Sentiment Analysis: Ordinal Logistic Regression

ChengXiang "Cheng" Zhai
Department of Computer Science
University of Illinois at Urbana-Champaign

Motivation: Rating Prediction

- Input: An opinionated text document **d**
- Output: Discrete rating **r** $\in${**1, 2, …, k**}
- Using regular text categorization techniques
  - Doesn't consider the order and dependency of the categories
  - The features distinguishing r=2 from r=1 may be the same as those distinguishing r=k from r=k-1 (e.g., positive words generally suggest a higher rating)
- Solution: Add order to a classifier (e.g., ordinal logistic regression)

Logistic Regression for Binary Sentiment Classification

Binary Response Variable: Y $\in\{0,1\}$

Predictors: $X = (x_1, x_2, \dots, x_M),\ \ x_i \in \Re$

$$Y = \begin{cases} 1 & X \text{ is POSITIVE} \\ 0 & X \text{ is NEGATIVE} \end{cases}$$

$$\log \frac{p(Y=1 \mid X)}{p(Y=0 \mid X)} = \log \frac{p(Y=1 \mid X)}{1 - p(Y=1 \mid X)} = \beta_0 + \sum_{i=1}^{M} x_i \beta_i \qquad \beta_i \in \Re$$

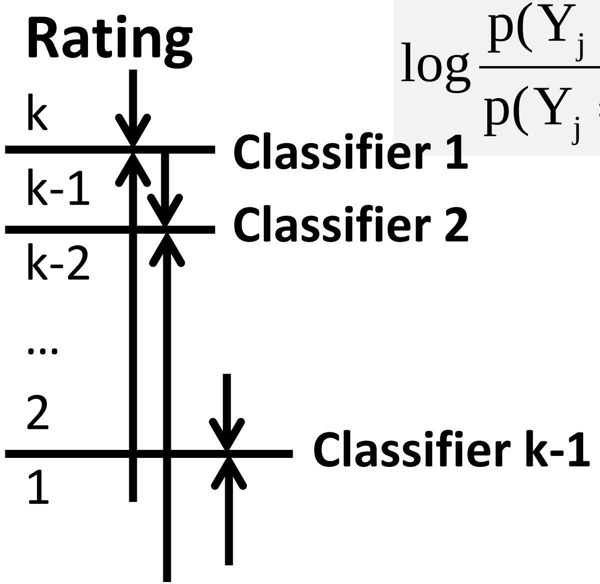
$$p(Y=1 \mid X) = \frac{e^{\beta_0 + \sum_{i=1}^{M} x_i \beta_i}}{e^{\beta_0 + \sum_{i=1}^{M} x_i \beta_i} + 1}$$

Logistic Regression for Multi-Level Ratings

$$Y_j = \begin{cases} 1 & \text{rating is } j \text{ or above} \\ 0 & \text{rating is lower than } j \end{cases}$$

Predictors: $X = (x_1, x_2, \ldots, x_M),\ x_i \in \Re$

Rating: r∈{1, 2, …, k}



$$\log \frac{p(Y_j = 1 | X)}{p(Y_j = 0 | X)} = \log \frac{p(r \geq j | X)}{1 - p(r \geq j | X)} = \alpha_j + \sum_{i=1}^{M} x_i \beta_{ji} \qquad \beta_{ji} \in \Re$$

$$p(r \geq j | X) = \frac{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}}}{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}} + 1}$$

