

# 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



## Discover Weekly

MADE FOR JILL

# Discover Weekly

Your weekly mixtape of fresh music. Enjoy new discoveries and deep cuts chosen just for you. Updated every Monday, so save your...

Made for Jill Cts by Spotify • 30 songs, 1 hr 47 min

**PLAY** **FOLLOWING** **...**

**Filter** **Download** **Toggle**

TITLE	ARTIST	DATE
+ The Weekend - Funk Wav Remix	SZA, Calvin H...	3 days ago
+ You Say	Ehrling	3 days ago
+ Grow Up	Bolier	3 days ago

# 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

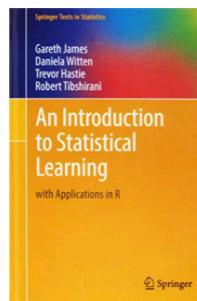


“Frequently bought together”

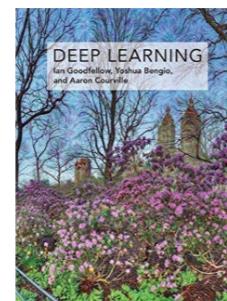
“Customers who bought this item also bought”

Customers who bought this item also bought

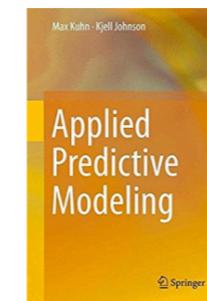
Page 1 of 17



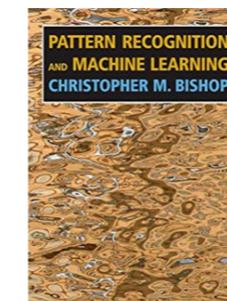
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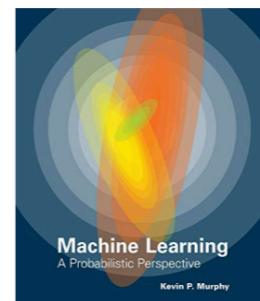
Deep Learning  
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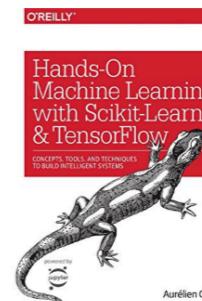
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# OkCupid



“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



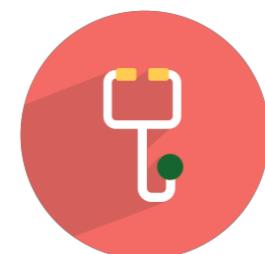
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Recommended  
Articles for You



**GitHub**

Repos “based on  
your interest”



**Medicine**

Facilitating clinical  
decision making

# Before e-commerce

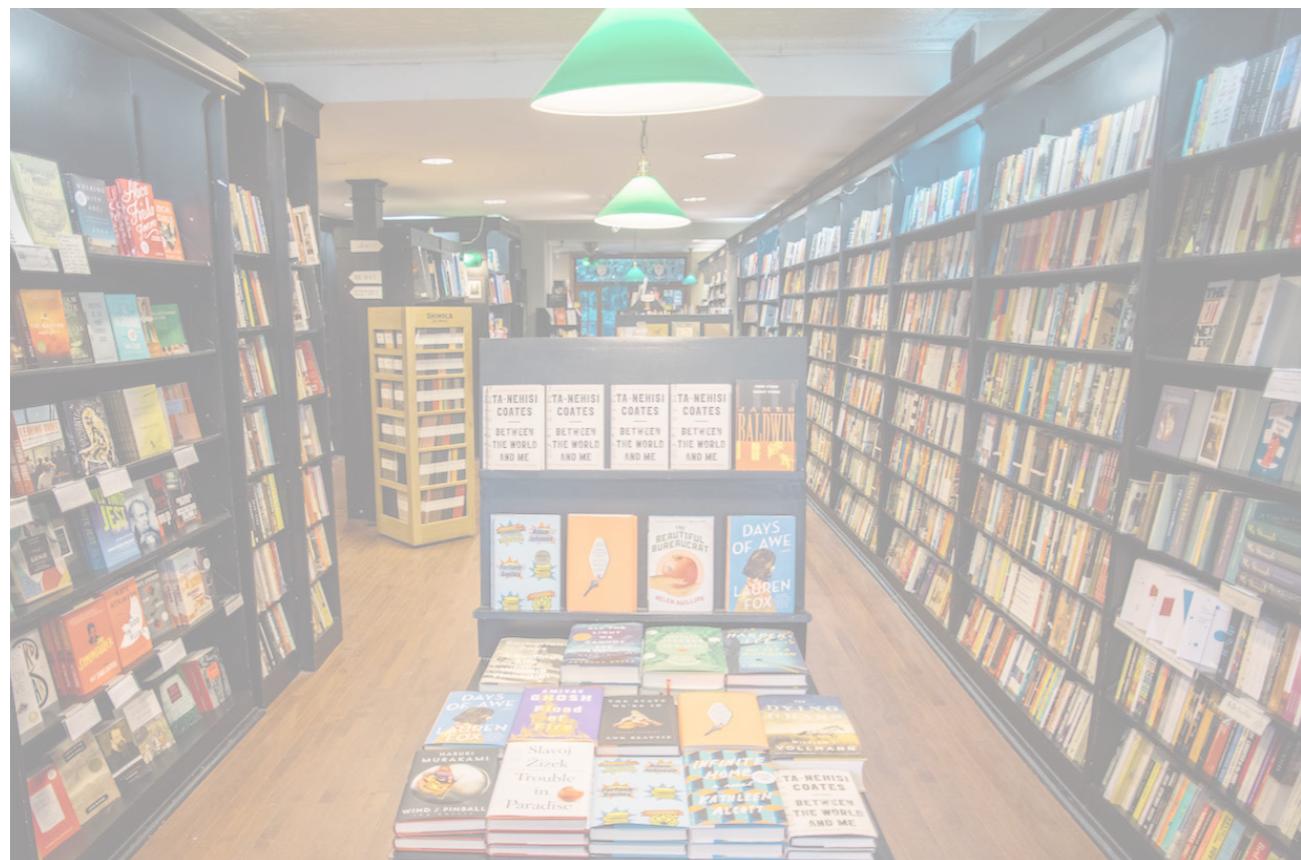
Things were sold exclusively in  
brick-and-mortar stores...



**limited inventory**

**mainstream products**

# Before e-commerce



Things were sold exclusively in  
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# 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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1-60 of over 5,000 results for Books : "python"

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—ERIC SCHMIDT, CEO, GOOGLE

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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.



