

# Recommendation Systems

## Part I

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# Outline

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## Introduction

### Background

Recommendation systems: why and what?

Example datasets

### Problem statement

Recommendation systems: a prediction problem

Model: from caricature to extremely complex

### Hands-on

Understanding data

# Background

# Recommendations

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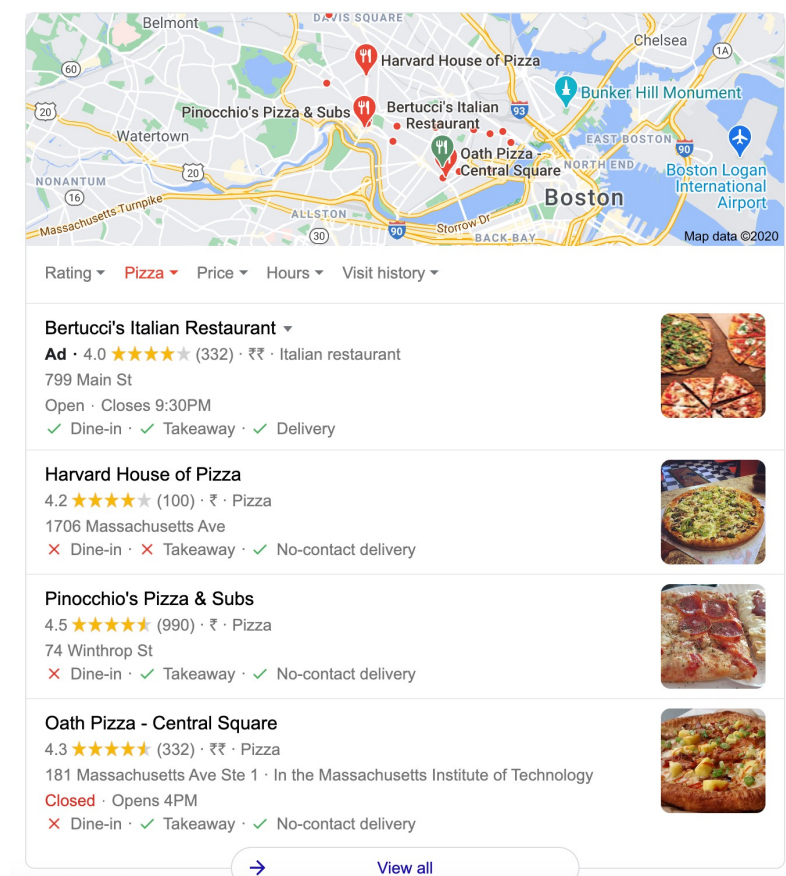
What is it, really?

What food should you eat today?

# Recommendations

Why not just search?

Want to eat Pizza, search for Pizza places near you



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But

Which of these *many* options should you be *recommended*?

Which of these *many* be *advertised*?

# Recommendations

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What is it, really?

What food should you eat today?

Which activities should you plan for the upcoming weekend?

Where should you plan your holidays?

Whom should you date (and marry)?

What are the professional connections of your interest?

Which advertisements should you be subjected to?

What content on YouTube or music on Spotify will fancy you?

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# Recommendations

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May be *data* can help. What data?

# Recommendations

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May be *data* can help. What data?

Example: Yelp data

Businesses: attributes (locations, category), hours

Users: attributes, friends

Reviews: rating, description, time

Check-ins: time

Tip

**Exercise:** go to link below, explore data and reproduce statistics reported

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>



# Explore: Yelp Data

Businesses: 209393 (~200k) in total

	address	attributes	business_id	categories	city	hours	is_open	latitude	longitude	name	postal_code	review_count	stars	state
0	10913 Bailey Rd	{u'BusinessParking': u'garage': False, 'stre...	f9NumwFMBDn751xgFiRbNA	Active Life, Gun/Rifle Ranges, Guns & Ammo, Sh...	Cornelius	{u'Monday': u'10:0-18:0', u'Tuesday': u'11:0-2...	1	35.462724	-80.852612	The Range At Lake Norman	28031	36	3.5	NC
1	8880 E Via Linda, Ste 107	{u'GoodForKids': u'True', u'ByAppointmentOnly'...	YzvJg0SayhoZgCljUJRF9Q	Health & Medical, Fitness & Instruction, Yoga,...	Scottsdale	None	1	33.569404	-111.890264	Carlos Santo, NMD	85258	4	5.0	AZ
2	3554 Rue Notre-Dame O	None	XNoUzKckATkOD1hP6vghZg	Pets, Pet Services, Pet Groomers	Montreal	None	1	45.479984	-73.580070	Felinus	H4C 1P4	5	5.0	QC
3	1015 Sharp Cir	{u'DogsAllowed': u'True', u'BusinessParking': ...}	6OAZjbxqM5ol29BuHsil3w	Hardware Stores, Home Services, Building Suppl...	North Las Vegas	{u'Friday': u'7:0-16:0', u'Tuesday': u'7:0-16:...	0	36.219728	-115.127725	Nevada House of Hose	89030	3	2.5	NV
4	4827 E Downing Cir	{u'BusinessAcceptsCreditCards': u'True', u'ByA...	51M2Kk903DFYI6gnB5I6SQ	Home Services, Plumbing, Electricians, Handyma...	Mesa	{u'Friday': u'9:0-16:0', u'Tuesday': u'9:0-16:...	1	33.428065	-111.726648	USE MY GUY SERVICES LLC	85205	26	4.5	AZ

