

How to Design and Build a Recommendation Pipeline in Python

Jill Cates
November 10th, 2018
PyCon Canada

Overview of the Recommender Pipeline

1. Pre-processing
2. Hyperparameter Tuning
3. Model Training and Prediction
4. Post-processing
5. Evaluation

Spotify



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Netflix



“Because you watched
this TV show...”

Because you watched Bloodline



Because you watched Orange Is the New Black



Because you watched House of Cards



Amazon

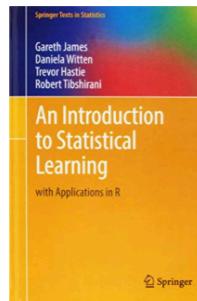


“Frequently bought together”

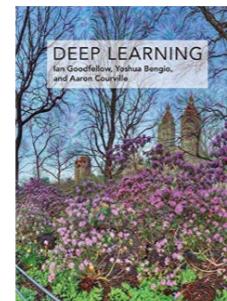
“Customers who bought this item also bought”

Customers who bought this item also bought

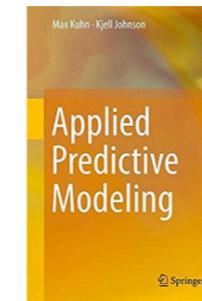
Page 1 of 17



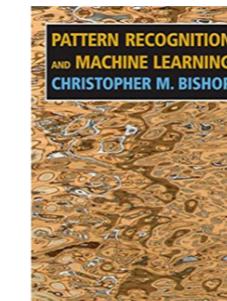
An Introduction to Statistical Learning: with Applications in R
Gareth James
★★★★★ 13
Hardcover
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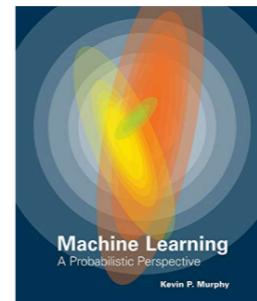
Deep Learning
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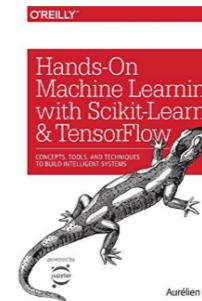
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OkCupid



“Finding your best match”

The image shows a mobile application interface for OkCupid's quiz feature. At the top, there is a navigation bar with three circular icons: the first is blue with a checkmark, the second is white with the number '2', and the third is white with the number '3'. To the right of these icons is the text "Answer 7 questions to calculate your best matches." and a "Skip >" button. Below the navigation bar is a large white rectangular box containing the text "1 of 7" at the top center. Inside this box is a question: "Are you a morning person?". At the bottom of this box is a "⟳ Next Question" button. Below the white box is a blue background area with two large buttons: an orange "No" button on the left and a green "Yes" button on the right.

1 of 7

Are you a morning person?

⟳ Next Question

No Yes

Recommender Systems in the Wild



Spotify

Discover Weekly



Amazon

Customers who bought
this item also bought



Netflix

Because you
watched this show...



LinkedIn

Jobs recommended for you



OkCupid

Finding your best match



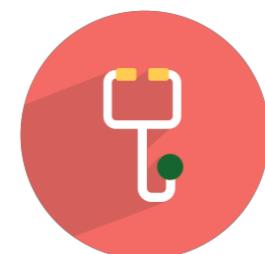
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Medicine

Facilitating clinical
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Before e-commerce

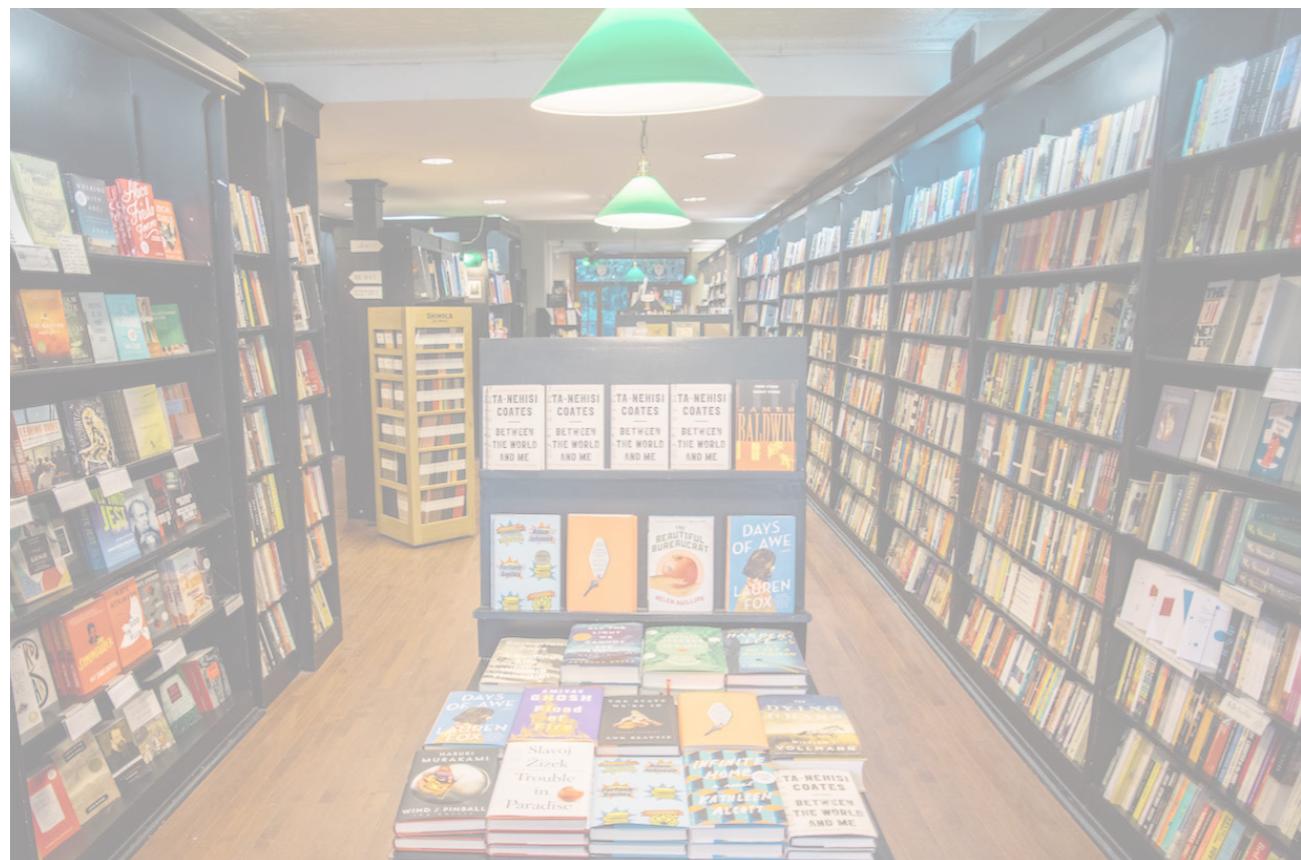
Things were sold exclusively in
brick-and-mortar stores...



limited inventory

mainstream products

Before e-commerce



Things were sold exclusively in
brick-and-mortar stores...

limited inventory

mainstream products

E-commerce

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unlimited inventory

niche products

Before e-commerce

Things were sold exclusively in brick-and-mortar stores...



limited inventory

mainstream products

E-commerce

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The Tasting Booth Experiment

When Choice is Demotivating: Can One Desire Too Much
of a Good Thing?

Sheena S. Iyengar
Columbia University

Mark R. Lepper
Stanford University

6 jam samples



24 jam samples

VS.