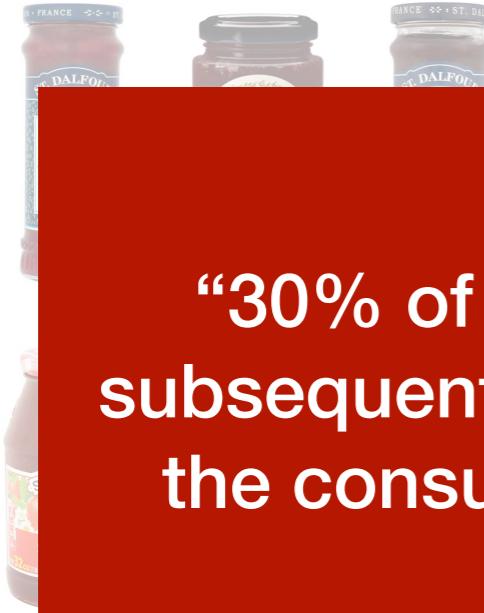
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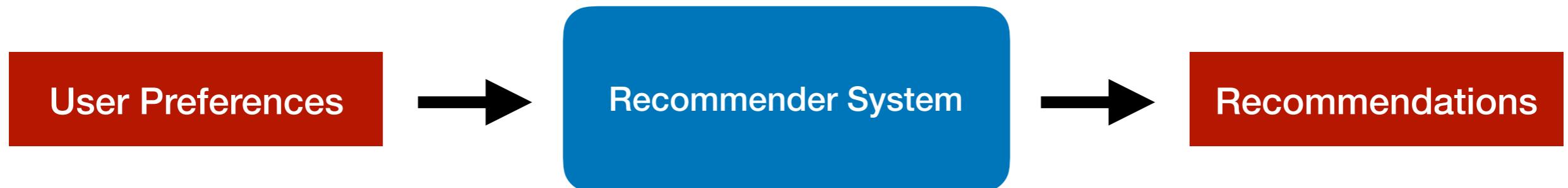
“30% of the consumers in the limited-choice condition subsequently purchased a jar of jam; in contrast, only 3% of the consumers in the extensive-choice condition did so”



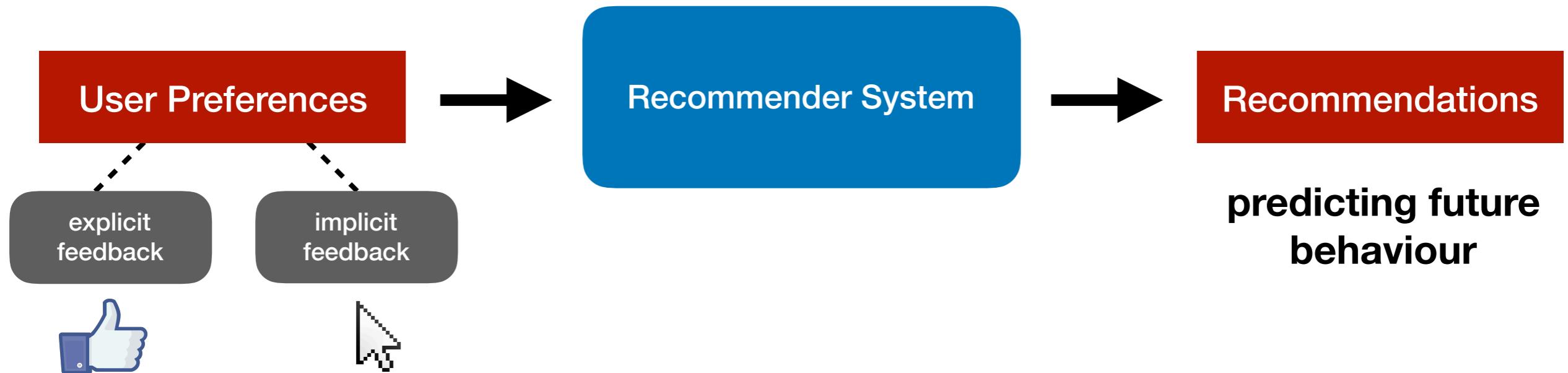
# Recommender Crash Course



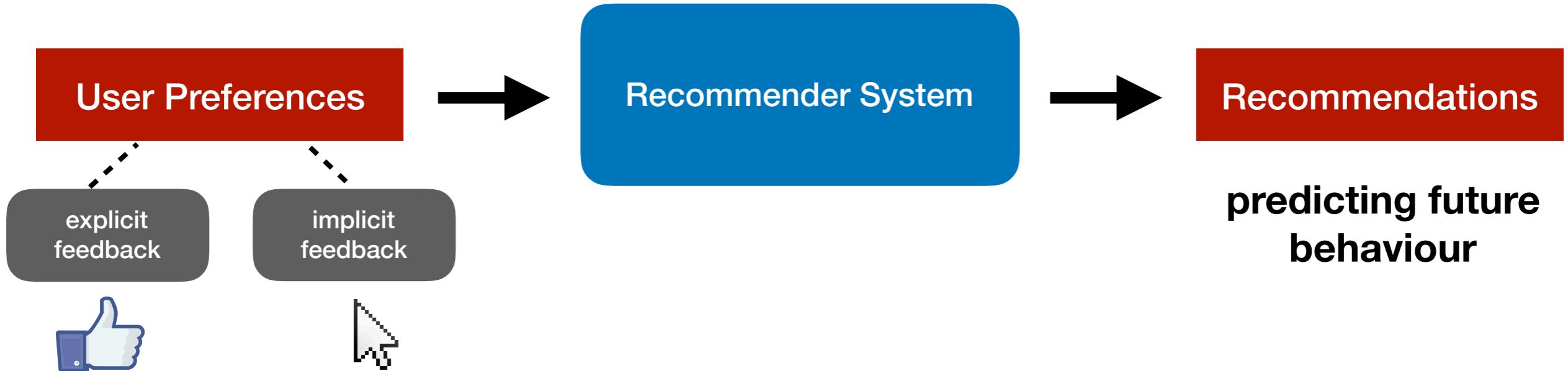
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# Recommender Crash Course