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Explore: Yelp Data

Users: 1968703 (~2M) in total

	average_stars	compliment_cool	compliment_cute	compliment_funny	compliment_hot	compliment_list	compliment_more	compliment_note
0	3.57	22	0	22	3	1	2	11
1	3.84	63	2	63	36	1	4	33
2	3.44	17	1	17	9	0	6	3
3	3.08	7	0	7	2	0	1	7
4	4.37	31	1	31	8	1	9	22

	elite	fans	friends	funny	name	review_count	useful	user_id	yelping_since
		14	oeMvJh94PiGQnx_6GIndPQ, wm1z1PaJKvHgSDRKfwhfDg...	225	Rafael	553	628	ntlvfPzc8eglqvk92iDIAw	2007-07-06 03:27:11
	2008,2009,2010,2011,2012,2013	27	ly7EnE8leJmyqyePVYFlug, pRIR63iDytsnnniPb3AOug...	316	Michelle	564	790	FOBRPIBHa3WPHFB5qYDIVg	2008-04-28 01:29:25
	2010	5	Uwlk0txjQBPw_JhHsQnyeg, Ybxr1tSCkv3IYA0I1qmnPQ...	125	Martin	60	151	zZUnPeh2hEp0WydbAZEEOg	2008-08-28 23:40:05
	2009	6	iog3Nyg1i4jeumiTVG_BSA, M92xWY2Vr9w0xoH8bPplfQ...	160	John	206	233	QaELAmRcDc5TfJEylaaP8g	2008-09-20 00:08:14
	2009,2010,2011,2012,2014,2015,2016,2017,2018	78	3W3ZMStjojCUirKEqAwGNw, eTlbuu23j9tOgmIa9POyLQ...	400	Anne	485	1265	xvu8G900tezTzbbfqmTKvA	2008-08-09 00:30:27

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Explore: Yelp Data

Reviews: 8021122 (~8M) in total

	business_id	cool	date	funny	review_id	stars	text	useful	user_id
0	-MhfebM0QIsKt87iDN-FNw	0	2015-04-15 05:21:16	0	xQY8N_XvtGbearJ5X4QryQ	2.0	As someone who has worked with many museums, I...	5	OwjRMXRC0KyPrllcjaXeFQ
1	lbrU8StCq3yDfr-QMnGrmQ	0	2013-12-07 03:16:52	1	UmFMZ8PyXZTY2QcwzsfQYA	1.0	I am actually horrified this place is still in...	1	nIJD_7ZXHq-FX8byPMOkMQ
2	HQI28KMwrEKHqhFrrDqVNQ	0	2015-12-05 03:18:11	0	LG2ZaYiOgpr2DK_90pYjNw	5.0	I love Deagan's. I do. I really do. The atmoosp...	1	V34qejxNsCbcgD8C0HVk-Q
3	5JxlZaqCnk1MnbgRirs40Q	0	2011-05-27 05:30:52	0	i6g_oA9Yf9Y31qt0wibXpw	1.0	Dismal, lukewarm, defrosted- tasting "TexMex" g...	0	ofKDkJKXSKZXu5xJNGiiBQ
4	IS4cv902ykd8wj1TR0N3-A	0	2017-01-14 21:56:57	0	6TdNDKywdbjoTkizeMce8A	4.0	Oh happy day, finally have a Canes near my cas...	0	UgMW8bLE0QMJDckQ1Ax5Mg

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Explore: Yelp Data

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Check-ins: 175187 (~175k) in total

	business_id	date
0	--1UhMGODdWsrMastO9DZw	2016-04-26 19:49:16, 2016-08-30 18:36:57, 2016...
1	--6MefnULPED_I942VcFNA	2011-06-04 18:22:23, 2011-07-23 23:51:33, 2012...
2	--7zmmkVg-IMGaXbuVd0SQ	2014-12-29 19:25:50, 2015-01-17 01:49:14, 2015...
3	--8LPVSo5i0Oo61X01sV9A	2016-07-08 16:43:30
4	--9QQLMTbFzLJ_oT-ON3Xw	2010-06-26 17:39:07, 2010-08-01 20:06:21, 2010...

