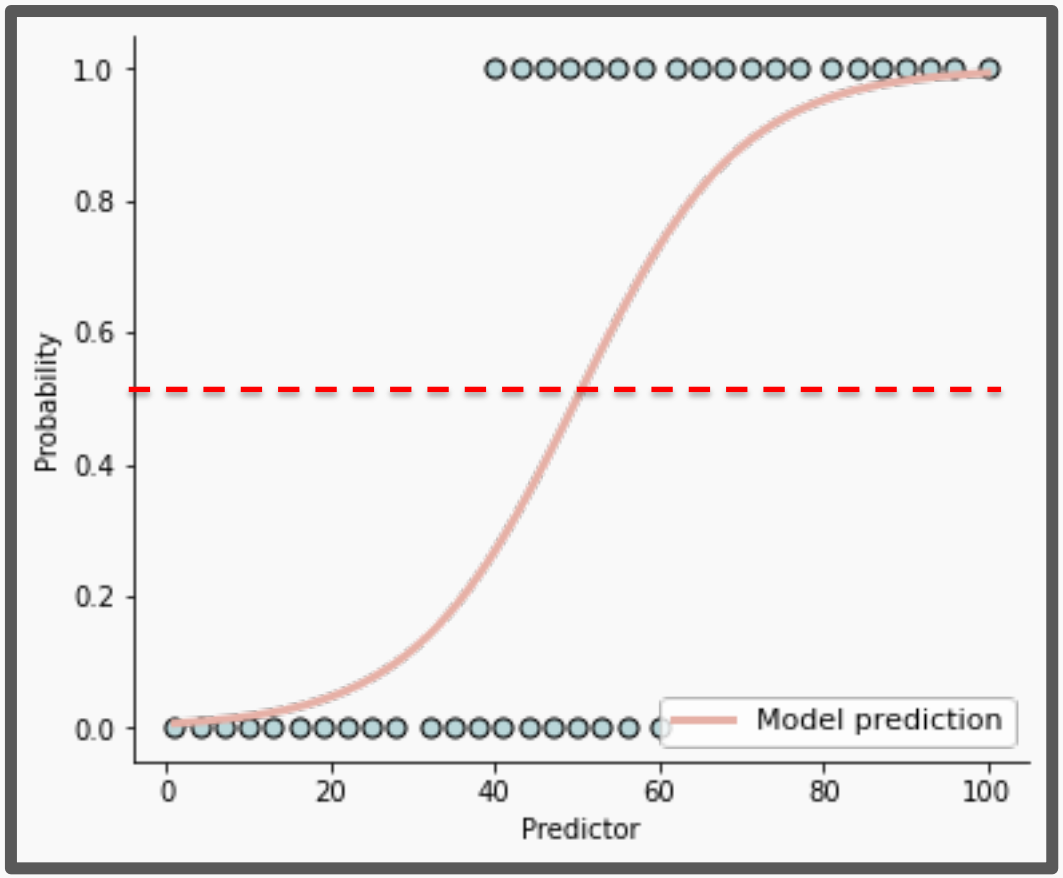
Model Comparison – Logistic vs kNN

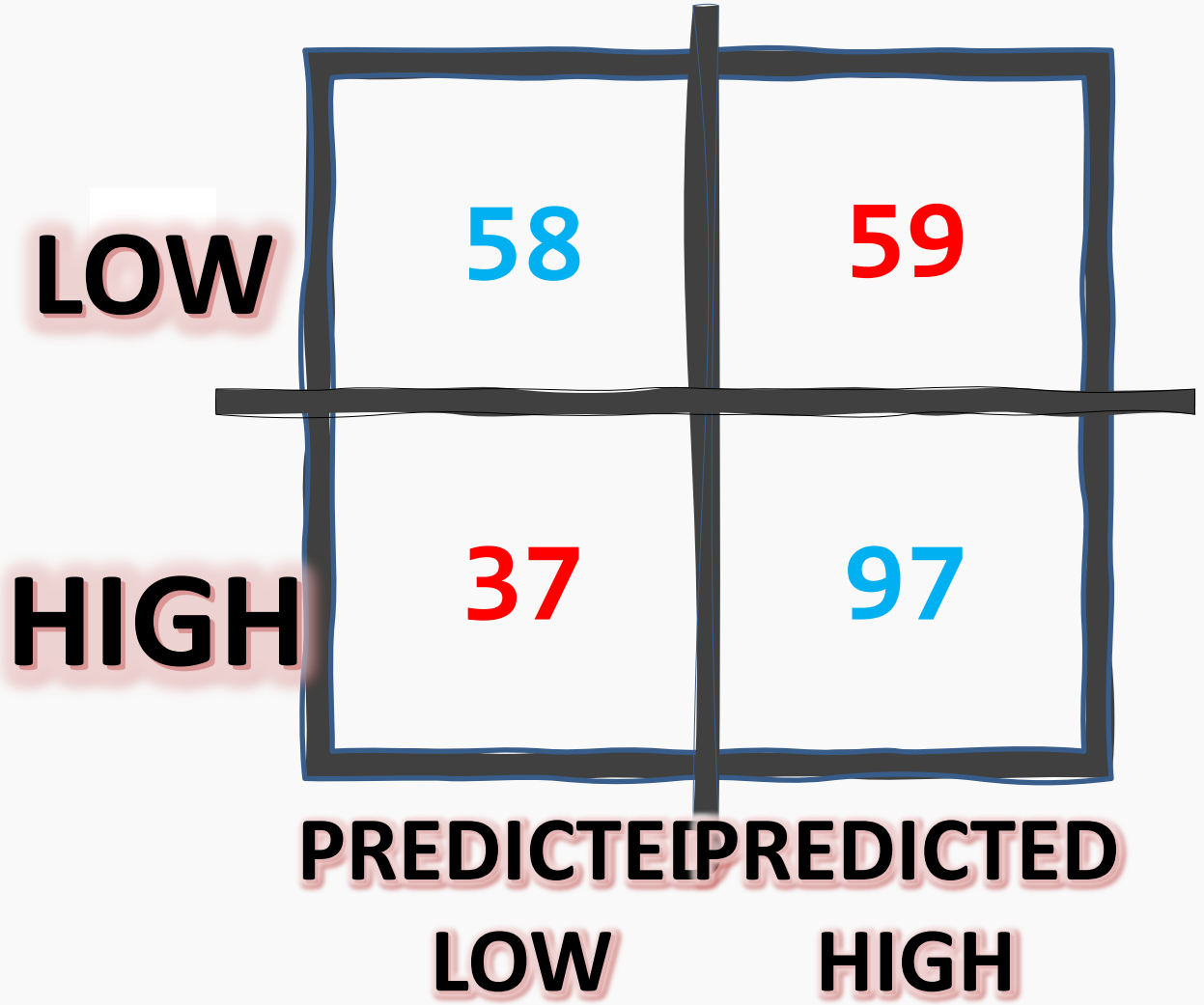
Classification Metric	Formula	Logistic Regression	kNN Classification
Accuracy	$\frac{TN + TP}{TP + TN + FP + FN}$		
Sensitivity (Recall)	$\frac{TP}{TP + FN}$		
Specificity	$\frac{TN}{TN + FP}$		
Precision	$\frac{TP}{TP + FP}$		
F1 score	$\frac{(2 * Precision * Recall)}{Precision + Recall}$		

