

# Search Ranking and Personalization at Airbnb

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# Airbnb

## Worldwide Accommodations Leader

- 4M listings in 190 Countries
- 2M guest stay at Airbnb every night

## 2-sided Marketplace:

- **Hosts:** looking to rent their space
- **Guests:** looking for a place to stay

Our job:

Connect guests with hosts



# Search At Airbnb

query: location, dates, guests, map, filters





FOR YOU HOMES EXPERIENCES PLACES

Room type Price range Instant Book More filters



From \$79 · Perfectly located Castro  
Private room · 1 bed  
★★★★★ 335 · Superhost



From \$149 · Grand and Cozy 1920's SF Studio  
Entire apartment · 2 beds  
★★★★★ 280 · Superhost



From \$185 · Garden Retreat steps from Haight St  
Entire house · 2 beds  
★★★★★ 186 · Superhost



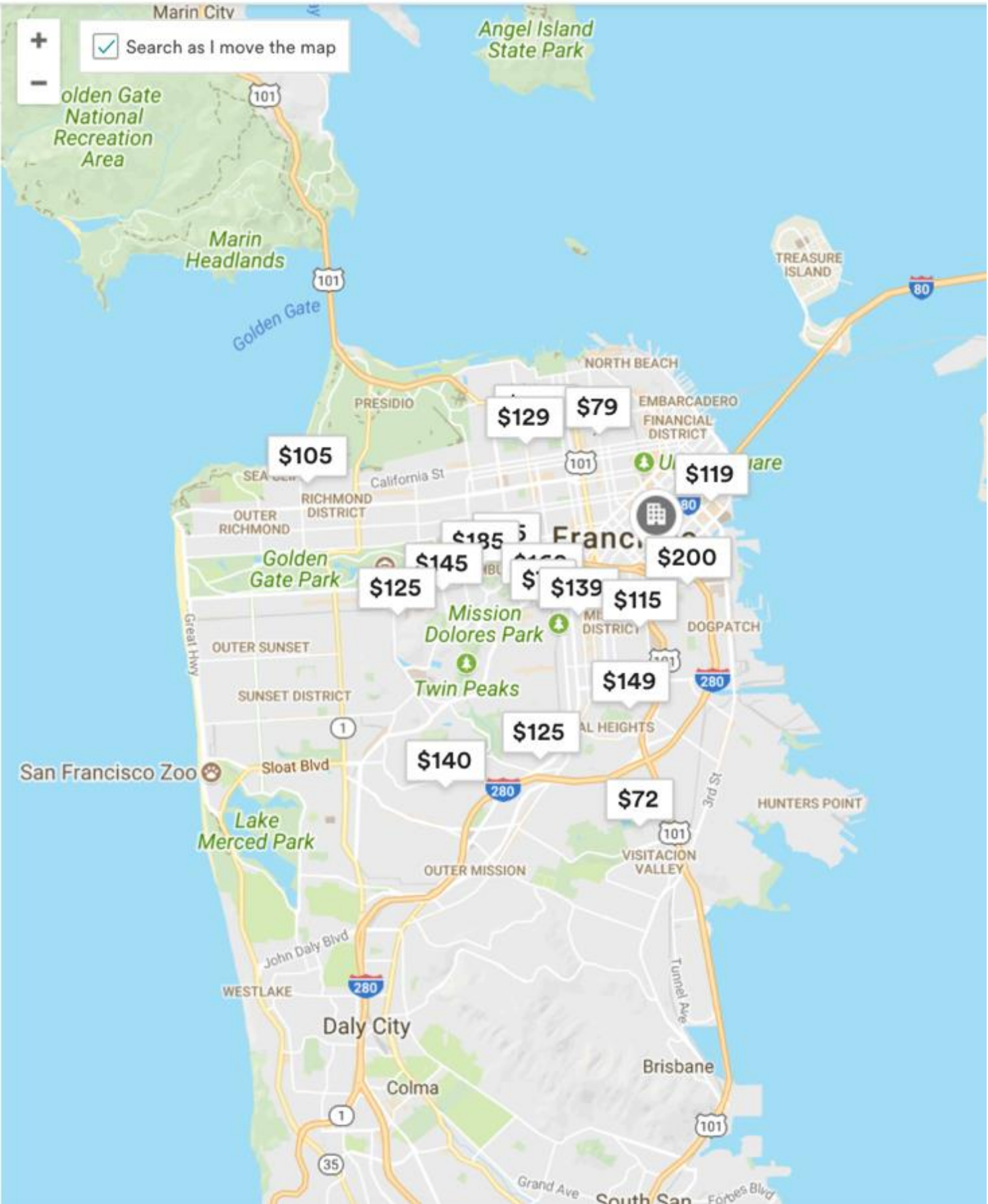
From \$105 · Charming SF 1911 Studio  
Entire condominium · 1 bed  
★★★★★ 136 · Superhost



From \$129 · Upscale Private Ensuite Bed & Bath  
Private room · 1 bed  
★★★★★ 289 · Superhost



From \$350 · Edwardian Style Pacific Heights 1BD  
Entire apartment · 1 bed  
★★★★★ 56





# Search At Airbnb

## Search Components

- **Retrieval of Listings**
  - **Location Queries** (e.g. **New York**): Rule based: fetch everything near by
  - **Broad Queries** (e.g. **Skiing in France**): Model based
- **Ranking of Listings**
  - **Model based:** query, user and listing features
  - **Trained using user actions:** clicks, wishlists, inquires, bookings and rejections
  - **Tradeoffs** **Guest** and **Host** preferences

# Typical Guest Flow

## Guest actions



## Instant Book

⚡ \$114 per night

Book



\$66 🍷  
★★★★★ 71 reviews  
I SETTE CONI - TRULLO EDERA  
Entire home/apt · 2 beds · 4 guests · Business Travel Ready

## Host actions

Request to Book

Contact host

Booking Request

Contact

Reject

Accept

No Response

- dates
- minimum nights
- short notice
- long term
- pets
- kids
- discount
- parties
- smoking

- One listing can accept only one guest for a certain set of dates



# Guest Sessions

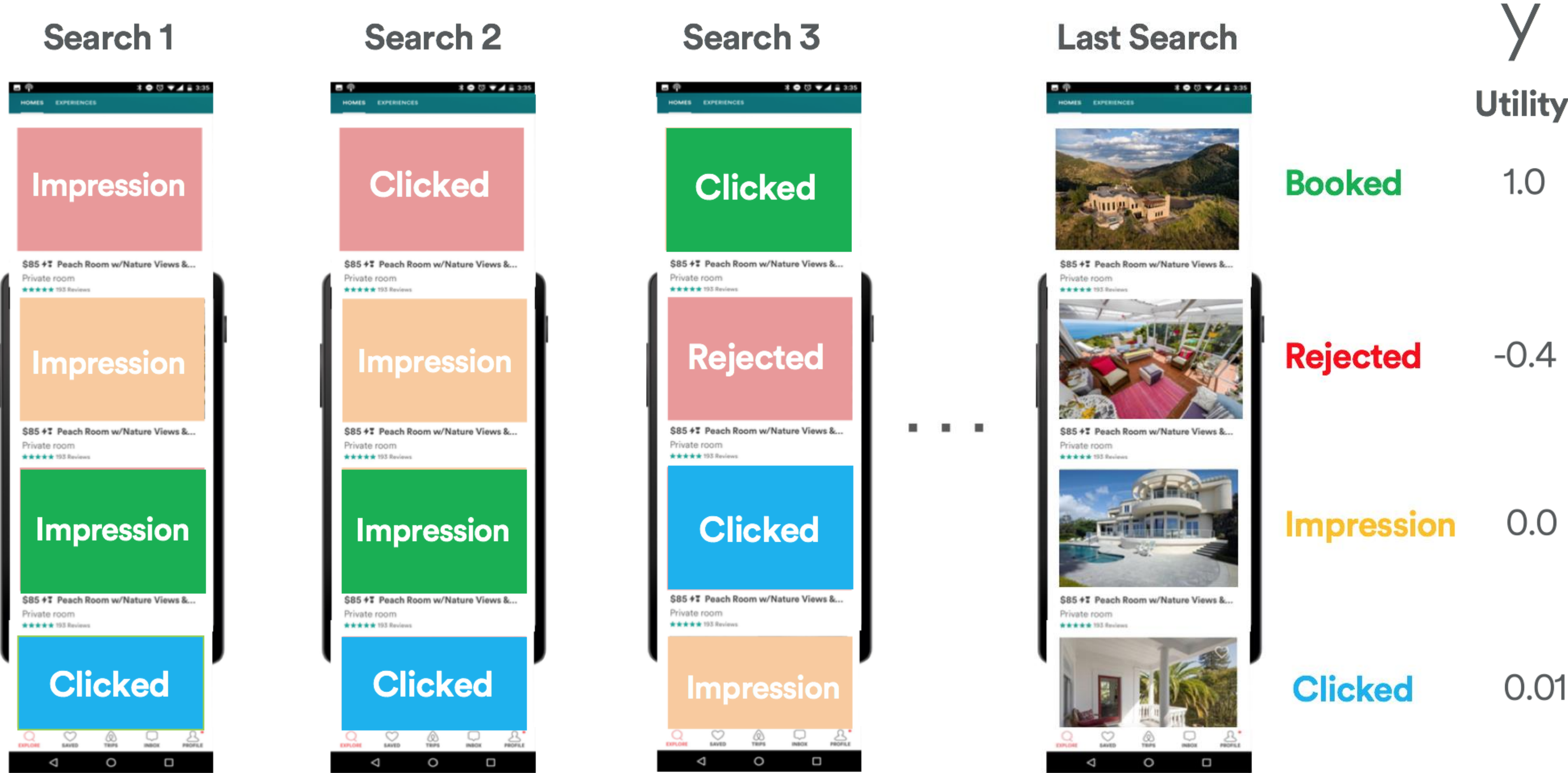
Average user does **dozens of searches** over **multiple days** before they book