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Explore: Yelp Data

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Tip: 1320761 (~1.3M) total

	business_id	compliment_count	date	text	user_id
0	UYX5zL_Xj9WEc_Wp-FrqHw	0	2013-11-26 18:20:08	Here for a quick mtg	hf27xTME3EiCp6NL6VtWZQ
1	Ch3HkwQYv1YKw_FO06vBWA	0	2014-06-15 22:26:45	Cucumber strawberry refresher	uEvusDwoSymbJJ0auR3muQ
2	rDoT-MgxGRiYqCmi0bG10g	0	2016-07-18 22:03:42	Very nice good service good food	AY-lalws3S7YXNI_f_D6rQ
3	OHXnDV01gLokiX1ELaQufA	0	2014-06-06 01:10:34	It's a small place. The staff is friendly.	Ue_7yUIkEbX4AhnYdUfL7g
4	GMrwDXRIAzu2zj5nH6I4vQ	0	2011-04-08 18:12:01	8 sandwiches, \$24 total...what a bargain!!! An...	LltbT_fUMqZ-ZJP-vJ84IQ

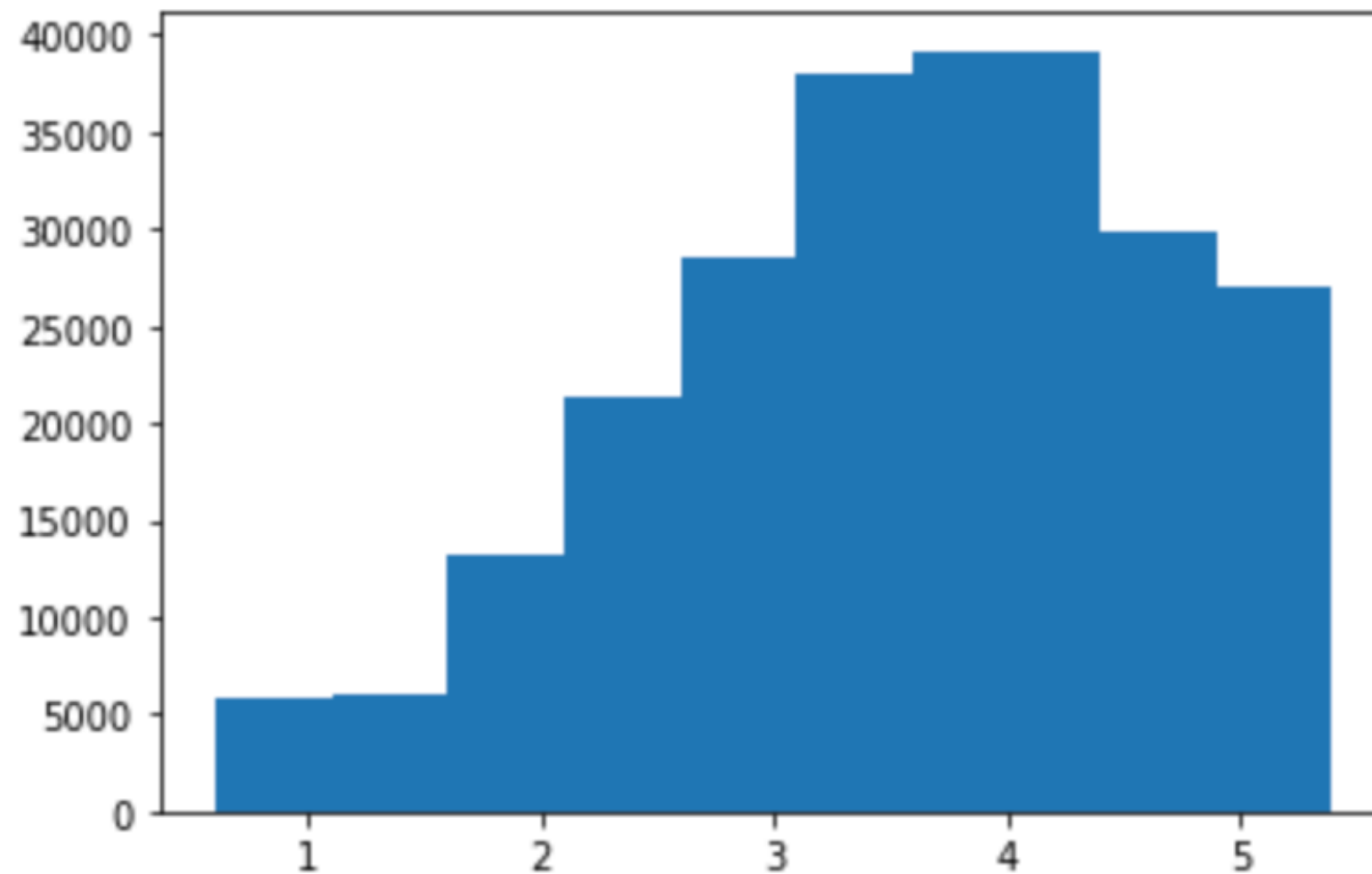
Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

## Explore: Yelp Data

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(Aggregate) Star Rating Distribution



Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

## Explore: Yelp Data

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What fraction of reviews are known?