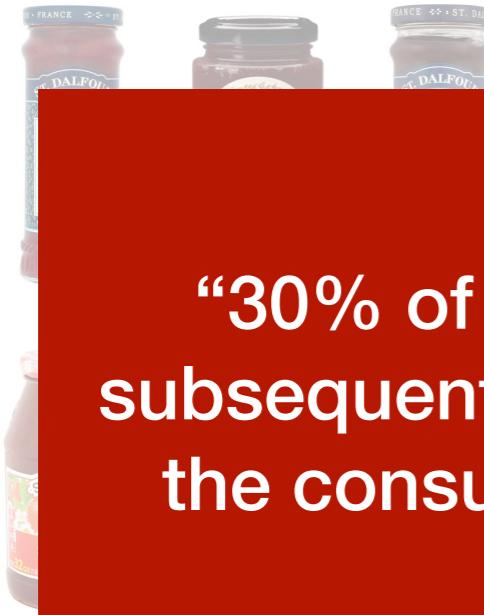
The Tasting Booth Experiment

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6 jam samples



24 jam samples



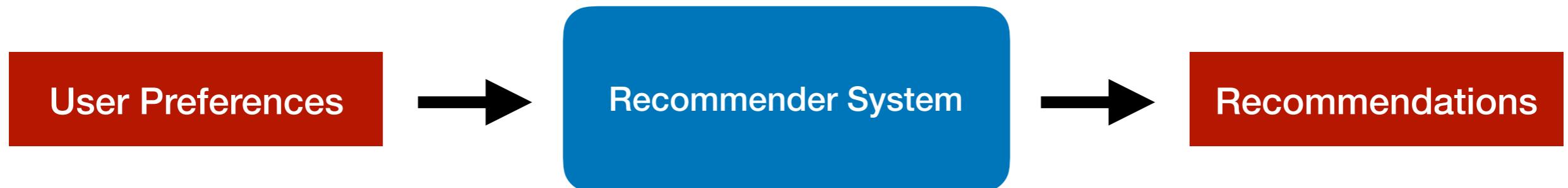
“30% of the consumers in the limited-choice condition subsequently purchased a jar of jam; in contrast, only 3% of the consumers in the extensive-choice condition did so”



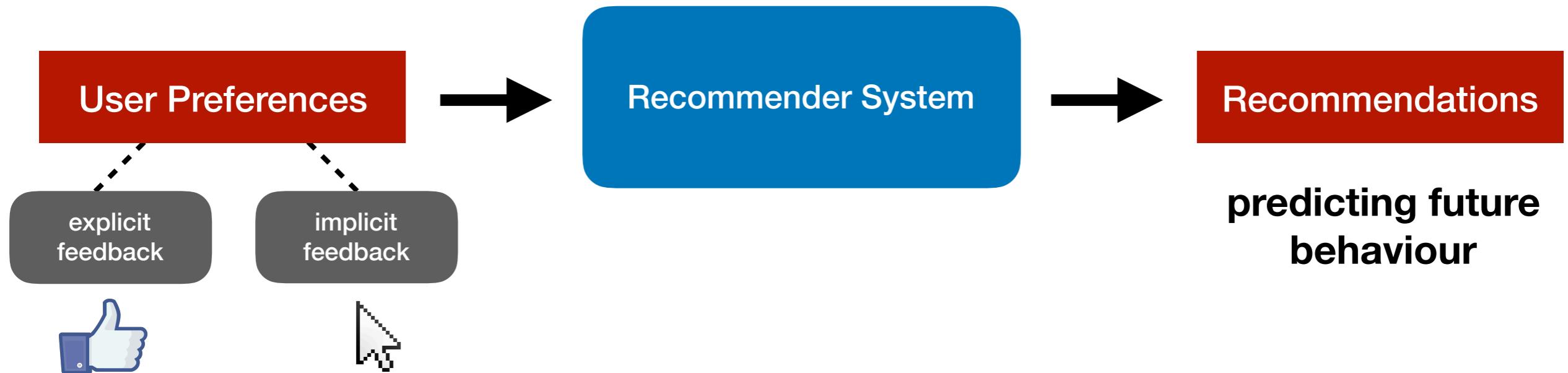
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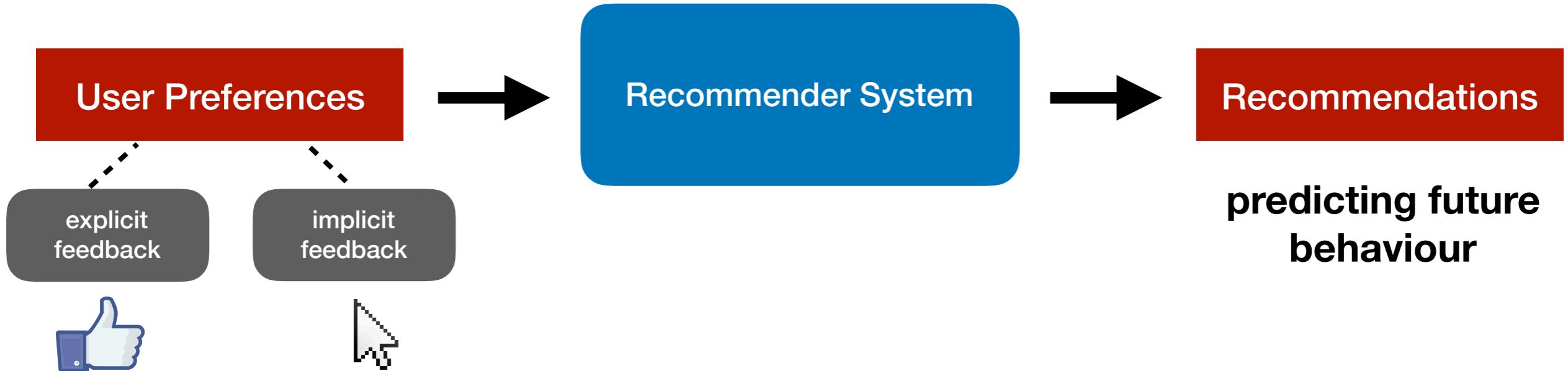
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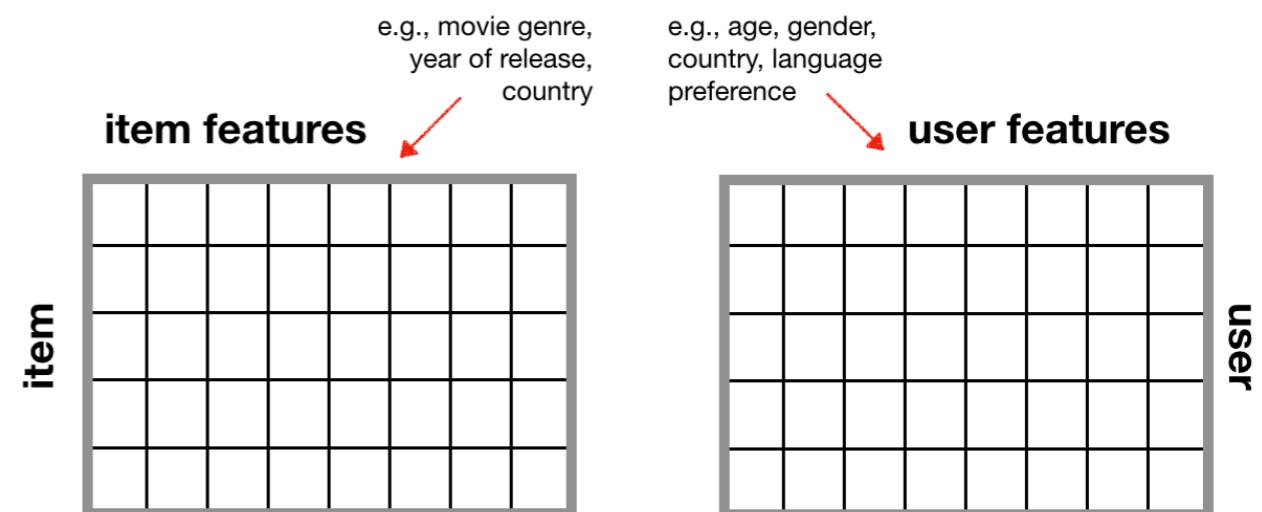


Collaborative filtering

user	John	Erica	Anne	Liz	Jim	
John	1	3		5	5	
Erica		5	2	4	4	5
Anne	5	2	1	4		2
Liz	3	4	3	4	5	
Jim	5	2	1	4	3	1