# Model v0:

Last Search (label propagation) + Utility Prediction



# Model v0:

## Last Search + Utility Prediction

- Regression:  $f(x) \rightarrow y$  Display Results in Descending Order of Predicted Utility
- Features (X) :
  - Listing Features (engagement, quality, type, capacity, etc.)
  - Query Features (destination, nights, guests, etc.)
  - Guest Features (origin, past bookings, listing preferences, short term history)
  - **Rejection Probability**: output of separate model that predicts Host rejections

- Model (f) : GBM model



### Search @ Airbnb

Airbnb ✓

11 months ago • 4,834 views

"Search Ranking: GBM & personalization Search is a universal problem among almost all internet companies. But Airbnb's search ...



# How we iterate?

$$f(x) \rightarrow y$$

- change prediction model (GBM, TF)

- change Loss function

- change how we create training data

- add new features

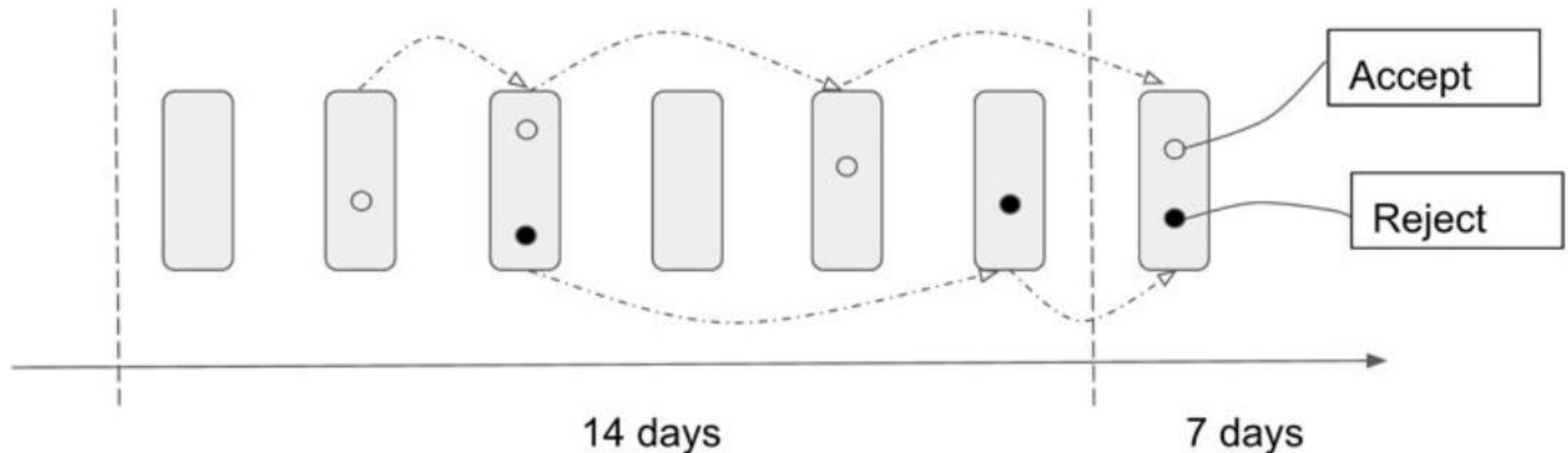
change what we predict

# Examples of Successful Iterations

Significant Booking Gains

## 1. Early Attribution

- Instead of only Last Search use Earlier Searches as well
- Propagate labels back





# Examples of Successful Iterations

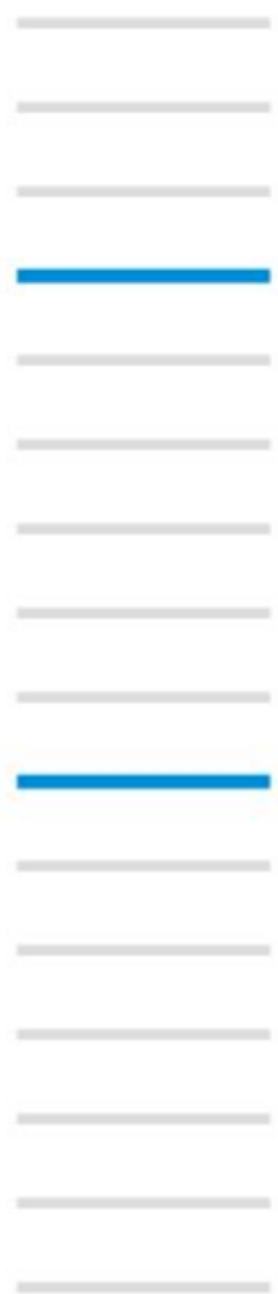
## 2. Pointwise to Pairwise

- Weighted Pairwise (LambdaRank)