Users =  $\sim 2\text{M}$

Businesses =  $\sim 200\text{k}$

Total possible reviews =  $\sim 2\text{M} \times \sim 200\text{k} = \sim 0.4\text{T}$

Known reviews =  $\sim 8\text{M}$

Fraction known =  $\sim 8\text{M} / 0.4\text{T} = 2 \times 10^{-5}$

i.e. 2 in every 100k reviews is known, rest are *unknown*

Finding these *unknown* reviews is the primary goal of Rec Sys

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Explore: MovieLens Data

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## MovieLens Data

Movies: attributes including title, release date, genre, actors, director

Users: demographics including age, gender, occupation, zip code

Reviews: ratings, timestamp

**Exercise:** go to link below, explore data and reproduce statistics reported

<https://grouplens.org/datasets/movielens/100k>



# Explore: MovieLens Data

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Reviews: 100000 (100k) in total

	userId	movieId	rating	timestamp
0	1	31	2.5	1260759144
1	1	1029	3.0	1260759179
2	1	1061	3.0	1260759182
3	1	1129	2.0	1260759185
4	1	1172	4.0	1260759205

Data URL:

<https://grouplens.org/datasets/movielens/100k>

# Explore: MovieLens Data

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Users: 1682 (~1.7k) in total

```
user id | age | gender | occupation | zip code
```

```
1|24|M|technician|85711
2|53|F|other|94043
3|23|M|writer|32067
4|24|M|technician|43537
5|33|F|other|15213
6|42|M|executive|98101
7|57|M|administrator|91344
8|36|M|administrator|05201
9|29|M|student|01002
10|53|M|lawyer|90703
```

Data URL:

<https://grouplens.org/datasets/movielens/100k>

# Explore: MovieLens Data

Movies: 943 (~1k) in total

movie id	movie title	release date	video release date	
IMDb URL	unknown	Action	Adventure	Animation
Children's	Comedy	Crime	Documentary	Drama
Film-Noir	Horror	Musical	Mystery	Romance
Thriller	War	Western		Sci-Fi

1 Toy Story (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Toy%20Story%20(1995) 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2 GoldenEye (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?GoldenEye%20(1995) 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
3 Four Rooms (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Four%20Rooms%20(1995) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
4 Get Shorty (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Get%20Shorty%20(1995) 0 1 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
5 Copycat (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Copycat%20(1995) 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 1 0 0
6 Shanghai Triad (Yao a yao yao dao waipo qiao) (1995) 01-Jan-1995  http://us.imdb.com/Title?Yao+a+yao+yao+dao+waipo+qiao+(1995) 0 0 0 0 0 0 0 0 0 1 0
7 Twelve Monkeys (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Twelve%20Monkeys%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0
8 Babe (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Babe%20(1995) 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
9 Dead Man Walking (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Dead%20Man%20Walking%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
10 Richard III (1995) 22-Jan-1996  http://us.imdb.com/M/title-exact?Richard%20III%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0
11 Seven (Se7en) (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Se7en%20(1995) 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0
12 Usual Suspects, The (1995) 14-Aug-1995  http://us.imdb.com/M/title-exact?Usual%20Suspects,%20The%20(1995) 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0
13 Mighty Aphrodite (1995) 30-Oct-1995  http://us.imdb.com/M/title-exact?Mighty%20Aphrodite%20(1995) 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
14 Postino, Il (1994) 01-Jan-1994  http://us.imdb.com/M/title-exact?Postino,%20Il%20(1994) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0
15 Mr. Holland's Opus (1995) 29-Jan-1996  http://us.imdb.com/M/title-exact?Mr.%20Holland's%20Opus%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
16 French Twist (Gazon maudit) (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Gazon%20maudit%20(1995) 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0
17 From Dusk Till Dawn (1996) 05-Feb-1996  http://us.imdb.com/M/title-exact?From%20Dusk%20Till%20Dawn%20(1996) 0 1 0 0 0 0 1 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0
18 White Balloon, The (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Badkonake%20Sefid%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
19 Antonia's Line (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Antonia%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
20 Angels and Insects (1995) 01-Jan-1995  http://us.imdb.com/M/title-exact?Angels%20and%20Insects%20(1995) 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0

## Data URL:

<https://grouplens.org/datasets/movielens/100k>

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# Explore: MovieLens Data

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Top rated movies

```
rating[ 'movieId' ].value_counts()
```

356	341
296	324
318	311
593	304
260	291
480	274
2571	259
1	247
527	244
589	237
1196	234