# Recommender Crash Course

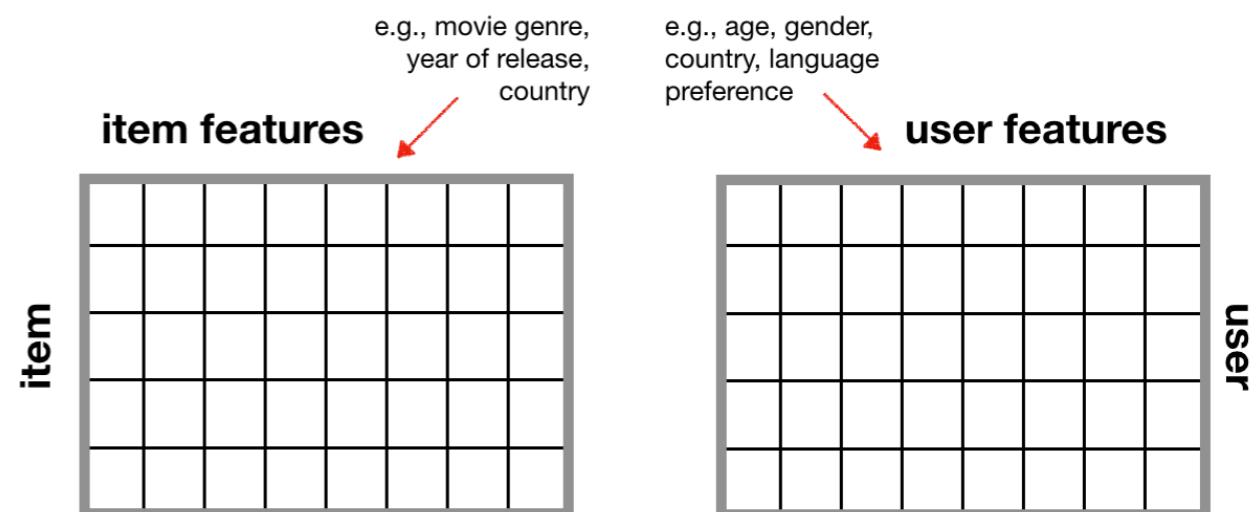


## Collaborative filtering

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

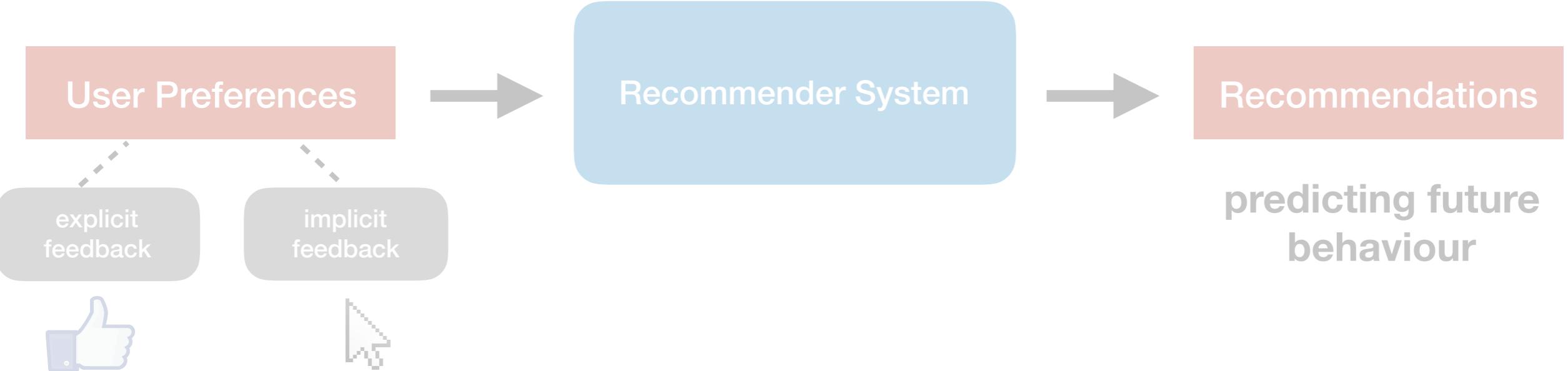
similar users like similar things

## Content-based filtering

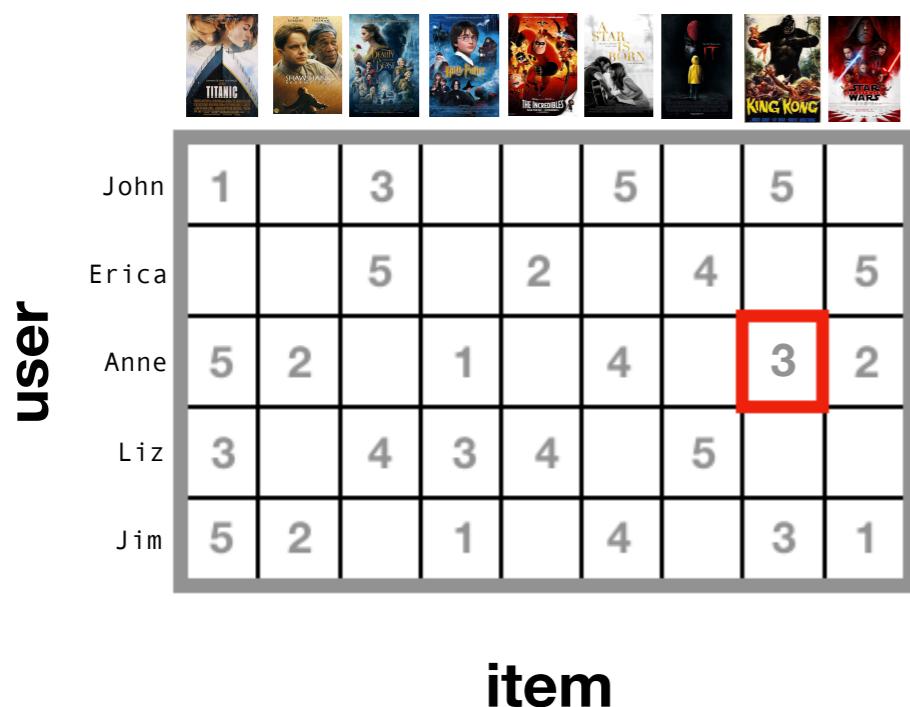


considers items/users features

# Recommender Crash Course



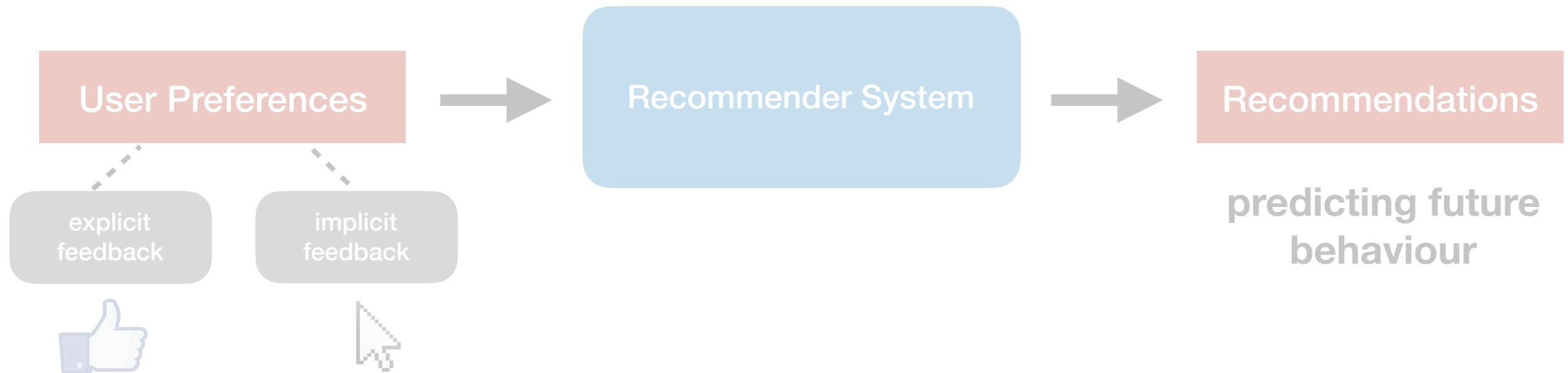
## Collaborative filtering



similar users like  
similar things

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