$\lambda$  Rank preferred



pairwise preferred

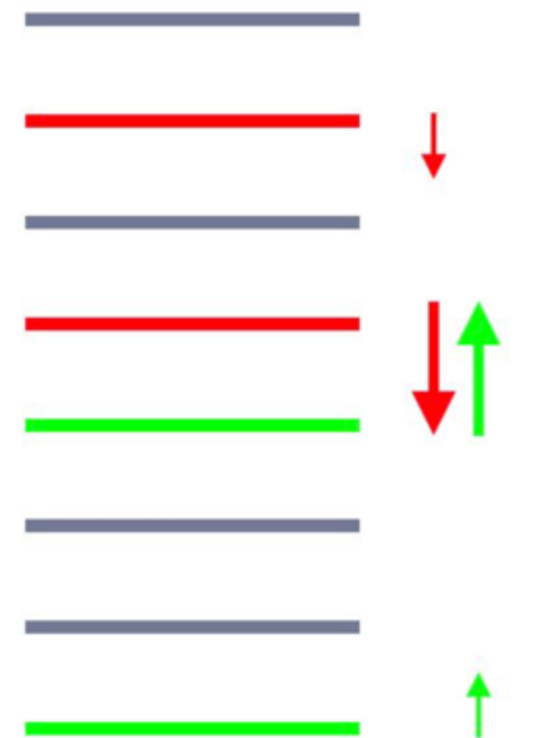


Weight Top Positions  
More in Pairwise  
Loss

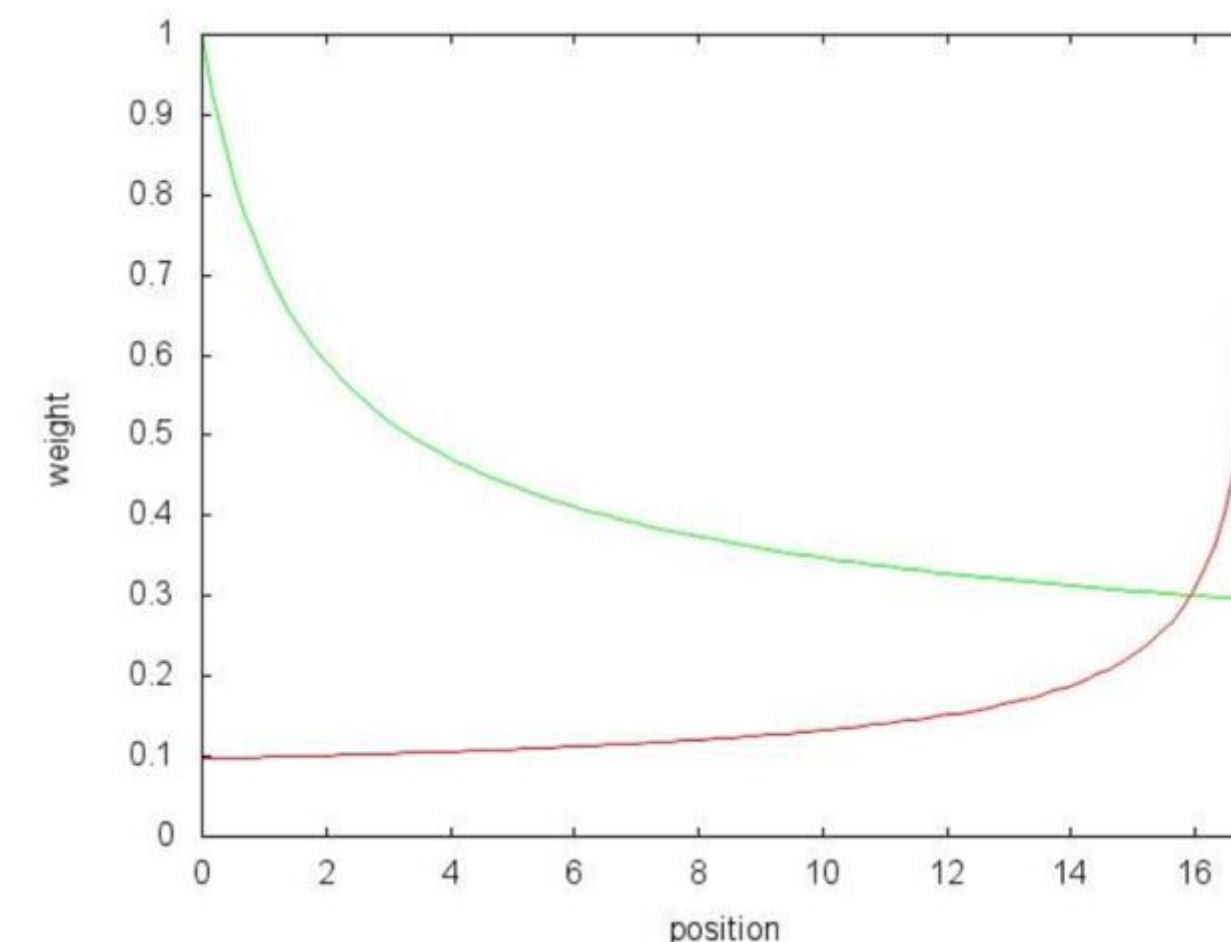


- Dual Discount Curve Pairwise (Modified LambdaRank)

- Lambda Rank focus only on **pushing good outcomes to the top**
- But its equally important to push **bad outcomes to the bottom**



Green: Good Outcomes  
Red: Bad Outcomes



# Examples of Successful Iterations

## 3. Real-time Personalization

### Main Challenges

- Guests do not visit every day (most travel up to 2-3 times a year)
- Preferences may change from visit to visit
- Rarely go to same location twice

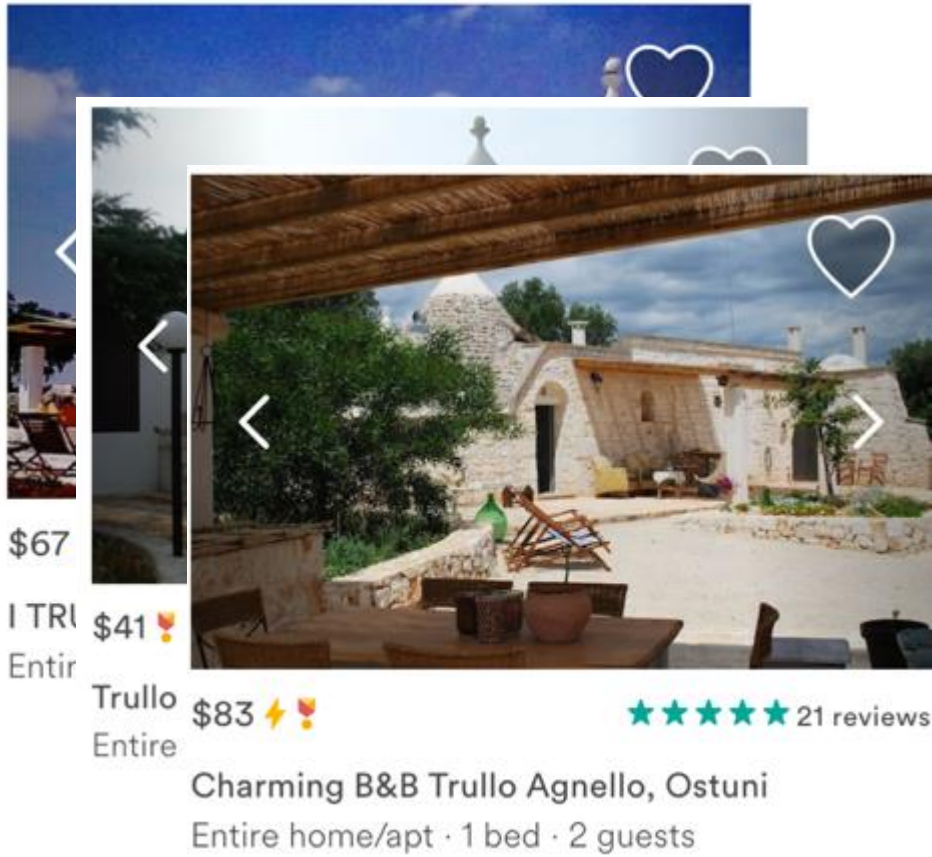
**Approach:** In-session personalization

1. Memorize listings you clicked on recently
2. Show similar listings to the one you liked (wishlisted, long clicked, contacted)



# Real-time Personalization using Embeddings

recently long-clicked listings  
by user (>60 sec)

