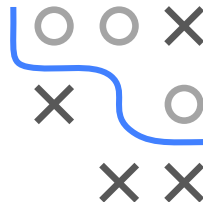


Introduction to Machine Learning

Evaluation

Multi-Class AUC



AUC(pos|neg) = AUC(1|3)

	Y	$\hat{\pi}_1$	$\hat{\pi}_2$	$\hat{\pi}_3$
pos	1	0.7	0.2	0.1
pos	1	0.5	0.3	0.2
	2	0.3	0.5	0.2
	2	0.4	0.5	0.1
neg	3	0.6	0.1	0.3
neg	3	0.1	0.1	0.8

AUC(pos|neg) = AUC(3|1)

	Y	$\hat{\pi}_1$	$\hat{\pi}_2$	$\hat{\pi}_3$
neg	1	0.7	0.2	0.1
neg	1	0.5	0.3	0.2
	2	0.3	0.5	0.2
	2	0.4	0.5	0.1
pos	3	0.6	0.1	0.3
pos	3	0.1	0.1	0.8

Learning goals

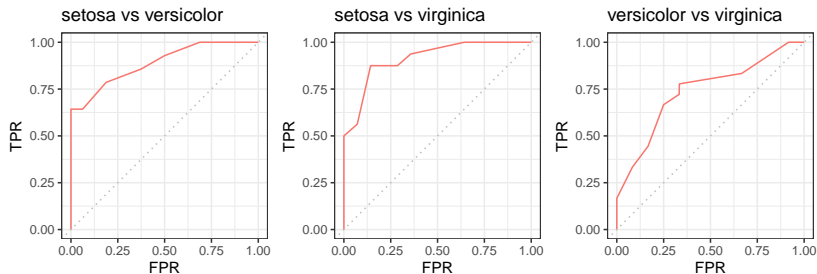
- Understand that generalizing AUC to multi-class is not trivial
- Learn how multi-class AUC can be derived

MULTI-CLASS AUC

- AUC and other ROC metrics for binary classification
- Different ways to estimate **multi-class AUC**
- Often based on aggregated binary AUCs:
e.g. 1-vs-1 or 1-vs-rest

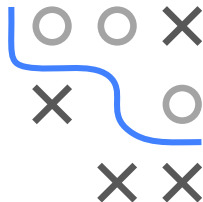


Example: 1-vs-1 on iris



MULTI-CLASS AUC

- Def $\text{AUC}(k | \ell)$ for classes k (pos) and ℓ (neg)
- Compute AUC: Subset preds to rows of true k and ℓ , use $\hat{\pi}_k$
- Interpret: Prob that random member of ℓ has a lower prob to belong to class k than random member of class k .



Example: $\text{AUC}(3|1)$ with $g = 3$ classes

$\text{AUC}(\text{pos} \text{neg}) = \text{AUC}(3 1)$				
	Y	$\hat{\pi}_1$	$\hat{\pi}_2$	$\hat{\pi}_3$
neg	1	0.7	0.2	0.1
neg	1	0.5	0.3	0.2
	2	0.3	0.5	0.2
	2	0.4	0.5	0.1
pos	3	0.6	0.1	0.3
pos	3	0.1	0.1	0.8

- 1 Subset pred rows to true classes 1 and 3
- 2 Use $k = 3$ as pos and $\ell = 1$ as neg class
- 3 Compute standard AUC with $\hat{\pi}_3$ as scores
- 4 $\text{AUC}(3|1) = 1$:
all pos have higher $\hat{\pi}_3$ than negs

MULTI-CLASS AUC

- For binary classes: always $AUC(1|0) = AUC(0|1)$
- For multi-class usually: $AUC(k | \ell) \neq AUC(\ell | k)$
- **Example** with $g = 3$ where $AUC(1|3) \neq AUC(3|1)$:
 - $AUC(3|1) = 1$ (RHS) as before
 - $AUC(1|3) \neq 1$ (LHS)

AUC(pos neg) = AUC(1 3)				
	Y	$\hat{\pi}_1$	$\hat{\pi}_2$	$\hat{\pi}_3$
pos	1	0.7	0.2	0.1
pos	1	0.5	0.3	0.2
	2	0.3	0.5	0.2
	2	0.4	0.5	0.1
neg	3	0.6	0.1	0.3
neg	3	0.1	0.1	0.8

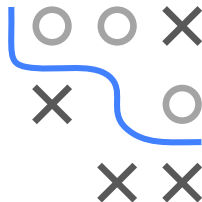
AUC(pos neg) = AUC(3 1)				
	Y	$\hat{\pi}_1$	$\hat{\pi}_2$	$\hat{\pi}_3$
neg	1	0.7	0.2	0.1
neg	1	0.5	0.3	0.2
	2	0.3	0.5	0.2
	2	0.4	0.5	0.1
pos	3	0.6	0.1	0.3
pos	3	0.1	0.1	0.8

MULTI-CLASS AUC

Hand and Till (2001) proposed to avg AUC via **1-vs-1**:

- For all class pairs, compute $AUC(k | \ell)$.

$$AUC_{MC} = \frac{1}{g(g-1)} \sum_{k \neq \ell} AUC(k | \ell) \in [0, 1].$$



Comments:

- Other defs use **1-vs-rest** and need to avg only g AUC values
- 1-vs-rest creates imbal classes even if orig classes are balanced
- Imbalanced classes can be considered by weighting individual AUC values with class priors [Ferri et al. (2003)]