# Recommender Crash Course



## 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

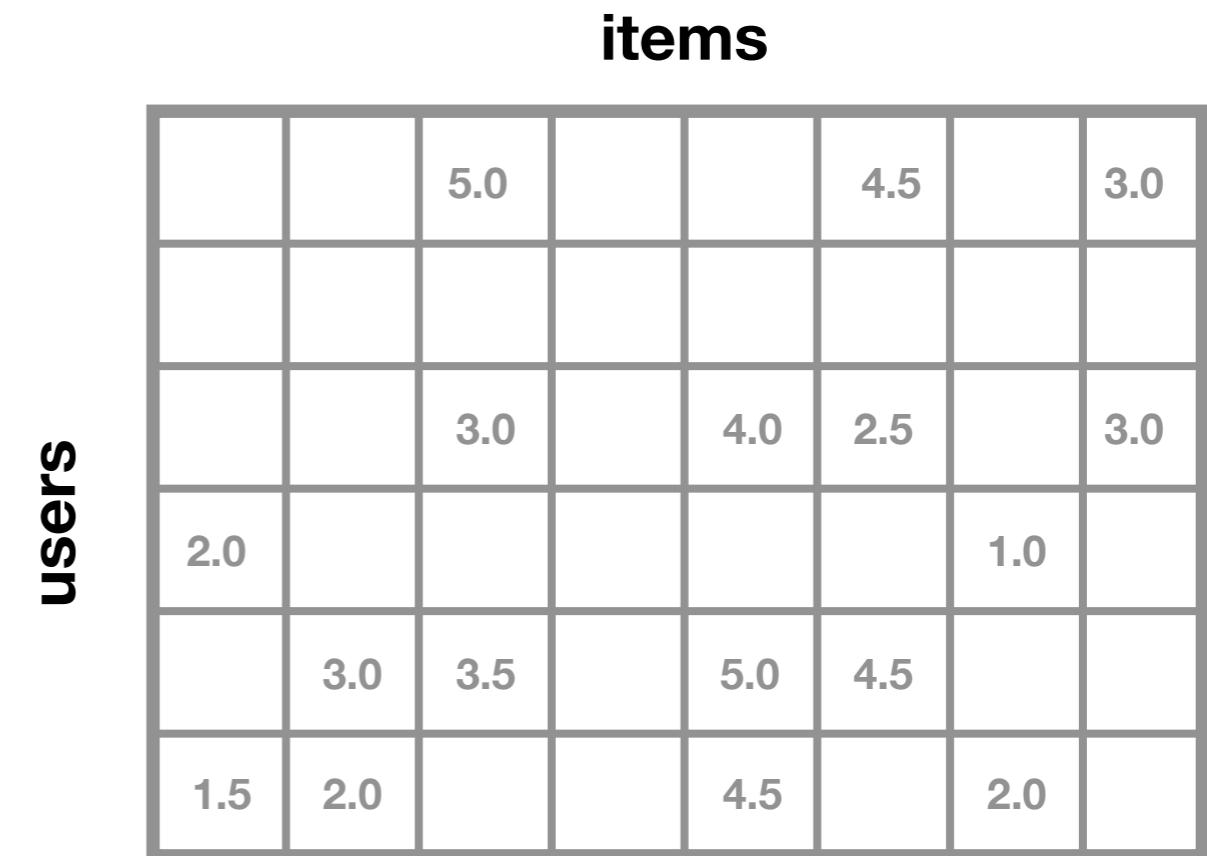
Model Training

Post-processing

Evaluation

# Step 1: Data Pre-processing

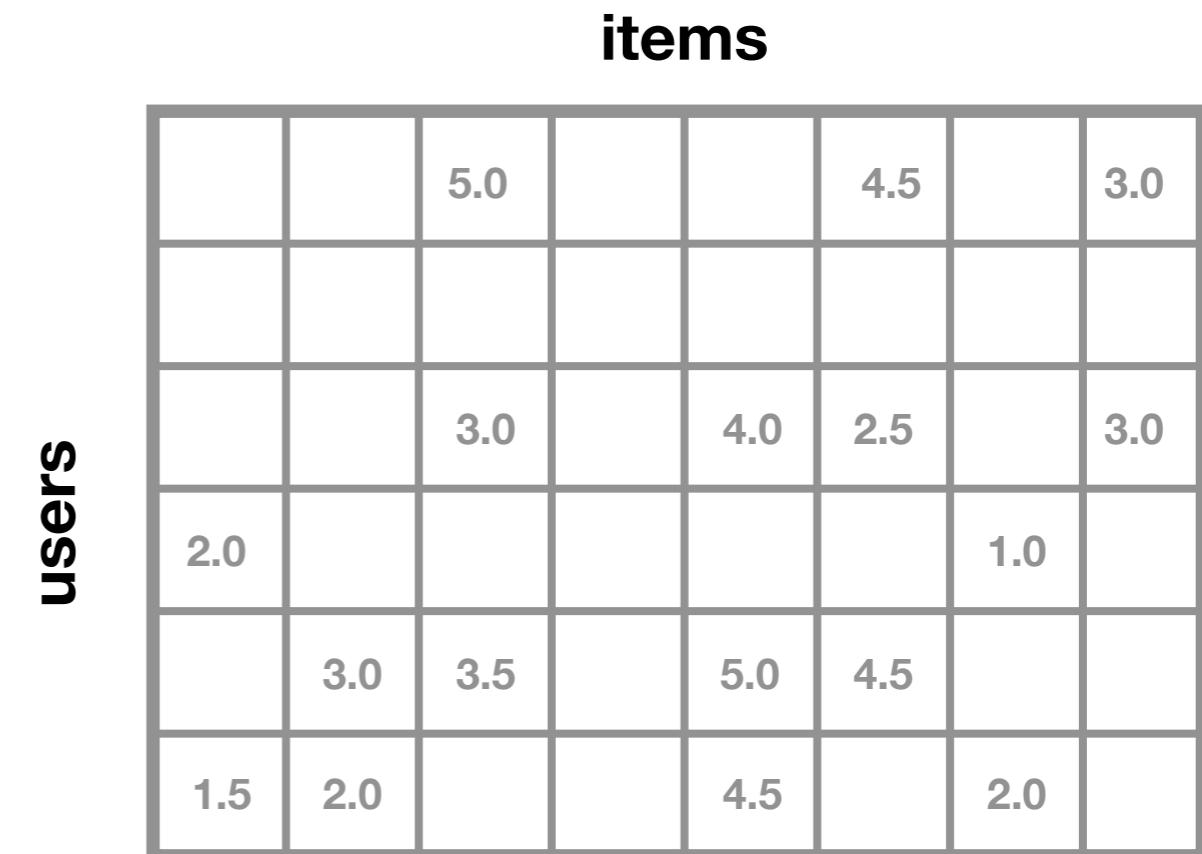
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3	439	3.5
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10	369	1.0



**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
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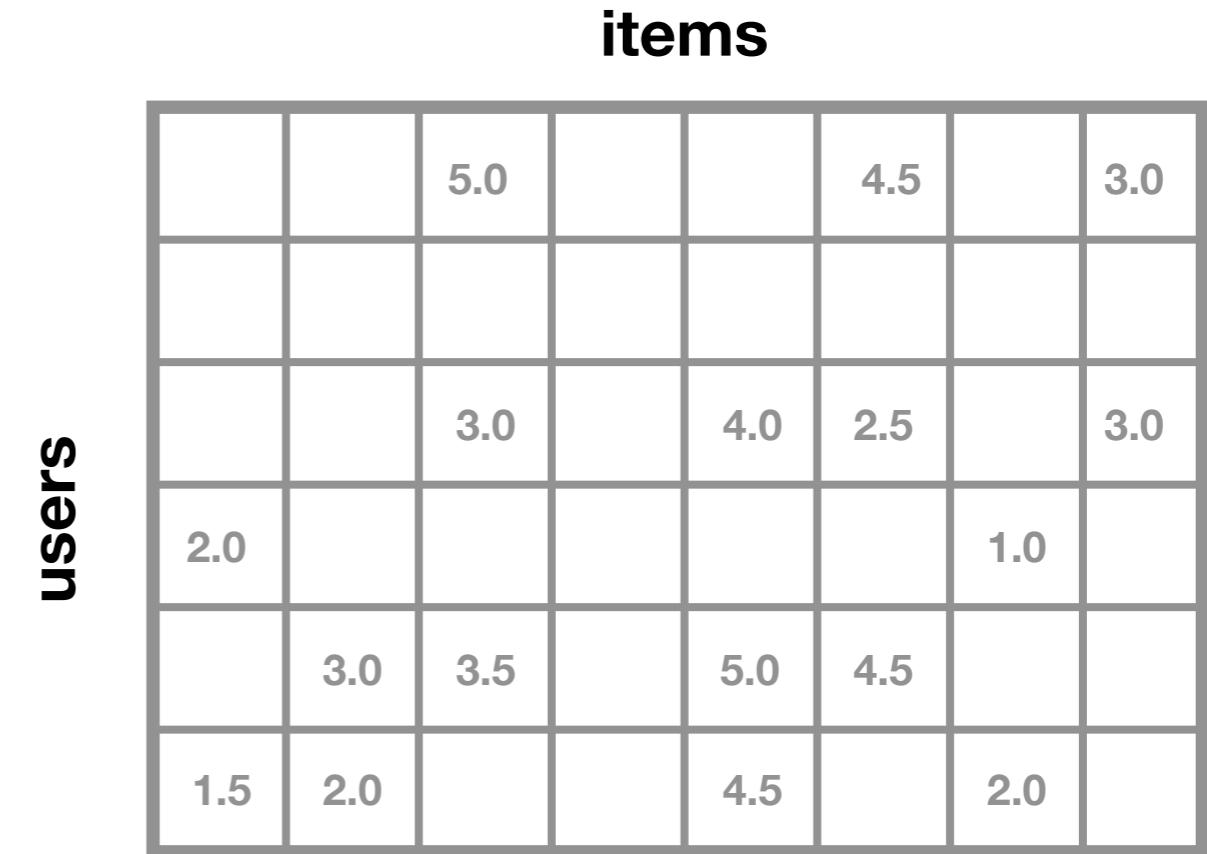