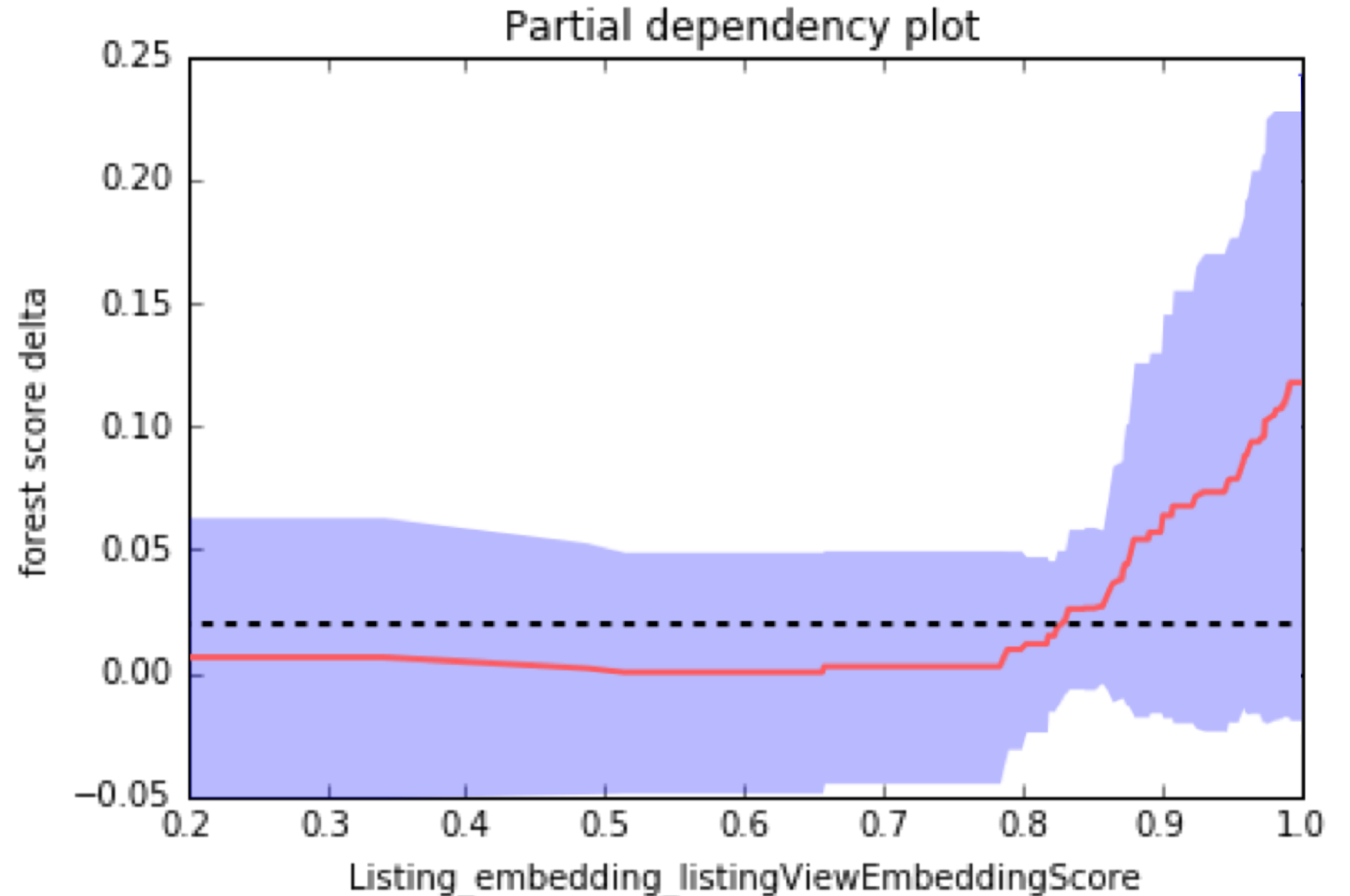


- Embedding Features:**
- 1. **longViewEmbeddingScore**
  - 2. wishlistEmbeddingScore
  - 3. contactEmbeddingScore

# Real-time Personalization using Embeddings

Partial dependency plot

Feature Importance: top 10





A photograph of a modern, bright kitchen with a large central island. Four people are present: a man on the left, a woman in the center, another woman on the right, and a man on the far right. They appear to be in a collaborative or social setting. The kitchen features large windows, pendant lights, and a clean, minimalist design. The entire image is overlaid with a semi-transparent red filter.

# Listing Embeddings in Search

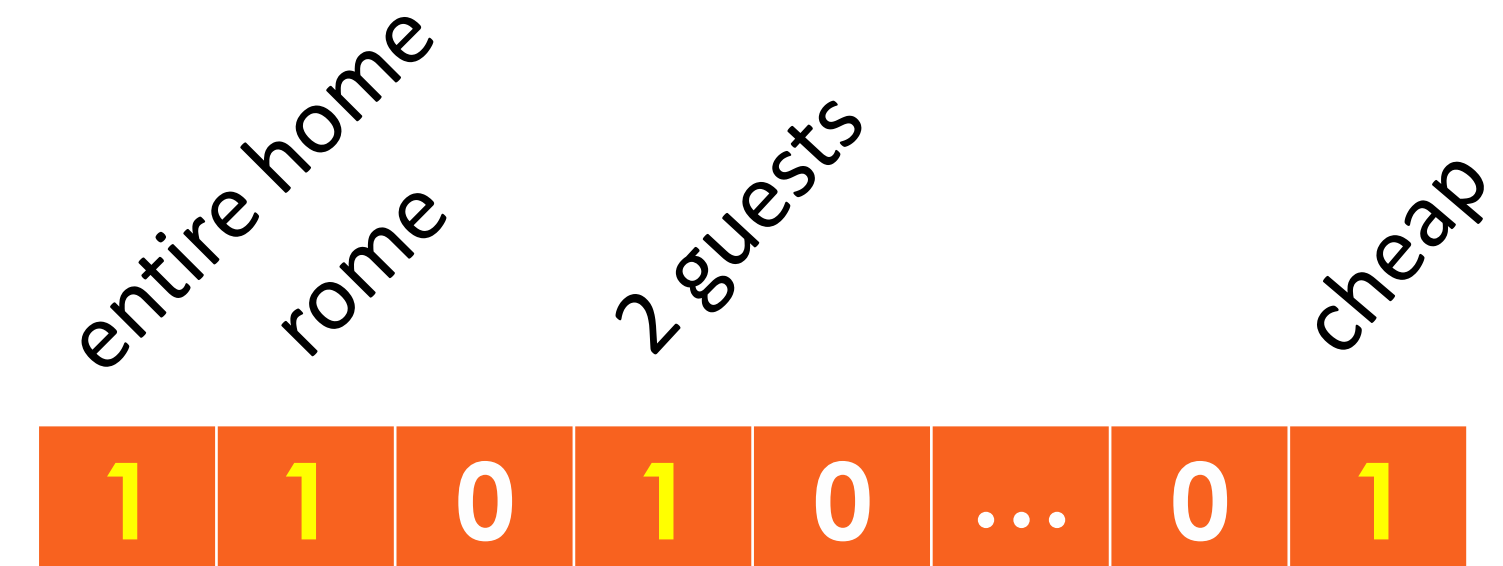
# Listing Embeddings

How to represent a **listing**?

**Listing**

Casa Vacanze in Rome

sparse



dense



embedding

- Represent **listings** as **numeric vectors**
- Vectors need to be learned using training data (**search sessions**)
- We want listings with **similar contexts** to have **similar vectors**
- Popular tool for training: **word2vec**



# Search Sessions

## Actions by single user (listing clicks, inquiries, bookings) ordered in time

S1 748612 4160766

**S2**    5473823    2582727    5473823    2582727    5473823    5473823

S3    6251934    9257649

**S4**   **7924193**   **10116733**   **8998529**   **9075420**   **4113166**

**\$5**   **5503478**   **4986017**   **5503478**   **5503478**   **5879904**   **4140396**

**S6**    10237904    8680483    8718513    11691507    4831342    8004575    7866901

# Search Sessions

We only use clicks that have >30 sec page view time (no accidental clicks)