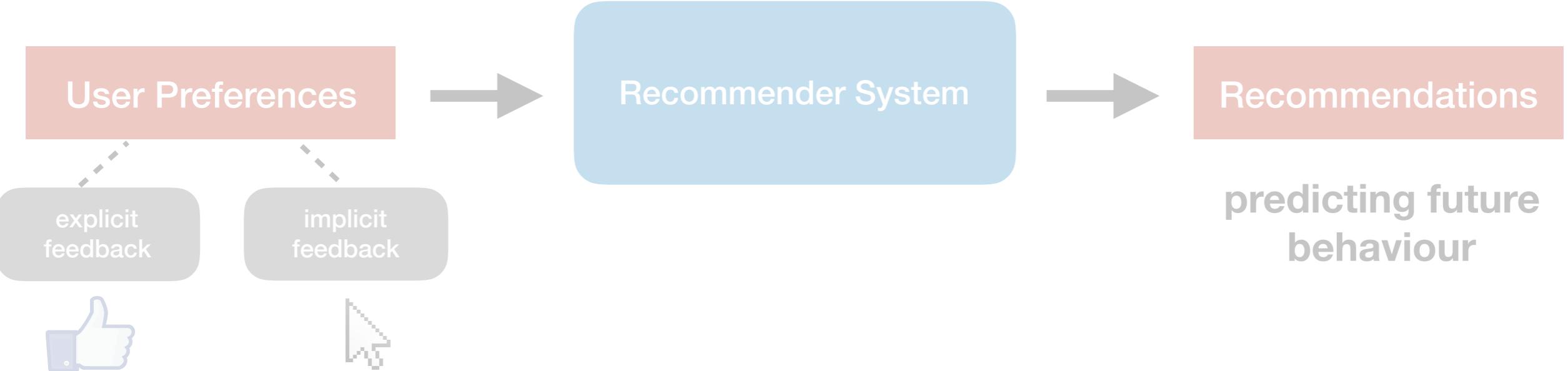
similar users like similar things

Content-based filtering

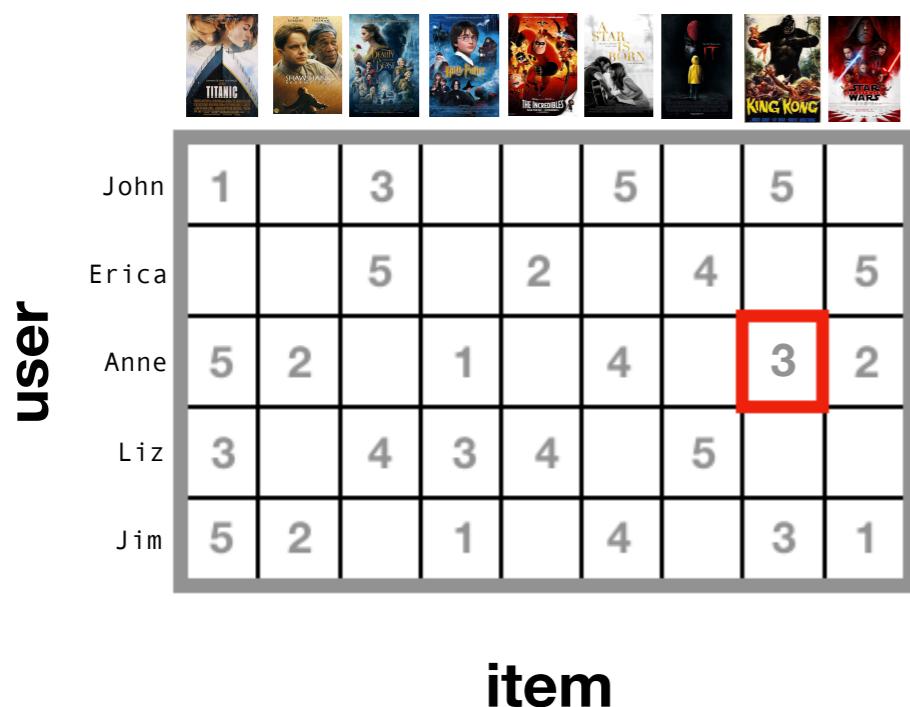


considers items/users features

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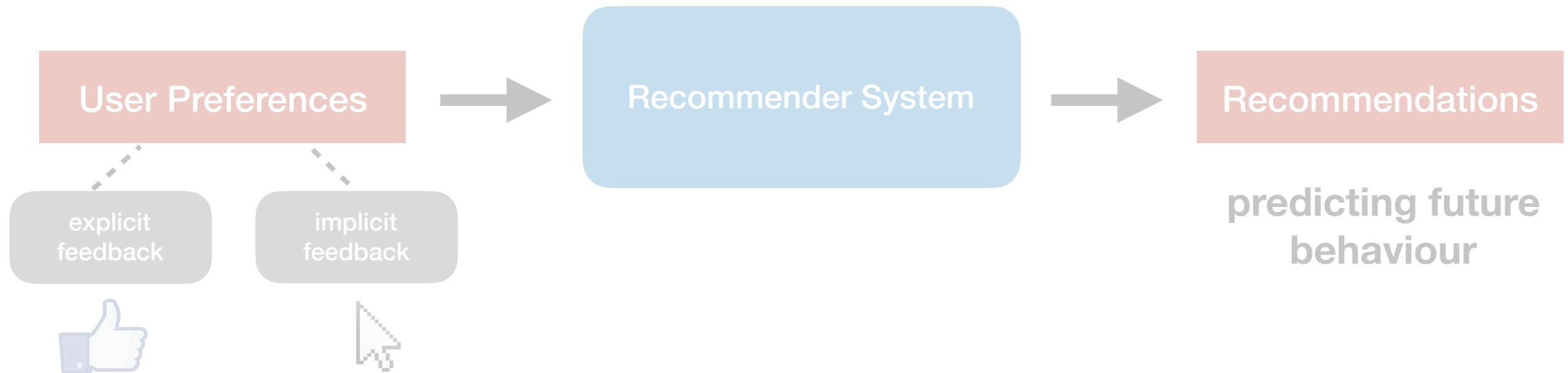
Collaborative filtering



similar users like
similar things

- “Because you watched Movie X”
- “Customers who bought this item also bought”

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Content-based filtering

users	age	gender	country	lang	kids?	religion	items
	scary	funny	family	anime	drama	indie	
John							
Erica							
Anne							
Liz							
Jim							

user and item features

- user features: age, gender, spoken language
- item features: movie genre, year of release, cast

Overview of the Recommender Pipeline

1. Pre-processing
2. Hyperparameter Tuning
3. Model Training and Prediction
4. Post-processing
5. Evaluation

Step 1: Data Pre-processing

user_id	movie_id	rating
2	439	4.0
10	368	4.5
14	114	5.0
19	371	1.0
2	371	3.0
19	114	4.5
3	439	3.5
54	421	2.0
32	114	3.0
10	369	1.0

