



Recommending the Best Hotels at TripAdvisor

Anyi Wang,
anwang@tripadvisor.com





Machine Learning at Tripadvisor



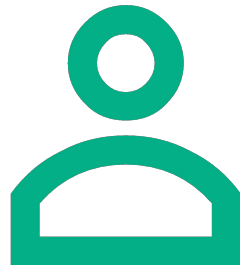


tripadvisor[®]

know better • book better • go better

About TripAdvisor

TripAdvisor is the world's largest travel site*



455M

average unique
monthly visitors **



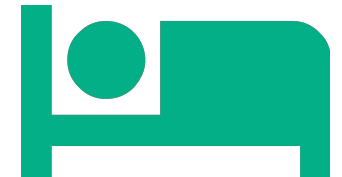
49

Markets
Worldwide



570M

Reviews and
Opinions



7M

Accommodations,
Restaurants and Attractions

*Source: comScore Media Metrix for TripAdvisor Sites, worldwide, March 2017

** Source: TripAdvisor log files, Q3 2017

TripAdvisor Machine Learning Group

- Review Fraud Detection
- Recommender Systems
- Bot detection
- Booking / Content models
- Machine Vision
- Search Result Ranking
- Automated Collection Generation
- Keyphrase Generation
- Location Classification

Blog: engineering.tripadvisor.com

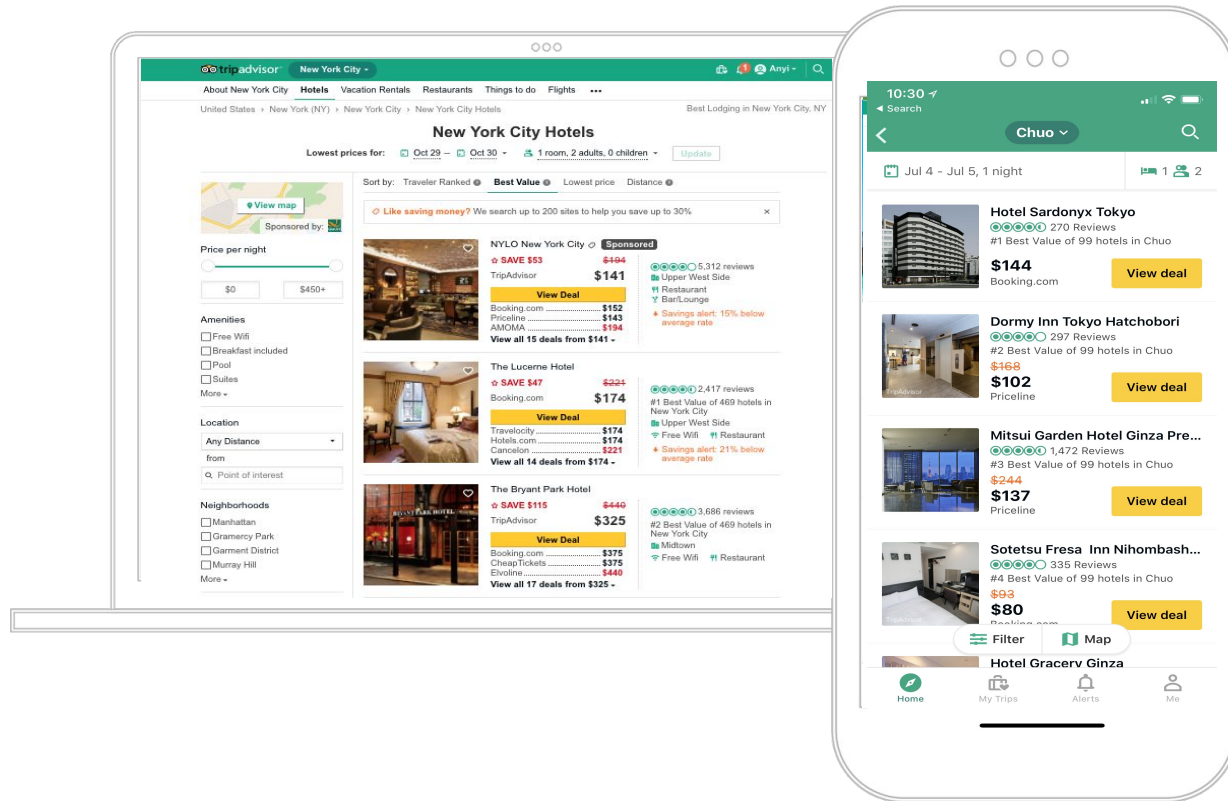




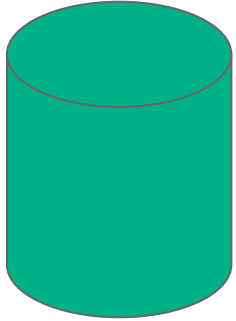
Recommending the Best Hotel



Hotel Sorting

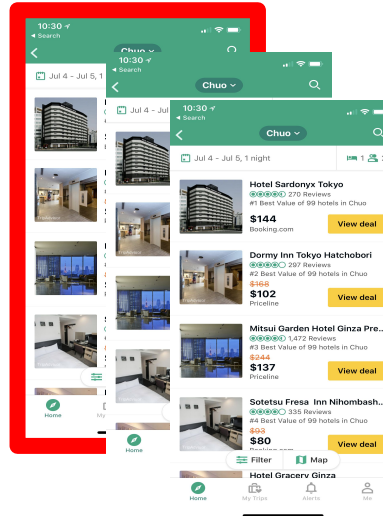


Hotel Sorting

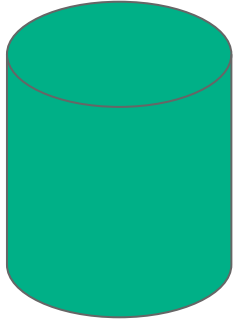


Documents

$D = \{d_1, d_2, \dots, d_n\}$

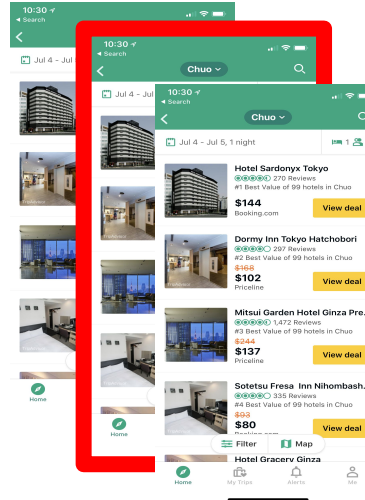


Hotel Sorting

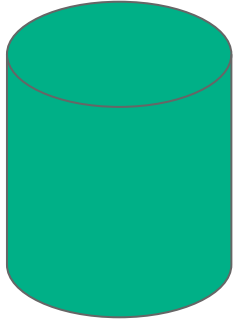


Documents

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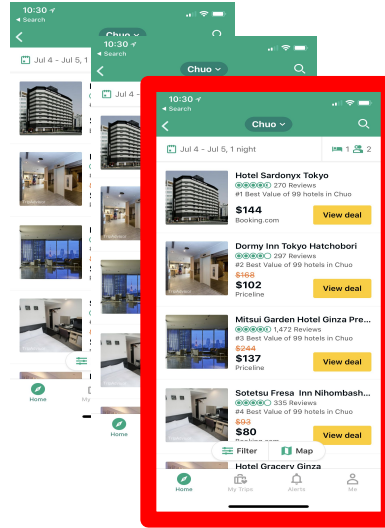


Hotel Sorting

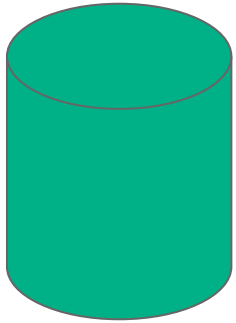


Documents

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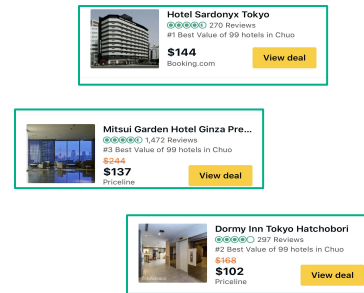
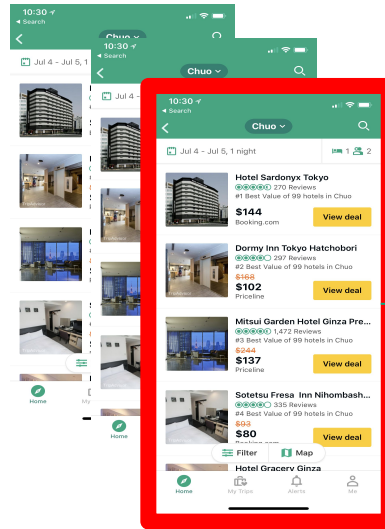


Hotel Sorting



Documents

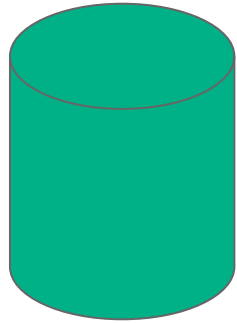
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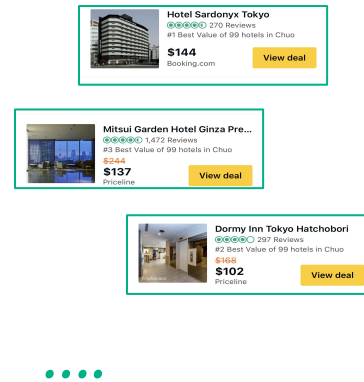
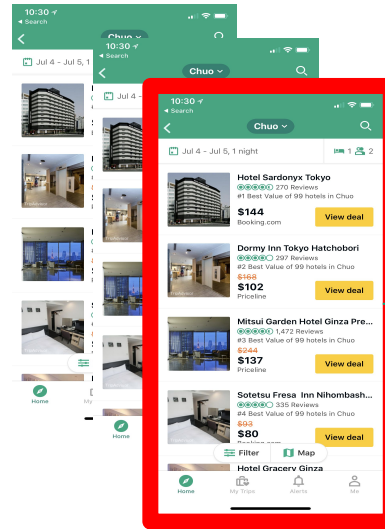
query q

Hotel Sorting



Documents

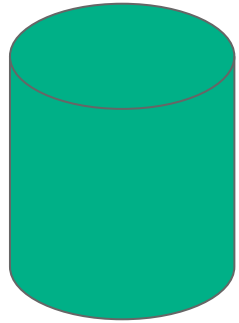
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query q

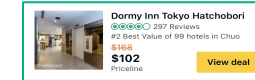
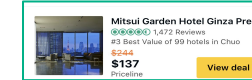
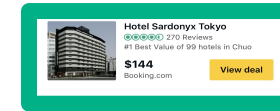
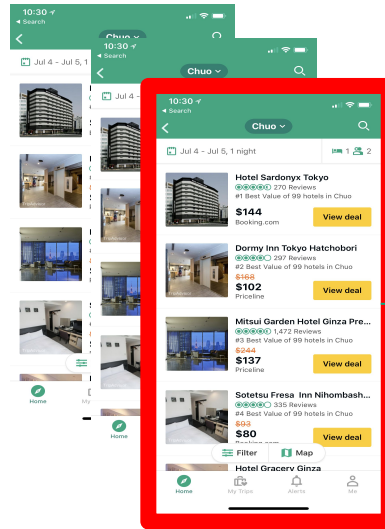
relevance score

Hotel Sorting



Documents

$D = \{d_1, d_2, \dots, d_n\}$

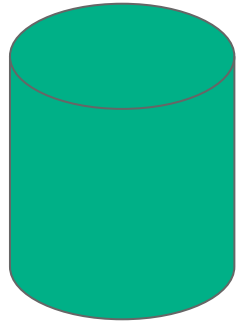


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query q

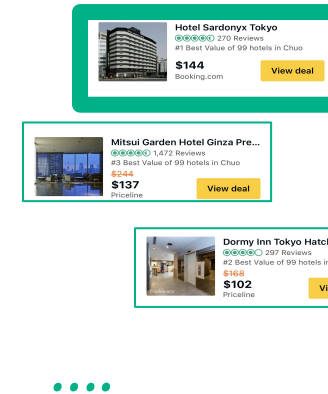
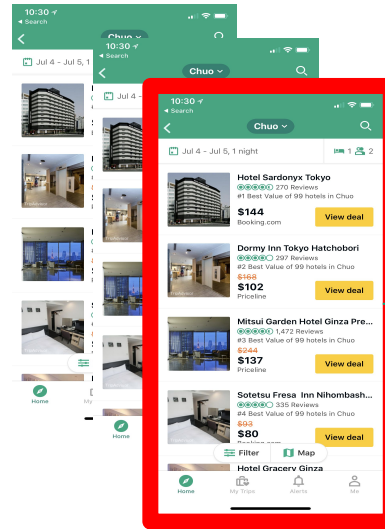
relevance score

Hotel Sorting



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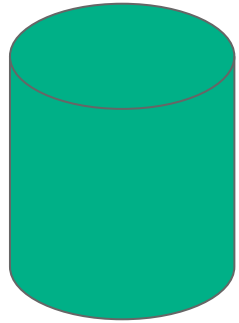
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query q

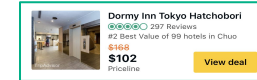
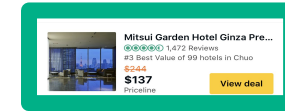
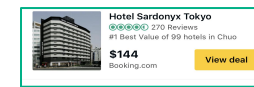
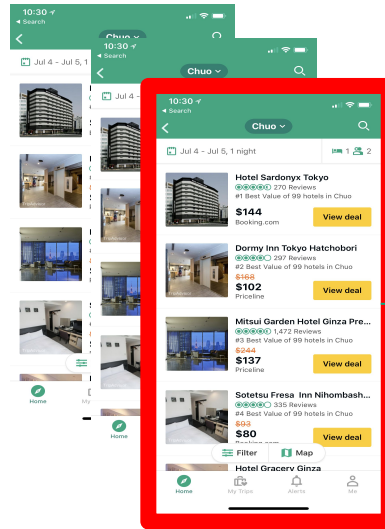
relevance score

Hotel Sorting



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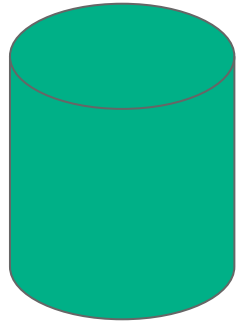
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query q



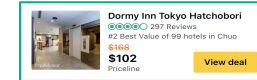
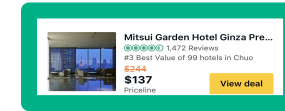
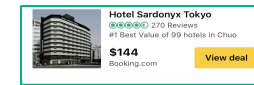
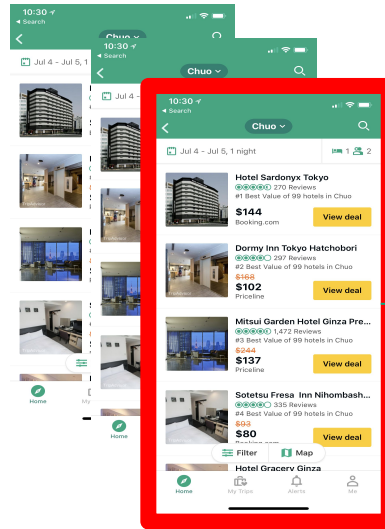
relevance score

Hotel Sorting



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...