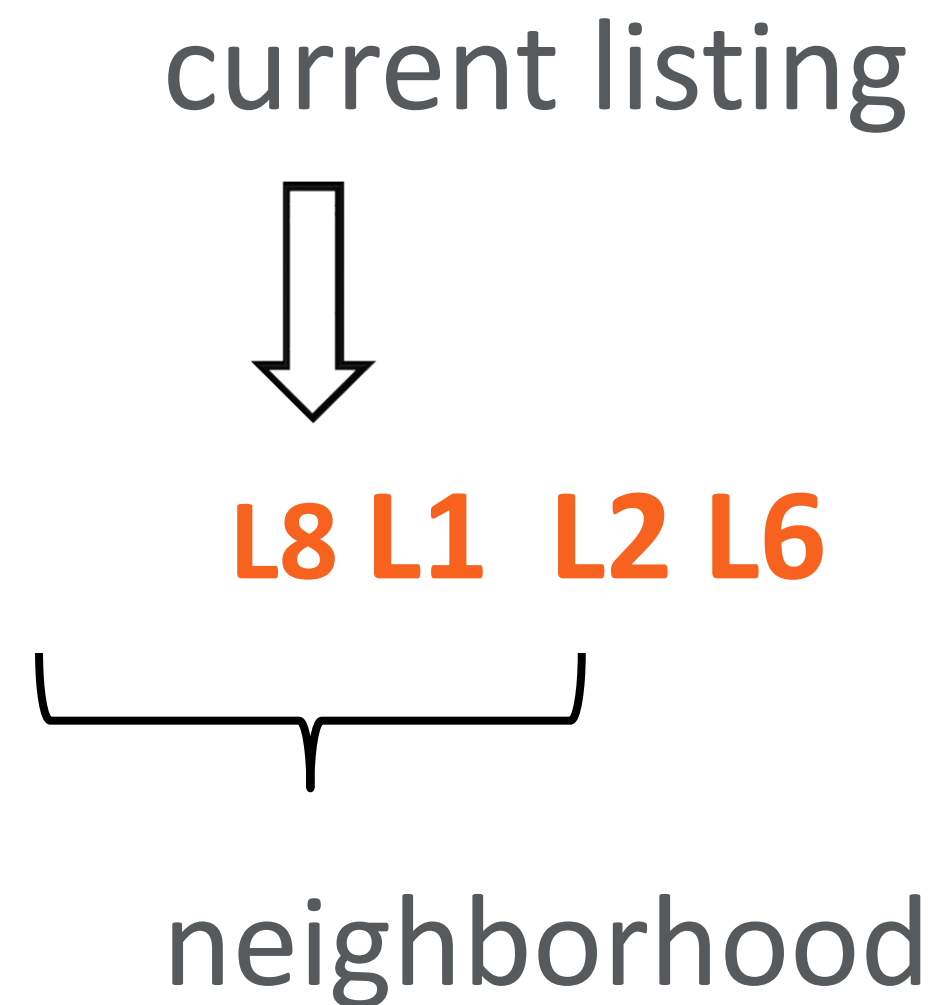
Session ends when there is more than 30 min inactivity



# Training

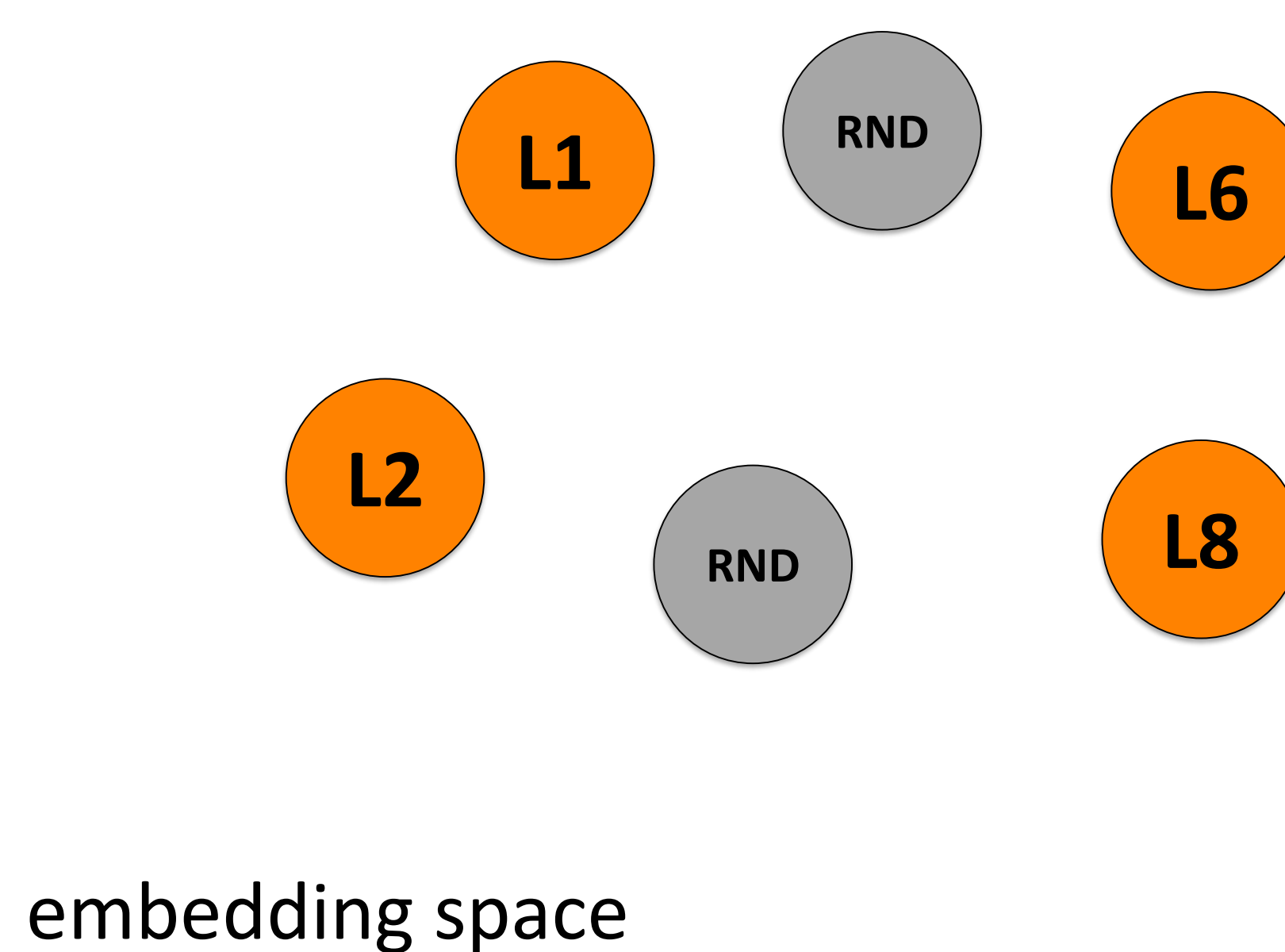
Example search session:

**Listing8, Listing1, Listing2, Listing6**



$$\mathbf{v}_i^{new} = \mathbf{v}_i + h \times (1 - S(\mathbf{v}_i^T \mathbf{u}_{neigh})) \times \mathbf{u}_{neigh}$$

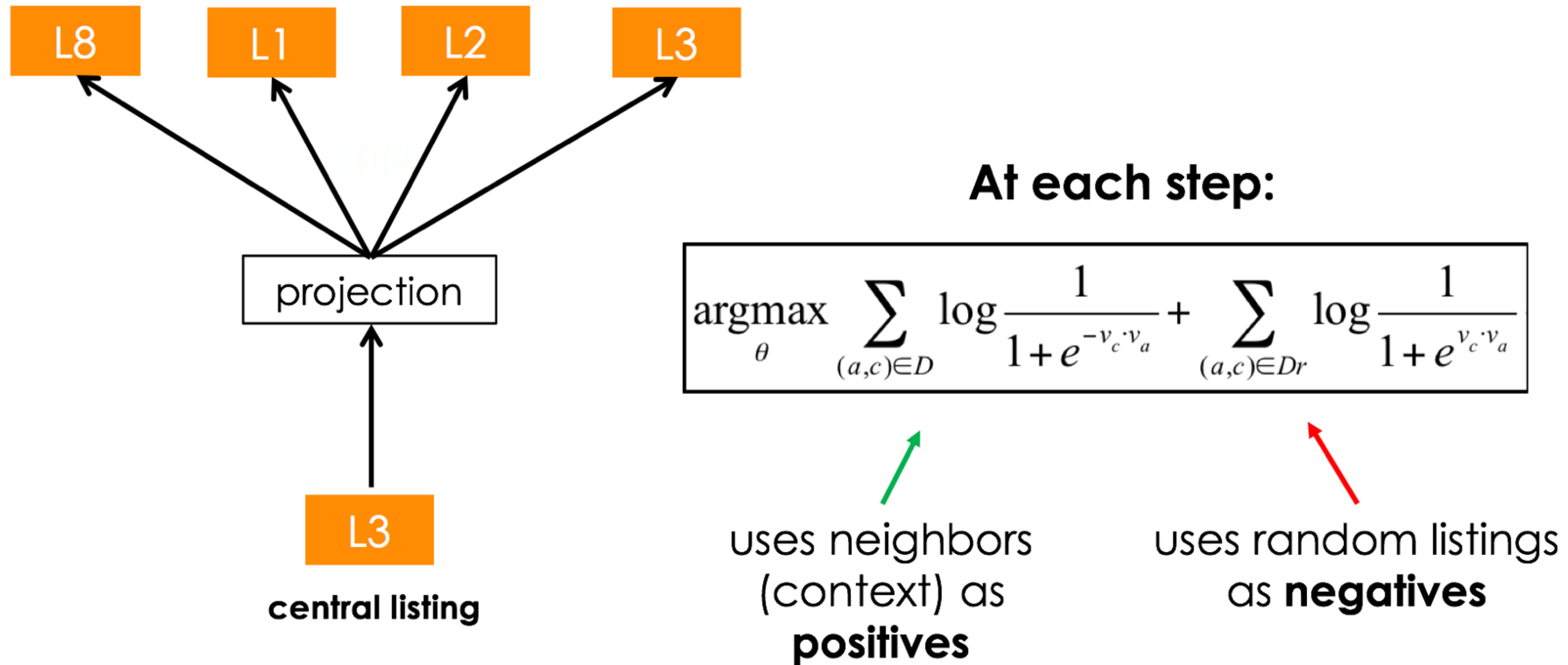
$$\mathbf{v}_i^{new} = \mathbf{v}_i - h \times S(\mathbf{v}_i^T \mathbf{u}_{neg}) \times \mathbf{u}_{neg}$$