Bayes threshold

Bayes Threshold

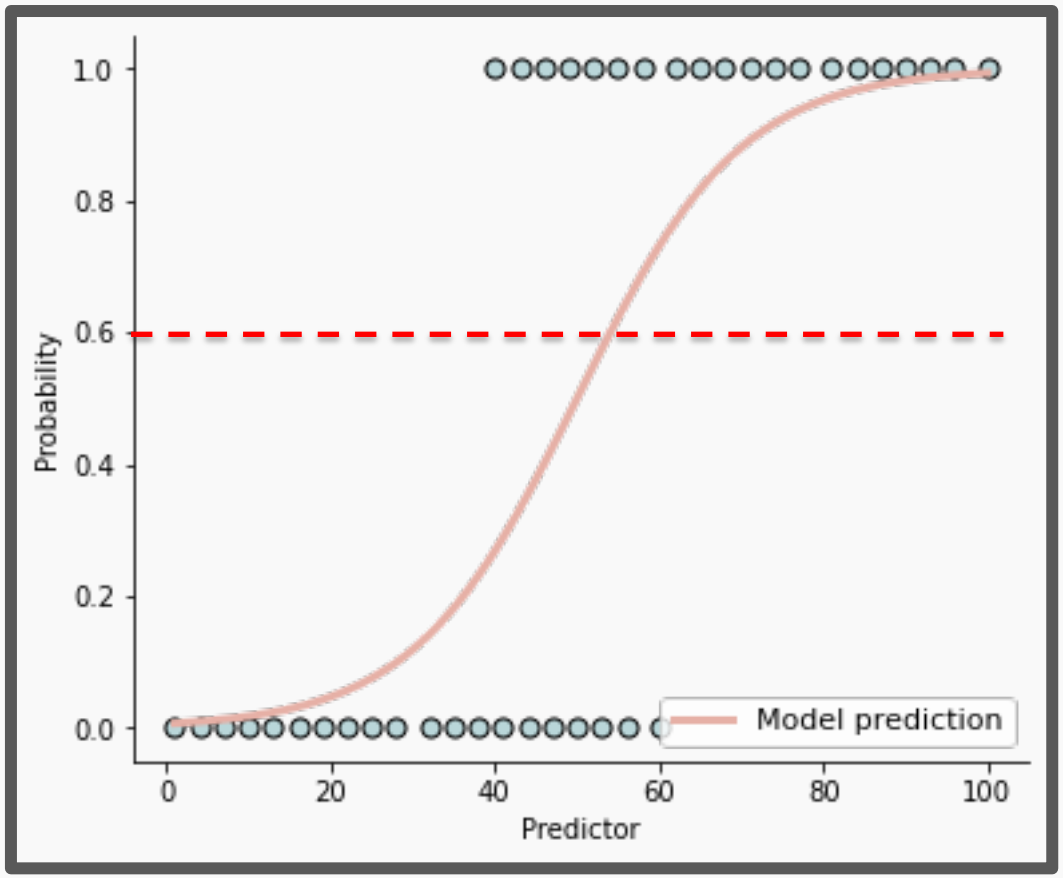
Logistic Regression

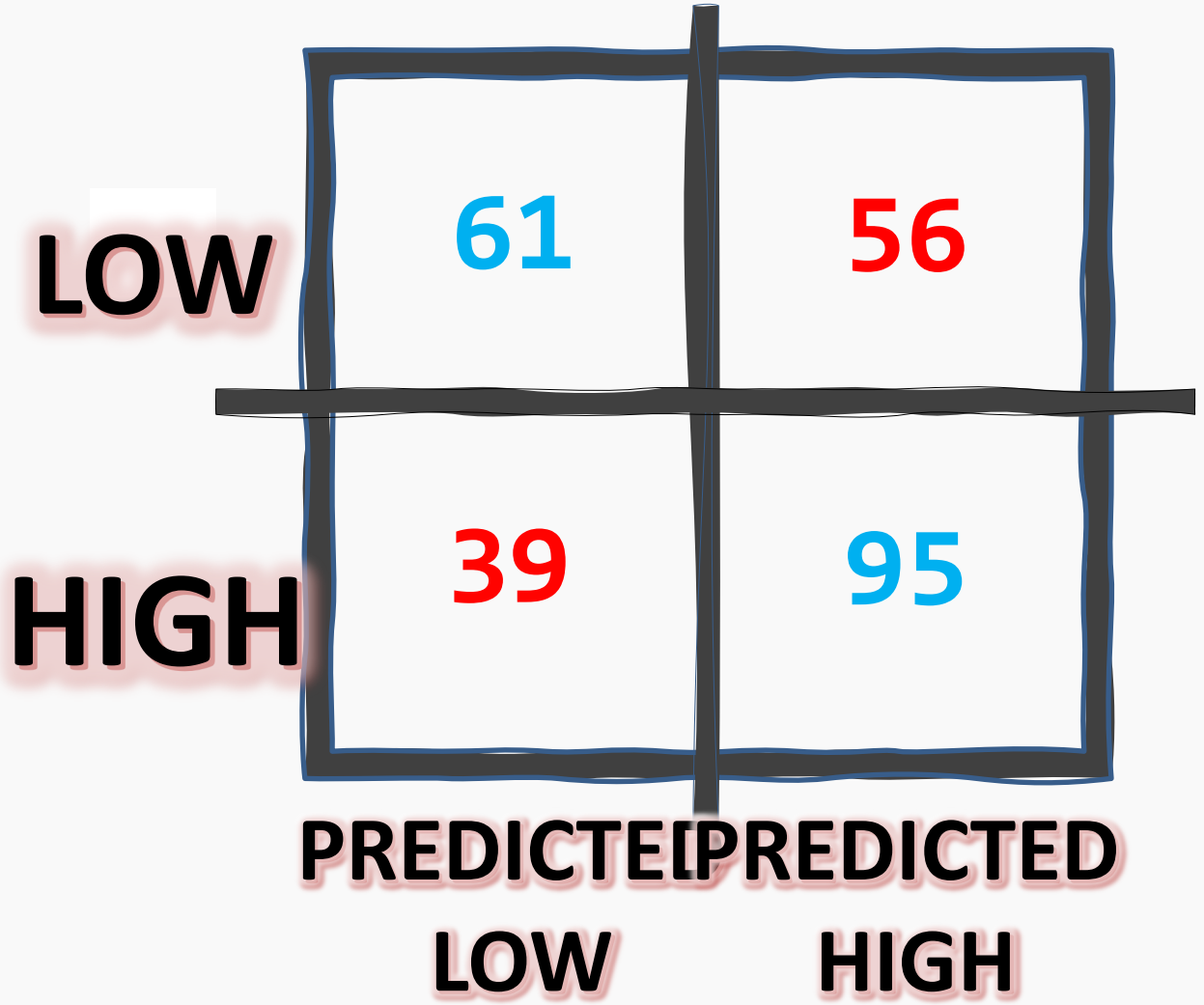




Bayes Threshold