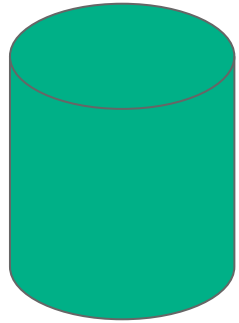
query q



-

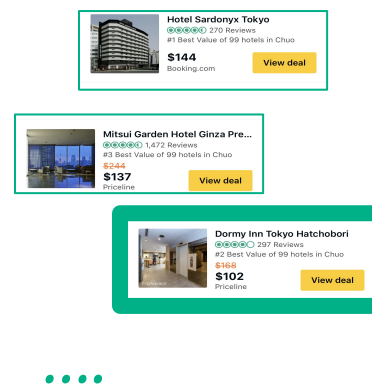
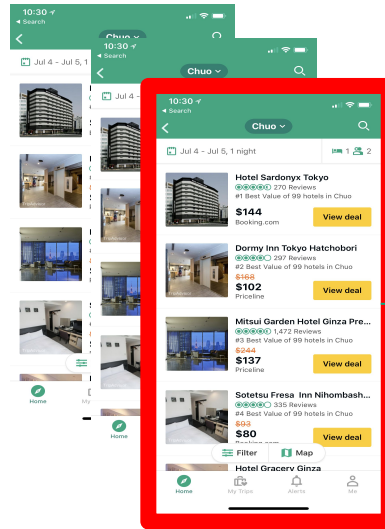
relevance score

Hotel Sorting



Documents

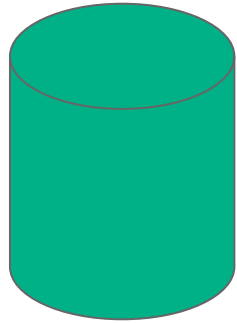
$D = \{d_1, d_2, \dots, d_n\}$



query q

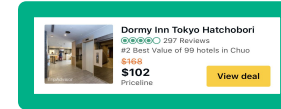
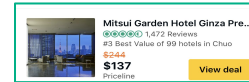
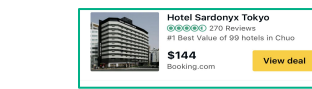
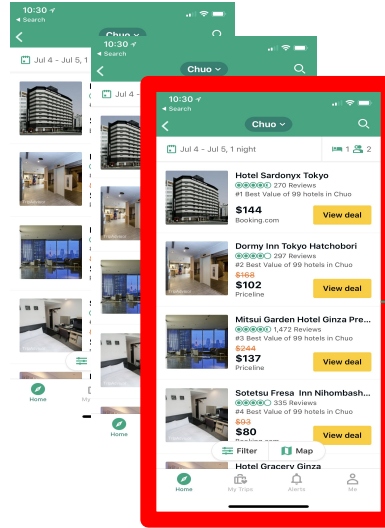
relevance score

Hotel Sorting



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...



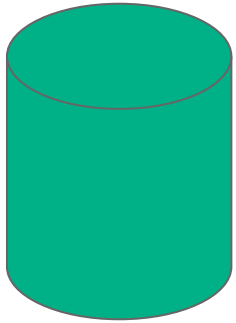
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query q

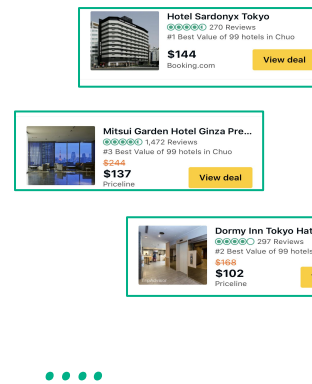
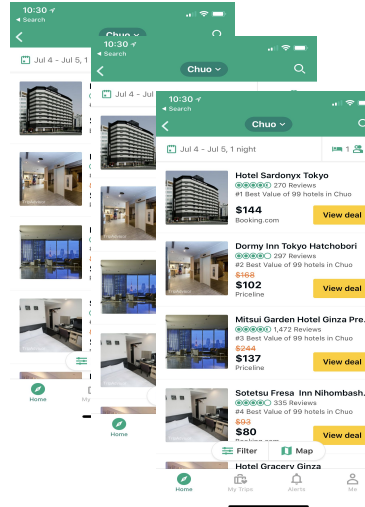
relevance score

Hotel Sorting



Documents

$D = \{d_1, d_2, \dots, d_n\}$



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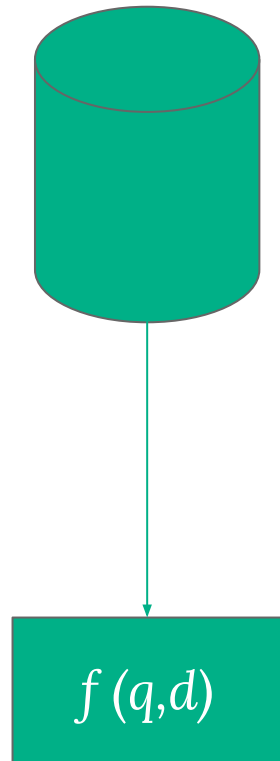
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+

query q

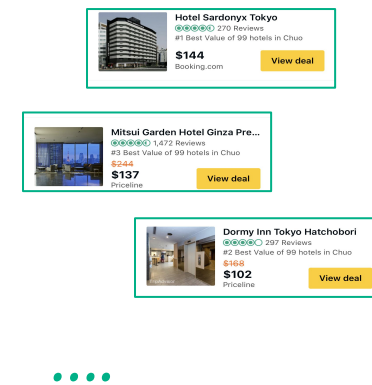
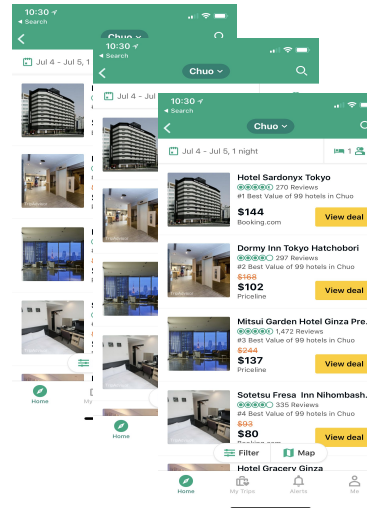
relevance score

Hotel Sorting



Documents

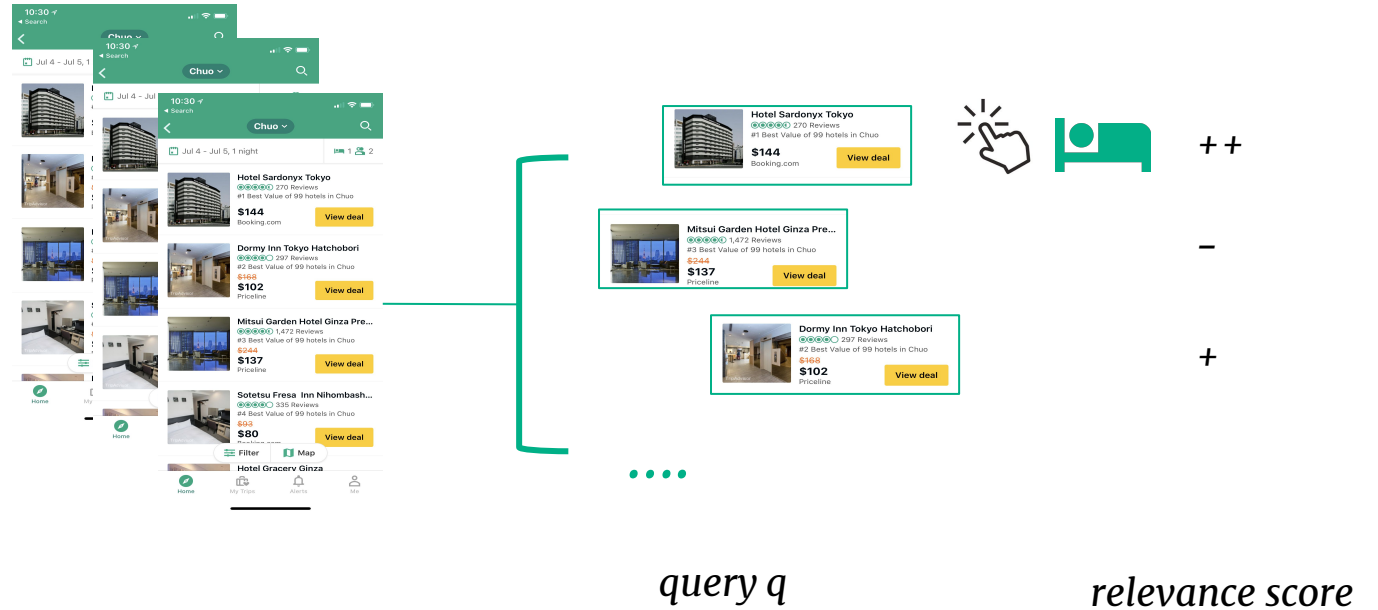
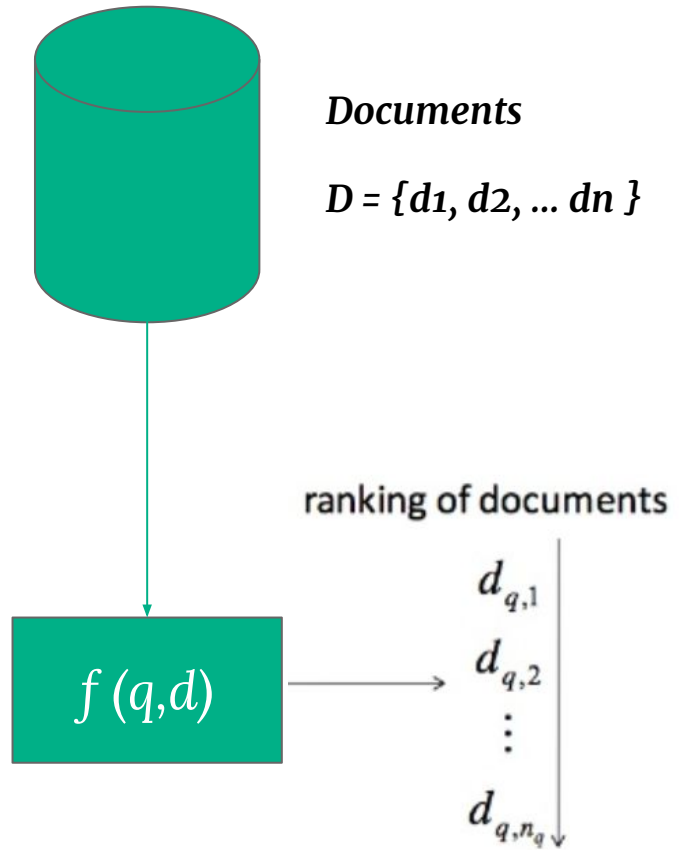
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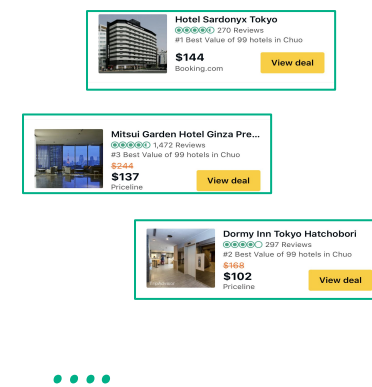
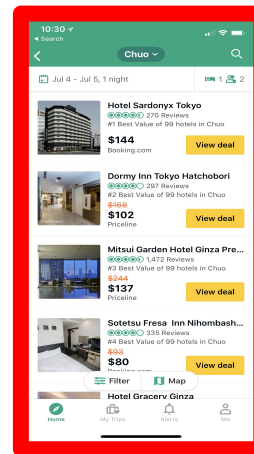
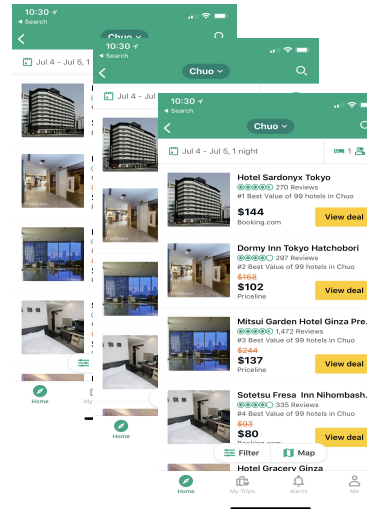
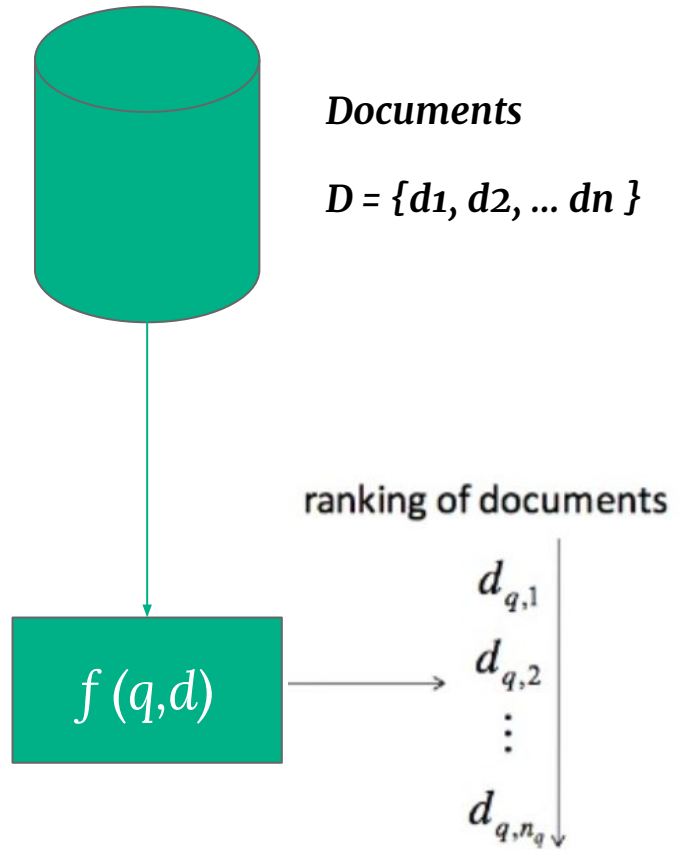
query q

