Activity

Confusion Matrix

Prerequisite Knowledge

- Binary Classification Models.

Learning Objectives

- Students will calculate the table of confusion to analyze the prediction results of classification models.
- Students will evaluate the binary classification models using precision, recall, accuracy, FPR, and two types of errors.

Process Skill Goals

- Students will implement a strategy to evaluate information predicted by machine learning models.

Model 1 – Table of Confusion

The table below summarizes the prediction results of a diagnostic procedure on cancer against the actual observations. The table presents the total number of individual patients in four categories

		Prediction Results	
		Cancer	Non-Cancer
Actual Observations	Cancer	10	2
	Non-Cancer	3	5

Questions

1. According to the model, how many patients had cancer, but the prediction result said they did not have cancer?

2. According to the model, how many patients did not have cancer, but the prediction result said they had cancer?

3. In a binary classification model, we usually say samples with specific attributes or properties as positive and samples without them as negative. Here, in model 1, we call cancer **Positive** and non-Cancer **Negative**. Please replace Cancer and Non-Cancer as Positive and Negative below.

		Prediction Results	
		?	?
Actual Observations	?	10	2
	?	3	5

4. We say a prediction is True if the prediction meets the actual observation. Otherwise, we say the prediction is False. Fill the table below indicating if the prediction is True or False. For example, it is True if the actual observation is positive and the prediction is also positive.

		Prediction Results	
		Positive	Negative
Actual Observations	Positive	?	?
	Negative	?	?

5. We say a prediction is True Positive if the prediction is Positive and it is True. Similarly, we can define True Negative, False Positive, and False Negative. Fill these four definitions below respectively.

		Prediction Results	
		Positive	Negative
Actual Observations	Positive	?	?
	Negative	?	?

6. Replace every question mark in the table below with the total number of positive or negative individuals in each row or column.

		Prediction Results	
	Total	Positive: ?	Negative: ?
Actual Observations	Positive: ?	10	2
	Negative: ?	3	5

The table below is called as confusion matrix. The acronym of each terminology is included in the parentheses.

		Prediction Results	
		Positive (PP)	Negative (PN)
Actual Observations	Positive (P)	True Positive (TP)	False Negative (FN)
	Negative (N)	False Positive (FP)	True Negative (TN)

7. A binary classification model is applied to predict the shopping decision based on the user's browsing data on a UK-based and registered non-store online retail from *The UCI Machine Learning Repository*. Each recording of the sample includes a group of browsing data of one visit and the final decision (buy or not buy) indicating if the visit finally led to a transaction. We denote "Buy" as positive and "Not Buy" as negative. The table below records the actual decisions and predictions of 10 visits. Please complete the confusion matrix for this table.

	Actual Decision	Prediction
Visit 1	Buy	Not Buy
Visit 2	Not Buy	Not Buy
Visit 3	Buy	Buy
Visit 4	Not Buy	Buy
Visit 5	Not Buy	Not Buy
Visit 6	Not Buy	Not Buy
Visit 7	Buy	Buy
Visit 8	Not Buy	Not Buy
Visit 9	Not Buy	Not Buy
Visit 10	Not Buy	Buy

		Prediction Results	
	Total	Positive: ?	Negative: ?
Actual Observations	Positive: ?	?	?
	Negative: ?	?	?

8. Based on the confusion matrix you calculated in question 7, what is the value of True Positive, and what does this value stand for?

9. Based on the confusion matrix you calculated in question 7, what is the value of False Negative, and what does this value stand for?

Model 2 – Precision, Recall, Accuracy, FPR, and type of errors.

Table 1: Statistics

		Prediction Results	
	Total	Cancer: 13	Non-Cancer: 7
Actual Observations	Cancer: 12	10	2
	Non-Cancer: 8	3	5

Table 2: Terminology

		Prediction Results		
		Positive (PP)	Negative (PN)	
Actual Observations	Positive (P)	True Positive (TP)	False Negative (FN, **Type II Error**)	**Recall, TPR = TP/P**
	Negative (N)	False Positive (FP, **Type I Error**)	True Negative (TN)	**FPR = FP/N**
		Precision = TP/PP		**Accuracy = (TP+TN)/(P+N)**

10. Based on the information in table 2, please describe the definition of precision and calculate the value of precision in table 1.

11. Work as a team to describe what this precision value evaluates about the diagnostic procedure in table 1.

12. Based on the information in table 2, please describe the definition of recall and calculate the value of recall in table 1. Other common names for recall are TPR (True Positive Rate) and sensitivity.

13. Work as a team to describe what this recall/TPR value evaluates about the diagnostic procedure in table 1.

14. Which quantity is more important to evaluate the procedure, precision or recall, if you want to find out actual positive individuals as many as possible? What evidence do you see in the model that supports this conclusion?

15. Which quantity is more important to evaluate the procedure, precision or recall, if you want to have more confidence that the individual is actually positive when the prediction says positive? What evidence do you see in the model that supports this conclusion?

16. As a team, summarize the differences between recall and precision.

17. FPR (False Positive Rate) is defined as FP/N, which, in other words, is the percentage of False Positive over the Actual Negative. Please calculate the FPR in table 1.

18. Please describe what this FPR value evaluates about the diagnostic procedure in table 1.

19. Is it possible that TPR is 1 and FPR is 1 in a confusion matrix? If yes, please describe what kind of predictions will result in this case.

20. Is it possible that TPR is 0 and FPR is 0 in a confusion matrix? If yes, please describe what kind of predictions will result in this case.

21. Is it possible that TPR is 1 and FPR is 0 in a confusion matrix? If yes, please describe what kind of predictions will result in this case.

22. Is it possible that TPR is 0 and FPR is 1 in a confusion matrix? If yes, please describe what kind of predictions will result in this case.

23. Accuracy is defined as (TP+TN)/(P+N), which, in other words, is the percentage of True Predictions. Please calculate the accuracy in table 1.

24. Please describe what this accuracy value evaluates about the diagnostic procedure in table 1.

25. We call False Positive as type I error and False Negative as type II error. How many type 1 and type 2 errors, respectively, are in model 2?

26. Which error has more dangerous consequences in diagnosing cancer?

27. Can you think of a situation where that type 1 error is more dangerous than type 2 error?

28. Suppose the cancer diagnostic procedure depends on a single numerical testing value measured from a kind of medical lab. The prediction is positive if the testing value is larger than a threshold and otherwise negative. Which error will increase and which error will decrease if the threshold increases?

29. Is it possible to change the threshold that simultaneously reduces type I and type II errors? Please also write several sentences to justify your answer.

30. Please complete the table below based on the confusion matrix you obtained in question 7 from Model 1.

		Prediction Results		
		Positive	Negative	
Actual Observations	Positive		Type II = ?	Recall, TPR = ?
	Negative	Type I = ?		FPR = FP/N = ?
		Precision = ?		Accuracy = ?

Reflection

As a team, summarize the most important thing you learned from this activity.