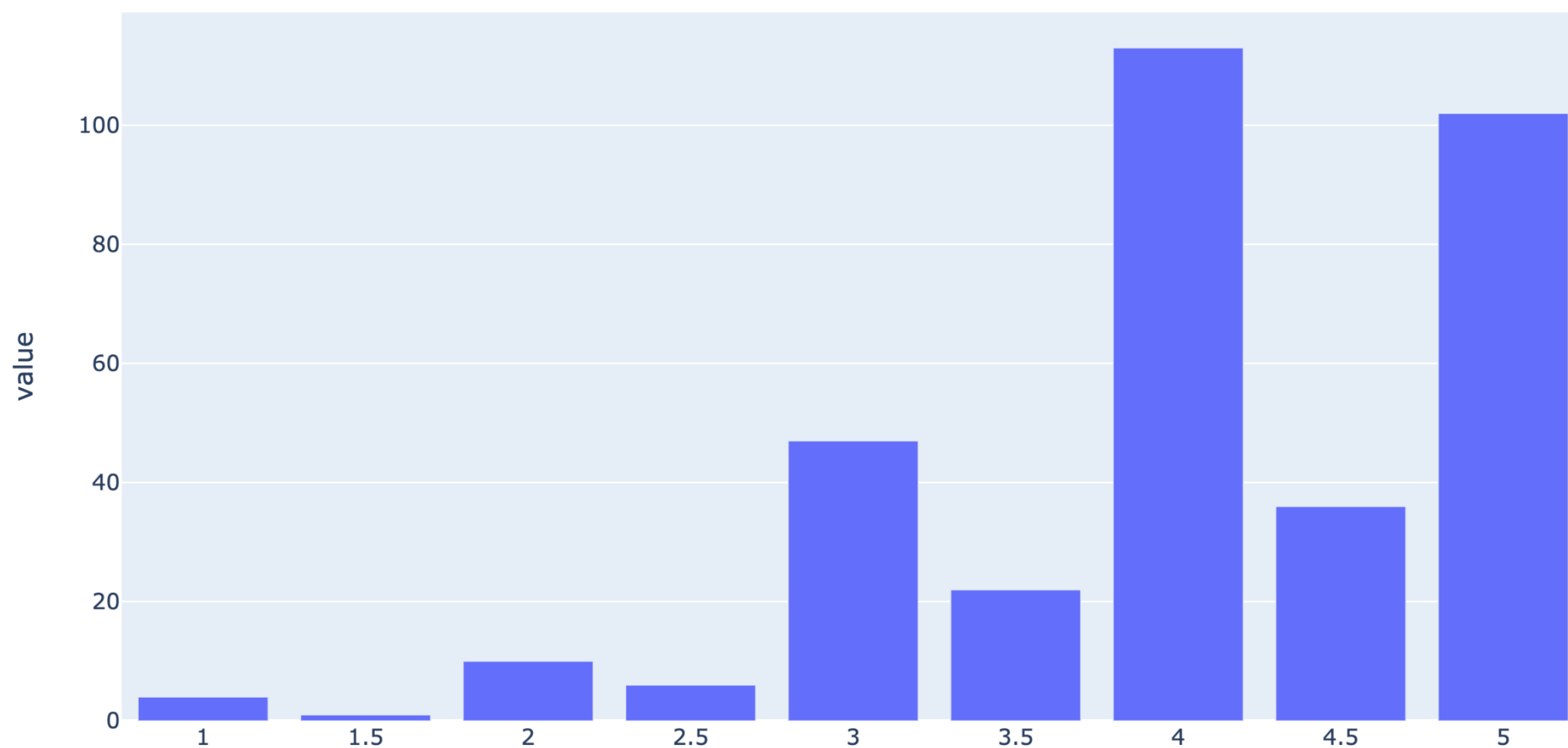
Data URL:

<https://grouplens.org/datasets/movielens/100k>

# Explore: MovieLens Data

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Distribution of top-rated movie (356)



Data URL:

<https://grouplens.org/datasets/movielens/100k>

## Explore: MovieLens Data

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What fraction of reviews are known?

Users =  $\sim 1.7k$

Movies =  $\sim 1k$

Total possible reviews =  $\sim 1.7k \times \sim 1k = \sim 1.7M$

Known reviews =  $\sim 100k$

Fraction known =  $\sim 100k / 1.7M = \sim 0.058$  or  $\sim 6\%$

i.e. 6 in every 100 reviews is known, rest are *unknown*

Finding these *unknown* reviews is the primary goal of Rec Sys

Data URL:

<https://www.kaggle.com/jagangupta/what-s-in-a-review-yelp-ratings-eda>

# Problem Statement

## Recommendation: Problem statement

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What does Yelp want to do?

Provide list of businesses

that satisfy your search criteria

*ordered* as per

user's interest or preference list at that moment

advertisement revenue considerations

so that ultimately *matching* happens within *few* clicks

that provides instant gratification to both user and Yelp

and continues bringing user back to Yelp



## Recommendation: Problem statement

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What about?

Linked In: connect people professionally

Facebook: filter friends' feed

Poshmark, Etsy: organize content of display

Amazon, Retail: display products and sellers

Tinder, Match: find suitable partner

Netflix, YouTube, Spotify: entertainment of interest

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So that ultimately *matching* happens within *few* clicks

providing instant gratification to *user, provider* and *platform*

and *users* and *providers* continue engaging with the *platform*

# Recommendation: Problem statement

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Prediction problem

what is the likelihood of *matching*

user

provider

at a given time

in a given *context*

Accurate solution to this prediction problem

provides essential ingredient for connecting users, providers on the platform

while respecting interests of users, providers and the platform

# Recommendation: Problem statement

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Prediction problem

N users

M providers or items (or other users)

