

A high-angle photograph of a suspension bridge stretching across a dense, green forest. The bridge is made of metal grating and has a railing. Several people are walking across the bridge, some looking down at the forest. The background is a thick canopy of evergreen trees.

Booking.com

User Experience and Data

Bridging the Gap

Themis Mavridis
Senior Data Scientist

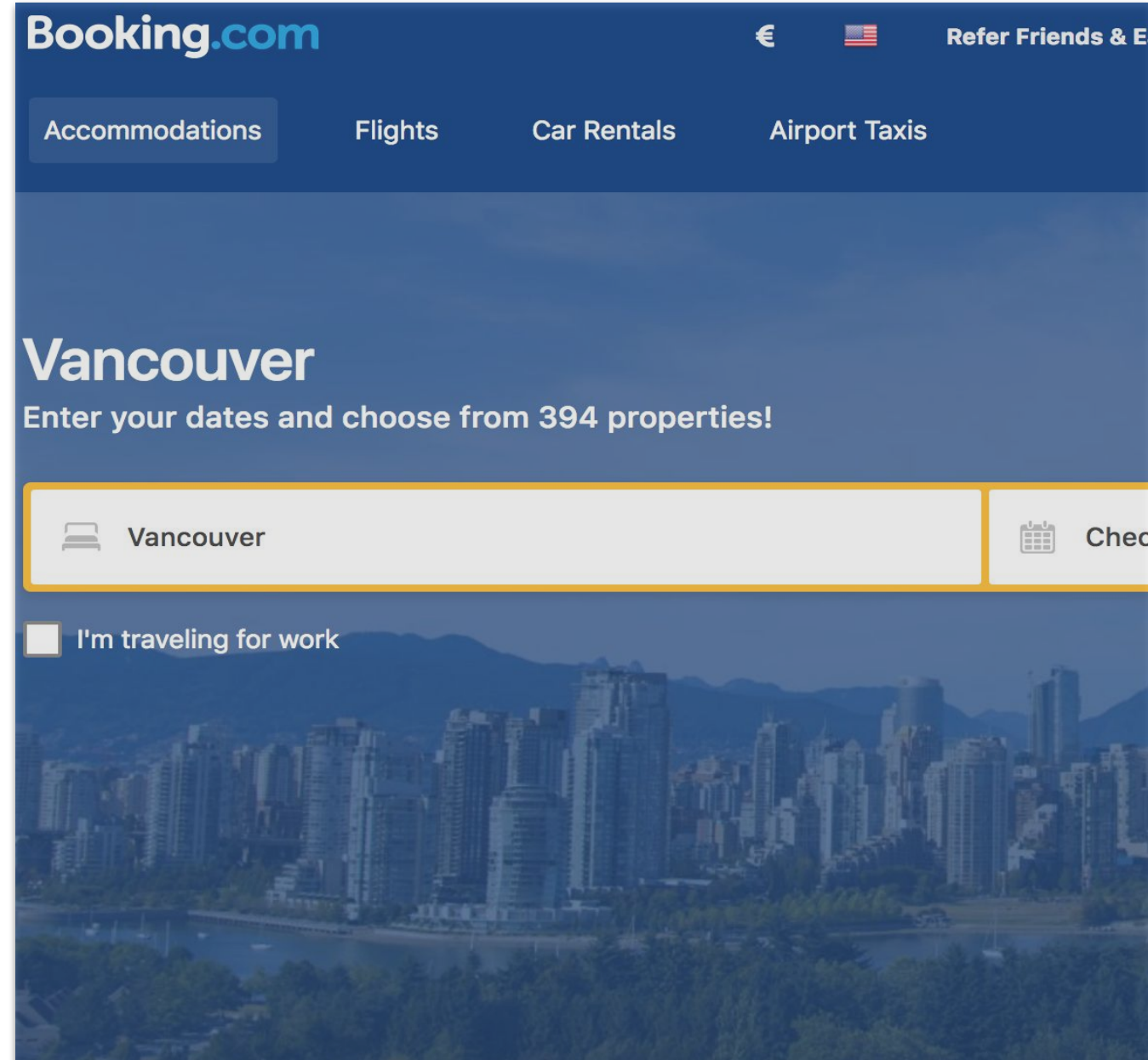
themistoklis.mavridis@booking.com

RecTour, RecSys 2018 - Vancouver

Largest Accommodation Marketplace

- 130,000+ global destinations
- 28 million listings
- 43 languages

- Terabytes of data every day
- 100+ Machine Learning Models Deployed
- 50+ Recommender Systems Deployed



Main
problems

Recs
& other ML

Modelling

Experimentation

Conclusion

Three problems...