`scipy.sparse.csr_matrix`



# 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
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3	439	3.5
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:

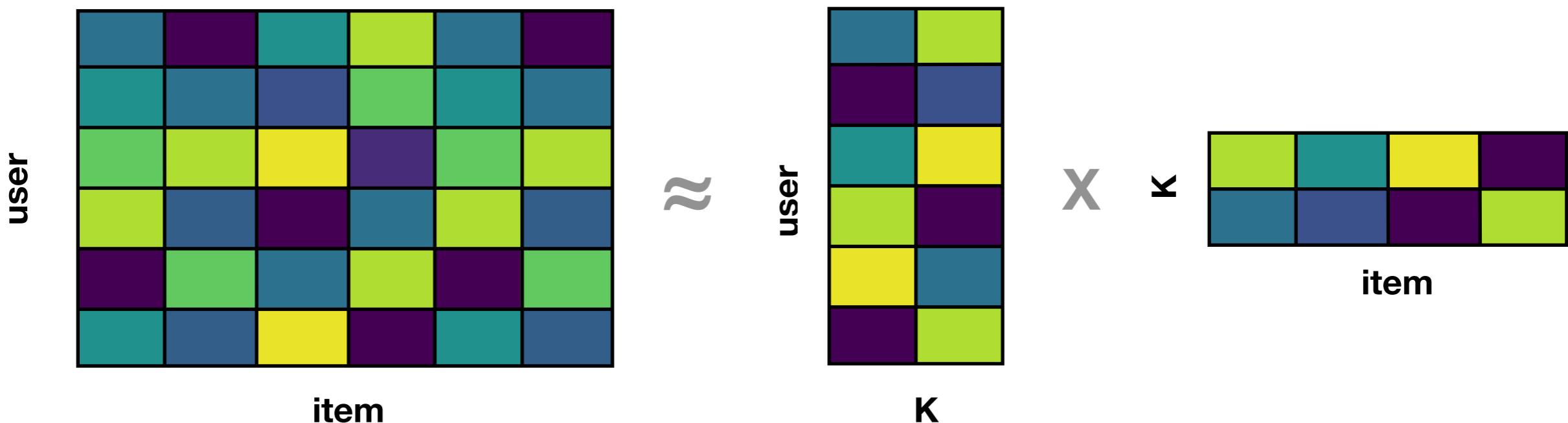
- A red arrow points to  $b_{ui}$  with the label "user-item rating bias".
- A red arrow points to  $\mu$  with the label "global avg".
- A red arrow points to  $b_i$  with the label "item's avg rating".
- A red arrow points to  $b_u$  with the label "user's avg rating".

