Paper Reading Note
Factorization Machines

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1.1 Factorization Machine Model

Factorization machines model all nested interactions up to order d between the p input variables in $\mathbf{x}$ using factorized interaction parameters. The factorization machine model of order $d = 2$ is defined as

$$\hat{y}(\mathbf{x}) := w_0 + \sum_{j=1}^{p} w_j x_j + \sum_{i=1}^{p} \sum_{j=i+1}^{p} x_i x_j \sum_{f=1}^{k} v_{if} v_{jf} \tag{1}$$

where k is the dimensionality of the factorization and the model parameters $\theta = \{w_0, w_1, \cdots, w_p, v_{1,1}, \cdots, v_{p,k}\}$ are

$$v_0 \in R, \mathbf{w} \in R^p, \mathbf{V} \in R^{p \times k} \tag{2}$$

Complexity. Let N_z be the number of nonzero elements in a matrix X or vector $\mathbf{x}$.

$$N_z(X) := \sum_i \sum_j \delta(x_{i,j} \neq 0) \tag{3}$$

The FM model in Equation(1) can be computed in $O(kN_z(\mathbf{x}))$ because it is equivalent to

$$\hat{y}(\mathbf{x}) = w_0 + \sum_{j=1}^{p} w_j x_j + \frac{1}{2} \sum_{f=1}^{k} \left[(\sum_{j=1}^{p} (v_{j,f} x_j))^2 - \sum_{j=1}^{p} v_{j,f}^2 x_j^2 \right] \tag{4}$$