Pre-processing

Hyperparameter
Tuning

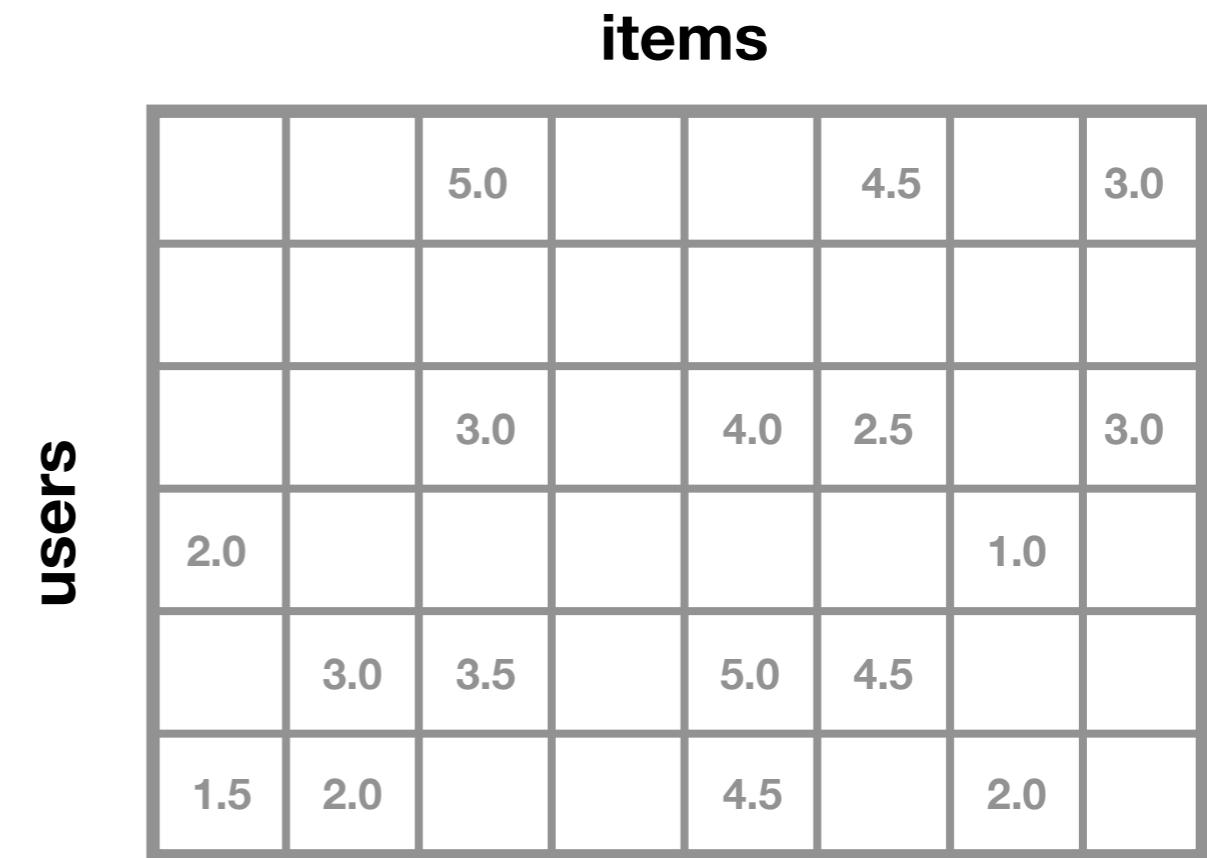
Model Training

Post-processing

Evaluation

Step 1: Data Pre-processing

user_id	movie_id	rating
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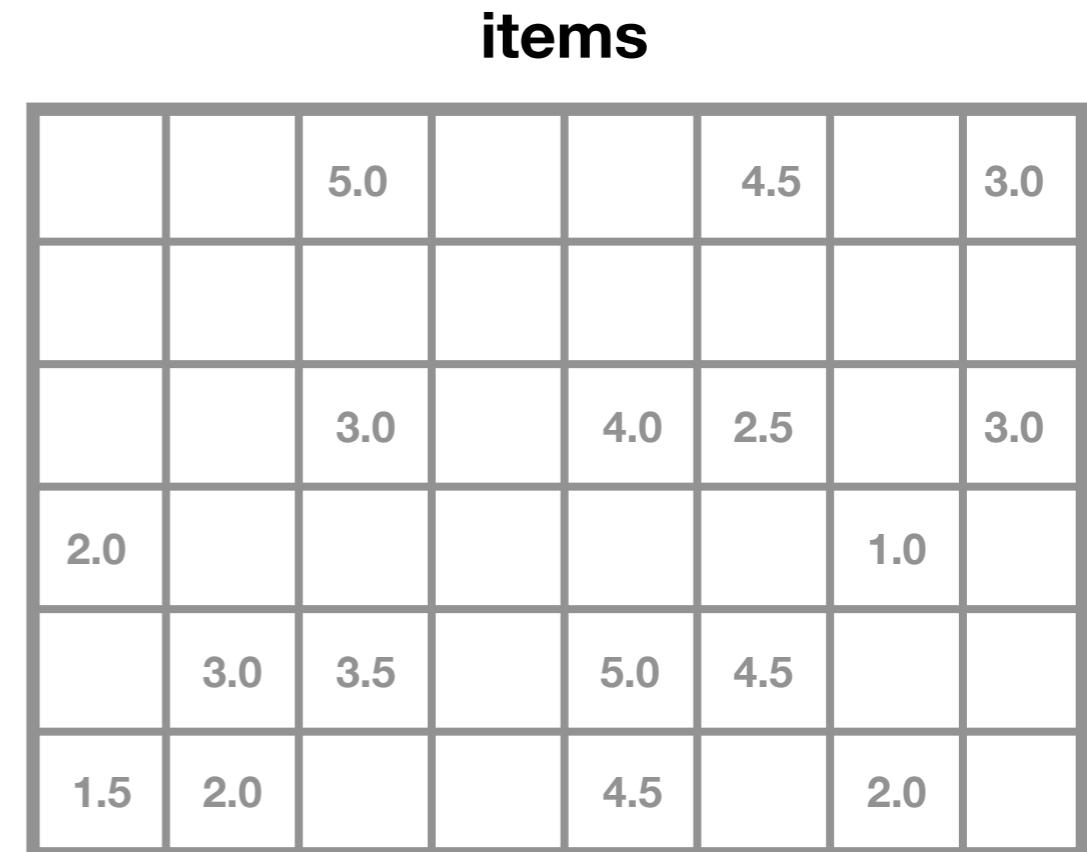
Transform original data to user-item (utility) matrix

Step 1: Data Pre-processing

user_id	movie_id	rating
2	439	4.0
10	368	4.5
14	114	5.0
19	371	1.0
2	371	3.0
19	114	4.5
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54	421	2.0
32	114	3.0
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Users

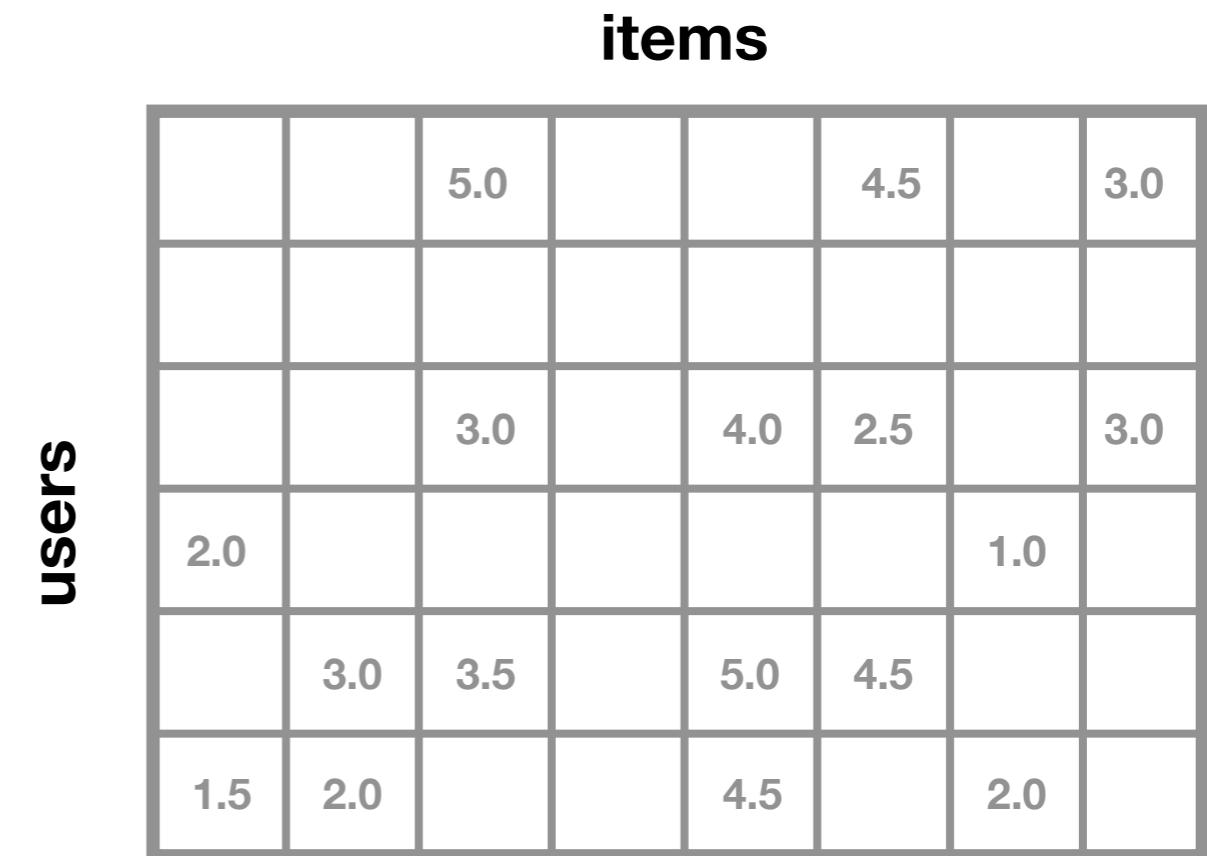


scipy.sparse.csr_matrix



Step 1: Data Pre-processing

user_id	movie_id	rating
2	439	4.0
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19	371	1.0
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54	421	2.0
32	114	3.0
10	369	1.0



