

Data: S_1 , O , users bias, items bias, P , Q , Y

Result: Updated model

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1 repeat
2   forall  $(u, i, r) \in S_1$  do
3      $e_{u,i} = r_{u,i} - \hat{r}_{u,i}$ ;
4      $\Delta b_u = e_{u,i} - \lambda_1 \cdot b_u$ ;  $\Delta b_i = e_{u,i} - \lambda_1 \cdot b_i$ ;
5      $\Delta p_u = e_{u,i} \cdot q_i - \lambda_2 \cdot p_u$ ;  $\Delta q_i \leftarrow e_{ui} \cdot \left( p_u + |N_u|^{-\frac{1}{2}} \sum_{j \in N_u} y_j \right) - \lambda_2 \cdot q_i$ ;
6     if  $u \in O$  then
7        $b_u = b_u + \gamma \cdot \Delta b_u$ ;  $p_u = p_u + \gamma \cdot \Delta p_u$ ;
8     end if
9     if  $i \in O$  then
10       $b_i = b_i + \gamma \cdot \Delta b_i$ ;  $q_i = q_i + \gamma \cdot \Delta q_i$ ;
11    end if
12    forall  $j \in N_u$  do
13      if  $j \in O$  then
14         $y_j = y_j + \gamma \cdot \left( e_{ui} \cdot |N_u|^{-\frac{1}{2}} \cdot q_i - \lambda_2 \cdot y_j \right)$ ;
15      end if
16    end forall
17  end forall
18 until regularized squared error  $\approx 0$ ;
```