Given user  $i$  *and* item  $j$

find the likelihood of  $i$  matching with  $j$

$$L_{ij} = ?$$

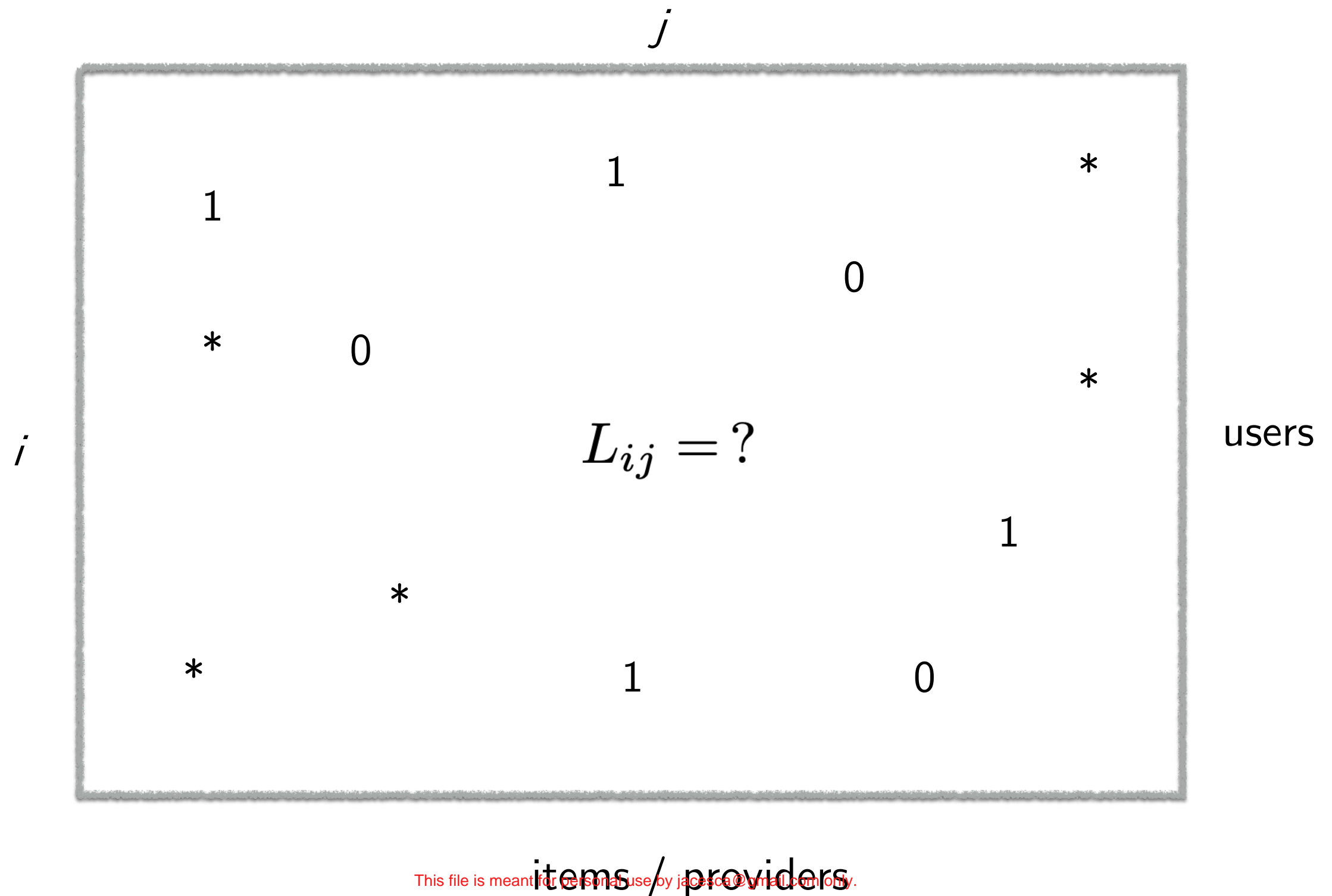
Using data

Historical matchings or preferences

# Recommendation: Problem statement

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Prediction problem: complete the matrix



