Evaluation

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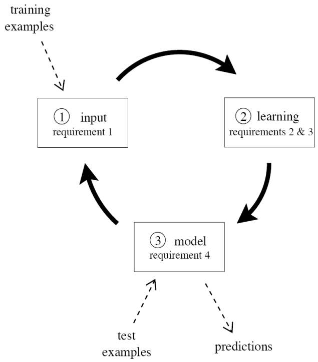
Data Streams

Big Data & Real Time

Data stream classification cycle

1. Process an example at a time, and inspect it only once (at most)
2. Use a limited amount of memory
3. Work in a limited amount of time
4. Be ready to predict at any point



Evaluation

1. Error estimation: *Hold-out or Prequential*
2. Evaluation performance measures: *Accuracy or κ-statistic*
3. Statistical significance validation: *MacNemar or Nemenyi test*

Evaluation Framework

Error Estimation

Data available for testing

- Holdout an independent test set
- Apply the current decision model to the test set, at regular time intervals
- The loss estimated in the holdout is an unbiased estimator

Holdout Evaluation

1. Error Estimation

No data available for testing

- The error of a model is computed from the sequence of examples.
- For each example in the stream, the actual model makes a prediction, and then uses it to update the model.

Prequential or
Interleaved-Test-Then-Train

1. Error Estimation

Hold-out or Prequential?

Hold-out is more accurate, but needs data for testing.

- Use prequential to approximate Hold-out
- Estimate accuracy using sliding windows or fading factors

Hold-out or Prequential or
Interleaved-Test-Then-Train

2. Evaluation performance measures

	Predicted Class+	Predicted Class-	Total
Correct Class+	75	8	83
Correct Class-	7	10	17
Total	82	18	100

Table: Simple confusion matrix example

- Accuracy = $\frac{75}{100} + \frac{10}{100} = \frac{75}{83}\frac{83}{100} + \frac{10}{17}\frac{17}{100} = 85\%$
- Arithmetic mean = $(\frac{75}{83} + \frac{10}{17})/2 = 74.59\%$
- Geometric mean = $\sqrt{\frac{75}{83}\frac{10}{17}} = 72.90\%$

2. Performance Measures with Unbalanced Classes

	Predicted Class+	Predicted Class-	Total
Correct Class+	75	8	83
Correct Class-	7	10	17
Total	82	18	100

Table: Simple confusion matrix example

	Predicted Class+	Predicted Class-	Total
Correct Class+	68.06	14.94	83
Correct Class-	13.94	3.06	17
Total	82	18	100

Table: Confusion matrix for chance predictor

2. Performance Measures with Unbalanced Classes

Kappa Statistic

- p_0: classifier's prequential accuracy
- p_c: probability that a chance classifier makes a correct prediction.
- κ statistic

$$\kappa = \frac{p_0 - p_c}{1 - p_c}$$

- $\kappa = 1$ if the classifier is always correct
- $\kappa = 0$ if the predictions coincide with the correct ones as often as those of the chance classifier

Forgetting mechanism for estimating prequential kappa

Sliding window of size w with the most recent observations

3. Statistical significance validation (2 Classifiers)

	Classifier A Class+	Classifier A Class-	Total
Classifier B Class+	c	a	c+a
Classifier B Class-	b	d	b+d
Total	c+b	a+d	a+b+c+d

$$M = |a - b - 1|^2/(a + b)$$

The test follows the χ^2 distribution. At 0.99 confidence it rejects the null hypothesis (the performances are equal) if $M > 6.635$.

McNemar test

3. Statistical significance validation ($>$ 2 Classifiers)

Two classifiers are performing differently if the corresponding average ranks differ by at least the critical difference

$$CD = q_\alpha \sqrt{\frac{k(k+1)}{6N}}$$

- k is the number of learners, N is the number of datasets,
- critical values q_α are based on the Studentized range statistic divided by $\sqrt{2}$.

Nemenyi test

3. Statistical significance validation ($>$ 2 Classifiers)

Two classifiers are performing differently if the corresponding average ranks differ by at least the critical difference

$$CD = q_\alpha \sqrt{\frac{k(k+1)}{6N}}$$

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# classifiers	2	3	4	5	6	7
$q_{0.05}$	1.960	2.343	2.569	2.728	2.850	2.949
$q_{0.10}$	1.645	2.052	2.291	2.459	2.589	2.693

Table: Critical values for the Nemenyi test

Cost Evaluation Example

	Accuracy	Time	Memory
Classifier A	70%	100	20
Classifier B	80%	20	40

Which classifier is performing better?

RAM-Hours

RAM-Hour

Every GB of RAM deployed for 1 hour

Cloud Computing Rental Cost Options

Cost Evaluation Example

	Accuracy	Time	Memory	**RAM-Hours**
Classifier A	70%	100	20	**2,000**
Classifier B	80%	20	40	**800**

Which classifier is performing better?

Evaluation

1. Error estimation: *Hold-out or Prequential*
2. Evaluation performance measures: *Accuracy or κ-statistic*
3. Statistical significance validation: *MacNemar or Nemenyi test*
4. **Resources needed**: *time and memory or RAM-Hours*

Evaluation Framework