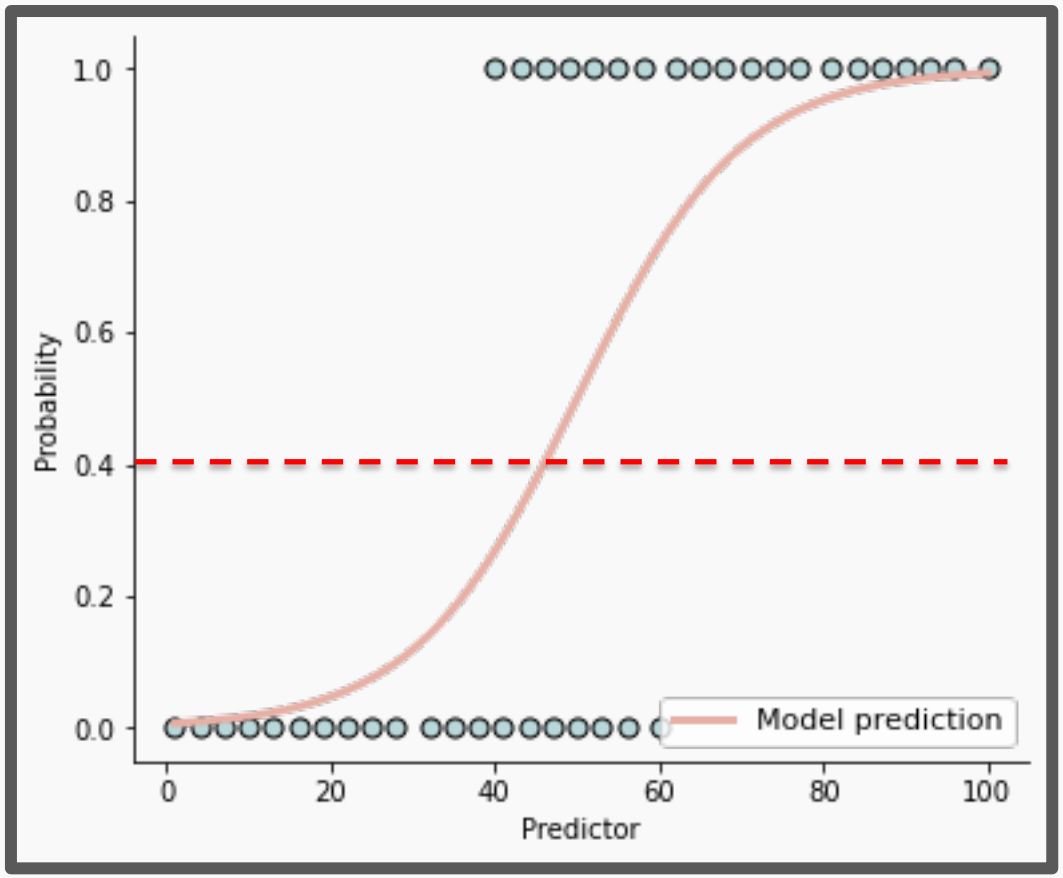
Logistic Regression

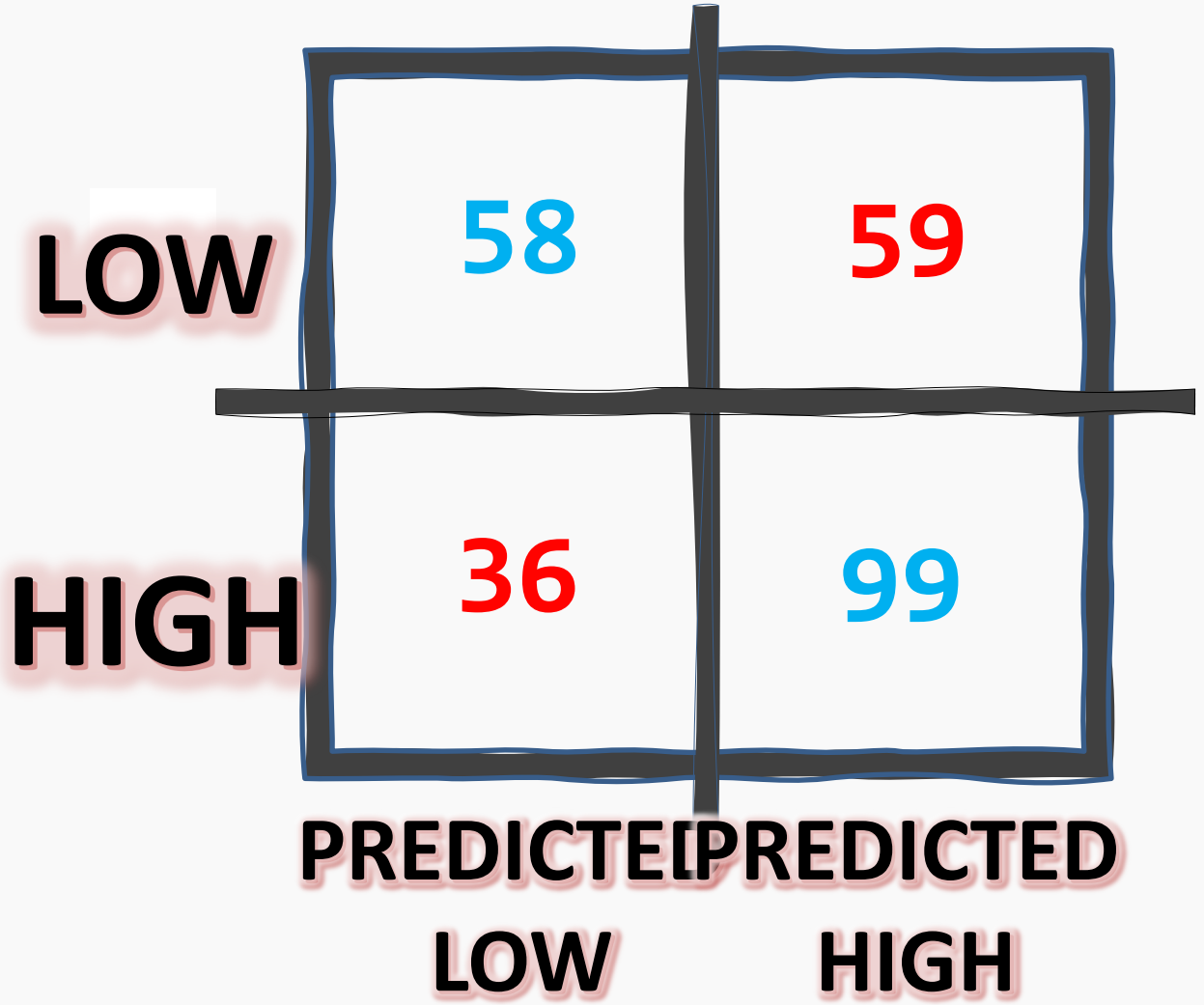




Bayes Threshold

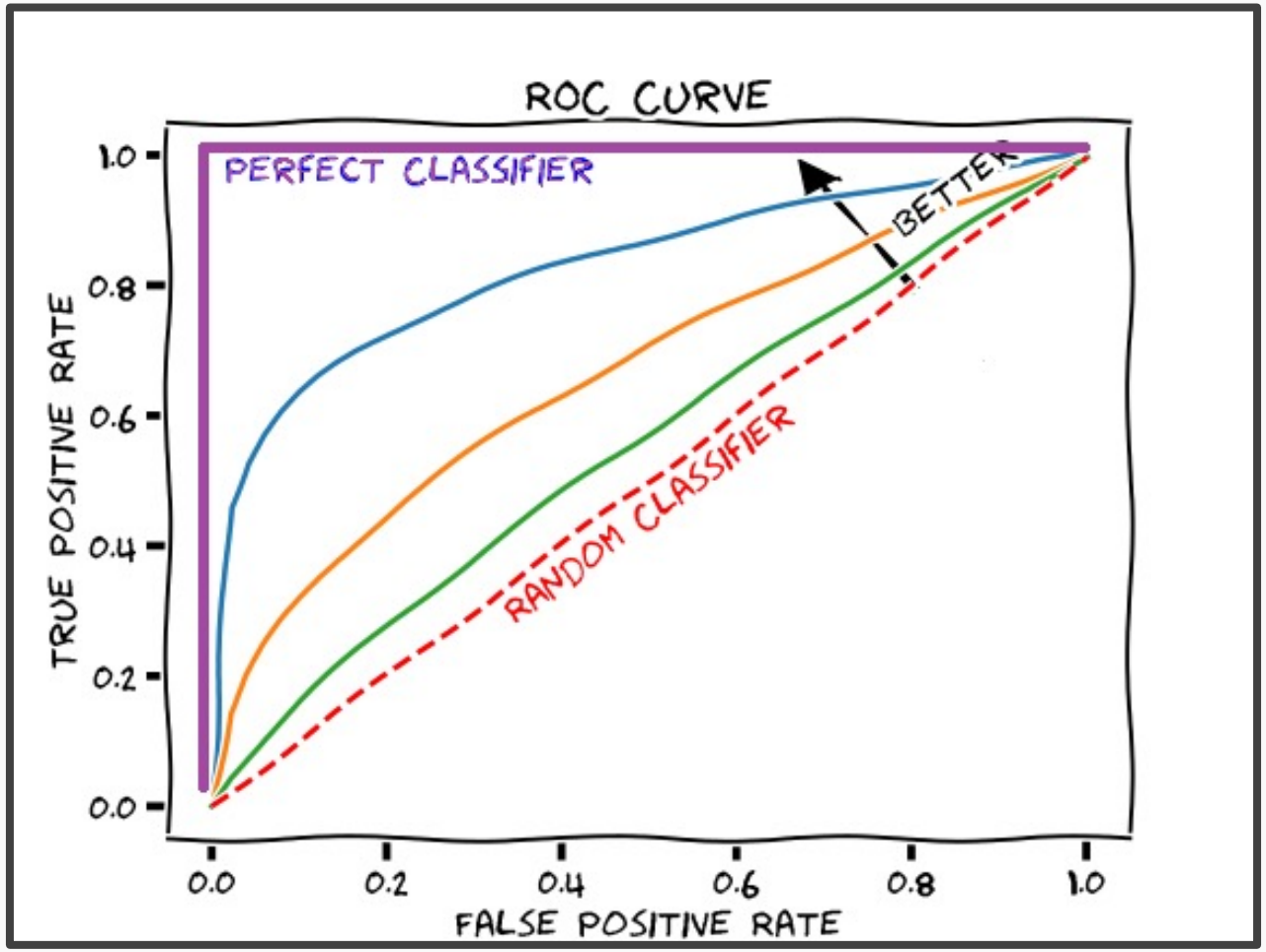
Logistic Regression