Calculate Matrix Sparsity

$$\text{sparsity} = \frac{\# \text{ ratings}}{\text{total } \# \text{ elements}}$$

Step 1: Data Pre-processing

Normalization

- Optimists → rate everything 4 or 5
- Pessimists → rate everything 1 or 2
- Need to normalize ratings by accounting for user and item bias
- Mean normalization
 - subtract b_i from each user's rating for given item i

$$b_{ui} = \mu + b_i + b_u$$

Annotations for the equation:

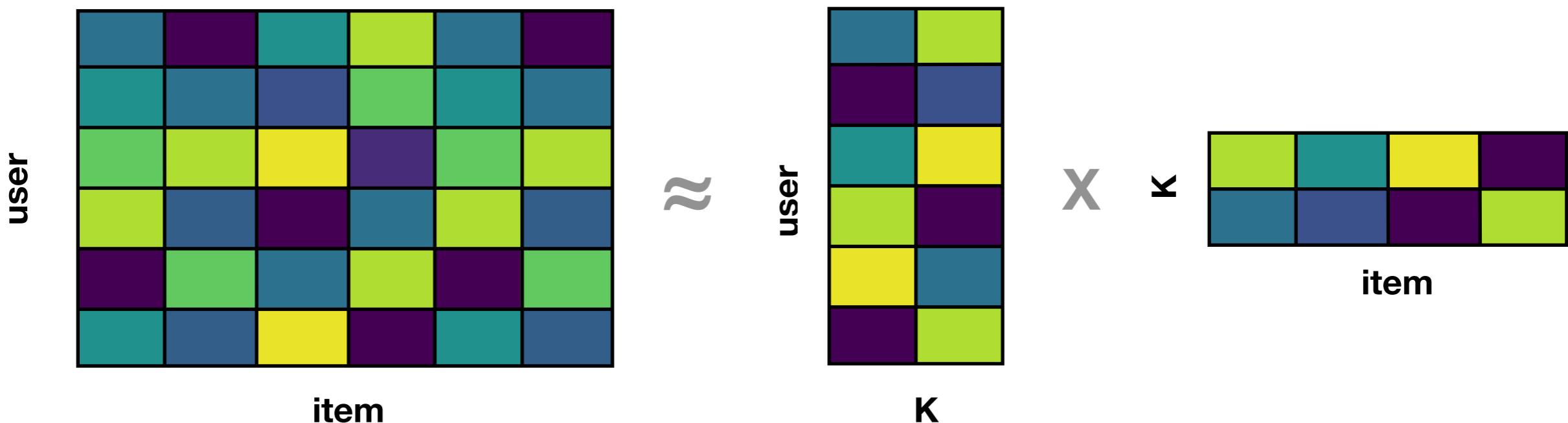
- A red arrow points to b_{ui} labeled "user-item rating bias".
- A red arrow points to μ labeled "global avg".
- A red arrow points to b_i labeled "item's avg rating".
- A red arrow points to b_u labeled "user's avg rating".

Pick a Model

Matrix Factorization

- factorize the user-item matrix to get 2 latent factor matrices:
 - user-factor matrix
 - item-factor matrix
- missing ratings are predicted from the inner product of these two factor matrices

$$X_{mn} \approx P_{mk} \times Q_{nk}^T = \hat{X}$$

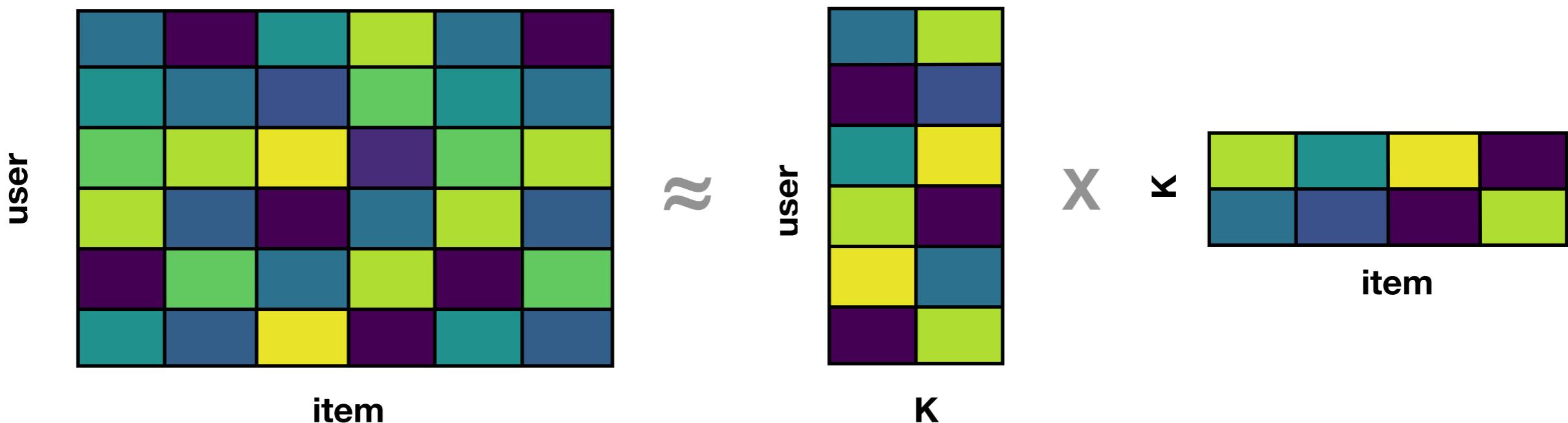


Pick a Model

Matrix Factorization

- Algorithms that perform matrix factorization:
 - Alternating Least Squares (ALS)
 - Stochastic Gradient Descent (SGD)
 - Singular Value Decomposition (SVD)

$$X_{mn} \approx P_{mk} \times Q_{nk}^T = \hat{X}$$

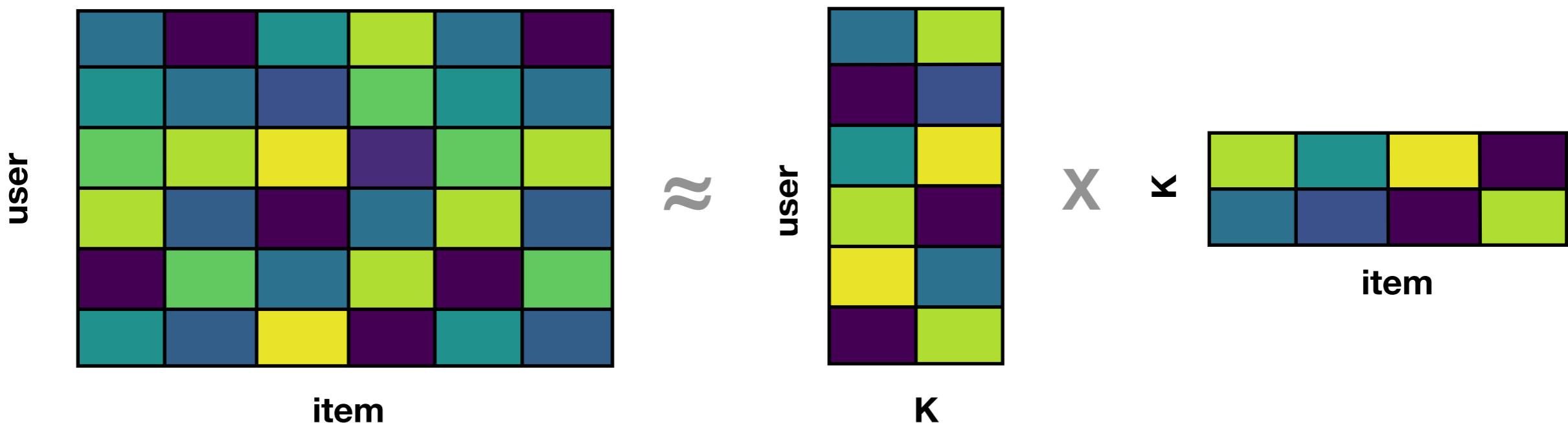


Pick a Model

Matrix Factorization

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 - Alternating Least Squares (ALS)
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$$X_{mn} \approx P_{mk} \times Q_{nk}^T = \hat{X}$$



Pick an Evaluation Metric

Precision@K

- Of the top K recommendations, what proportion are relevant to the user?