relevance score

Hotel Sorting



Hotel Sorting



query q

relevance score

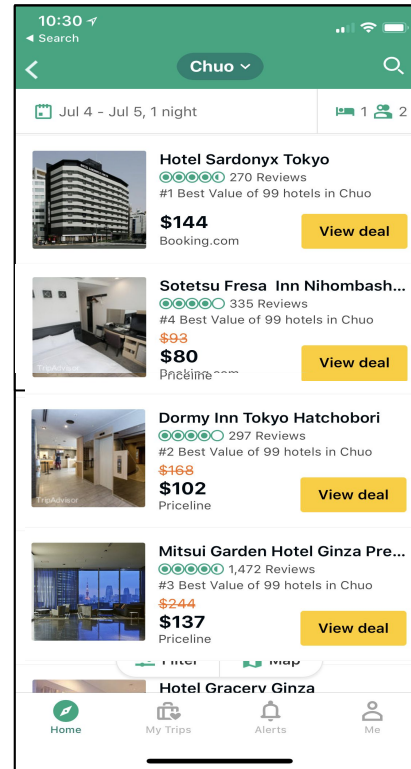
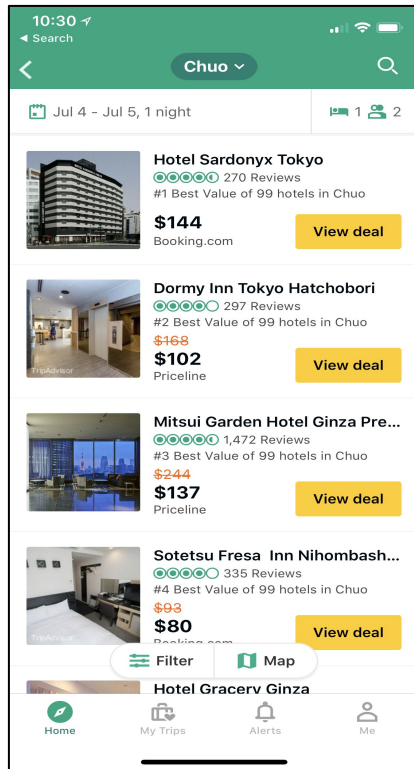
Mean Average Precision

Mean Average Precision

$$\text{AP} = \sum_{k=1}^N p(k) \Delta r(k)$$

Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$

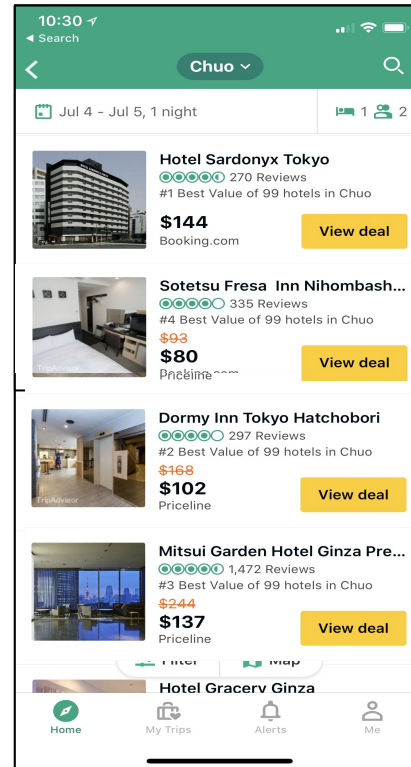
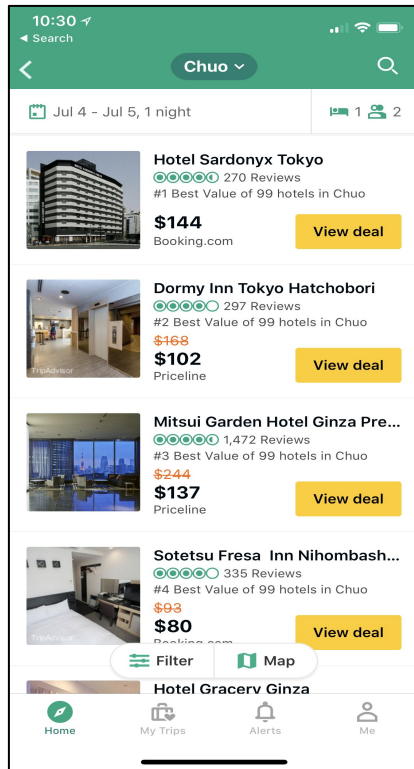


Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$

Precision

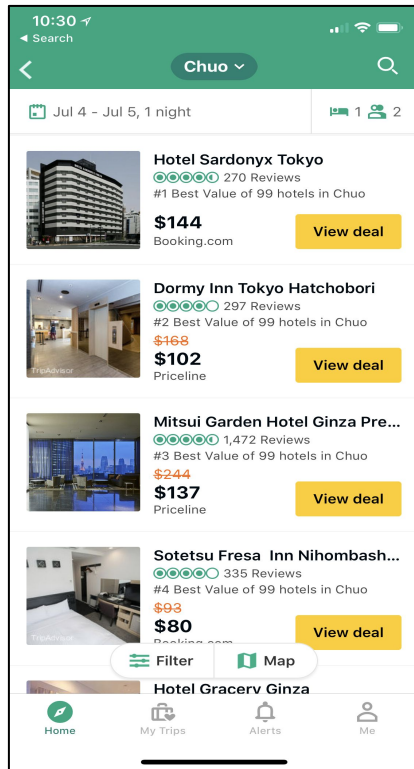
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Mean Average Precision

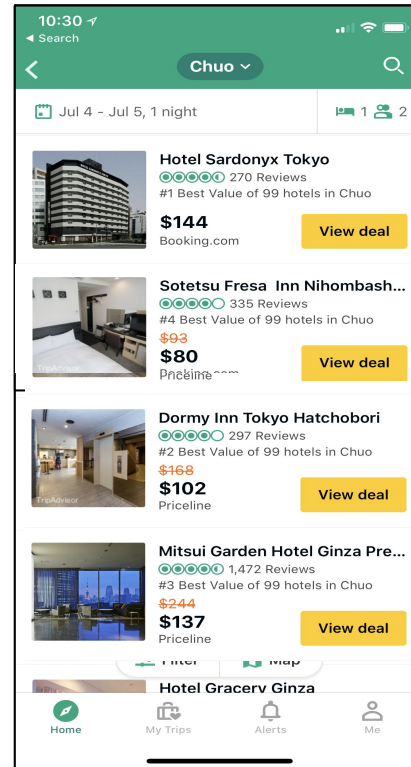
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Precision