# 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

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

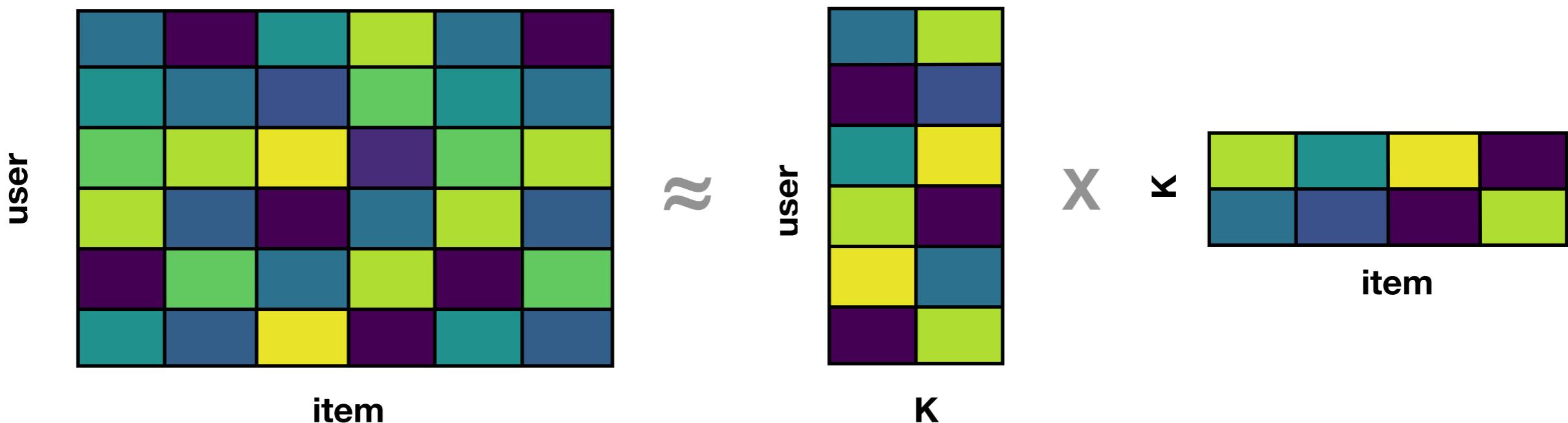


# Pick a Model

## Matrix Factorization

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

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

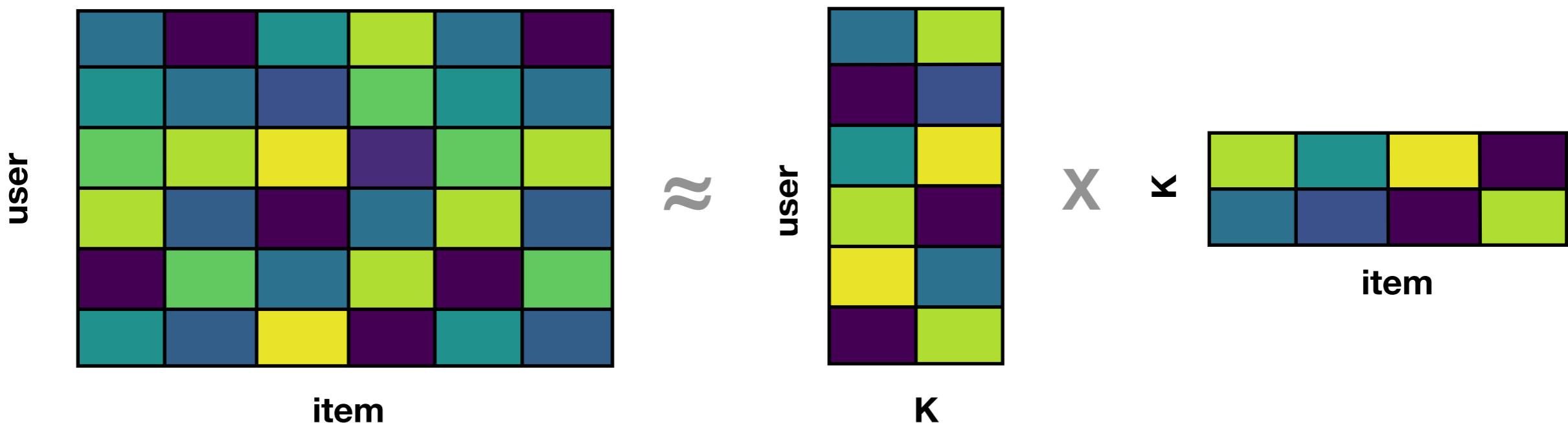


# Pick a Model

## Matrix Factorization

- 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 an Evaluation Metric

## **Precision@K**

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

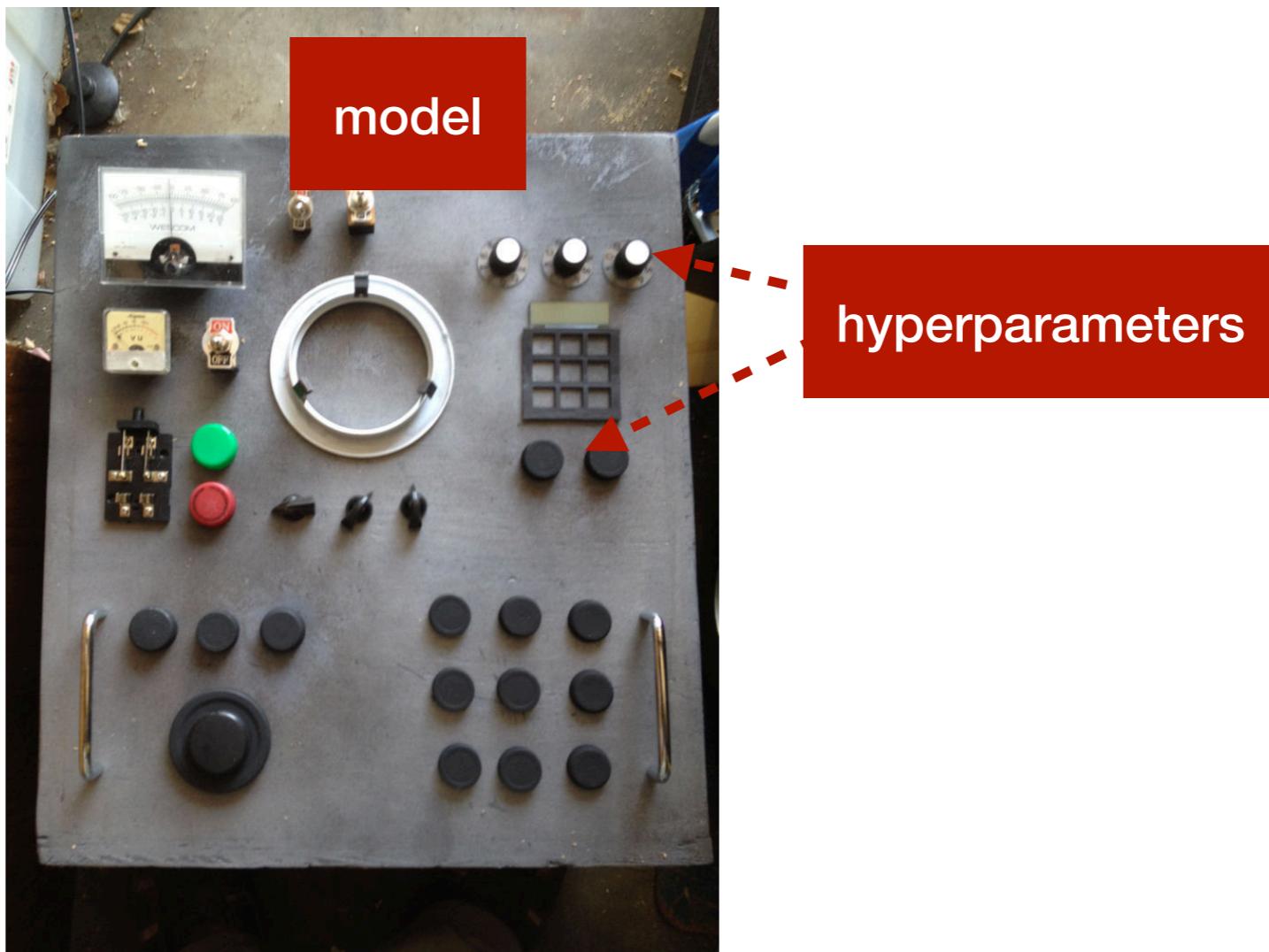
# Pick an Evaluation Metric

## **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)
- $\lambda$  (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

