

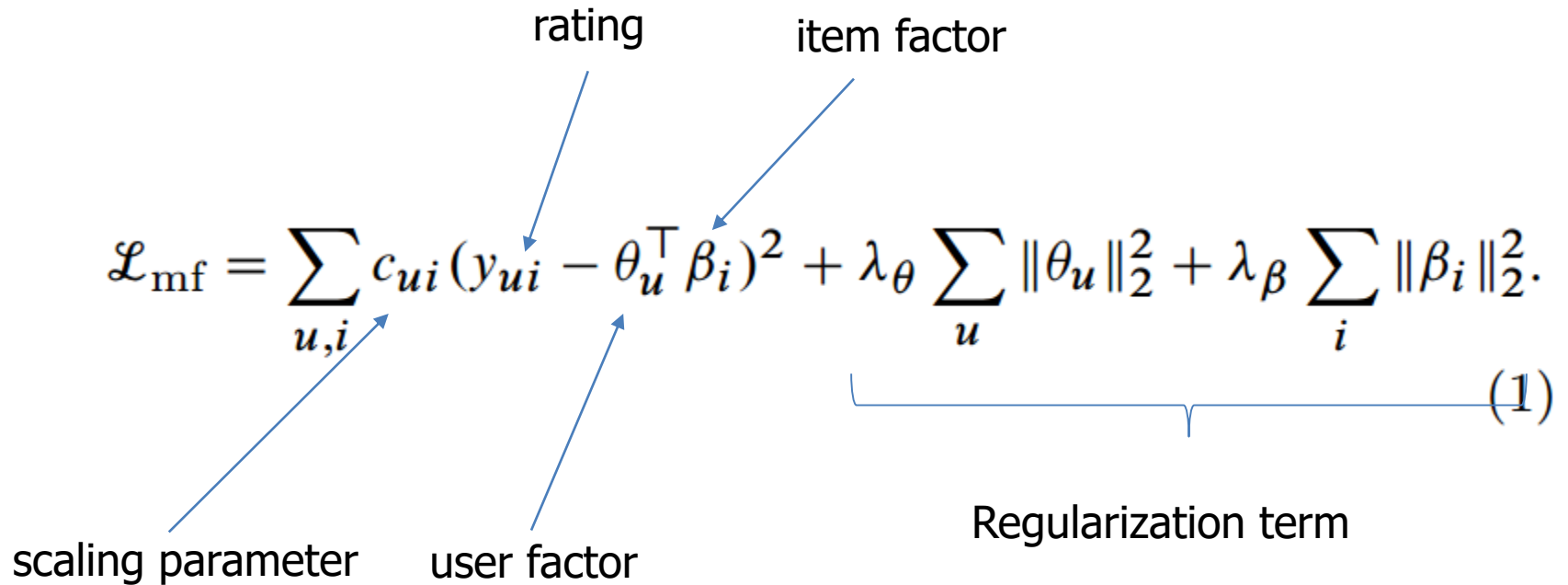


**Factorization meets the Item Embedding
: Regularizing Matrix Factorization with
Item Co-occurrence**

Main Idea

- 다른 사용자가 연달아 소비한 아이템들의 쌍이 유사할 것임
- **simultaneously factorization**
 - ⊙ the click matrix and the item co-occurrence matrix
 - ⊙ Matrix factorization + item embedding
 - ⊙ Cofactor model 제안

Matrix factorization



The diagram illustrates the matrix factorization loss function \mathcal{L}_{mf} with several annotations. A blue wavy line at the top of the slide contains three spheres: a green one on the left, a blue one on the right, and a purple one below the blue one. The equation is
$$\mathcal{L}_{\text{mf}} = \sum_{u,i} c_{ui} (y_{ui} - \theta_u^\top \beta_i)^2 + \lambda_\theta \sum_u \|\theta_u\|_2^2 + \lambda_\beta \sum_i \|\beta_i\|_2^2. \quad (1)$$
 Annotations include: 'rating' pointing to y_{ui} ; 'item factor' pointing to β_i ; 'scaling parameter' pointing to c_{ui} ; 'user factor' pointing to θ_u ; and 'Regularization term' pointing to the last two terms of the equation.

$$\mathcal{L}_{\text{mf}} = \sum_{u,i} c_{ui} (y_{ui} - \theta_u^\top \beta_i)^2 + \lambda_\theta \sum_u \|\theta_u\|_2^2 + \lambda_\beta \sum_i \|\beta_i\|_2^2. \quad (1)$$

rating

item factor

scaling parameter

user factor

Regularization term

Word embedding

- $\#(i,j)$ is the number of times word j appears in the context of word i
- D is the total number of word-context pairs

$$\text{PMI}(i, j) = \log \frac{\#(i, j) \cdot D}{\#(i) \cdot \#(j)}. \quad (2)$$