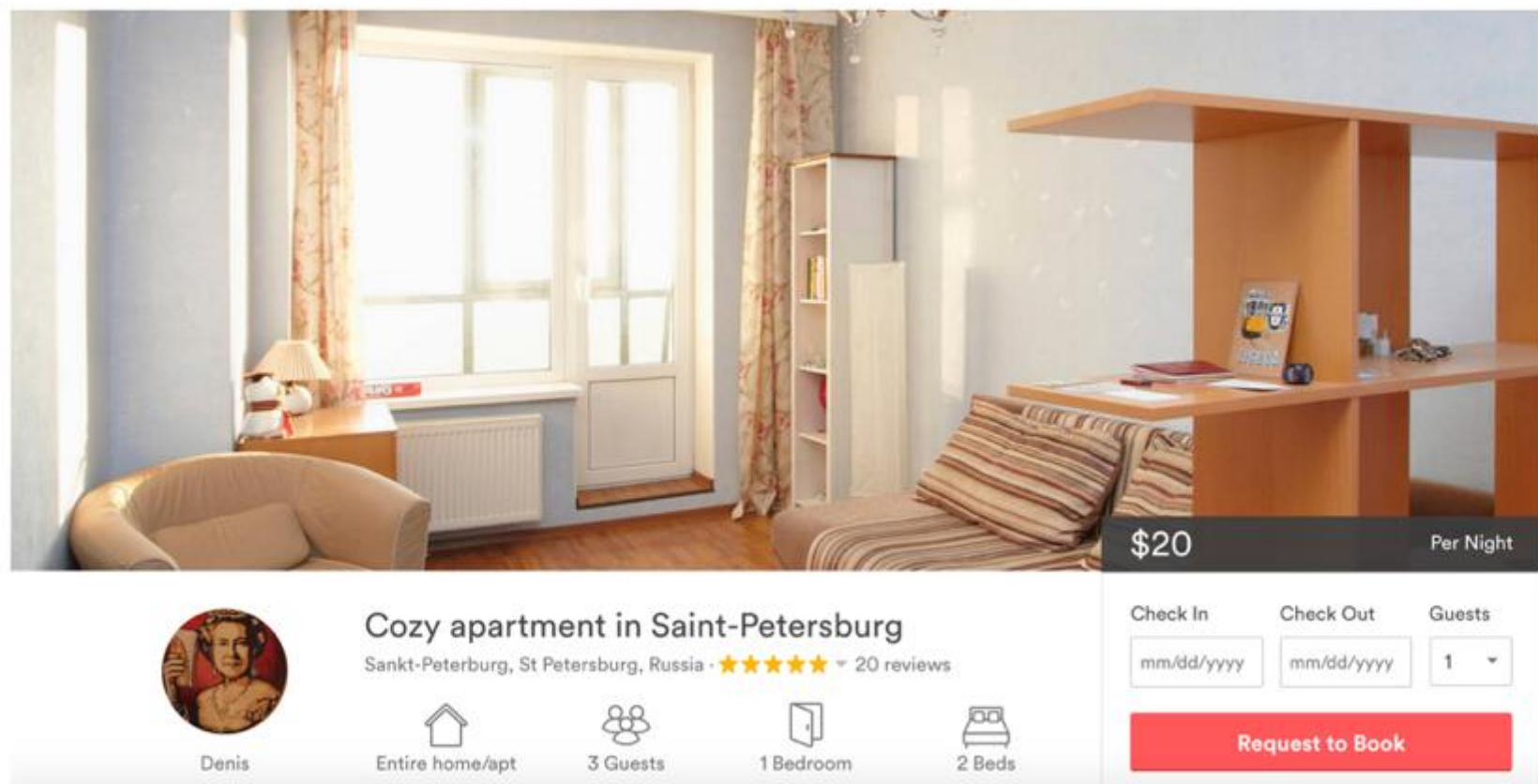
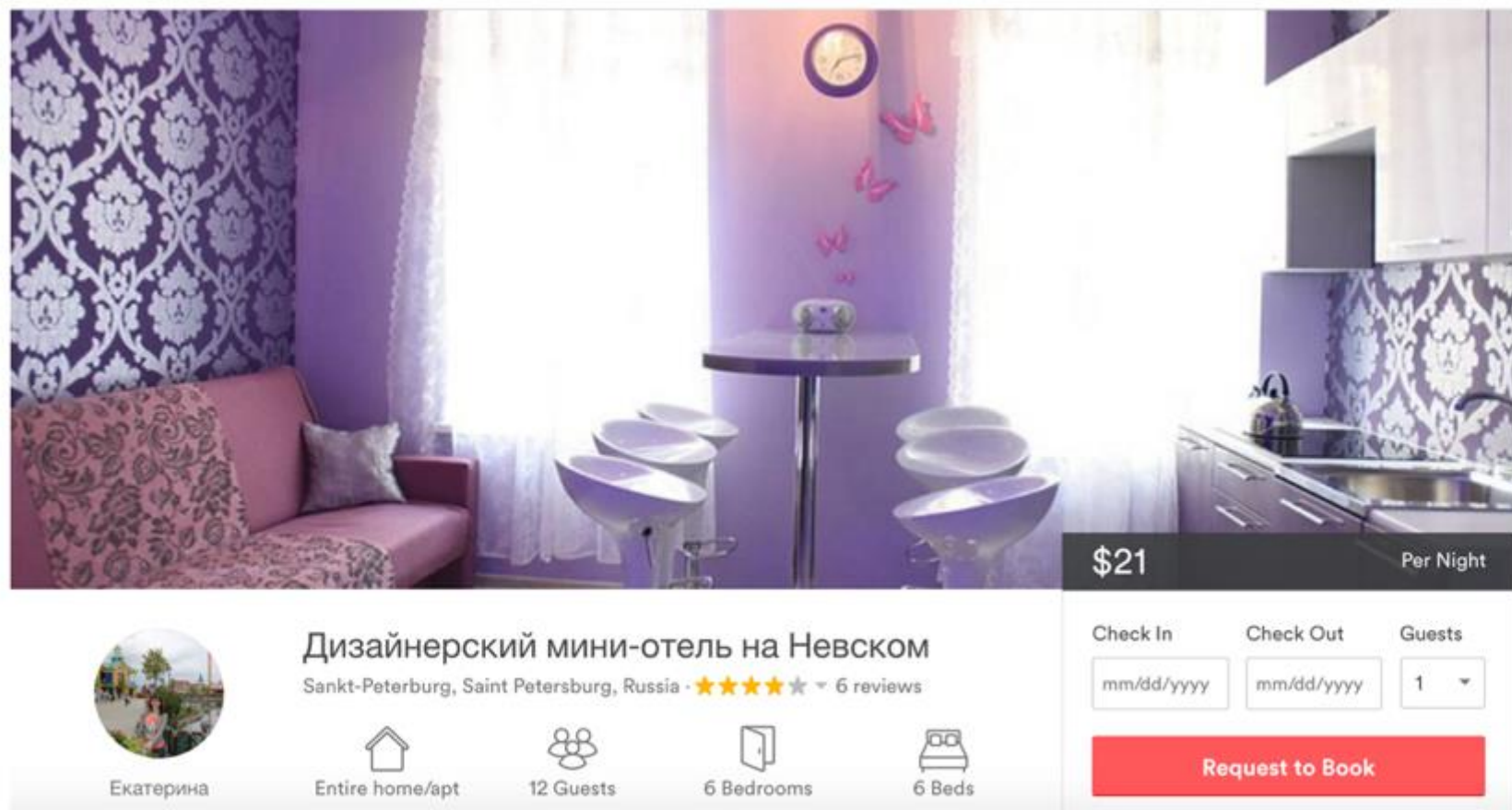
# Training