Rating Prediction with Multiple Logistic Regression Classifiers

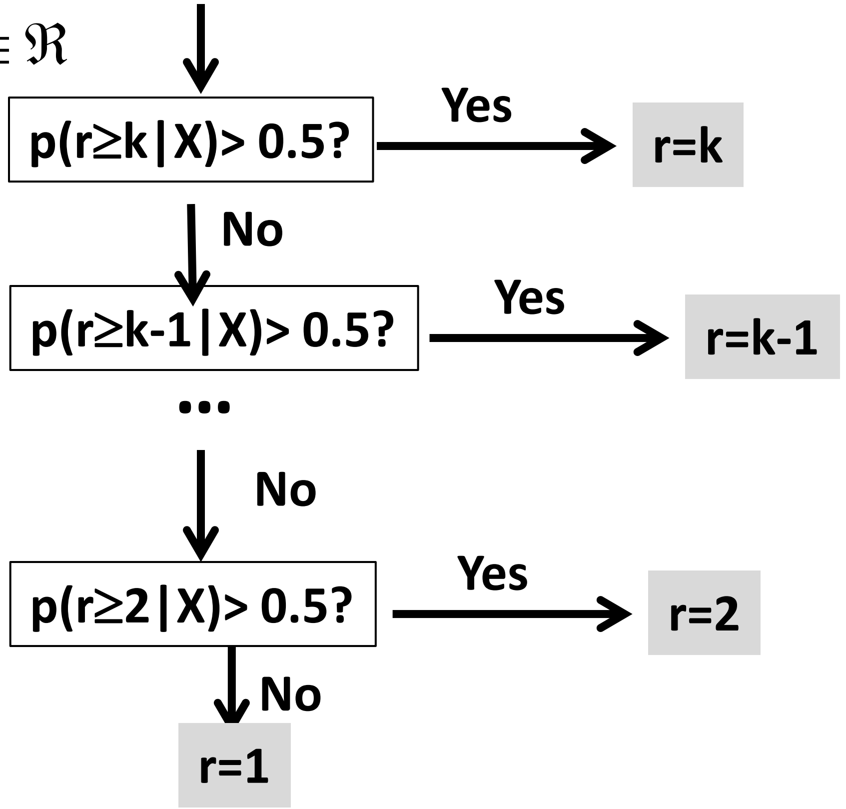
Text Object: $X = (x_1, x_2, \ldots, x_M),\ \ x_i \in \Re$

Rating: r∈{1, 2, …, k}

After training k-1
Logistic Regression Classifiers

$$p(r \geq j \mid X) = \frac{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}}}{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}} + 1}$$

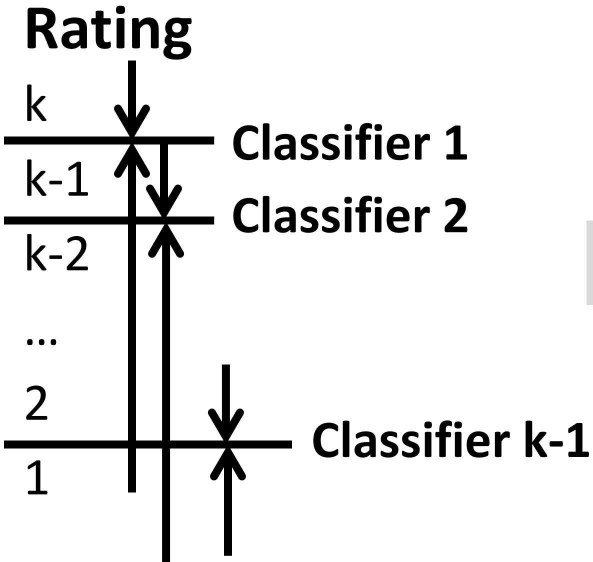
j=k, k-1, …, 2



Problems with k-1 Independent Classifiers?

$$\log \frac{p(Y_j = 1 | X)}{p(Y_j = 0 | X)} = \log \frac{p(r \geq j | X)}{1 - p(r \geq j | X)} = \alpha_j + \sum_{i=1}^{M} x_i \beta_{ji} \quad \beta_{ji} \in \Re$$

$$p(r \geq j | X) = \frac{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}}}{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_{ji}} + 1}$$



How many parameters are there in total? **(k-1)*(M+1)**

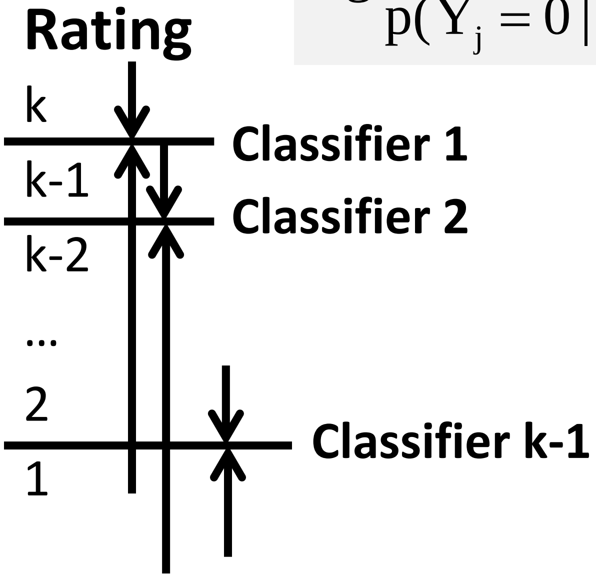
The k-1 classification problems are dependent.
The positive/negative features tend to be similar!