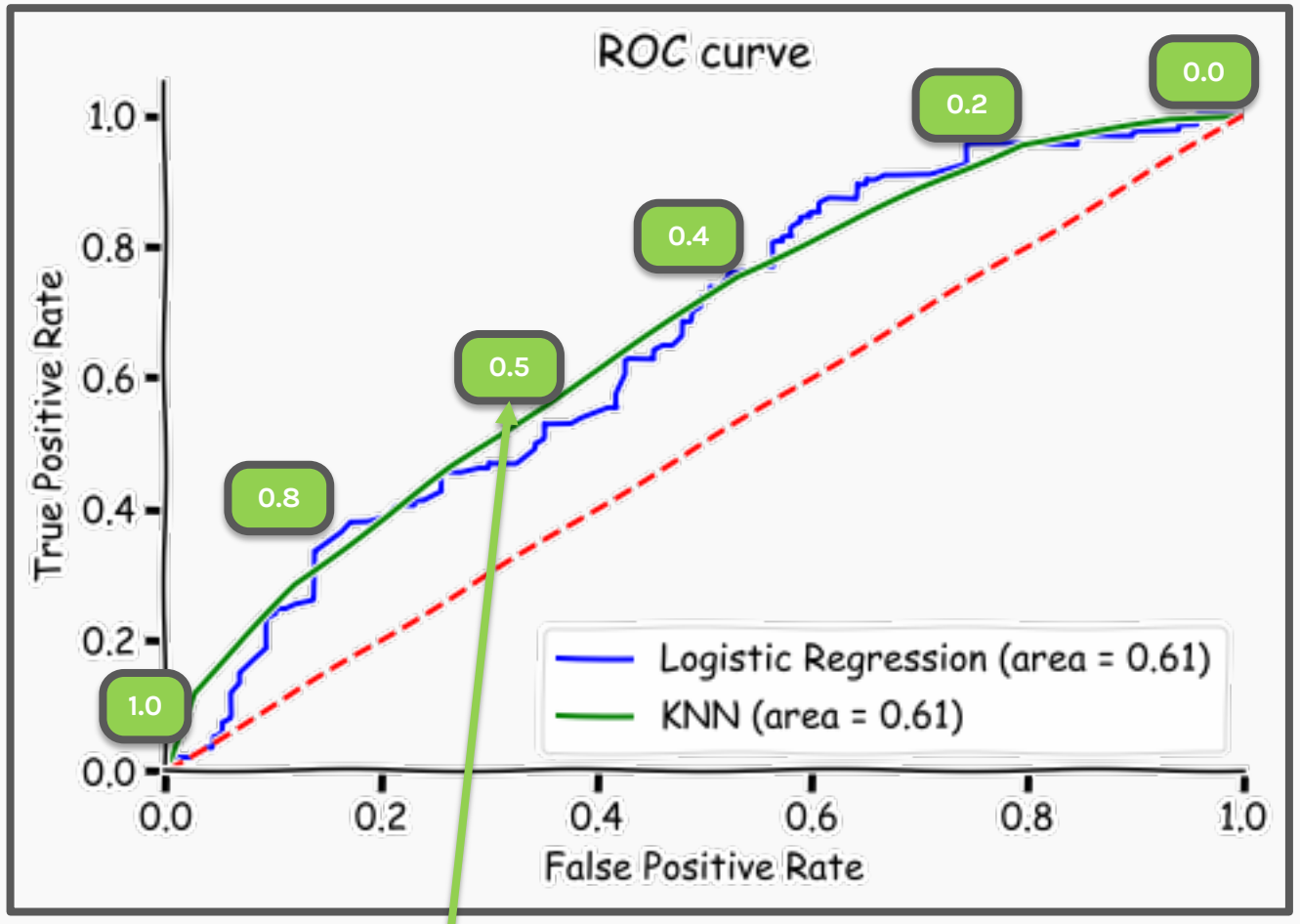


Receiver Operating Characteristic curve (ROC)

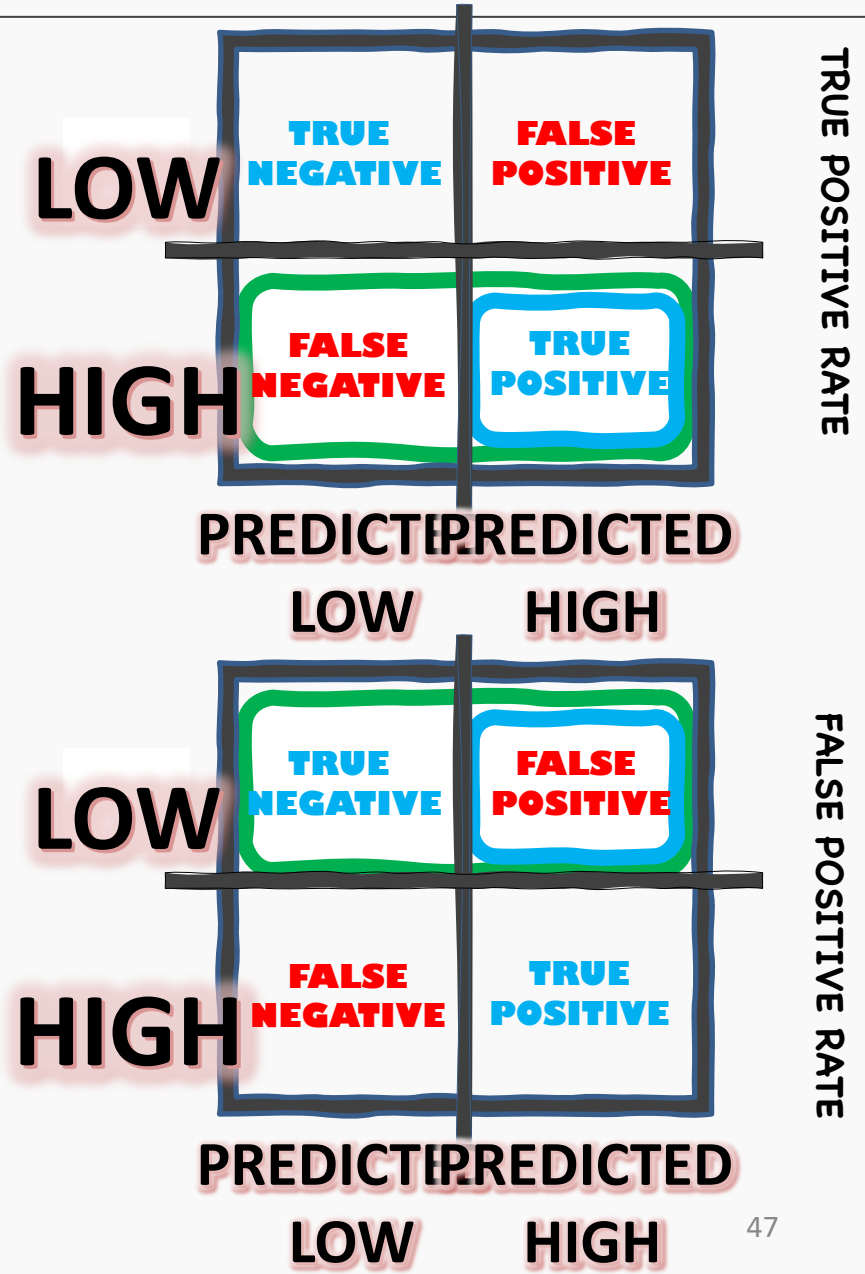
- The ROC curve was first developed by radar engineers during World War II for detecting enemy objects in battlefields.
- The ROC curve is created by plotting the true positive rate (TPR) against the false positive rate (FPR) at various threshold settings.
- If used correctly, ROC curves are a very powerful tool as a statistical performance measure in detection/classification theory.