## Skip-gram model (word2vec)



# After Training

Can calculate similarity between any two listings



0.7 2.4 5.1 0.9 6.2

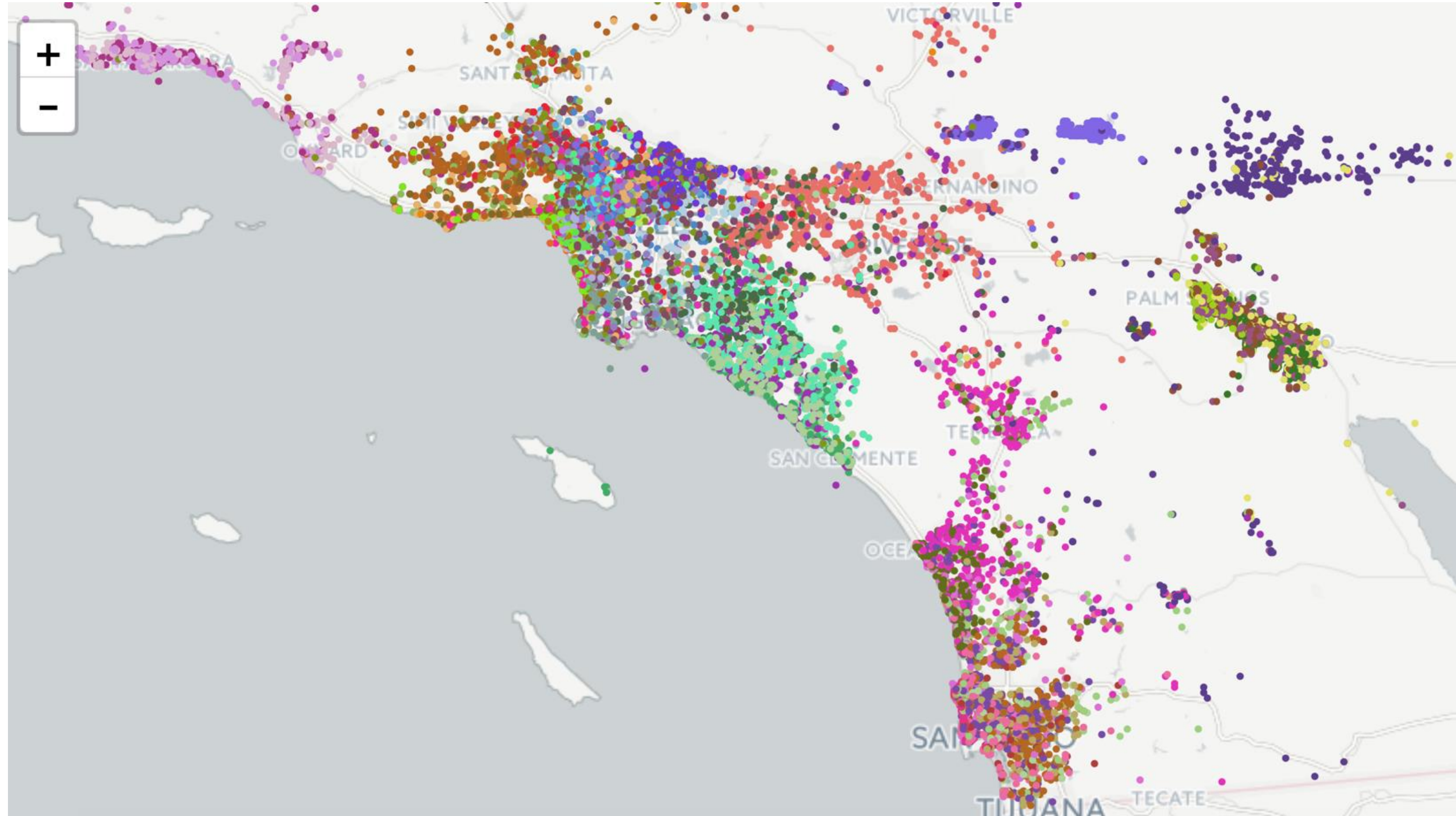
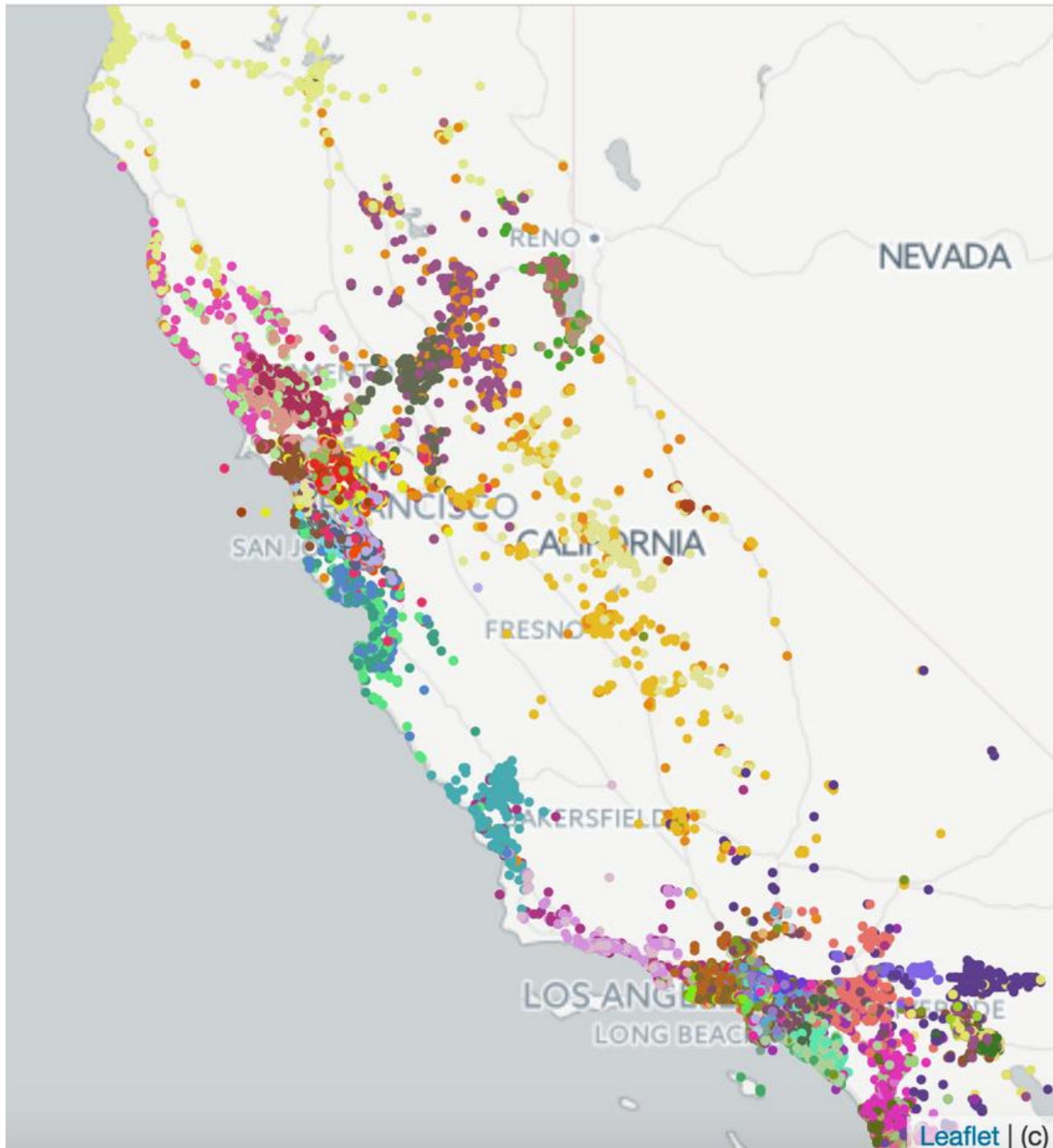
cosine sim = 0.734

