Exercices 3

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1 Bayes estimator and Bayes risk

Consider the following joint random variable (X, Y).

— $\mathcal{X} = \{0, 1, 2\}$

— $\mathcal{Y} = \{0, 1\}$.

— X follows a uniform law on $\mathcal{X}$.

—

$$Y = \begin{cases} B(1/5) \text{ if } X = 0 \\ B(3/4) \text{ if } X = 1 \\ B(2/3) \text{ if } X = 2 \end{cases}$$

With $B(p)$ a Bernoulli law with parameter p.

Compute the Bayes estimator and the bayes risk.

2 Logistic regression

Summary of the setting : in the context of binary classification, we consider the following setting.

— $\mathcal{X} = \mathbb{R}^d$

— $\mathcal{Y} = \{0, 1\}$ (sometimes $\mathcal{Y} = \{-1, 1\}$)

— $l_{0-1}(y, z) = 1_{y \neq z}$ ("0-1" loss)

Note that we can extend these definitions to non-binary classification. We would like a predictor that minimizes the binary loss.

Definition 1. Binary loss function

$$\hat{R}_n(\theta) = \frac{1}{n} \sum_{i=1}^{n} \mathbb{1}_{y_i \neq \hat{f}(x_i)}$$

However, as we have seen in the class, it is hard to minimize the binary loss as it is neither differentiable nor convex in θ. We can replace it by a **convex, differentiable surrogate loss** (**substitut convexe**). Several possibilities exist instead of using $\mathbb{1}_{y_i \neq \hat{f}(x_i)}$ as l (binary loss). The **logistic loss** is one of them

Definition 2. Logistic loss

$$l(\hat{y}, y) = y \log(1 + e^{-\hat{y}}) + (1 - y) \log(1 + e^{\hat{y}}) \tag{1}$$

We can define the corresponding empirical risk.

$$R_n(\theta) = \frac{1}{n} \sum_{i=1}^{n} l(x_i^T \theta, y_i) \tag{2}$$

Definition 3. Logistic regression estimator
If l is the logistic loss, it is defined as

$$\hat{\theta}_{logit} = \arg\min_{\theta \in \mathbb{R}^d} R_n(\theta)$$

Compute the gradient of $R_n(\theta)$, $\nabla_\theta R_n$.

3 OLS RISK DECOMPOSITION

Show the first part of proposition 15 in FTML.pdf (Risk decomposition for OLS, linear model, fixed design).

$$R_X(\theta) - R_X(\theta^*) = ||\theta - \theta^*||^2_{\hat{\Sigma}}$$

where $R_X(\theta)$ is the fixed design risk, defined by

$$R_X(\theta) = E_Y\left[\frac{1}{n}||Y - X\theta||^2\right] \tag{3}$$