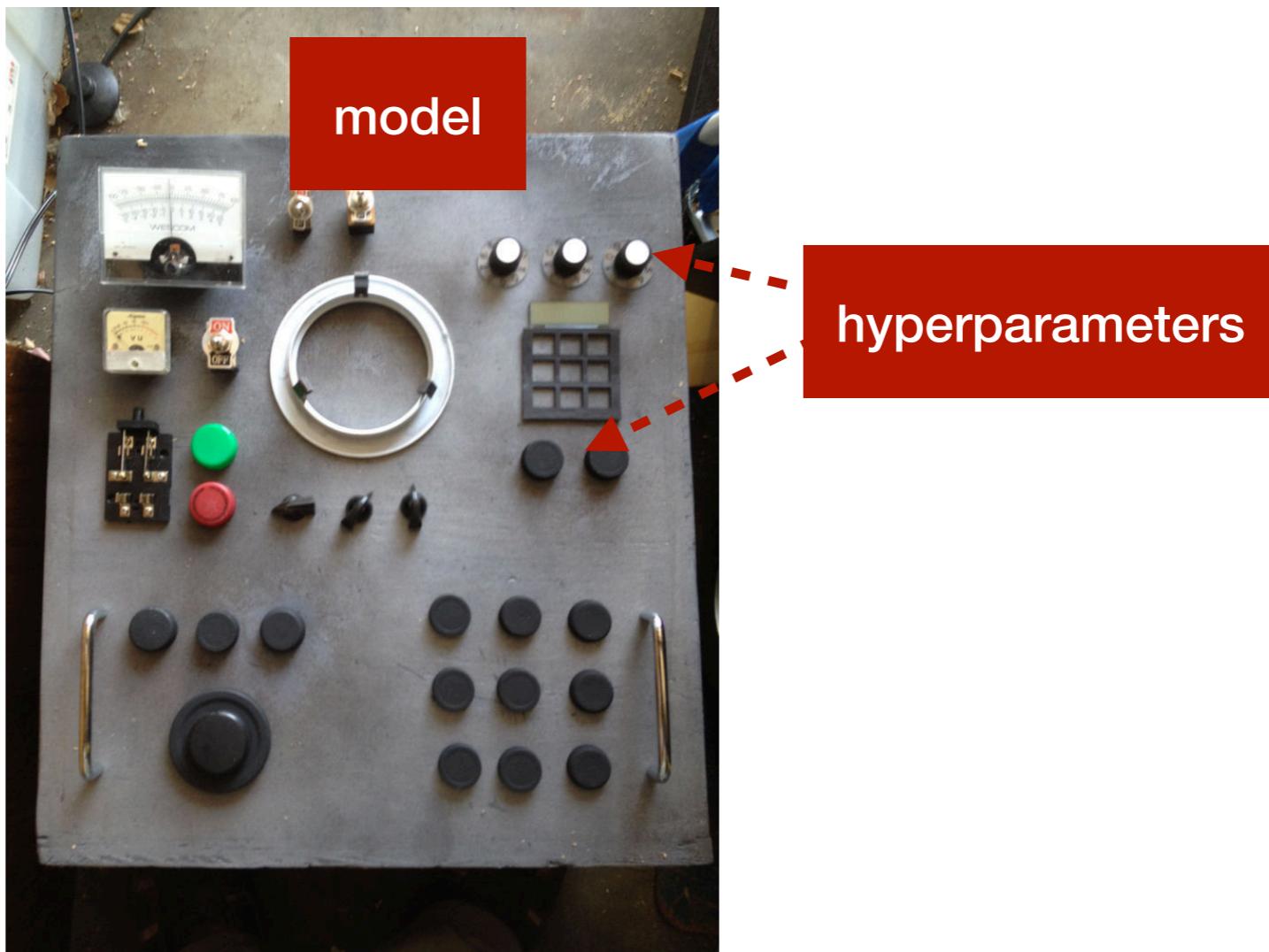
Pick an Evaluation Metric

Precision@10

- Of the top 10 recommendations, what proportion are relevant to the user?

Step 2: Hyperparameter Tuning

What is a hyperparameter?



configuration that is external to the model

Pre-processing

Hyperparameter
Tuning

Model Training

Post-processing

Evaluation

Step 2: Hyperparameter Tuning

Alternating Least Square's Hyperparameters

- k (# of factors)
- λ (regularization parameter)

Goal: find the hyperparameters that give the best precision@10

* (or any other evaluation metric that you want to optimize)

Pre-processing

Hyperparameter
Tuning

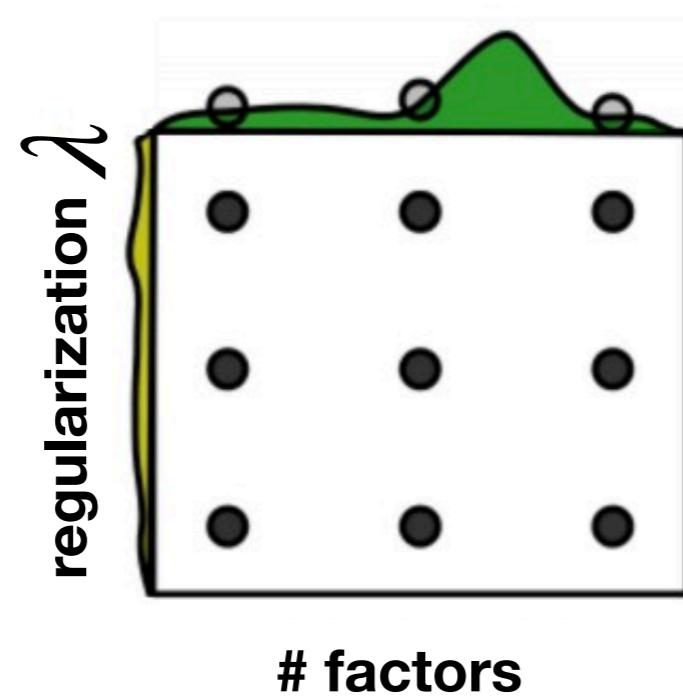
Model Training

Post-processing

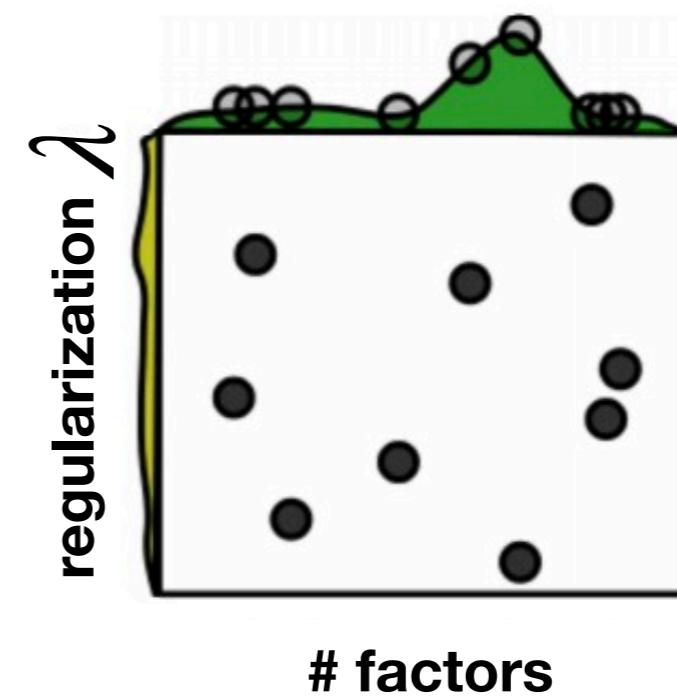
Evaluation

Step 2: Hyperparameter Tuning

Grid Search



Random Search



source: blog.kaggle.com

```
sklearn.model_selection.GridSearchCV  
sklearn.model_selection.RandomizedSearchCV
```

