

$$\begin{array}{l} \text{?} \quad \text{??} \\ \text{?} \quad uiuiui? \\ \text{?} \text{?} 1- \\ \frac{1}{e} - \\ \frac{1}{e} - \\ \frac{1}{e} \end{array}$$

$$\text{??} \quad 23\text{MFWMFLLORMA4LWMFDCGASC56}$$

$$\begin{array}{l} \mathbf{R}_{um}^h \mathcal{U}^h \\ \mathbf{R}_{um}^h \mathbf{R}_h \mathbf{R}_{um}^{h\top} \\ N, M \\ K \ll \\ \min(N, M) \\ H \\ \mathbf{R} \end{array}$$

$$\begin{array}{l} \in \\ \mathbf{C} \quad R^{N \times M} \\ \in \\ R^{N \times M} \end{array}$$

$$\begin{array}{l} \mathbf{W} \\ \mathbf{P}, \mathbf{Q} \\ \mathbf{R}^h \\ \mathbf{C}^h \\ \mathbf{W}^h \\ \mathbf{T}^h \\ \mathcal{U}^h, \mathcal{V}^h \end{array} \quad \begin{array}{l} h \\ h \\ \mathbf{C}^h \\ \mathbf{C}^h \mathbf{C}^h \end{array}$$

$$\begin{array}{l} \mathbf{P}_u^h, \mathbf{Q}_m^h \\ \mathcal{R}^{hum} \in \\ R^K \end{array}$$

$$\begin{array}{l} A \\ a_i = \langle u_i, m_i \rangle \\ \langle u_i, m_i \rangle \end{array}$$

$$\begin{array}{l} \in \\ \mathcal{A} \\ \subset \end{array}$$

$$\begin{array}{l} \hat{a}_h = \langle \hat{u}_h, \hat{m}_h \rangle \\ \mathcal{A} \\ \in \\ \mathcal{A} \end{array}$$

$$\text{?} \quad E(a_i, a_j)$$

$$\begin{array}{l} \text{?} \\ \text{?}Netflix^1 \\ KDD2011^{23} \mathbf{R} \in \\ R^{N \times M} \end{array}$$

$$\begin{array}{l} \mathbf{O}K \ll \\ \min\{N, M\} \\ N \quad M \end{array}$$

$$\min_{\mathbf{P}, \mathbf{Q}} \sum_{u=1}^N \sum_{m=1}^M \mathbf{O}_{um} (\mathbf{R}_{um} - \mathbf{P}_u^\top \mathbf{Q}_m)^2$$

$$(1) \quad \mathbf{R}_{um}um\mathbf{P}_u\mathbf{Q}_mum\mathbf{O}_{um}um$$

$$\sum_{u=1}^N \sum_{m=1}^M \mathbf{O}_{um} (\mathbf{R}_{um} - \mathbf{P}_u^\top \mathbf{Q}_m)^2 + \lambda_{\mathbf{P}} \|\mathbf{P}\|_F^2 + \lambda_{\mathbf{Q}} \|\mathbf{Q}\|_F^2$$

$$\begin{array}{l} (2) \quad \lambda_{\mathbf{P}} \lambda_{\mathbf{Q}} \\ \text{?} \mathbf{R}_{um} \\ \mathbf{P}_{uk}^+ \leftarrow \\ \ell((\mathbf{R}_{um} - \\ \mathbf{P}_u^\top \mathbf{Q}_m) \mathbf{Q}_{mk} - \\ \lambda_{\mathbf{P}} \mathbf{P}_{uk}) \\ \mathbf{Q}_{mk} \leftarrow \\ \mathbf{Q}_{mk}^+ \\ \ell((\mathbf{R}_{um} - \\ \mathbf{P}_u^\top \mathbf{Q}_m) \mathbf{P}_{uk} - \\ \lambda_{\mathbf{Q}} \mathbf{Q}_{mk}) \\ \ell \mathbf{P}_{uk} uk \\ \mathbf{Q}_{mk} mk \\ \text{?} \\ \text{?} \\ \text{?} \end{array}$$

$$(3)_{\varepsilon} \quad \mathbf{W}_{um} = 1 + \log(1 + \mathbf{R}_{um} \times 10^{\varepsilon})$$

$$\lambda \left(\sum_{u=1}^N \sum_{m=1}^M \mathbf{W}_{um} (\mathbf{G}_{um} - \mathbf{P}_u^\top \mathbf{Q}_m)^2 + \lambda_{\mathbf{P}} \|\mathbf{P}\|_F^2 + \lambda_{\mathbf{Q}} \|\mathbf{Q}\|_F^2 \right)$$