$$\#(i) = \sum_j \#(i, j) \text{ and } \#(j) = \sum_i \#(i, j)$$

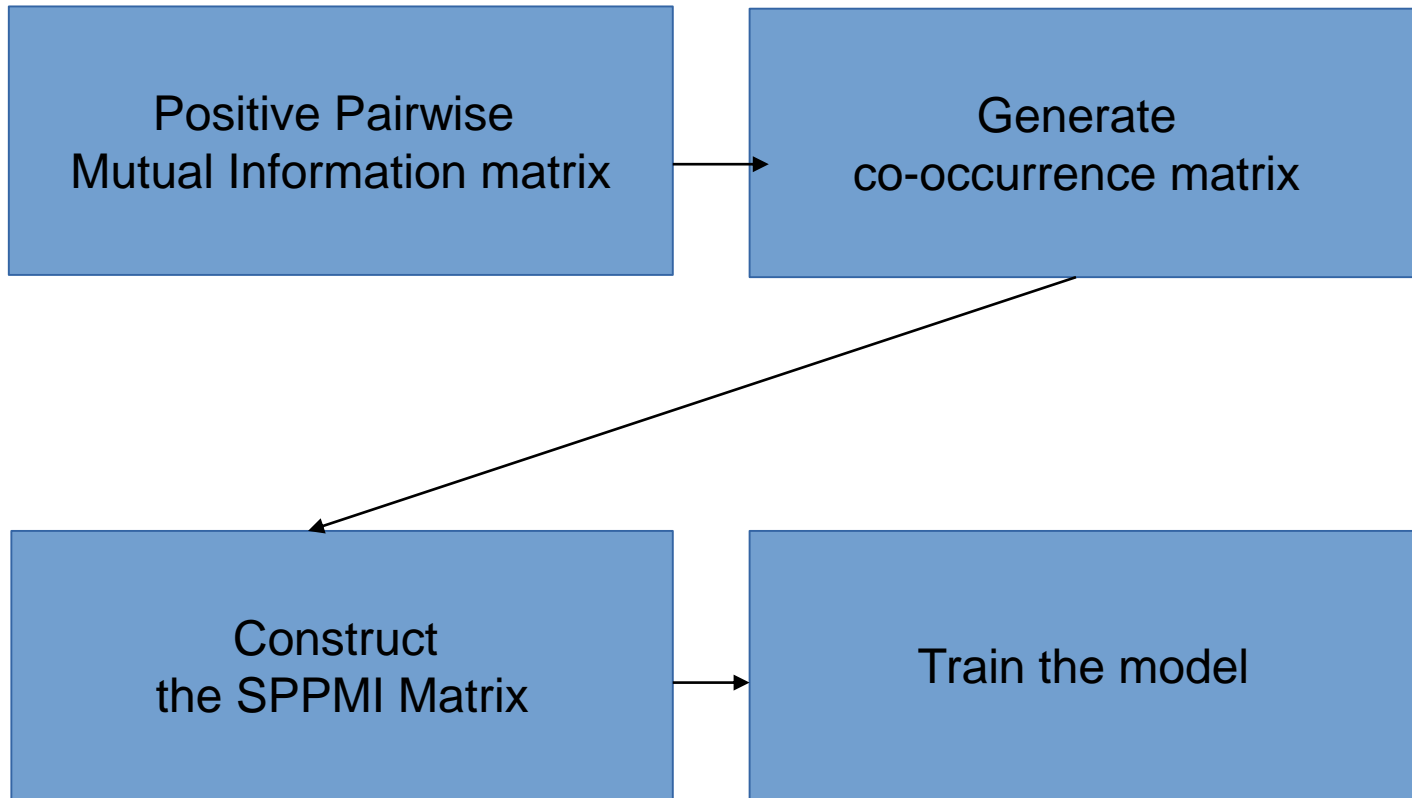
$$\text{SPPMI}(i, j) = \max \{ \text{PMI}(i, j) - \log k, 0 \}$$

Cofactor model

- MF + item embedding

$$\mathcal{L}_{\text{co}} = \underbrace{\sum_{u,i} c_{ui} (y_{ui} - \theta_u^\top \beta_i)^2}_{\text{MF}} + \underbrace{\sum_{m_{ij} \neq 0} (m_{ij} - \beta_i^\top \gamma_j - w_i - c_j)^2}_{\text{item embedding}} + \lambda_\theta \sum_u \|\theta_u\|_2^2 + \lambda_\beta \sum_i \|\beta_i\|_2^2 + \lambda_\gamma \sum_j \|\gamma_j\|_2^2 \quad (3)$$

Process



Example

	4.5	3.0	
4.0		3.5	
	5.0		2.0
	3.5	4.0	2.0

0	1	1	0
1	0	1	0
0	1	0	1
0	1	1	1

Example

v	0	1	1	0
1	0	1	1	0
0	1	0	1	1
0	1	1	1	1

PPMI matrix

```
(0, 1) 1
(0, 2) 1
(1, 0) 1
(1, 2) 1
(2, 1) 1
(2, 3) 1
(3, 1) 1
(3, 2) 1
(3, 3) 1
```

```
[[0 1 1 0]
 [1 0 1 0]
 [0 1 0 1]
 [0 1 1 1]]
```

Co-occurrence matrix

```
(1, 3) 1.0
(2, 3) 2.0
(2, 4) 2.0
(3, 1) 1.0
(3, 2) 2.0
(3, 4) 1.0
(4, 2) 2.0
(4, 3) 1.0
```

```
[[ 0.  0.  1.  0.]
 [ 0.  0.  2.  2.]
 [ 1.  2.  0.  1.]
 [ 0.  2.  1.  0.]]
```

SPPMI matrix

```
[ 1.09861231  0.4054651  0.69314718  1.09861231  0.4054651  0.69314718]
```

```
[[ 0.  0.  1.09861231  0.
 [ 0.  0.  0.4054651  0.69314718]
 [ 1.09861231  0.4054651  0.  0.
 [ 0.  0.69314718  0.  0.]]]
```


Experiment

- movielens의 20M dataset
 - 138,000 user
 - 20million ratings
 - 27,000 movies
 -

```
Test Recall@20: 0.1448  
Test Recall@50: 0.1765
```