Pre-processing

Hyperparameter
Tuning

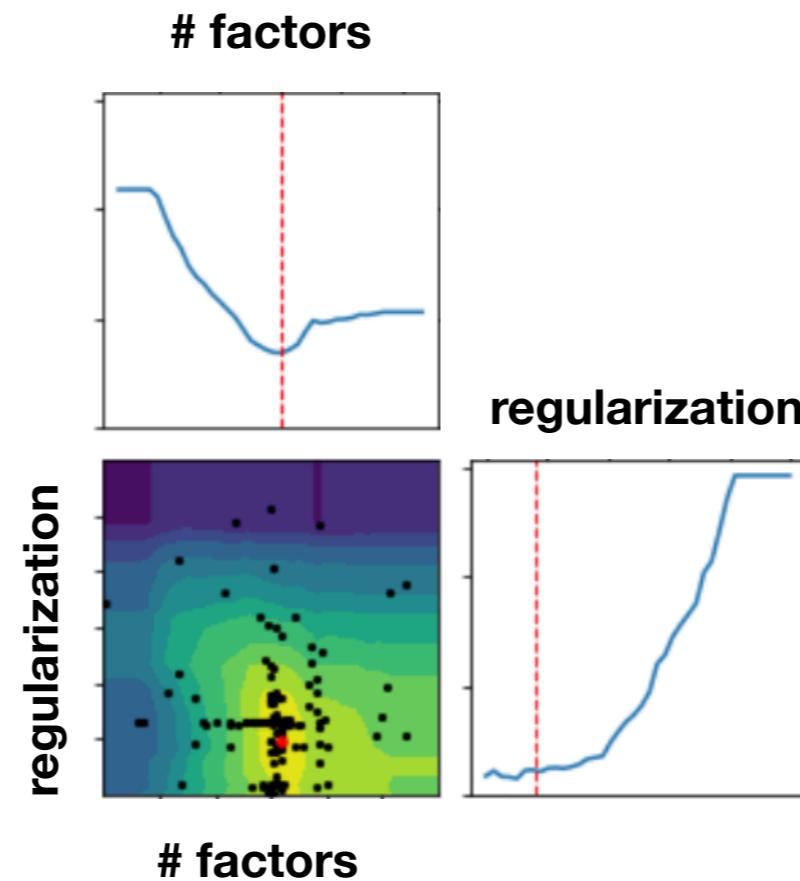
Model Training

Post-processing

Evaluation

Step 2: Hyperparameter Tuning

Sequential Model-Based Optimization



scikit-optimize (skopt)
hyperopt
Metric Optimization Engine (MOE)

Pre-processing

Hyperparameter
Tuning

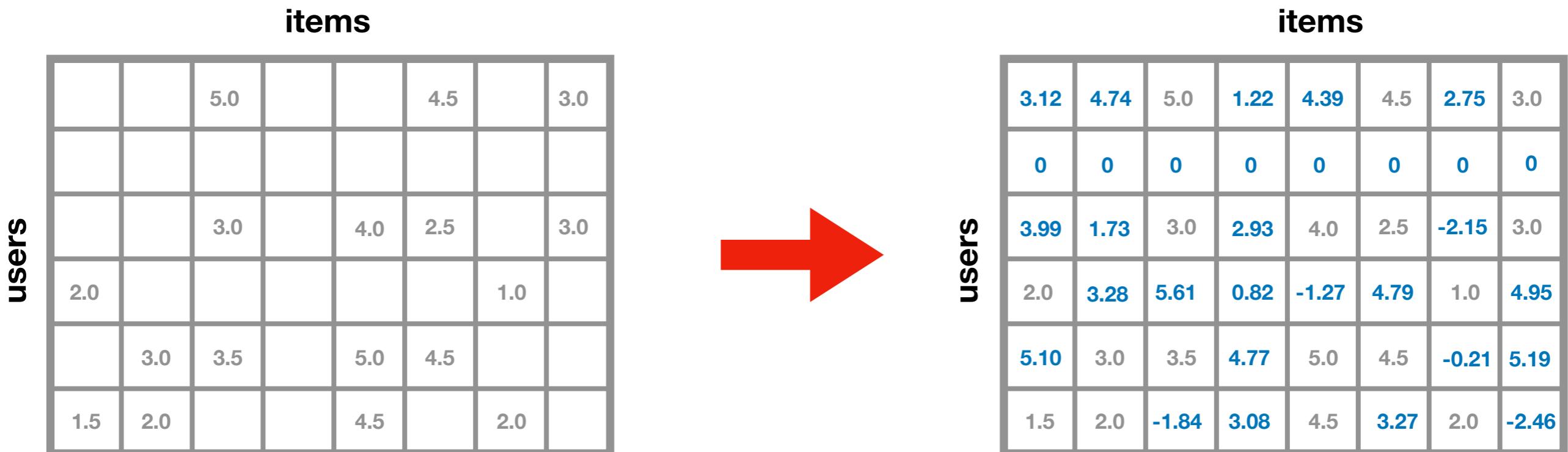
Model Training

Post-processing

Evaluation

Step 3: Model Training

AlternatingLeastSquares(k=8,
regularization=0.001)



Pre-processing

Hyperparameter
Tuning

Model Training

Post-processing

Evaluation

Step 4: Post-processing

- Sort recommendations and get top N
- Filter out items that a user has already purchased, watched, interacted with
- Increase diversity of recommendations
- Item-item recommendations
 - Use a similarity metric (e.g., cosine similarity)
 - “Because you watched Movie X”

Pre-processing

Hyperparameter
Tuning

Model Training

Post-processing

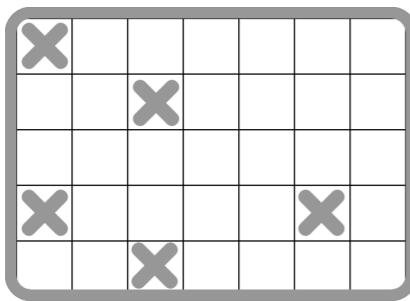
Evaluation

Step 5: Evaluation

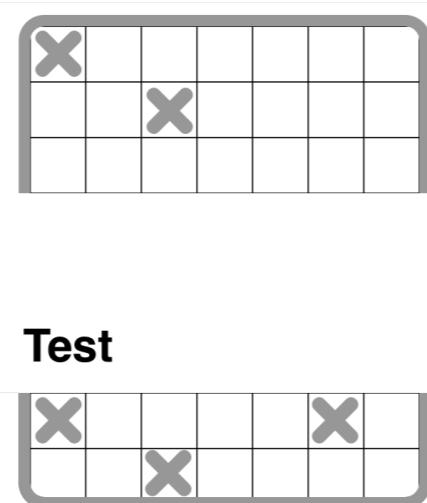
How do we evaluate recommendations?