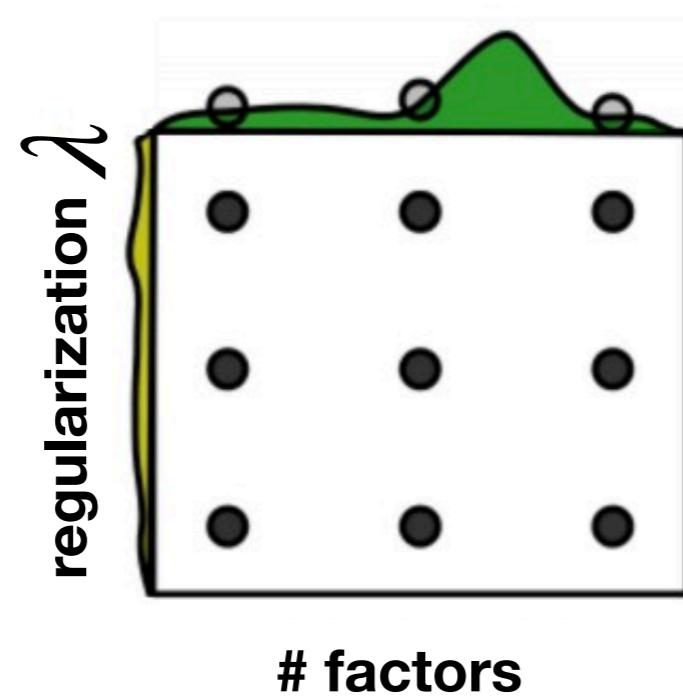
Model Training

Post-processing

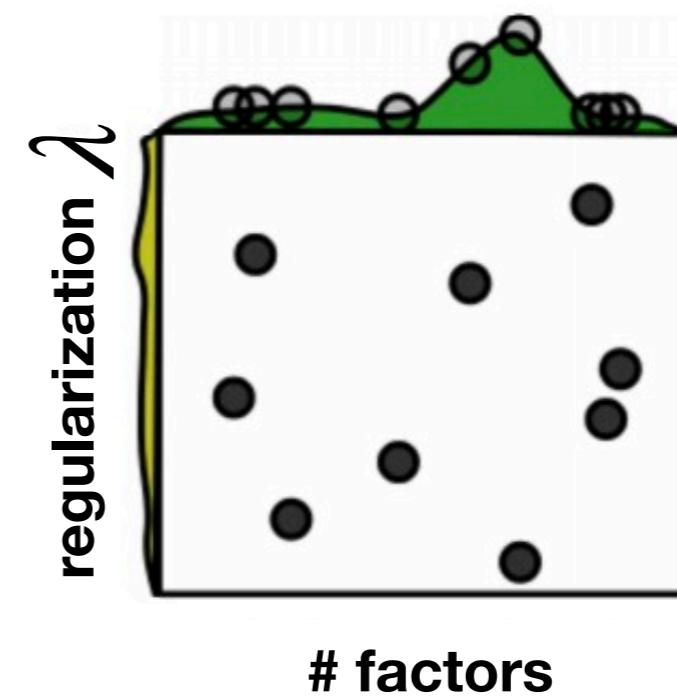
Evaluation

# Step 2: Hyperparameter Tuning

**Grid Search**



**Random Search**

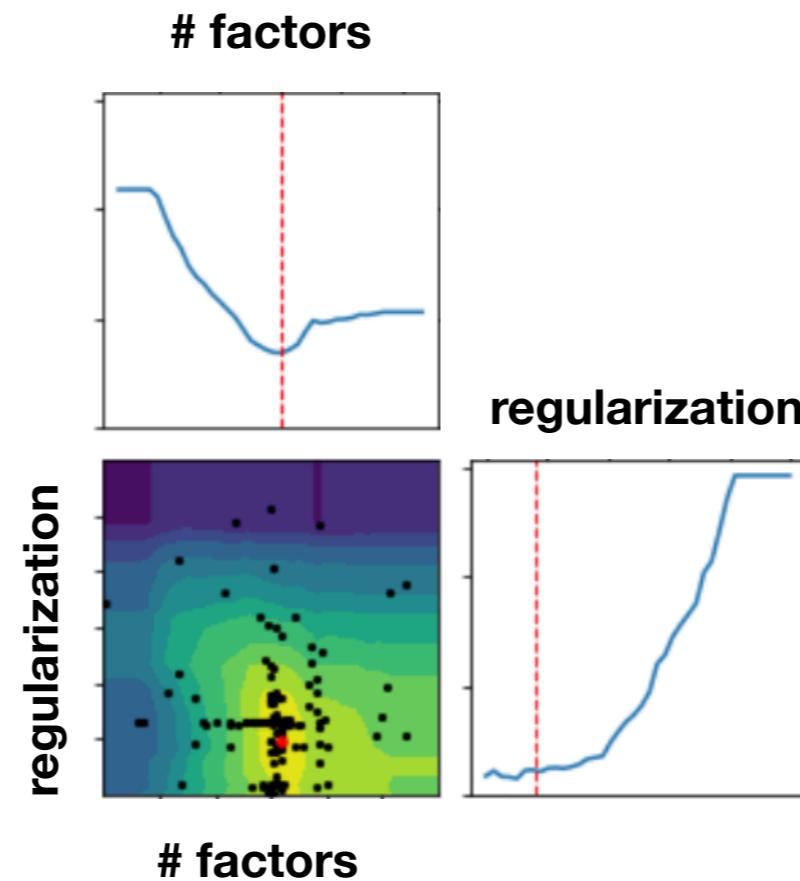


source: blog.kaggle.com

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

# Step 2: Hyperparameter Tuning

## Sequential Model-Based Optimization



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

Pre-processing

Hyperparameter  
Tuning

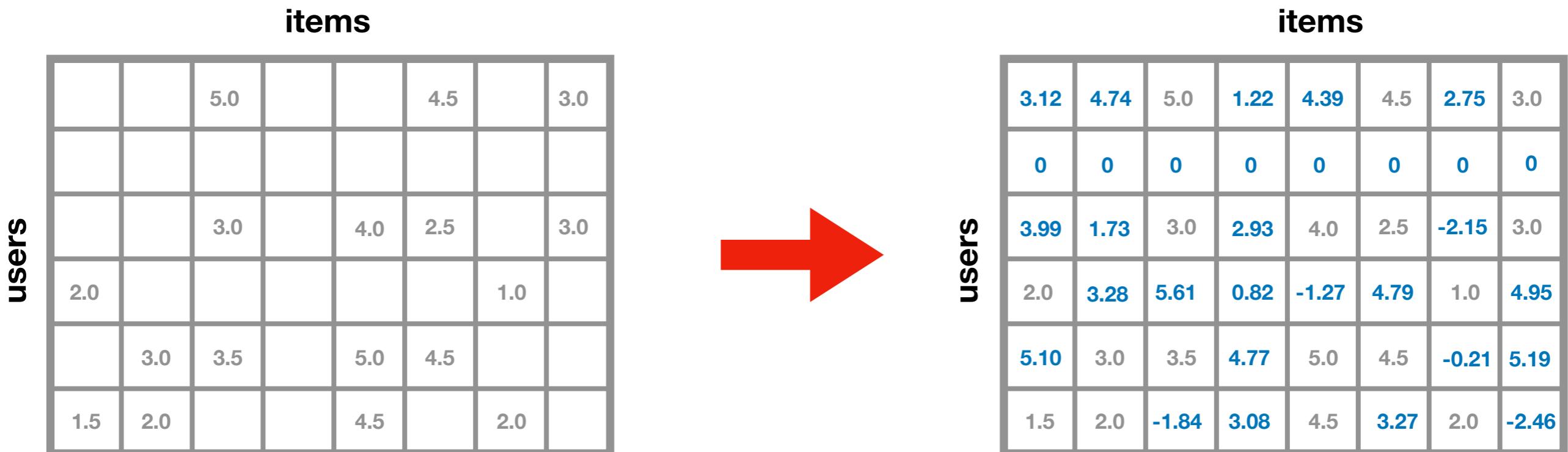
Model Training

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

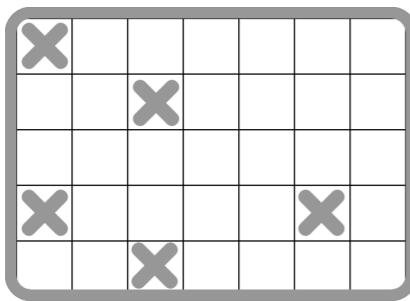
Evaluation

# Step 5: Evaluation

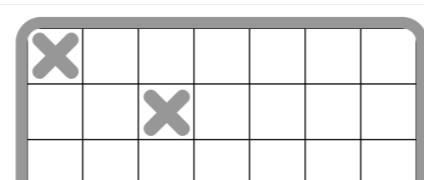
How do we evaluate recommendations?