# Recommendation: Problem statement

Complete the matrix

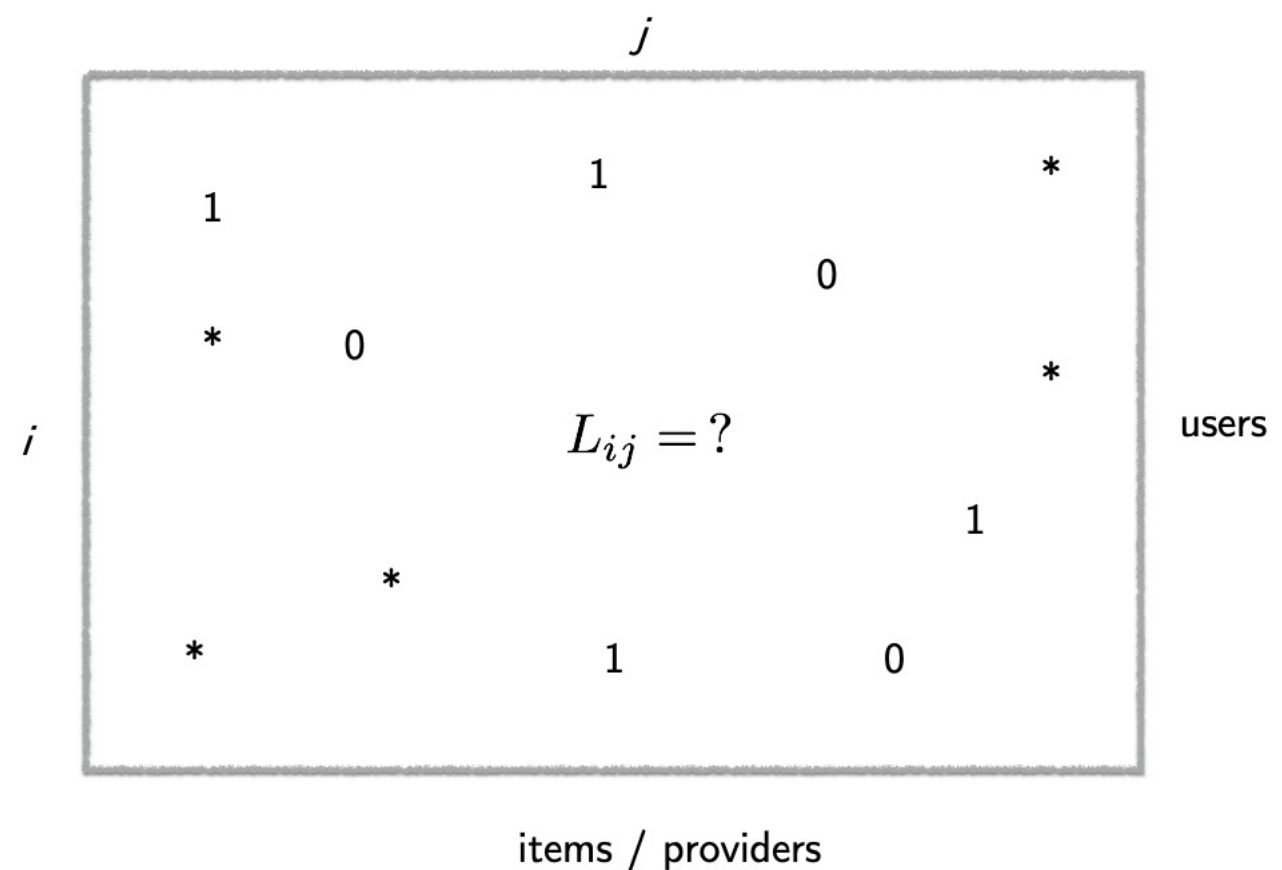
Observations:  $Y_{ij}$  over  $i$  in users,  $j$  in items

If  $(i, j)$  is observed

$$E[Y_{ij}] = L_{ij}$$

If  $(i, j)$  is *not* observed

$$Y_{ij} = \star \text{ or } ?$$



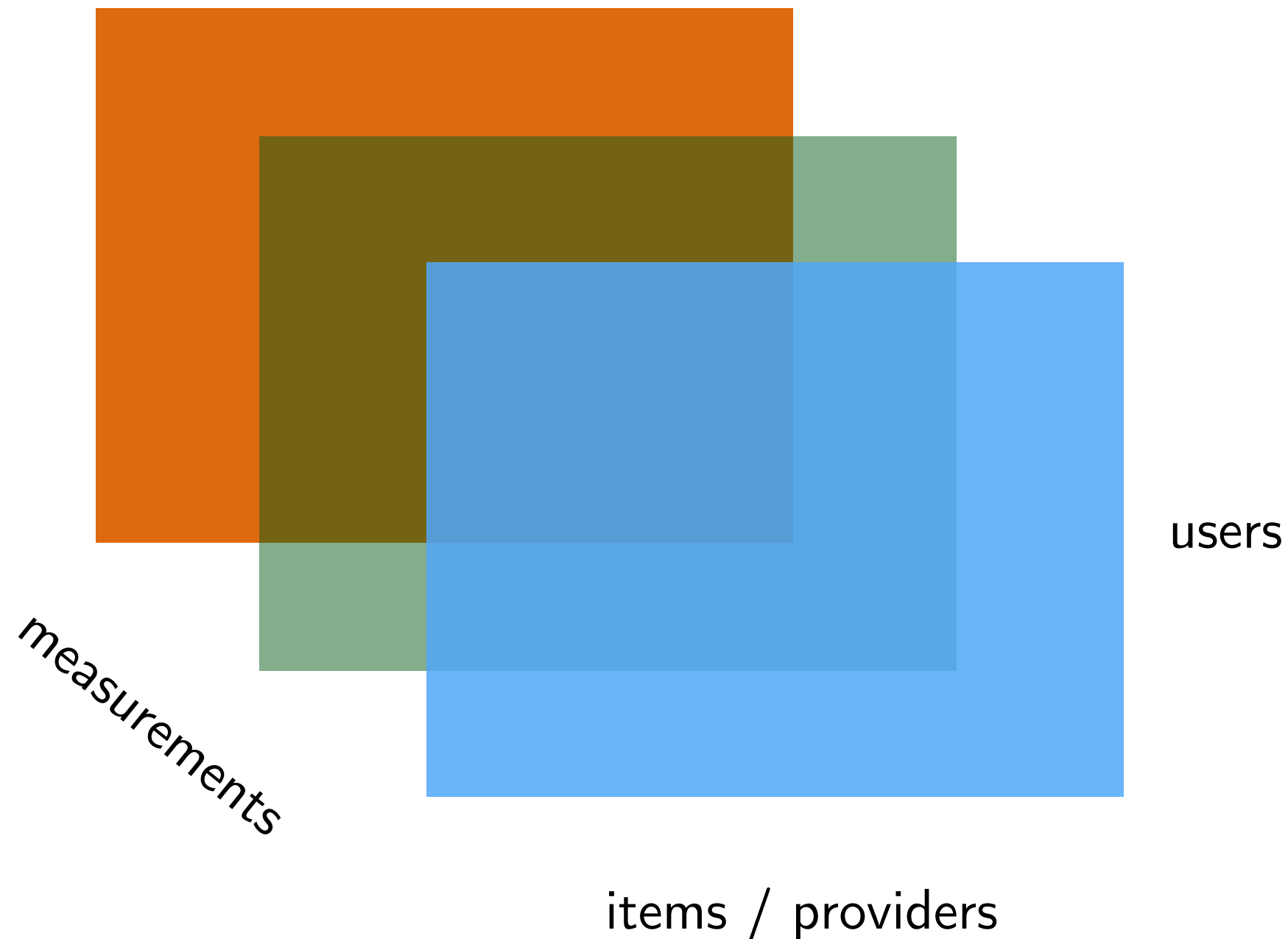
Goal: produce estimation  $\hat{L}_{ij}$  for all  $i, j$

