

Confusion Matrix

	p' (Predicted)	n' (Predicted)
p (Actual)	True Positive	False Negative
n (Actual)	False Positive	True Negative

Accuracy

Accuracy

Accuracy measures a fraction of the classifier's predictions that are correct.

$$\text{Accuracy} = \frac{TN + TP}{TN + FN + TP + FP}$$

Accuracy

	Predict P	Predict N
True P	100	70
True N	30	9800

$$\text{Accuracy} = \frac{9900}{10,000} = 0.99$$

Accuracy

- ▶ However, accuracy is not an informative metric if the proportions of the classes are skewed in the population. (**Class Imbalance**)
- ▶ For example, a classifier that predicts whether or not credit card transactions are fraudulent may be more sensitive to false negatives than to false positives.
- ▶ To promote customer satisfaction, the credit card company may prefer to risk verifying legitimate transactions than risk ignoring a fraudulent transaction.

Accuracy

- ▶ Because most transactions are legitimate, accuracy is not an appropriate metric for this problem.
- ▶ A classifier that always predicts that transactions are legitimate could have a high accuracy score, but would not be useful.
- ▶ For these reasons, classifiers are often evaluated using two additional measures called **precision** and **recall**.

Precision and Recall

- ▶ **Precision** (or positive predictive value (PPV))

$$PPV = TP / (TP + FP)$$

- ▶ **Recall** (or Sensitivity , true positive rate (TPR))

$$TPR = TP / P = TP / (TP + FN)$$

- ▶ **Specificity** (or true negative rate (TNR))

$$SPC = TN / N = TN / (TN + FP)$$

Some Related Metrics

- ▶ Negative predictive value (NPV)

$$NPV = TN / (TN + FN)$$

- ▶ False positive rate (FPR) also called "fallout"

$$FPR = FP / N = FP / (FP + TN)$$

- ▶ False negative rate (FNR)

$$FNR = FN / (FN + TP) = 1 - TPR$$

- ▶ False discovery rate (FDR)

$$FDR = FP / (FP + TP) = 1 - PPV$$

Precision and Recall

- ▶ Precision is the fraction of positive predictions that are correct.
- ▶ For instance, in our SMS spam classifier, precision is the fraction of messages classified as spam that are actually spam.
- ▶ Precision is given by the following ratio:

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

The Confusion Matrix

- ▶ The confusion matrix indicates that there were four true negative predictions, three true positive predictions, two false negative predictions, and one false positive prediction.
- ▶ Confusion matrices become more useful in multi-class problems, in which it can be difficult to determine the most frequent types of errors.

Recall

- ▶ Recall is the fraction of the truly positive instances that the classifier recognizes. A recall score of one indicates that the classifier did not make any false negative predictions.
- ▶ For our SMS spam classifier, recall is the fraction of spam messages that were truly classified as spam. Recall is calculated with the following ratio:

$$\text{Recall} = \frac{tp}{tp + fn}$$

- ▶ Recall is often called sensitivity in medical contexts.

Precision and Recall

- ▶ Individually, precision and recall are seldom informative; they are both incomplete views of a classifier's performance.
- ▶ Both precision and recall can fail to distinguish classifiers that perform well from certain types of classifiers that perform poorly.
- ▶ A trivial classifier could easily achieve a perfect recall score by predicting positive for every instance.

Precision and Recall

- ▶ For example, assume that a test set contains ten positive examples and ten negative examples.
- ▶ A classifier that predicts positive for every example will achieve a recall of one, as follows:

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- ▶ A classifier that predicts negative for every example, or that makes only false positive and true negative predictions, will achieve a recall score of zero.
- ▶ Similarly, a classifier that predicts that only a single instance is positive and happens to be correct will achieve perfect precision.