Traditional ML

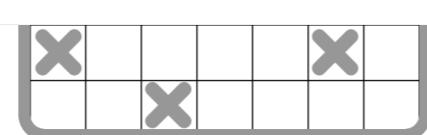
Original



Train

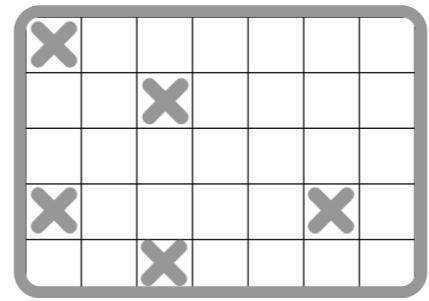


Test

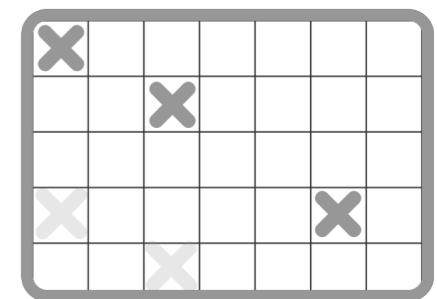


Recommendation Systems

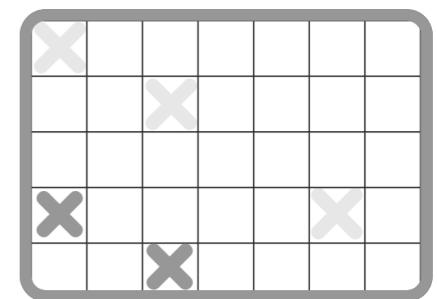
Original



Train



Test



Pre-processing

Hyperparameter
Tuning

Model Training

Post-processing

Evaluation

Step 5: Evaluation

Metrics

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (y - \hat{y})^2}{N}}$$

$$precision = \frac{TP}{TP + FP}$$

$$recall = \frac{TP}{TP + FN}$$

$$F1 = 2 \cdot \frac{precision \cdot recall}{precision + recall}$$

Pre-processing

Hyperparameter
Tuning

Model Training

Post-processing

Evaluation

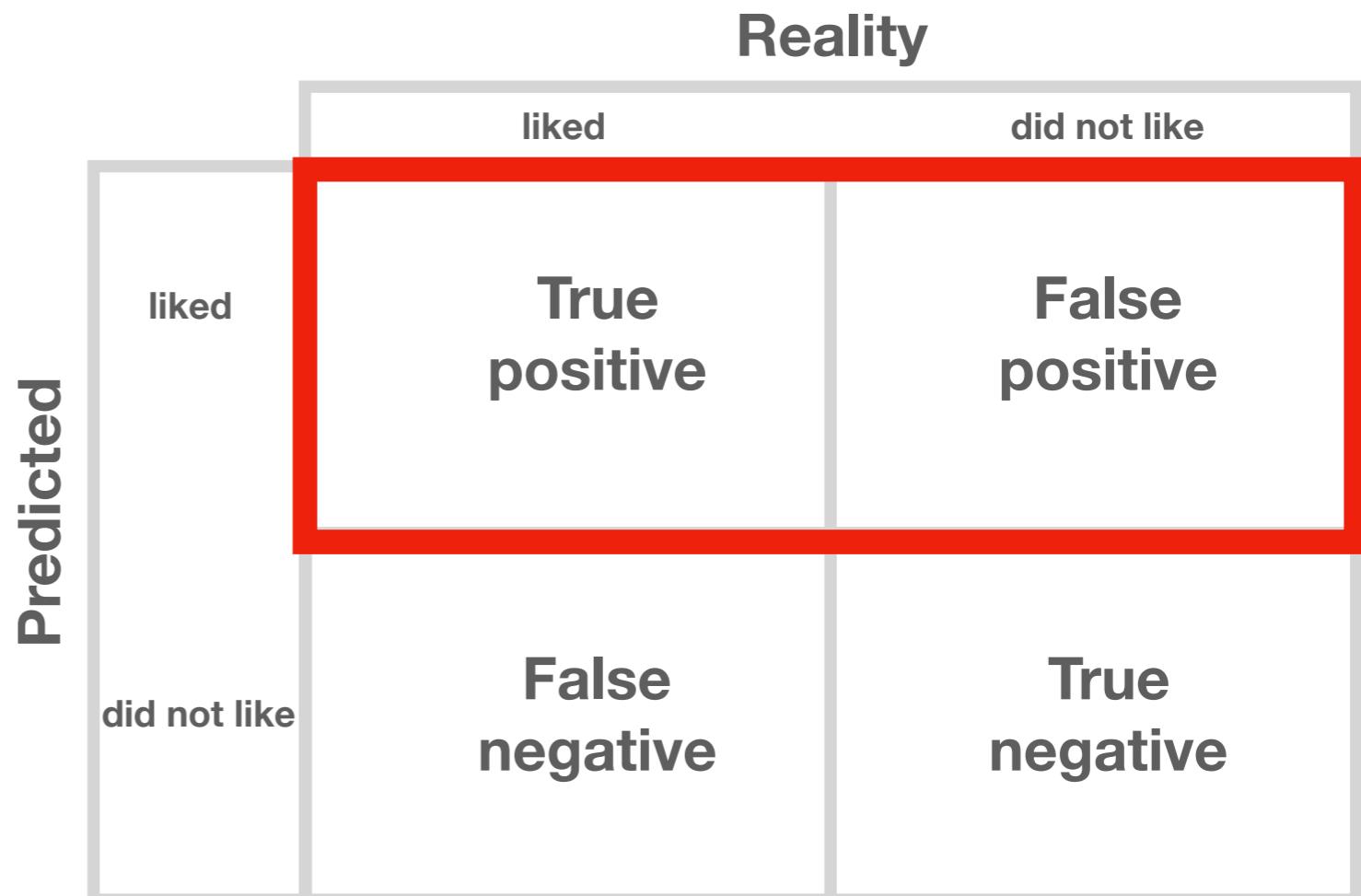
Step 5: Evaluation

Precision@K

Of the top k recommendations, what proportion are actually “relevant”?

Recall@K

Proportion of items that were found in the top k recommendations.



$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

$$\text{recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

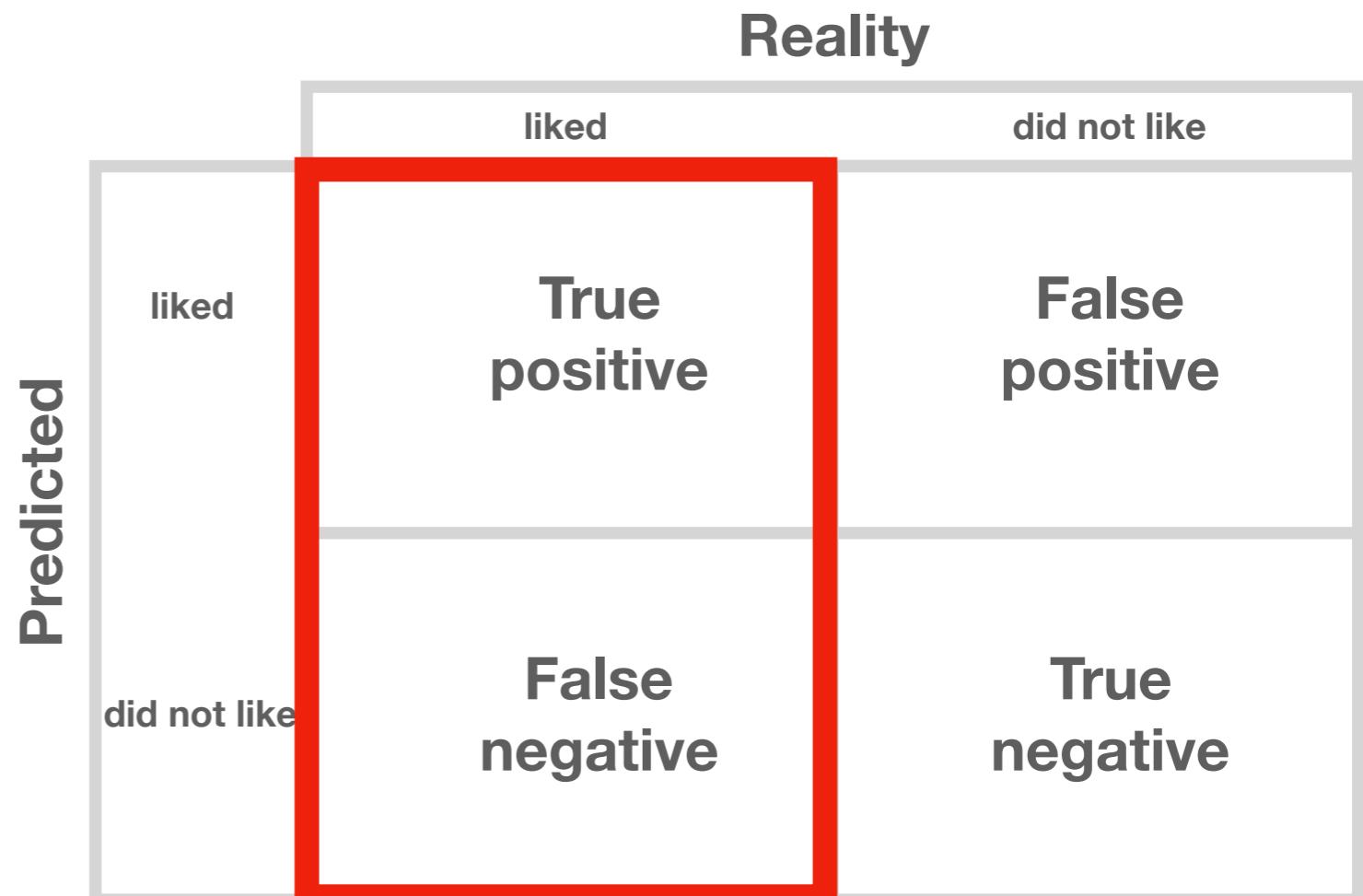
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Precision@K

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Recall@K

Proportion of items that were found in the top k recommendations.



$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

~~$$\text{recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$~~

Important Considerations

- Interpretability
- Efficiency and scalability
- Diversity
- Serendipity

Python Tools

- import surprise (@NicolasHug)
- import implicit (@benfred)
- import LightFM (@lyst)
- import pyspark.mllib.recommendation

Thank you!



Jill Cates
Data Scientist at BioSymetrics
github: [@topspinj](https://github.com/@topspinj)
cates.jill@gmail.com