1.0

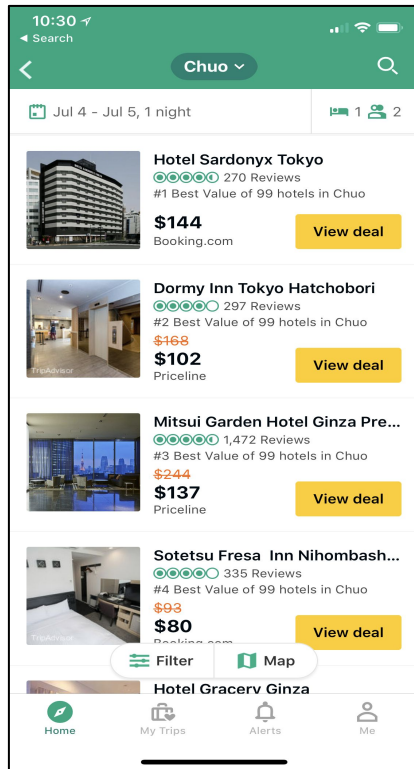
0.5



Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$

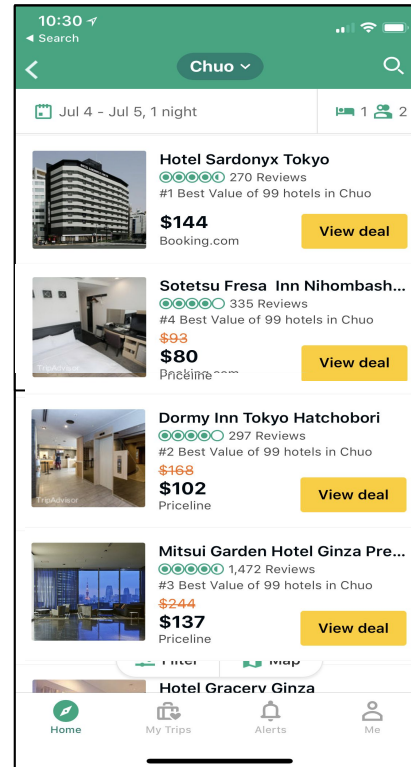
Precision



1.0

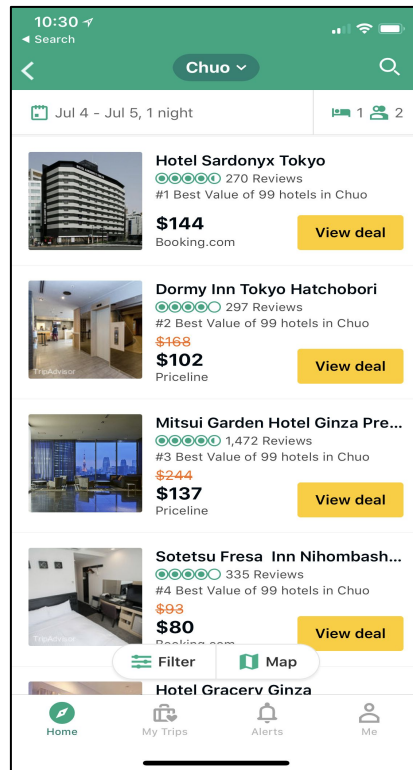
0.5

0.67



Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$



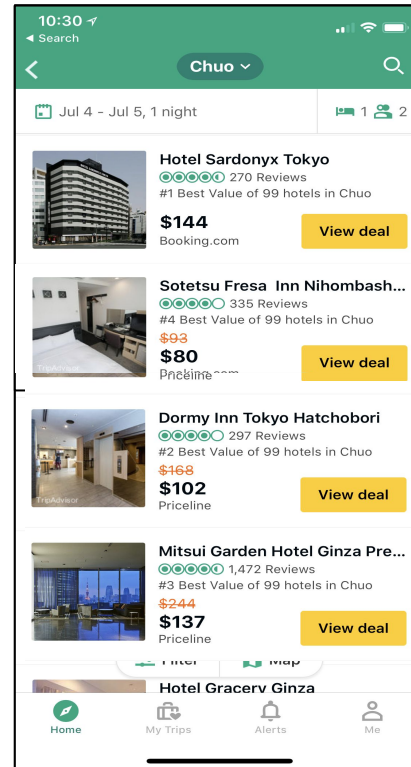
Precision

1.0

0.5

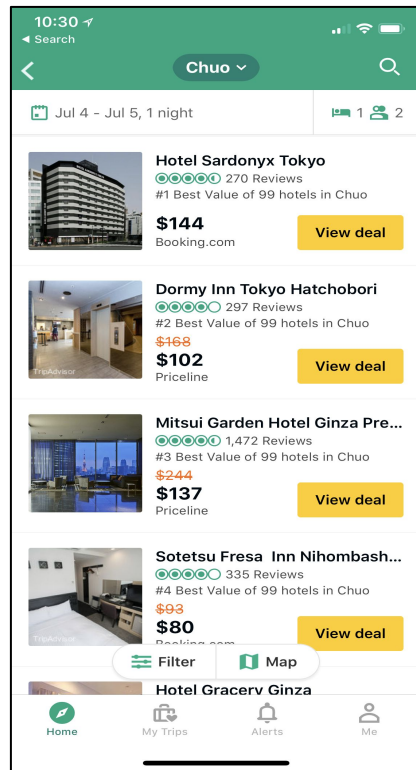
0.67

0.75



Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$



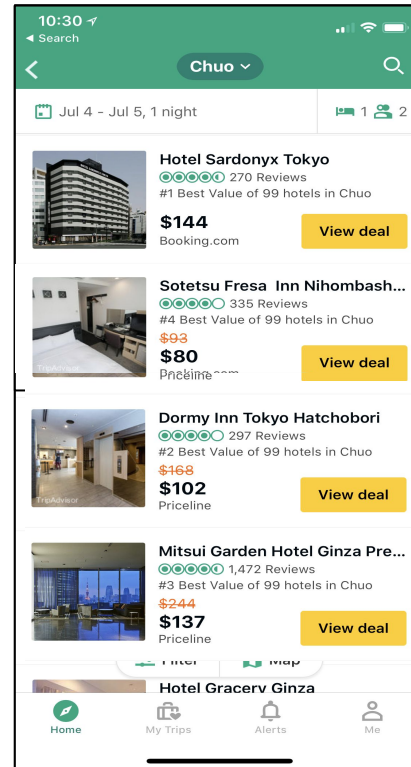
Precision

1.0

0.5

0.67

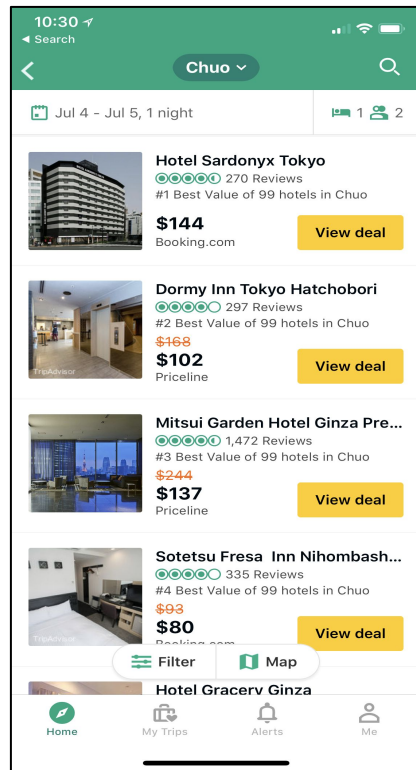
0.75



$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$

Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$



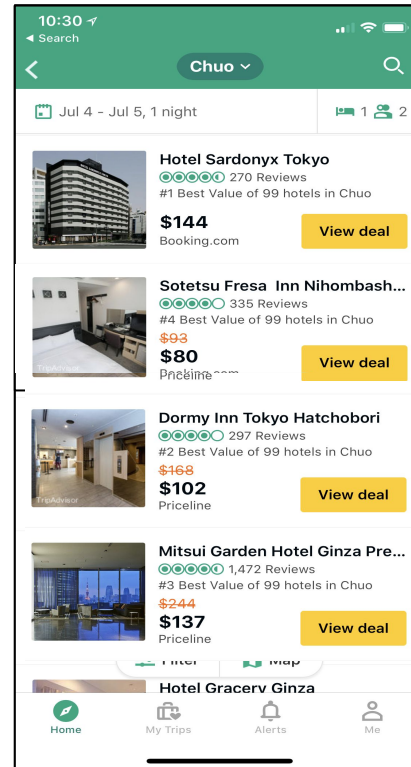
Precision

1.0

0.5

0.67

0.75



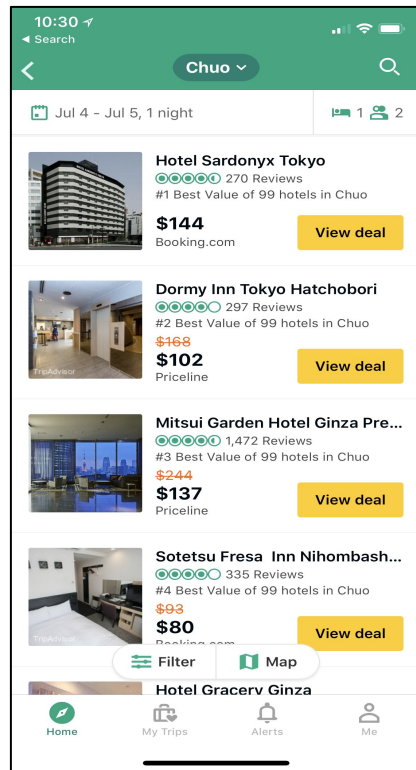
Precision

0

$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$

Mean Average Precision

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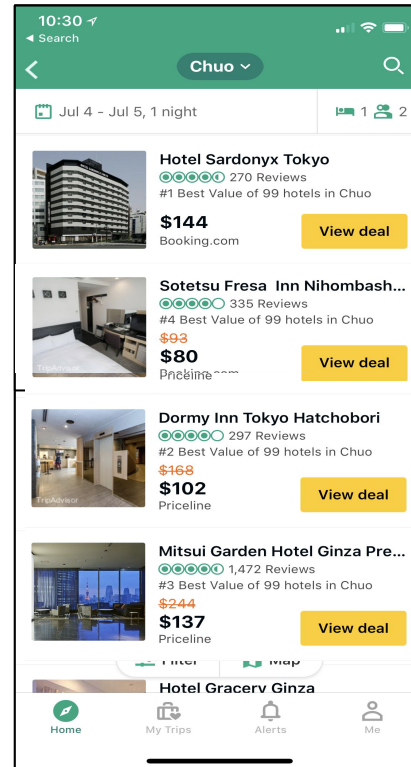
Precision

1.0

0.5

0.67

0.75



Precision

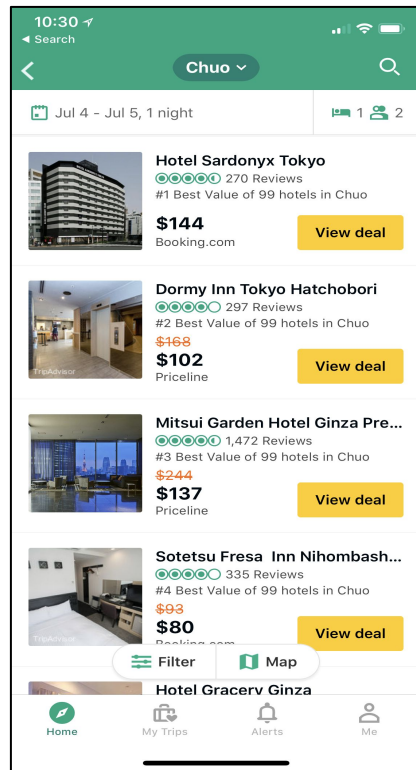
0

0.5

$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$

Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$



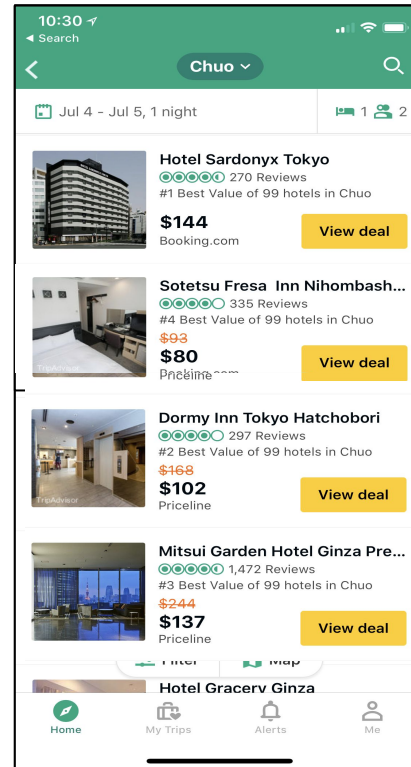
Precision

1.0

0.5

0.67

0.75



Precision

0

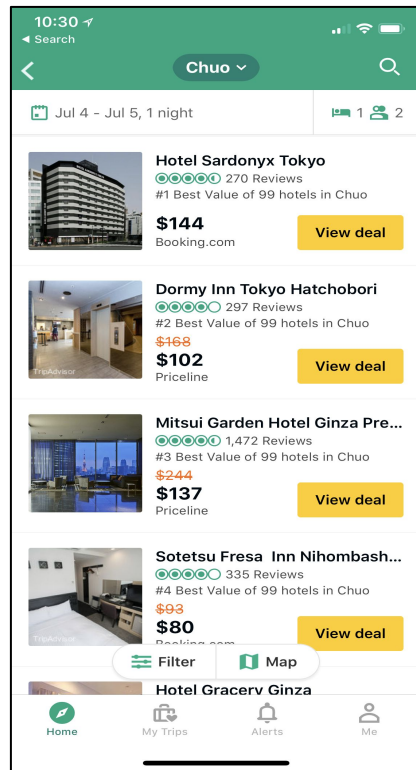
0.5

0.67

$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$

Mean Average Precision

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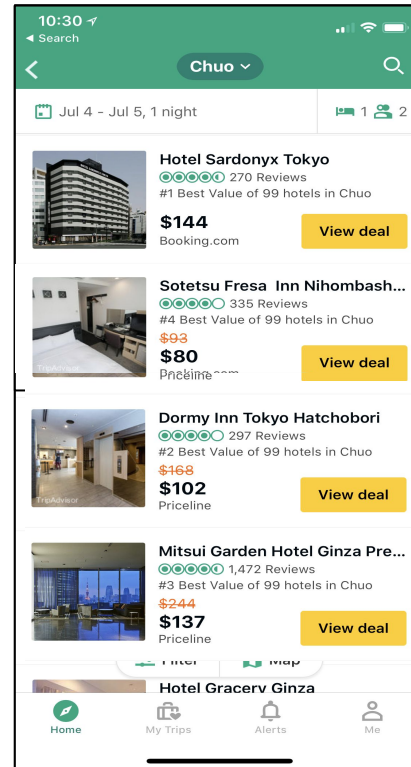
Precision

1.0

0.5

0.67

0.75



Precision

0

0.5

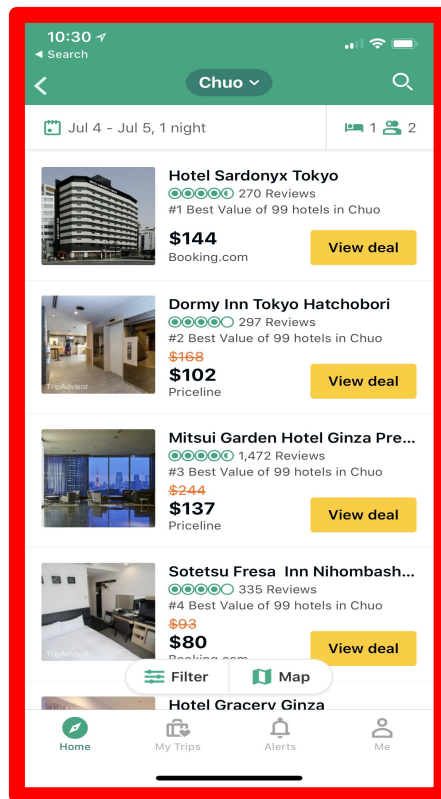
0.67

0.5

$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$

Mean Average Precision

$$AP = \sum_{k=1}^N p(k) \Delta r(k)$$



Precision



1.0

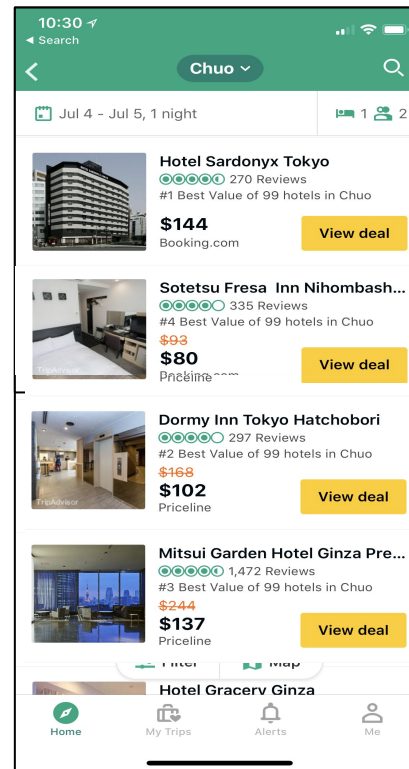


0.67



0.75

$$AP = (1 + 0.67 + 0.75) / 3 = 0.80$$



Precision

0



0.5

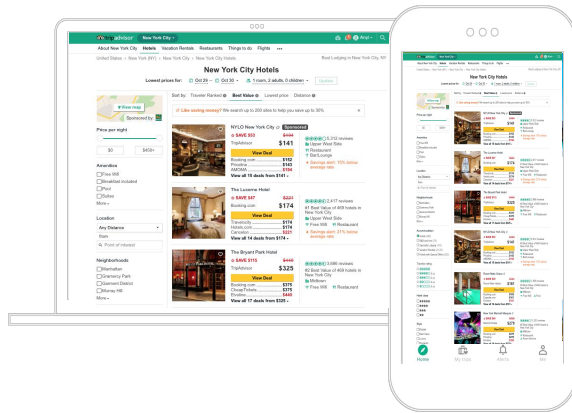


0.67

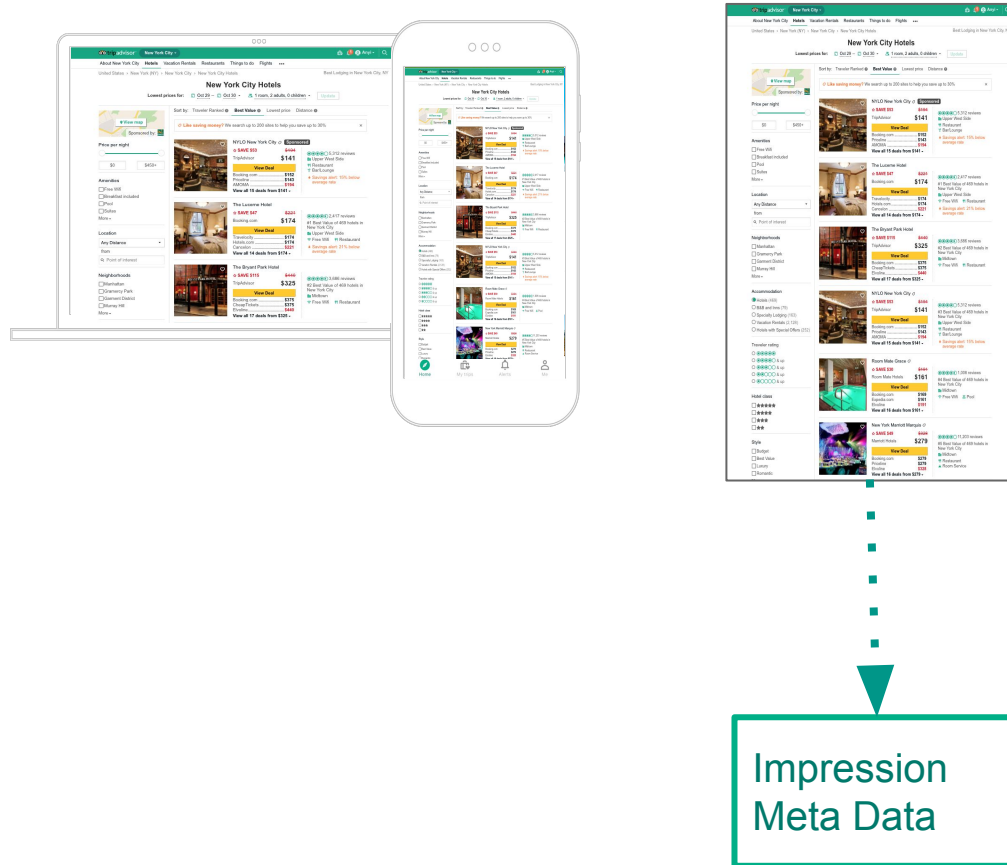
0.5

$$AP = (0.5 + 0.67) / 2 = 0.585$$

Hotel Sorting - Features



Hotel Sorting - Features



Hotel Sorting - Features

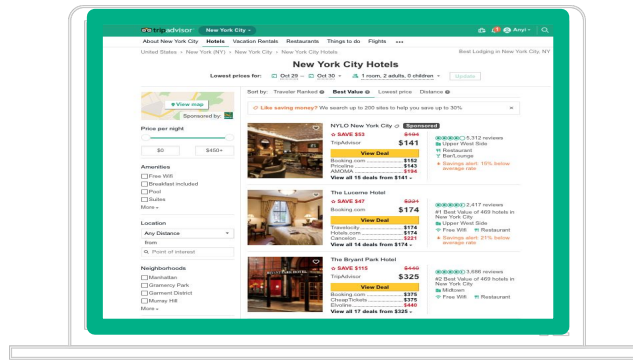


Hotel Sorting - Features

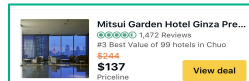
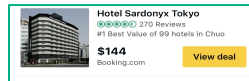
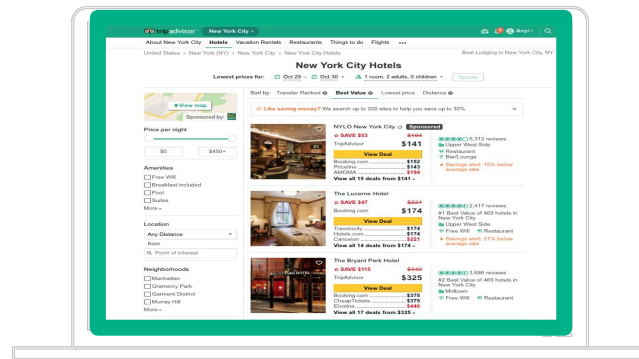