## Traditional ML

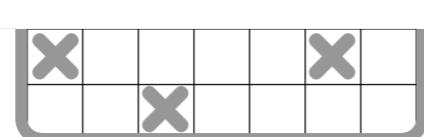
Original



Train

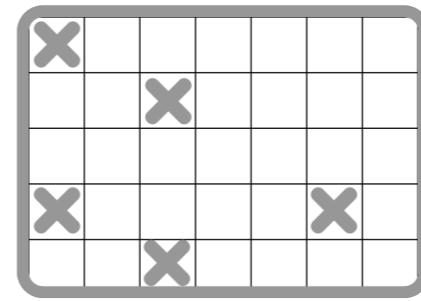


Test

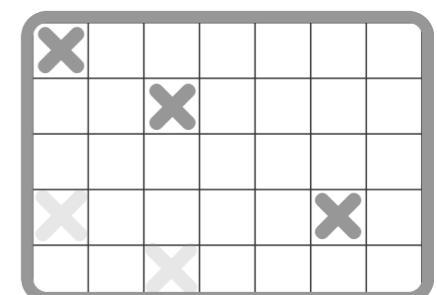


## Recommendation Systems

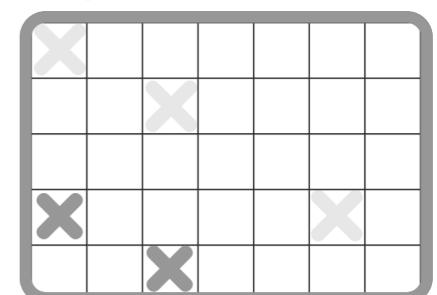
Original



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

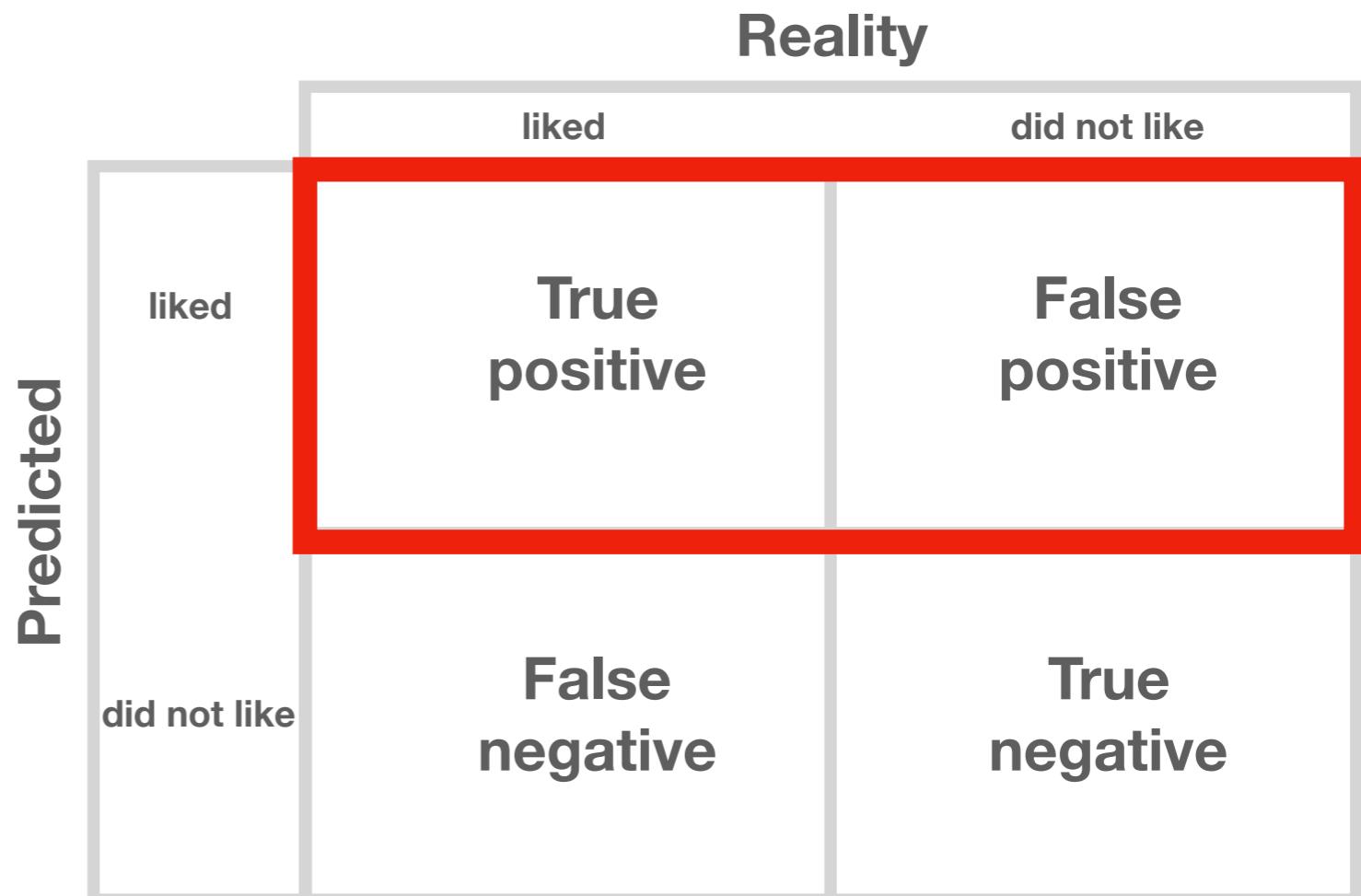
# Step 5: Evaluation

## 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.



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

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

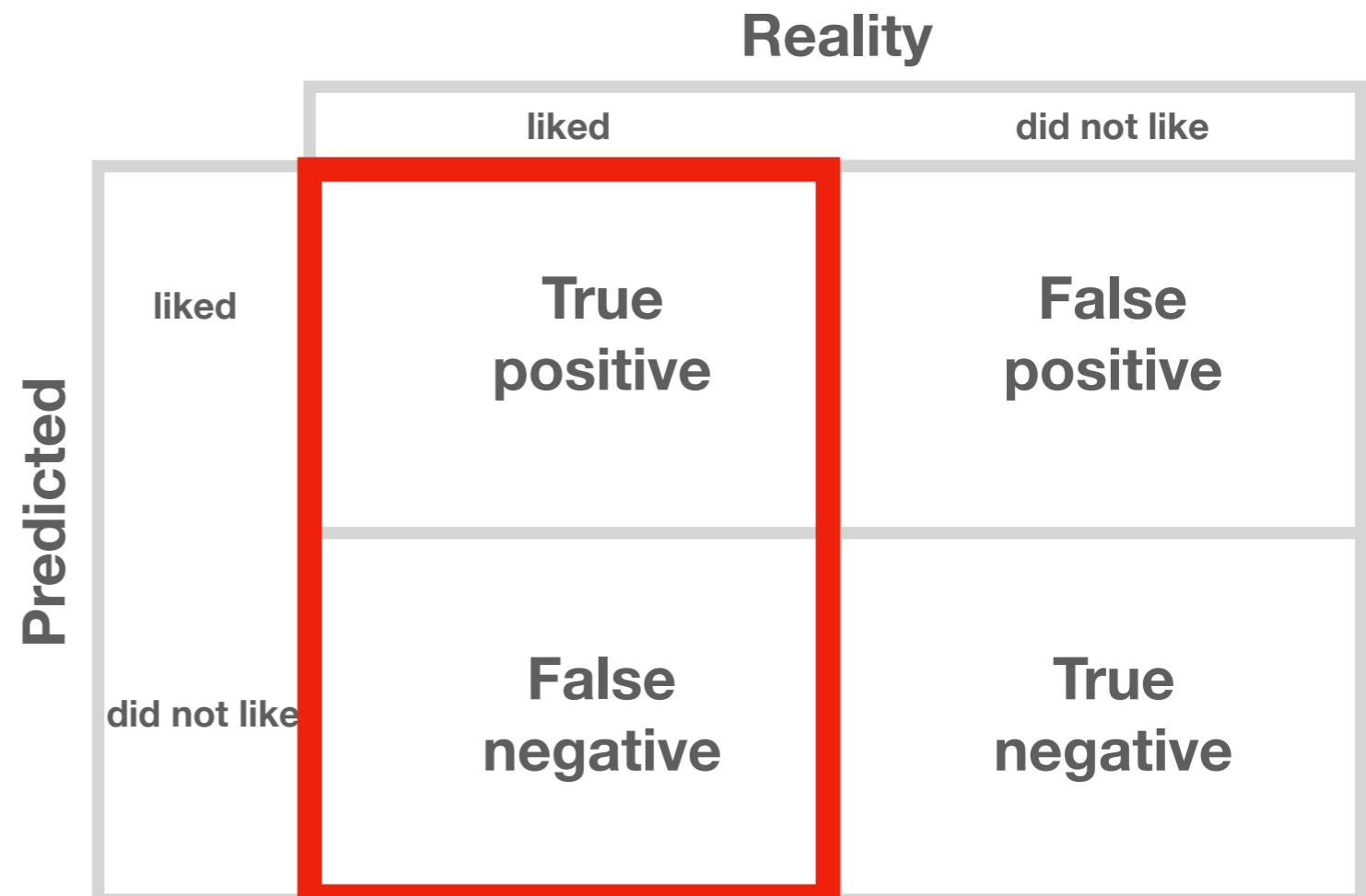
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$$\text{precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

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

# 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](mailto:cates.jill@gmail.com)

# Cross-validation

- Prevent overfitting with k-fold cross-validation