0.6 1.3 5.8 2.1 6.2



# After Training

Can cluster listings: California





# word2vec Modifications that Worked for us

## 1. Not all interactions between two **listings** are the same

co-click session:      **5473823**   **2582727**   **5473823**   **2582727**   **5473823**   **5473823**

co-inquiry session:      **6251934**   **9257649**

sessions that end in booking:      **5473823**   **2582727**   **5473823**   **2582727**   **5473823**   **5473823**

### Positive interactions

- **co-click** – default weight
- **co-inquiry** – larger weight
- **booking sessions** – larger weight

# word2vec Modifications that Worked for us

## 2. Better **negative sampling**

- **Random negatives**: probability of sampling a negative from same city very low (not a problem if you have 1-2 cities but we have thousands)
- **Random negatives from same city**: leads to better within city listing similarities
- Analogous to learning word vectors when data comes from many languages



# Applications

## Can Find Similar Listings



\$156 🏆 ⭐⭐⭐⭐⭐ 237 reviews

LUXURY INDEPENDENT STUDIO on SHIP : fr...  
Private room · 2 beds · 3 guests

Listing	Cosine distance
579851	0.989346
851044	0.982895
64736	0.979351
2024269	0.976072
802052	0.974991
884329	0.974928
3850766	0.972117
5207034	0.968444
2126459	0.963931
1025482	0.963376



\$143 ⚡ ⭐⭐⭐⭐⭐ 249 reviews

Studio on Spectacular Houseboat  
Private room · 1 bed · 2 guests



\$98 ⚡ ⭐⭐⭐⭐⭐ 306 reviews

Houseboat,garden,center,freeparking  
Private room · 1 bed · 2 guests



\$133 ⚡ ⭐⭐⭐⭐⭐ 318 reviews

HOUSEBOAT NOVA 80m2 + FREE BIKES  
Private room · 3 beds · 4 guests



\$138 ⚡🏆 ⭐⭐⭐⭐⭐ 245 reviews

Authentic houseboat with privacy and comfort  
Private room · 1 bed · 2 guests



\$100 🏆 ⭐⭐⭐⭐⭐ 263 reviews

Sleeping on a ship in the centre.  
Private room · 1 bed · 2 guests



\$161 🏆 ⭐⭐⭐⭐⭐ 71 reviews

Luxury Houseboat  
Entire home/apt · 1 bed · 2 guests



# Applications

## Similar Listings



\$66 🍷 ★★★★★ 71 reviews  
I SETTE CONI - TRULLO EDERA  
Entire home/apt · 2 beds · 4 guests · Business Travel Ready

### Similar listings



\$55 TRADITIONAL HOUSE IN OSTUNI!!!  
Entire house · 1 bed  
★★★★★ 55



\$57 PIETRACHIARAHOUSE PANORAMIC TE...  
Entire house · 1 bed  
★★★★★ 53



\$67 REhoUSE Ostuni  
Entire apartment · 2 beds  
★★★★★ 56

Before

### Similar Listings



\$99 ⚡ ★★★★★ 147 reviews  
Trullo of 1800 in the Itria Valley  
Entire home/apt · 5 beds · 5 guests



\$76 ⚡ 🍷 ★★★★★ 17 reviews  
Trulli Tramonti d'Itria - Trullo Luna  
Entire home/apt · 3 beds · 4 guests



\$67 ⚡ 🍷 ★★★★★ 30 reviews  
I TRULLINI OSTUNI - MARTINA FRANCA  
Entire home/apt · 1 bed · 2 guests

After



# Query Embeddings in Search



# Query Embeddings

Query (geo\_id available)

San Francisco, California, USA



embedding:

0.2	1.1	7.2	0.8	3.1
-----	-----	-----	-----	-----

Query (geo\_id not available)

Skiing France



embedding:

0.7	3.4	2.8	0.1	2.2
-----	-----	-----	-----	-----

- Represent **queries** as **numeric vectors**
- Vectors need to be learned using training data (**search sessions**)
- We want queries with **similar contexts** to have **similar vector**



# Search Sessions

Actions by single user (queries) ordered in time

- S1

skiing\_germany

geo\_fs2342f61IHgQ

Garmisch-Partenkirchen
- S2

winter\_wanderland

winter\_wonderland

winter\_wonderland\_neitherlands

skiing

geo\_f23432dfHf
- S3

portugal\_surfing

portugal\_surf

geo\_MgsRQfBOHA

geo\_Hw0RU41424Da

Peniche, Portugal
- S4

grant\_park\_chicago

lollapalooza

grant\_park\_chicago

geo\_Llq58sDogRHf1
- S5

geo\_Kyvb07vZg

french\_quarter\_mardi\_gras

geo\_ChIjf5407f1

# After Training

We can calculate similarities between queries

mardi\_gras

0.2	1.2	7.1	0.8	3.2
-----	-----	-----	-----	-----

0.993


geo\_ChIJf5407BG

French Quarter, New Orleans, LA, United States

0.2	1.1	7.2	0.8	3.1
-----	-----	-----	-----	-----

Application: Autocomplete (Type-ahead)

Before



FOR YOU

Oktoberfest Pub, Bucharest, Romania

Oktoberfest, East 21st Street, Tulsa, OK, United States

Oktoberfest Grounds, La Crosse, WI, United States

Oktoberfest, Brighton 4th Street, Brooklyn, NY, United States

OKTOBERFEST BEAG CORK, Centre Park Road, Cork, Ireland

Q

oktoberfest|

X


Calendar icon

Anyti...

People icon

1 guest

After



FOR YOU

Theresienwiese, Munich, Germany

Moosach, München

Münchner Oktoberfest, Theresienhöhe, Munich, Germany

Laim, München

Munich, Germany

Q

Oktoberfest

X

Calendar icon


Anytime

People icon

1 guest



Before



Greek Islands

×

Anyti...

1 guest

FOR YOU

Greek Islands, South Halsted Street, Chicago, IL, United States


Greek Islands Taverna, North Ocean Boulevard, Fort Lauderdale, FL, United States

Greek Islands, East 22nd Street, Lombard, IL, United States

Greek Islands, Center Street, Omaha, NE, United States

Greek Islands, East Andreas Road, Palm Springs, CA, United States

After



Greek Islands

×

Anyti...

1 guest

Santorini, Thira, Greece


Mykonos, Greece

Ionian Islands, Greece

Lesvos, Greece

Cephalonia, Greece

Before



California beach towns

×

Anyti...

1 guest

FOR YOU

Township, North California Avenue, Chicago, IL, United States


California Street, Johannesburg, South Africa

Township High School District 211, California Avenue, Palatine, IL, United States


California Avenue, Pleasanton, CA, United States

Township High School District 211, California Street, Elk Grove Village, IL, United States

Room Ty



After



California Beach Towns

×

Anytime

1 guest

FOR YOU

Laguna Beach, CA, United States


Santa Monica, CA, United States

Huntington Beach, CA, United States


Santa Catalina Island, Avalon, CA, United States

Newport Beach, CA, United States

Exper



Before



FOR YOU

Q France Skiing

×

Anyti...

1 guest

France Skiing, Castellan Avenue, Romford, United Kingdom


Courchevel Tourisme, Saint-Bon-Tarentaise, France

Ecole du ski Français Cambre d'Aze Eyne, Place de l'Europe, Eyne, France

Skiing at Isola 2000, Isola, France

Ecole De Ski La Foux D'Allos (ESF), Les Pointus, Allos, France

After



FOR YOU

Exper

Q France Skiing

×

Anytime

1 guest

Morzine, France

La Rosière

Chamonix, France

Sainte-Foy-Tarentaise

French Alps, Courmayeur, Aosta Valley, Italy



# Questions?

Press questions:

[press@airbnb.com](mailto:press@airbnb.com)

We are hiring ML  
Scientists

Contact me:

[mihajlo.grbovic@airbnb.com](mailto:mihajlo.grbovic@airbnb.com)



**airbnb**