Linear CTR Model

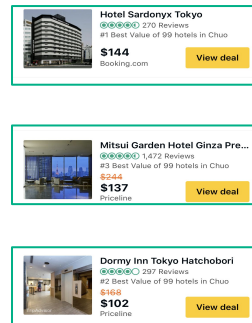
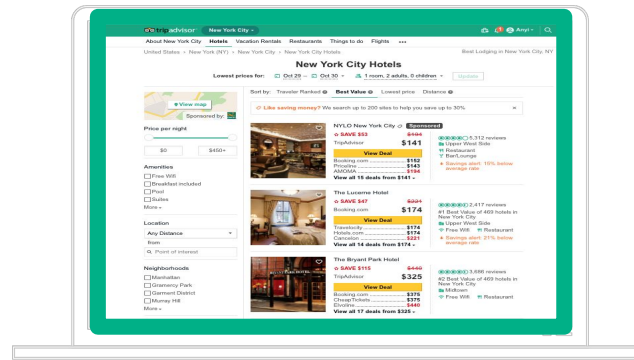
Linear CTR Model



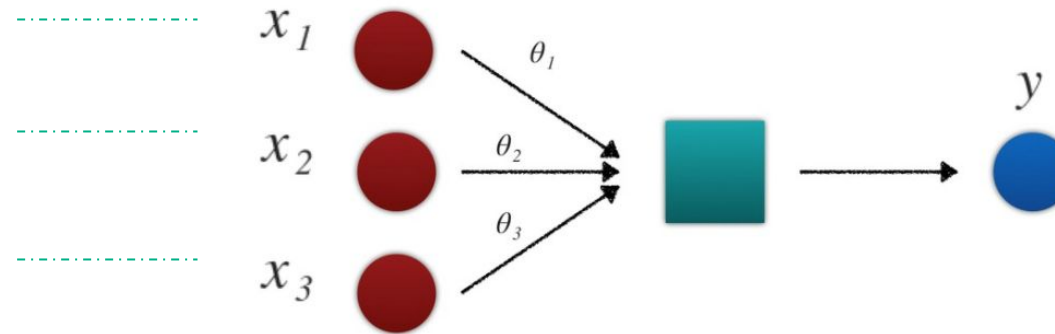
Linear CTR Model



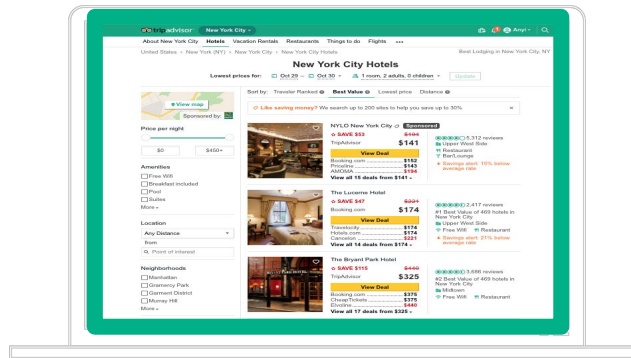
Linear CTR Model



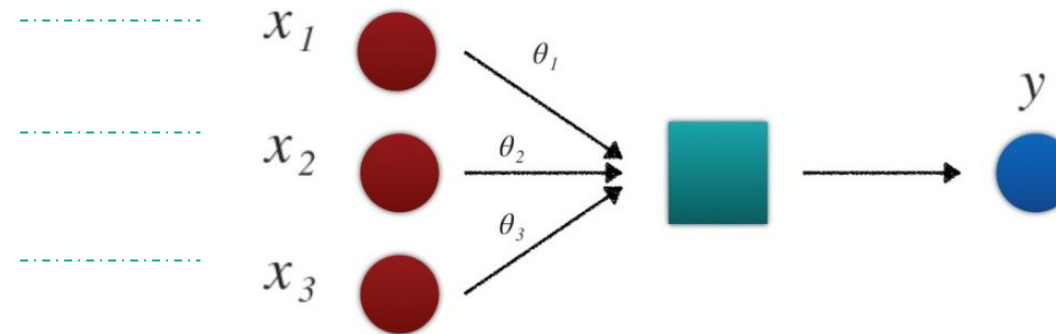
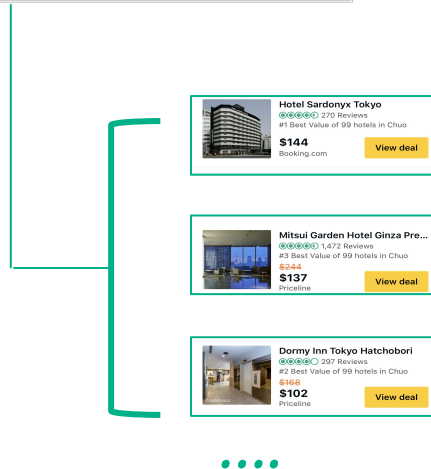
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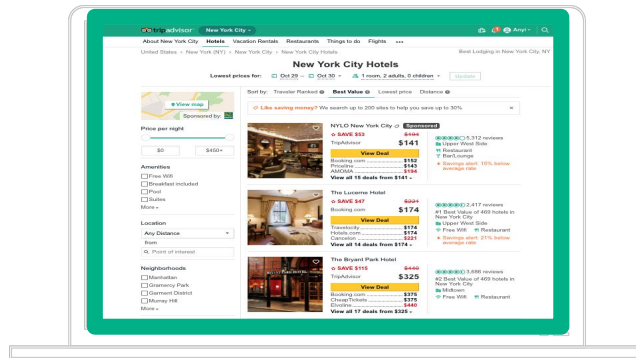
Linear CTR Model



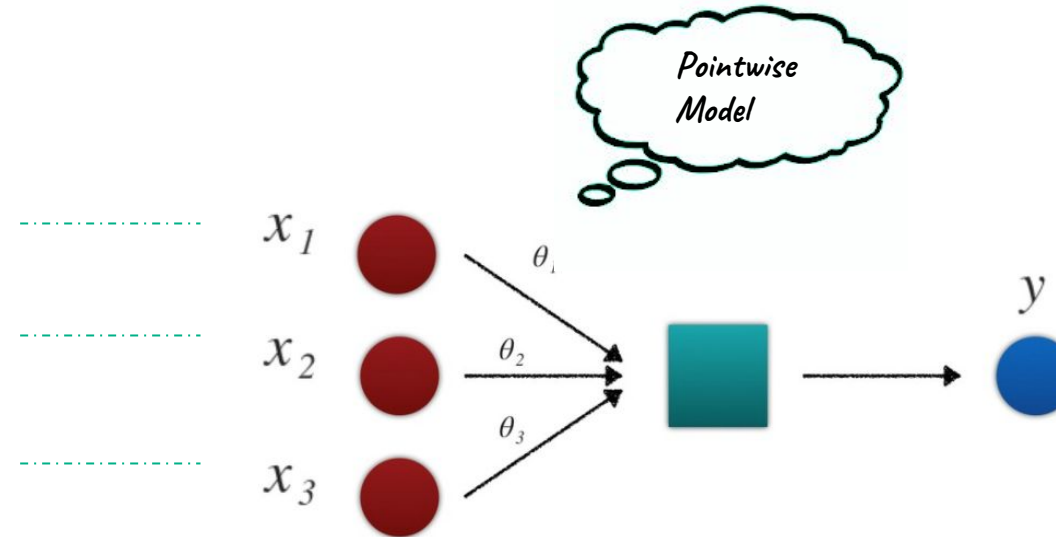
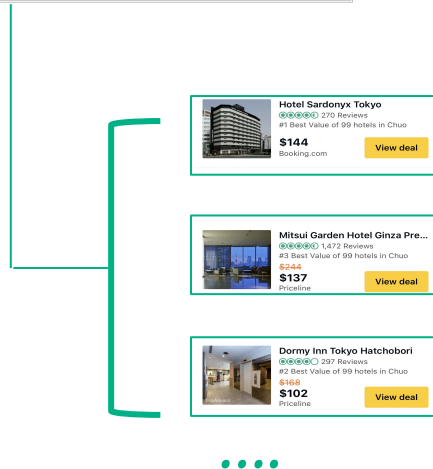
For every hotel, the model predicts CTR(click through rate) based on different feature values



Linear CTR Model

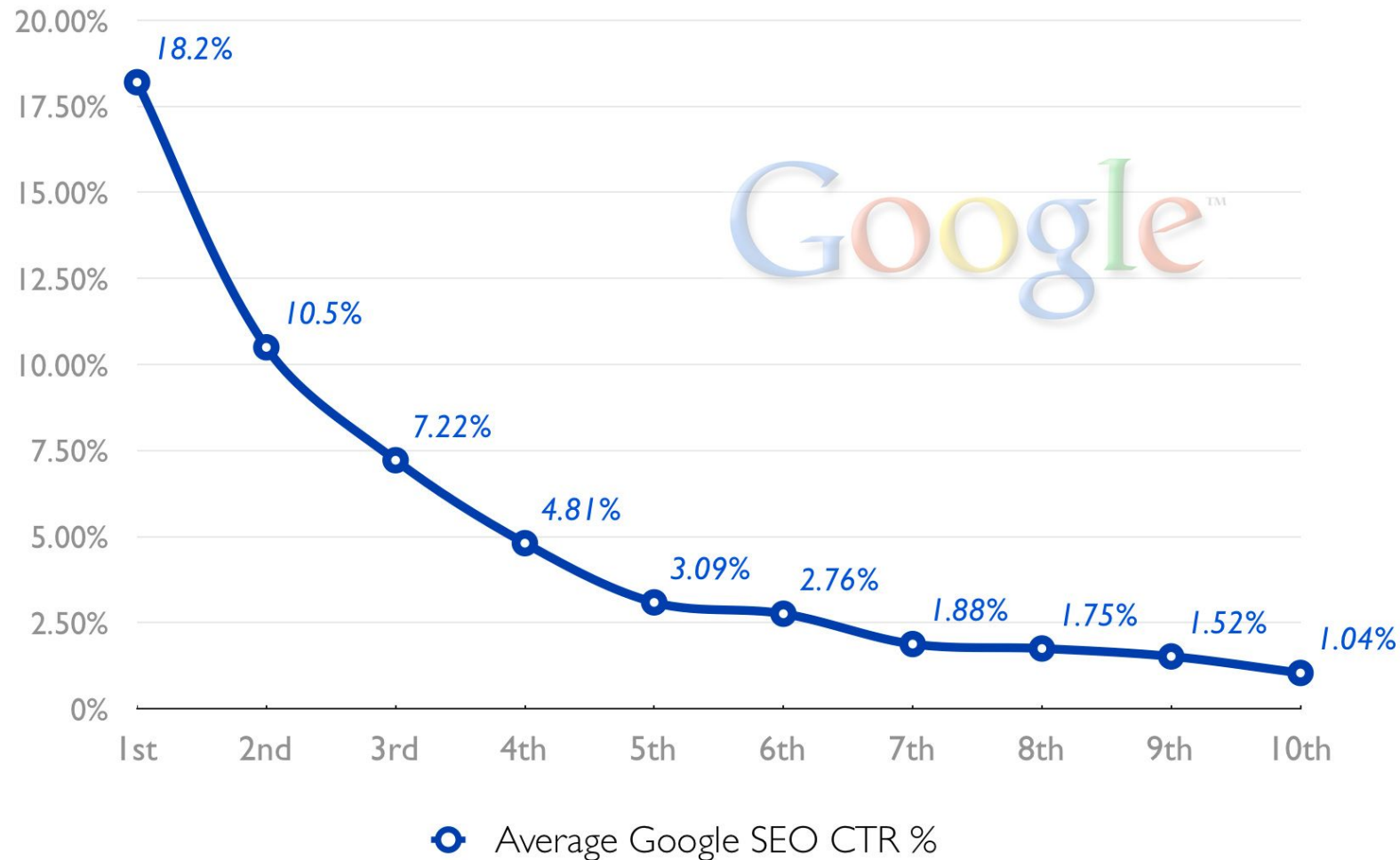


For every hotel, the model predicts CTR(click through rate) based on different feature values



Position Matters

Position Matters

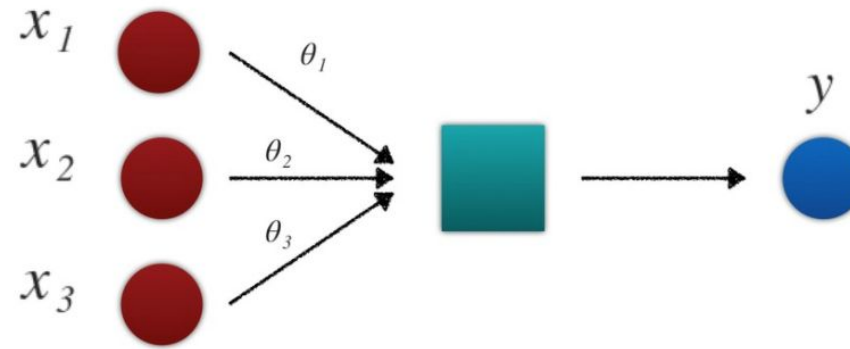


Getting rid of position factor

Impression Meta Data

Location Level Look Back Data

User Related Meta Data



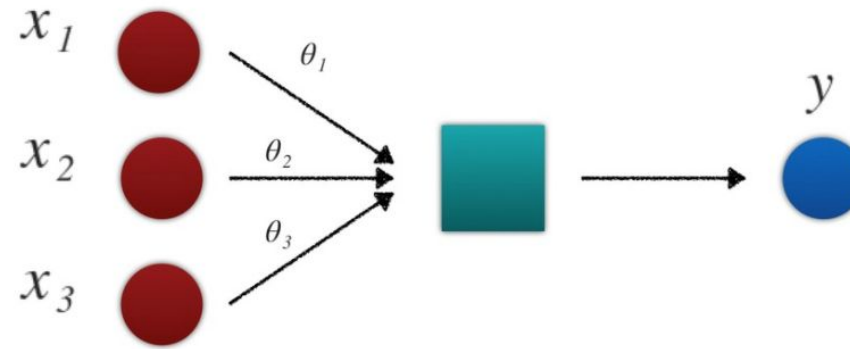
Getting rid of position factor

Impression Meta Data

Location Level Look Back Data

User Related Meta Data

Position in list



Problems of pointwise model

Problems of pointwise model


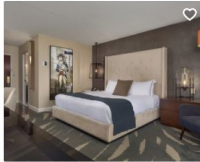





User not sensitive to price
in some travel destination?

Problems of pointwise model



User not sensitive to price
in some travel destination?