ROC curve for various thresholds



THRESHOLD



Two models

Logistic Regression

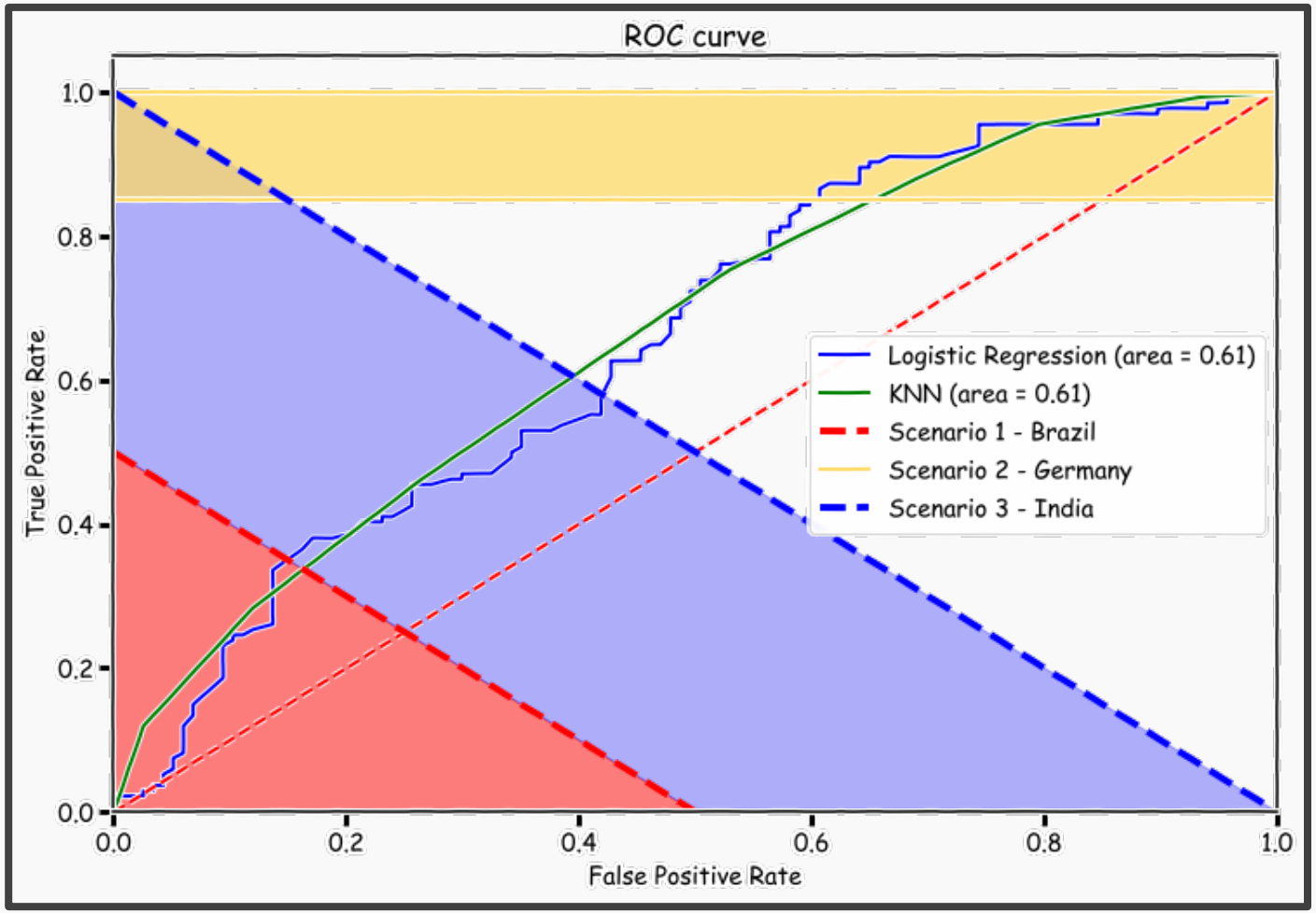
v/s

kNN Classification

Choice of Classifier

Based on the constraints we have the following choice of classifier:

- BRAZIL: Logistic regression with a high threshold
- GERMANY: Logistic regression with a low threshold
- INDIA: kNN classifier with a moderate threshold



The choice of classifier depends on the constraints and the threshold value.