so that  $\hat{L}_{ij} \approx L_{ij}$  for all  $i, j$

# Recommendation: Problem statement

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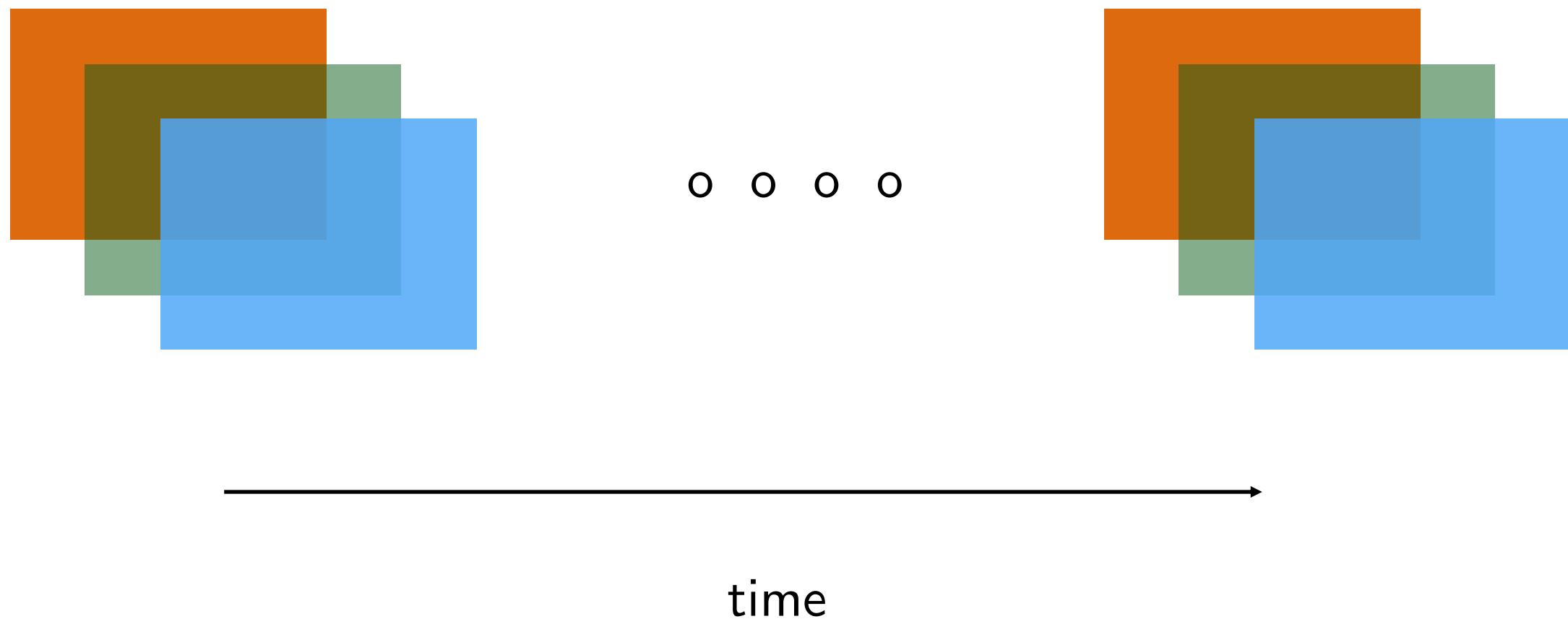
Prediction problem: complete the tensor



# Recommendation: Problem statement

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Prediction problem: complete the time varying tensor



# Recommendation: Problem statement

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Challenges that we will not discuss

- user provided data

  - not generated at random

  - can be strategic

  - can be driven by innate preference

- provider / item

  - can be systematically manipulated

  - convenient location

  - strategically modified content



# Recommendation: Problem statement

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Challenges that we will not discuss

Side effects of recommendation systems

Information bubble

Feedback loops

Too powerful platforms

Regulation of platforms

Interplay with recommendation systems