	Hotel Commonwealth Orbitz.com ↗ \$688 \$549 View Deal View all 13 deals from \$549 ▼	4,632 reviews Certificate of Excellence #1 Best Value of 154 hotels in Boston Free Wifi Restaurant
	Revere Hotel Boston Common Expedia.com ↗ \$604 \$518 View Deal View all 14 deals from \$517 ▼	4,384 reviews Certificate of Excellence #2 Best Value of 154 hotels in Boston Free Wifi Pool
	The Ritz-Carlton, Boston ↗ RitzCarlton.com ↗ \$1,995 \$795 View Deal View all 11 deals from \$795 ▼	861 reviews Certificate of Excellence #3 Best Value of 154 hotels in Boston Pool Restaurant
	XV Beacon Expedia.com ↗ \$577 View Deal View all 11 deals from \$575 ▼	1,157 reviews Certificate of Excellence #4 Best Value of 154 hotels in Boston Free Wifi Restaurant
	Residence Inn by Marriott Boston Harbor on Tudor Wharf ↗ Expedia.com ↗ \$639 View Deal View all 8 deals from \$639 ▼	914 reviews Certificate of Excellence #5 Best Value of 154 hotels in Boston Free Wifi Breakfast included


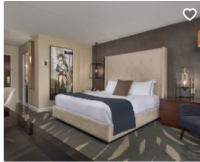





Problems of pointwise model



User not sensitive to price
in some travel destination?

Price only matters within
context !

	Hotel Commonwealth \$688 \$549 Orbitz.com ↗ View Deal View all 13 deals from \$549 ▼	4,632 reviews Certificate of Excellence #1 Best Value of 154 hotels in Boston Free Wifi Restaurant
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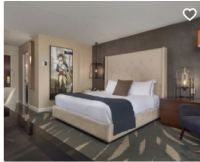



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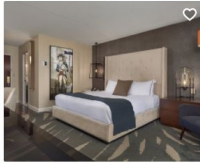



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Problems of pointwise model




CTR negatively correlated to
popularity score generated
by user review

Problems of pointwise model



CTR negatively correlated to popularity score generated by user review



Hampton Inn by Hilton Cancun Cumbres


SAVE \$20 ~~\$429~~
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Orbitz.com ~~\$129~~
Expedia.com ~~\$129~~
View all 8 deals from \$109

134 reviews
#1 Best Value of 180 hotels in Cancun

Free Wifi
Breakfast included



City Express Cancun


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Hotwire.com ~~\$88~~
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454 reviews
#2 Best Value of 180 hotels in Cancun

Free Wifi
Free Parking



LQ Hotel by La Quinta Cancun


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894 reviews
#3 Best Value of 180 hotels in Cancun

Free Wifi
Free Parking
Hotel website
Special offer



One Cancun Centro

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565 reviews
#4 Best Value of 180 hotels in Cancun

Free Wifi
Free Parking
Hotel website

Problems of pointwise model



CTR negatively correlated to popularity score generated by user review



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565 reviews
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Problems of pointwise model



CTR negatively correlated to popularity score generated by user review

Popularity is sensitive to availability!

Hampton Inn by Hilton Cancun Cumbres

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Orbitz.com ~~\$129~~
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4.5 stars 134 reviews
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Free Parking
Hotel website
Special offer

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4.5 stars 565 reviews
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Free Parking
Hotel website

Problems of pointwise model



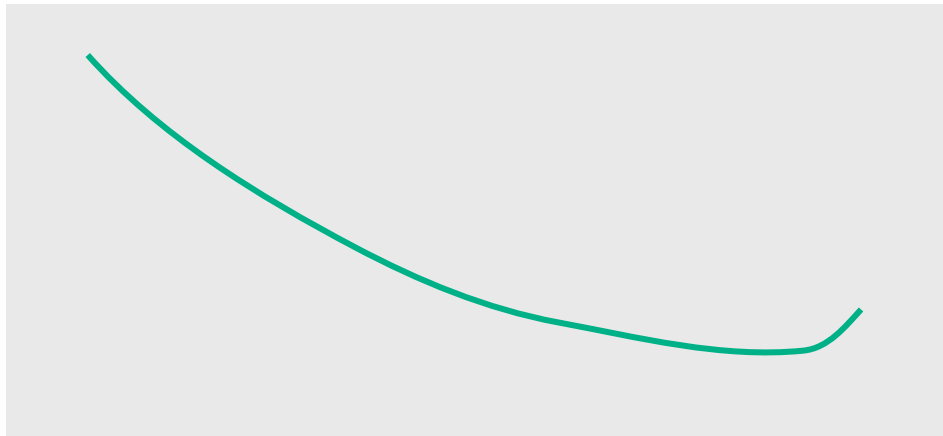
Has the user actually
seeing the hotel on the
page?

Problems of pointwise model

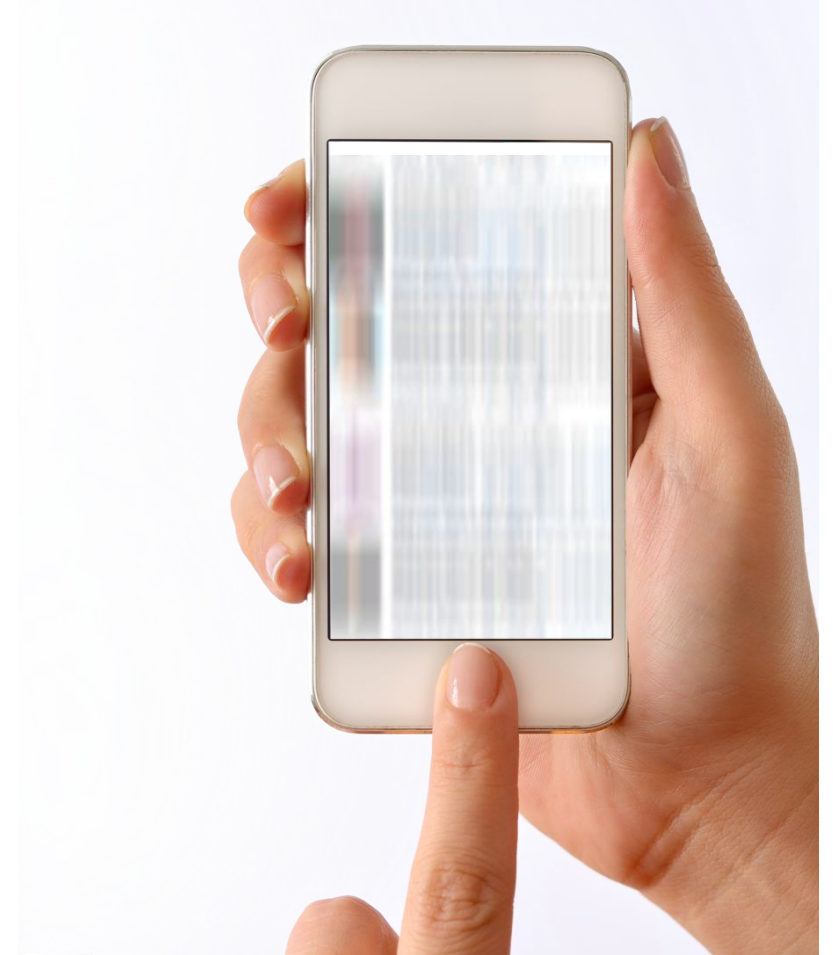


Has the user actually
seeing the hotel on the
page?

CTR



Position



Getting rid of position factor



User not sensitive to price
in some travel destination

Pointwise



CTR negatively correlated
to popularity score



Has the user actually
seeing the hotel on the
page?

Getting rid of position factor



User not sensitive to price
in some travel destination



CTR negatively correlated
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Has the user actually
seeing the hotel on the
page?

Pointwise



Pairwise

Pairwise Learning to Rank

Pairwise Learning to Rank

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Travelocity \$174
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C The Bryant Park Hotel
SAVE \$115 ~~\$440~~
TripAdvisor **\$325**
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CheapTickets \$375
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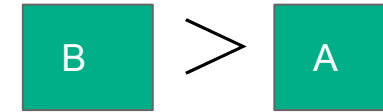
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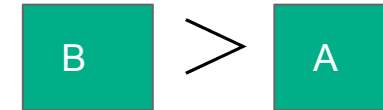
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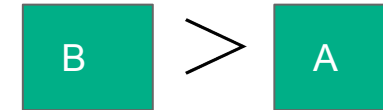
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Booking.com \$152
Priceline \$143
AMOMMA \$194
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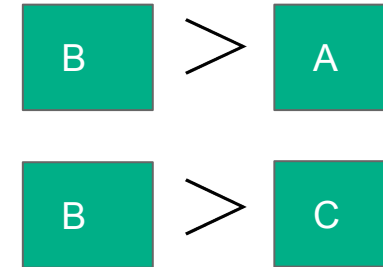
B The Lucerne Hotel
SAVE \$47 ~~\$221~~
Booking.com **\$174**
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Travelocity \$174
Hotels.com \$174
Cancelon \$221
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C The Bryant Park Hotel
SAVE \$115 ~~\$440~~
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TripAdvisor **\$141**
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Booking.com \$152
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E Room Mate Grace
SAVE \$30 ~~\$194~~
Room Mate Hotels **\$161**
View Deal
Booking.com \$169
Expedia.com \$161
Evoline \$191
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F New York Marriott Marquis
SAVE \$49 ~~\$228~~
Marriott Hotels **\$279**
View Deal
Booking.com \$279
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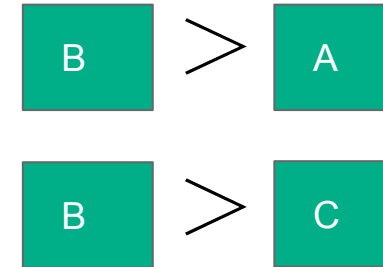
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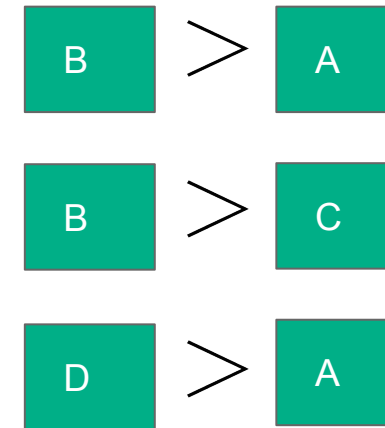
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Pairwise Learning to Rank

The screenshot shows a TripAdvisor search results page for "NYLO New York City". A red box highlights the top four results, labeled A, B, C, and D. Result A is the NYLO New York City hotel, Result B is The Lucerne Hotel, Result C is The Bryant Park Hotel, and Result D is the NYLO New York City hotel again. Results E and F are also visible below the red box. A hand cursor icon is shown pointing to the results.

Label	Hotel	Price	Rating
A	NYLO New York City	\$141	4.5
B	The Lucerne Hotel	\$174	4.5
C	The Bryant Park Hotel	\$325	4.5
D	NYLO New York City	\$141	4.5
E	Room Mate Grace	\$161	4.5
F	New York Marriott Marquis	\$279	4.5



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View Deal
Booking.com \$152
Priceline \$143
AMOMMA \$194
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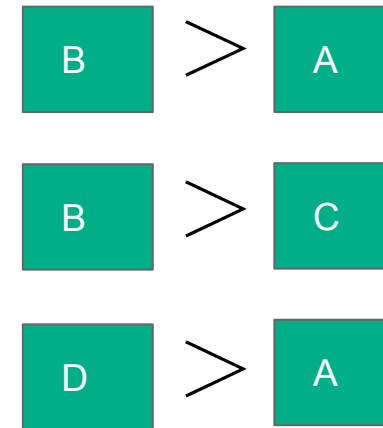
B The Lucerne Hotel
SAVE \$47 ~~\$221~~
Booking.com **\$174**
View Deal
Travelocity \$174
Hotels.com \$174
Cancelon \$221
View all 14 deals from \$174

C The Bryant Park Hotel
SAVE \$115 ~~\$440~~
TripAdvisor **\$325**
View Deal
Booking.com \$375
CheapTickets \$375
Evoline \$440
View all 17 deals from \$325

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SAVE \$53 ~~\$194~~
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AMOMMA \$194
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E Room Mate Grace
SAVE \$30 ~~\$194~~
Room Mate Hotels **\$161**
View Deal
Booking.com \$169
Expedia.com \$161
Evoline \$191
View all 16 deals from \$161

F New York Marriott Marquis
SAVE \$49 ~~\$228~~
Marriott Hotels **\$279**
View Deal
Booking.com \$279
Priceline \$279
Evoline \$328
View all 16 deals from \$279