Ordinal Logistic Regression

Key Idea: $\forall i = 1, \ldots, M, \forall j = 3, \ldots, k, \beta_{ji} = \beta_{j-1i}$

➔ **Share training data** ➔ **Reduce # of parameters**

$$\log\frac{p(Y_j = 1 \mid X)}{p(Y_j = 0 \mid X)} = \log\frac{p(r \ge j \mid X)}{1 - p(r \ge j \mid X)} = \alpha_j + \sum_{i=1}^{M} x_i \beta_i \quad \beta_i \in \Re$$



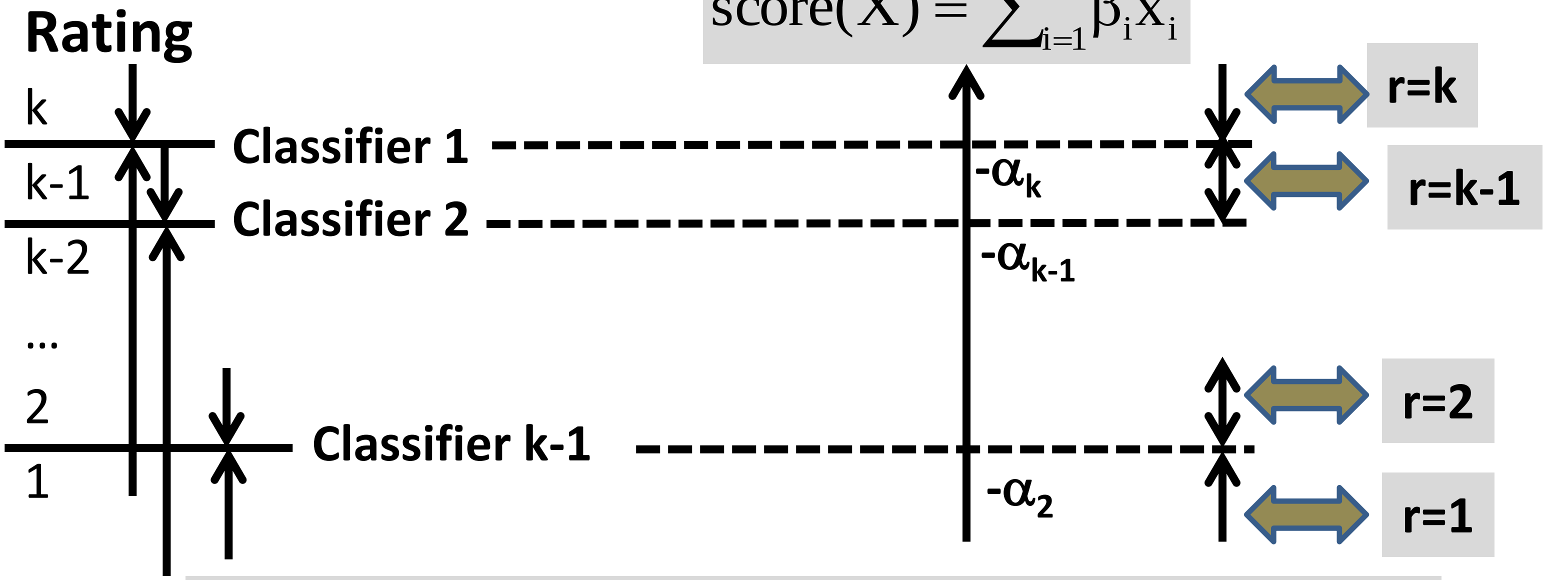
$$p(r \ge j \mid X) = \frac{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_i}}{e^{\alpha_j + \sum_{i=1}^{M} x_i \beta_i} + 1}$$

How many parameters are there in total? **M+k-1**

Ordinal Logistic Regression: Rating Prediction

$$p(r \ge j \mid X) \ge 0.5 \Leftrightarrow \frac{e^{\alpha_j + \mathrm{score}(X)}}{e^{\alpha_j + \mathrm{score}(X)} + 1} \ge 0.5 \Leftrightarrow \mathrm{score}(X) \ge -\alpha_j$$

$$\mathrm{score}(X) = \sum_{i=1}^{M} \beta_i x_i$$



$r=j \Leftrightarrow \mathrm{score} \in [-\alpha_j, -\alpha_{j+1})$, define $\alpha_1=\infty$, $\alpha_{k+1}=-\infty$