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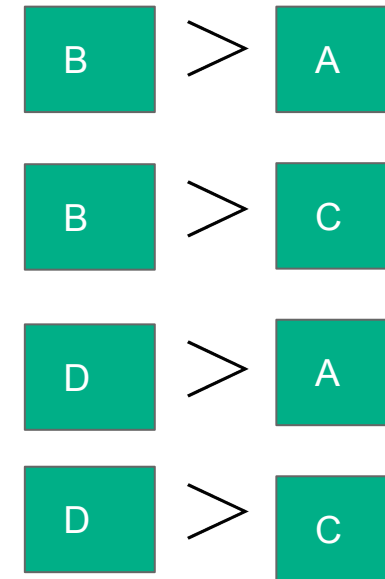
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Booking.com
View Deal
Travelocity \$174
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Cancelon \$221
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TripAdvisor
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F New York Marriott Marquis
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Marriott Hotels
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Booking.com \$279
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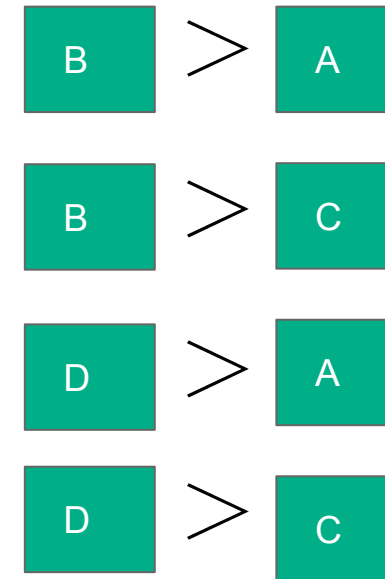
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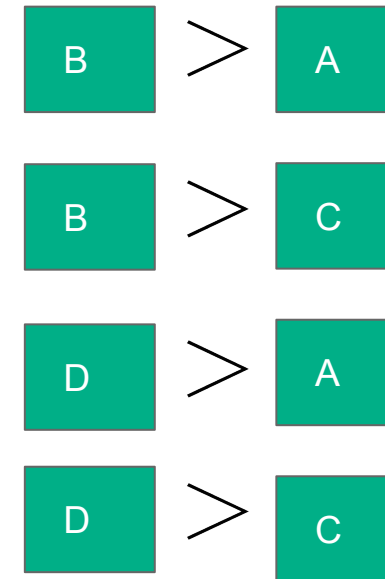
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 Travelocity \$174
 Hotels.com \$174
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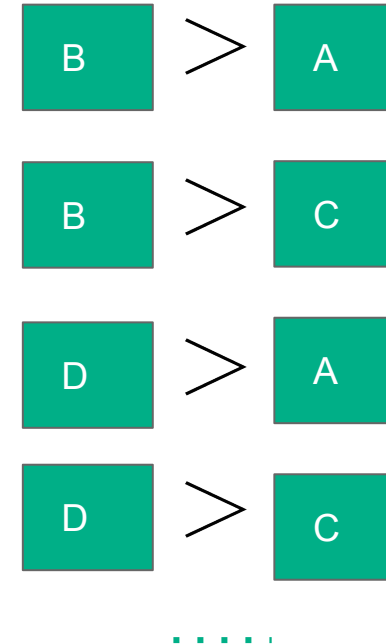
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A	NYLO New York City ✦ SAVE \$53 TripAdvisor \$141 View Deal Booking.com \$152 Priceline \$143 AMOMMA \$194 View all 15 deals from \$141	5,312 reviews Upper West Side Restaurant Bar/Lounge Savings alert: 15% below average rate
B	The Lucerne Hotel ✦ SAVE \$47 Booking.com \$174 View Deal Travelocity \$174 Hotels.com \$174 Cancelon \$221 View all 14 deals from \$174	2,417 reviews #1 Best Value of 469 hotels in New York City Upper West Side Free Wifi Restaurant Savings alert: 21% below average rate
C	The Bryant Park Hotel ✦ SAVE \$115 TripAdvisor \$325 View Deal Booking.com \$375 CheapTickets \$375 Elviline \$440 View all 17 deals from \$325	3,686 reviews #2 Best Value of 469 hotels in New York City Midtown Free Wifi Restaurant
D	NYLO New York City ✦ SAVE \$53 TripAdvisor \$141 View Deal Booking.com \$152 Priceline \$143 AMOMMA \$194 View all 15 deals from \$141	5,312 reviews #3 Best Value of 469 hotels in New York City Upper West Side Restaurant Bar/Lounge Savings alert: 15% below average rate
E	Room Mate Grace ✦ SAVE \$30 Room Mate Hotels \$161 View Deal Booking.com \$169 Expedia.com \$161 Elviline \$191 View all 16 deals from \$161	1,008 reviews #4 Best Value of 469 hotels in New York City Midtown Free Wifi Pool
F	New York Marriott Marquis ✦ SAVE \$49 Marriott Hotels \$279 View Deal Booking.com \$279 Priceline \$279 Elviline \$328 View all 16 deals from \$279	11,203 reviews #5 Best Value of 469 hotels in New York City Midtown Restaurant Room Service

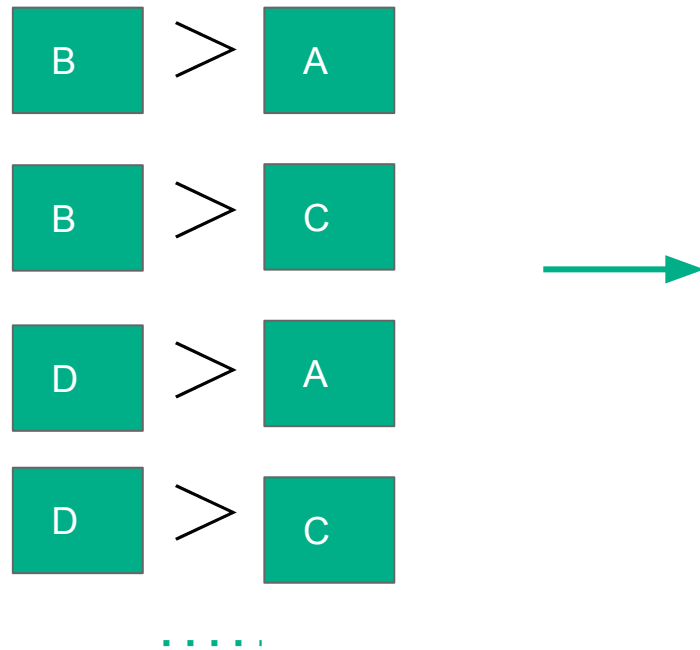


$$\{(\mathbf{x}_i^{(r)}, \mathbf{x}_j^{(r)}) \mid \forall i, j (y_i^{(r)} = 1 \wedge y_j^{(r)} = 0)\}$$

Cao, Z., Qin, T., Liu, T.Y., Tsai, M.F. and Li, H., 2007, June. Learning to rank: from pairwise approach to listwise approach. In *Proceedings of the 24th international conference on Machine learning* (pp. 129-136). ACM.

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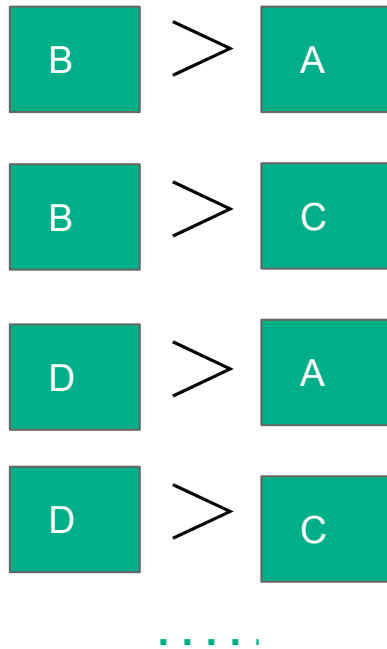
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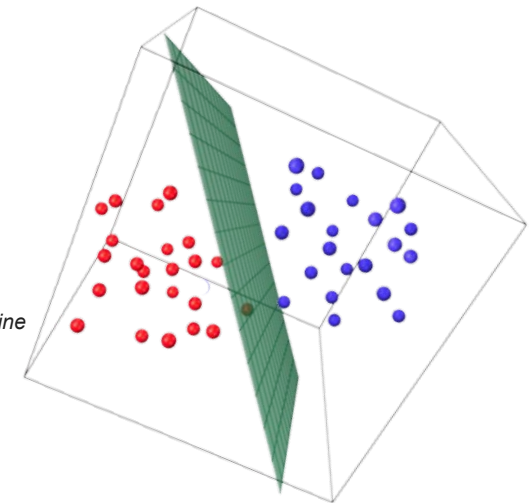
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Pairwise Learning to Rank



$$\min \left(\sum_{i>0} w_i^2 \right) + C \left(\sum_{j=1}^n \xi_{jk} \right)^k$$

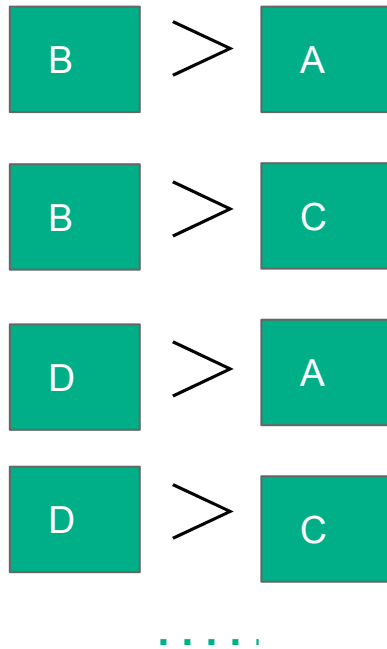
new objective function



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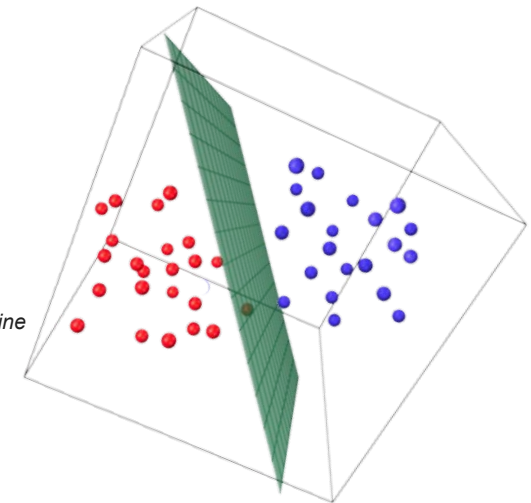
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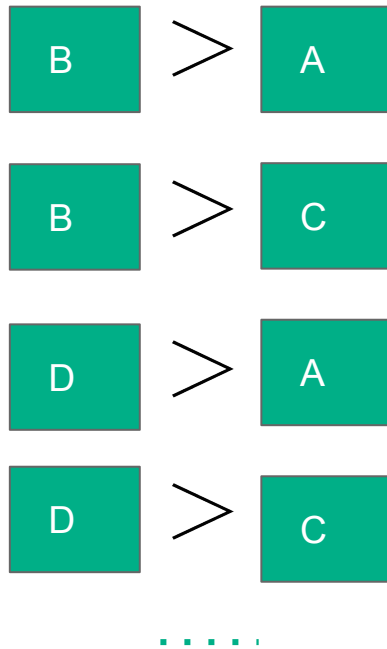
for each $j > k$:



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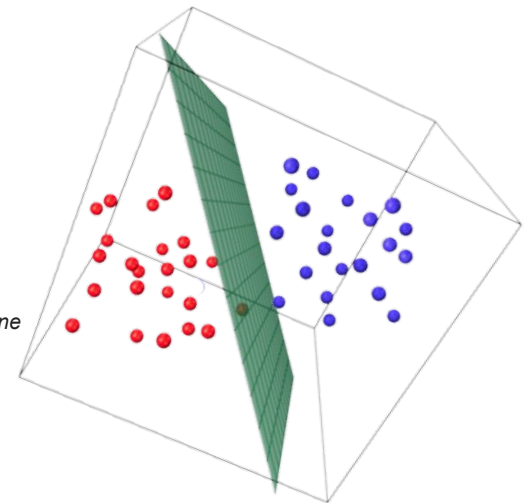
Pairwise Learning to Rank



$$\min \left(\sum_{i>0} w_i^2 \right) + C \left(\sum_{j=1}^n \xi_{jk} \right)^k \quad \text{new objective function}$$

for each $j > k$:

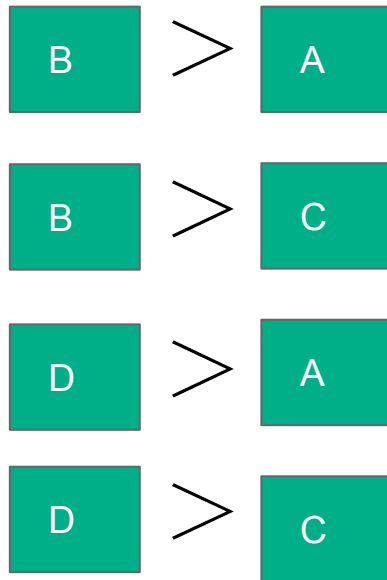
$$\sum_i w_i x_{j,i} \geq \sum_i w_i x_{k,i} + 1 - \xi_{jk}$$



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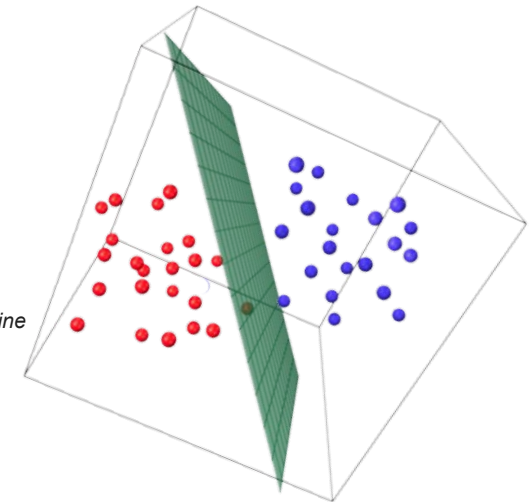
.....

$$\min \left(\sum_{i>0} w_i^2 \right) + C \left(\sum_{j=1}^n \xi_{jk} \right)^k$$

new objective function

for each $j > k$:

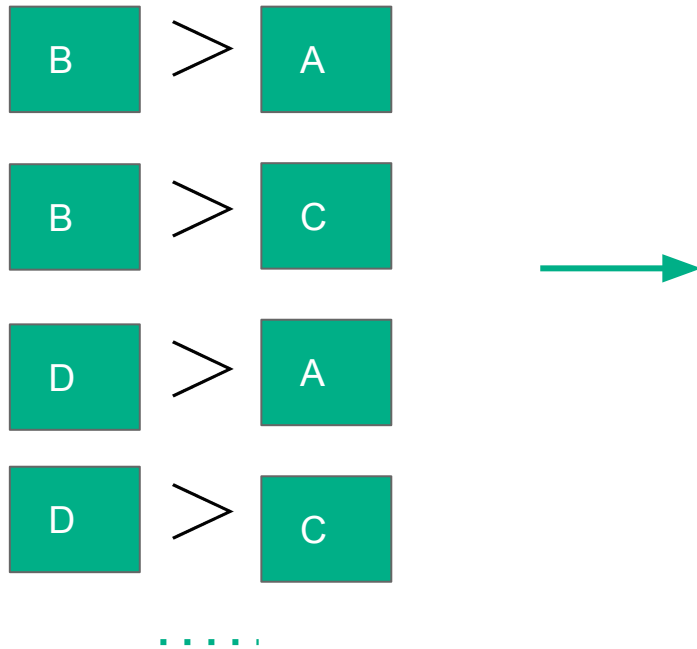
$$\underbrace{\sum_i w_i x_{j,i}}_{\text{score}(j)} \geq \underbrace{\sum_i w_i x_{k,i}}_{\text{score}(k)} + 1 - \xi_{jk}$$



Cao, Z., Qin, T., Liu, T.Y., Tsai, M.F. and Li, H., 2007, June. Learning to rank: from pairwise approach to listwise approach. In *Proceedings of the 24th international conference on Machine learning* (pp. 129-136). ACM.

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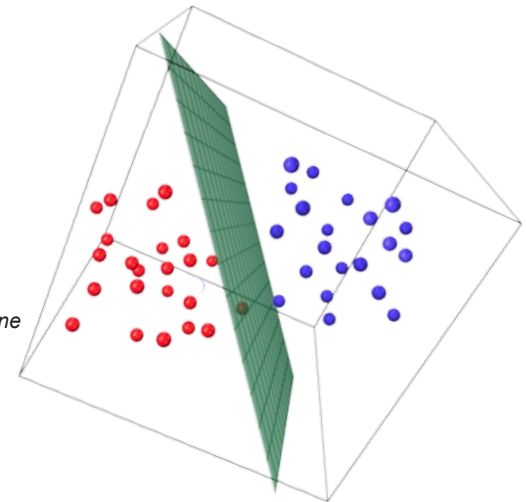


$$\min \left(\sum_{i>0} w_i^2 \right) + C \left(\sum_{j=1}^n \xi_{jk} \right)^k \quad \text{new objective function}$$

for each $j > k$:

$$\underbrace{\sum_i w_i x_{j,i}}_{\text{score}(j)} \geq \underbrace{\sum_i w_i x_{k,i}}_{\text{score}(k)} + 1 - \xi_{jk}$$


$$\sum_i w_i (x_{j,i} - x_{k,i}) \geq +1 - \xi_{jk}$$



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	<p>Hotel Commonwealth</p> <p>\$688 \$549 Orbitz.com ↗</p> <p>View Deal</p> <p>View all 13 deals from \$549 ▼</p> <p> 4,632 reviews Certificate of Excellence #1 Best Value of 154 hotels in Boston Free Wifi Restaurant </p>
	<p>Revere Hotel Boston Common</p> <p>\$594 \$518 Expedia.com ↗</p> <p>View Deal</p> <p>View all 14 deals from \$517 ▼</p> <p> 4,384 reviews Certificate of Excellence #2 Best Value of 154 hotels in Boston Free Wifi Pool </p>
	<p>The Ritz-Carlton, Boston ↗</p> <p>\$1,095 \$795 RitzCarlton.com ↗</p> <p>View Deal</p> <p>View all 11 deals from \$795 ▼</p> <p> 861 reviews Certificate of Excellence #3 Best Value of 154 hotels in Boston Pool Restaurant </p>
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	<p>Residence Inn by Marriott Boston Harbor on Tudor Wharf ↗</p> <p>\$639 Expedia.com ↗</p> <p>View Deal</p> <p>View all 8 deals from \$639 ▼</p> <p> 914 reviews Certificate of Excellence #5 Best Value of 154 hotels in Boston Free Wifi Breakfast included </p>



Hotel Commonwealth

~~\$688~~ **\$549**
Orbitz.com ↗

View Deal


View all 13 deals from \$549 ▼

4,632 reviews

Certificate of Excellence

#1 Best Value of 154 hotels in Boston

Free Wifi Restaurant



Revere Hotel Boston Common

~~\$594~~ **\$518**
Expedia.com ↗

View Deal


View all 14 deals from \$517 ▼

4,384 reviews

Certificate of Excellence

#2 Best Value of 154 hotels in Boston

Free Wifi Pool



The Ritz-Carlton, Boston ↗

~~\$1,095~~ **\$795**
RitzCarlton.com ↗

View Deal


View all 11 deals from \$795 ▼

861 reviews

Certificate of Excellence

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Pool Restaurant



XV Beacon

\$577
Expedia.com ↗

View Deal


View all 11 deals from \$575 ▼

1,157 reviews

Certificate of Excellence

#4 Best Value of 154 hotels in Boston

Free Wifi Restaurant



Residence Inn by Marriott Boston Harbor on Tudor Wharf ↗

\$639
Expedia.com ↗

View Deal

View all 8 deals from \$639 ▼


914 reviews

Certificate of Excellence

#5 Best Value of 154 hotels in Boston

Free Wifi Breakfast included





DoubleTree Suites by Hilton Boston-Cambridge (Great Value!) ↗

~~\$417~~ **\$378**
Expedia.com ↗

View Deal


View all 13 deals from \$378 ▼

1,933 reviews

Certificate of Excellence

#1 Best Value of 154 hotels in Boston

Free Wifi Pool



Club Quarters Hotel in Boston (Great Value!) ↗

\$395
Expedia.com ↗


View Deal

View all 9 deals from \$395 ▼

2,051 reviews

#2 Best Value of 154 hotels in Boston

Free Wifi Restaurant



Sheraton Boston Hotel (Great Value!) ↗

~~\$374~~ **\$251**
Expedia.com ↗

View Deal


View all 13 deals from \$251 ▼

2,600 reviews

Certificate of Excellence

#3 Best Value of 154 hotels in Boston

Pool Restaurant



Omni Parker House (Great Value!) ↗

~~\$453~~ **\$422**
Booking.com ↗

View Deal

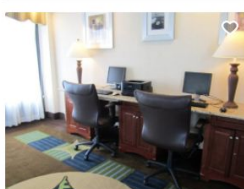
View all 11 deals from \$422 ▼

8,422 reviews

Certificate of Excellence

#4 Best Value of 154 hotels in Boston

Restaurant Room Service



Holiday Inn Express Boston (Great Value!) ↗

~~\$253~~ **\$238**
Expedia.com ↗

View Deal

View all 13 deals from \$238 ▼

850 reviews

Certificate of Excellence

#5 Best Value of 154 hotels in Boston

Free Wifi Free Parking Hotel website



+ 12 % Increase in Clicks
(On average, cross all platform)



+ 12 % Increase in Clicks
(On average, cross all platform)



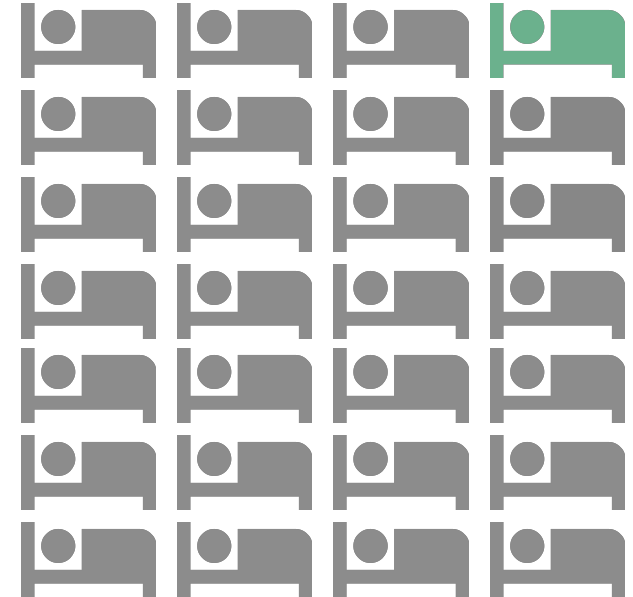
+ 3.4 % increase in Revenue*
(On average, cross all platform)



+ 12 % Increase in Clicks
(On average, cross all platform)



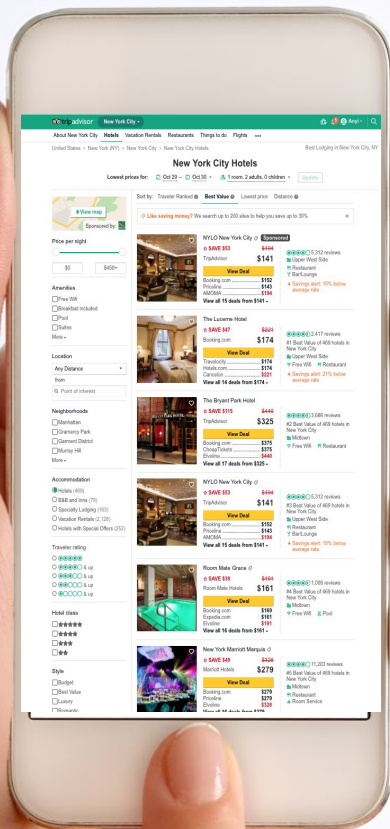
+ 3.4 % increase in Revenue*
(On average, cross all platform)



+ 1.3 % Increase in Booking

Further Improvement

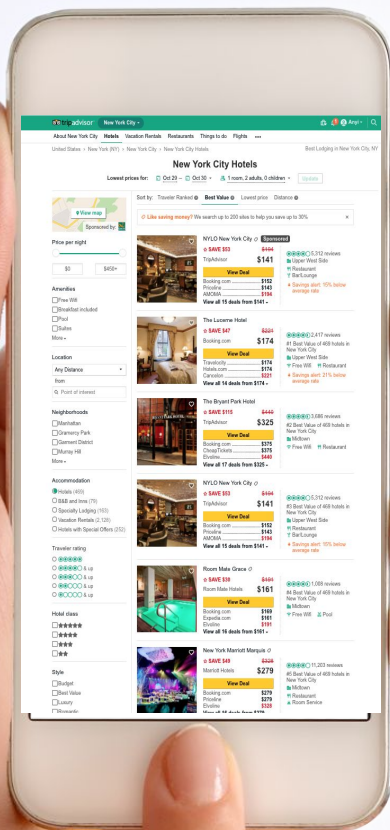
Further Improvement



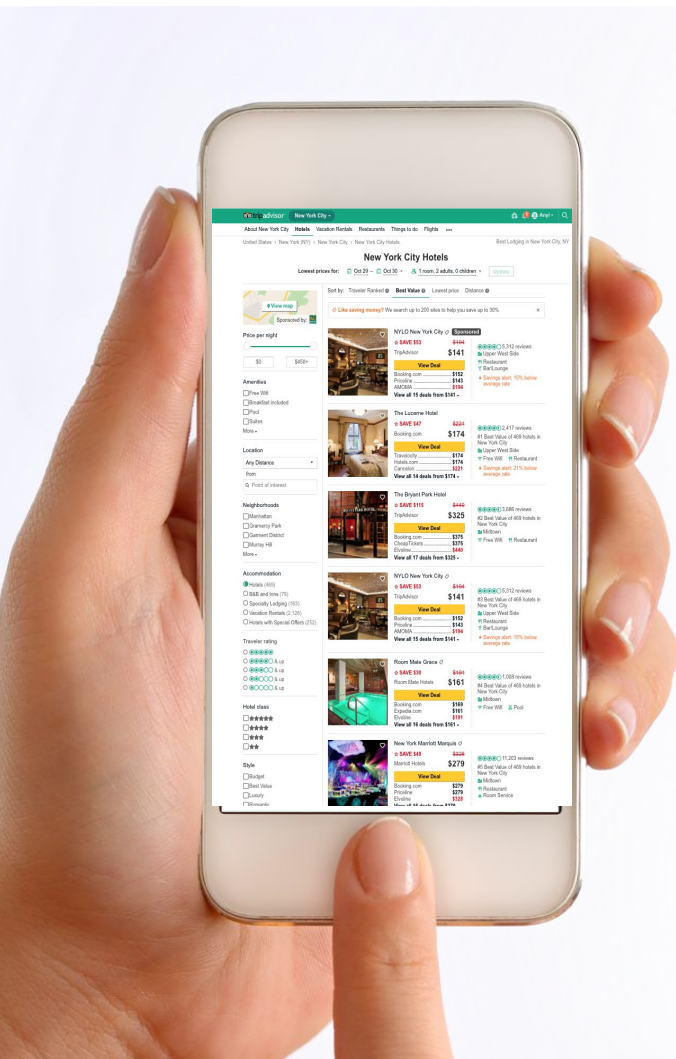
- Search Related Features got cancelled out during pairwise transformation
- Pair generation and bucketing was expensive

Further Improvement

- MAP was invisible to model during the training phase - Minimizing the mis ranked pair != maximizing MAP



Further Improvement



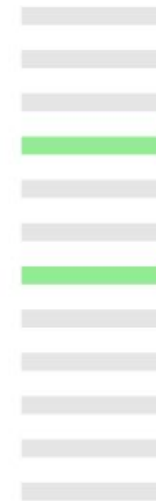
- MAP was invisible to model during the training phase - Minimizing the mis ranked pair \neq maximizing MAP



(a)



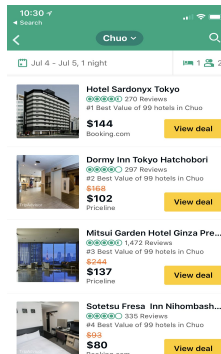
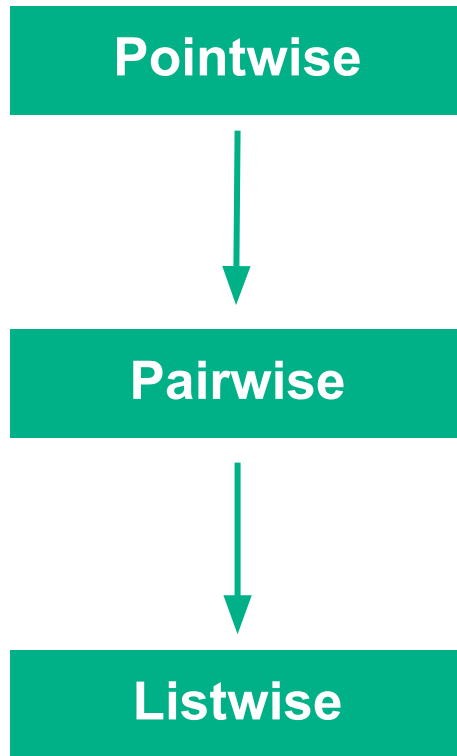
(b)



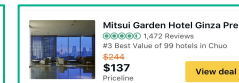
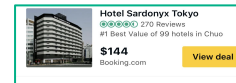
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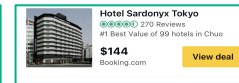
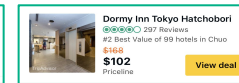
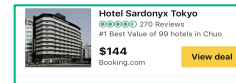
Further Improvement



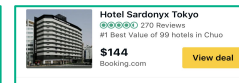
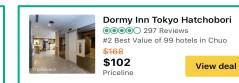
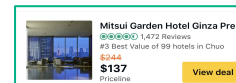
$f()$



... MAP(r1)



... MAP(r2)



... MAP(r3)

...

References

- [1] Cao, Z., Qin, T., Liu, T.Y., Tsai, M.F. and Li, H., 2007, June. Learning to rank: from pairwise approach to listwise approach. In *Proceedings of the 24th international conference on Machine learning* (pp. 129-136). ACM.
- [2] Tagami, Y., Ono, S., Yamamoto, K., Tsukamoto, K. and Tajima, A., 2013, August. Ctr prediction for contextual advertising: Learning-to-rank approach. In *Proceedings of the Seventh International Workshop on Data Mining for Online Advertising* (p. 4). ACM.
- [3] Gneric Click Through Rate 2017 C<https://www.advancedwebranking.com/cloud/ctrstudy/>
- [4] <http://homepages.inf.ed.ac.uk/vlavrenk/>
- [5] Zhang, Dongxiang, et al. "Targeted advertising in public transportation systems with quantitative evaluation." *ACM Transactions on Information Systems (TOIS)* 35.3 (2017): 20.
- [6] Tagami, Yukihiro, et al. "Ctr prediction for contextual advertising: Learning-to-rank approach." *Proceedings of the Seventh International Workshop on Data Mining for Online Advertising*. ACM, 2013.

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