Multi-dimensional Item space

- Destination
- Dates
- Properties
- Rooms
- Policies



High Stakes

- No "undo" option
- Trips are expensive
- Maximize Trust



Zero query

- Optimal shopping experience with minimal info

...Three more problems



Rich Content

- Photos
- Descriptions
- Reviews
- Destination endorsements
- Etc



Continuous Cold Start

- Guests
- Properties



Supply Constraint

- Availability
 - Finite
 - Dynamic
- Price
 - Dynamic

Main
problems

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& other ML

Modelling

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Conclusion



What kind of recs?



Recommender Systems.



Destinations

Plain Recommendations

Autocomplete

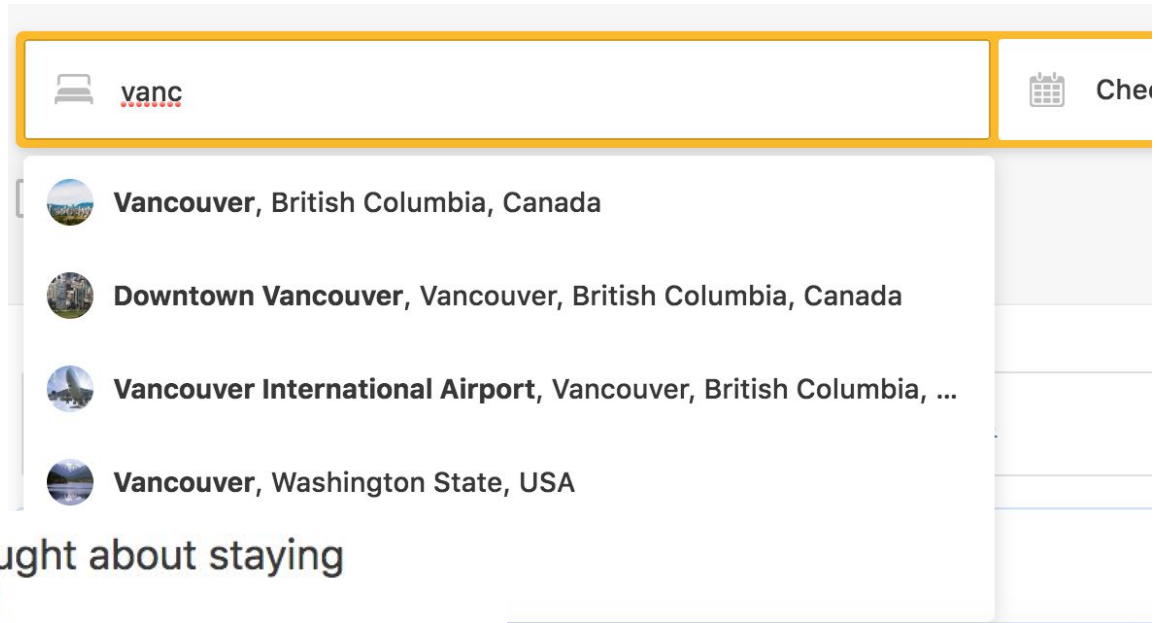
Similar Destinations

Multi-city Trip Destinations





Nearby Destinations

Vancouver

Top reasons to visit:
scenery, sightseeing, nature



The screenshot shows a search bar with the text 'vanc' and a dropdown menu with the following suggestions:

-  Vancouver, British Columbia, Canada
-  Downtown Vancouver, Vancouver, British Columbia, Canada
-  Vancouver International Airport, Vancouver, British Columbia, ...
-  Vancouver, Washington State, USA

Have you thought about staying further away?

Richmond

13.5 km from Vancouver
101 properties available

North Vancouver

5.5 km from Vancouver
14 properties available

*23% cheaper

Burnaby

11.6 km from Vancouver
28 properties available

*34% cheaper

Recommender Systems.



Accommodations

Default Ranking

Click History

Personalized Ranking

Similar/Different

Low availability

We found hotels similar to JW Marriott Parq Vancouver that other travelers liked

The Fairmont Waterfront

★★★★★



Featuring an outdoor heated pool, this hotel is connected to the Vancouver Convention Center and Canada Place Cruise Ship Terminal.

Vancouver's Gastown is just 5 minutes' walk away.

2 people are looking right now

9.1 Wonderful
621 reviews

Total price from:
€ 724

[Book now](#)

Hyatt Regency Vancouver

★★★★★



Located 1.2 mi from BC Place Stadium, this Vancouver hotel features a heated outdoor pool and a hot tub. A 42" flat-screen

TV is provided in every room. Free WiFi is featured throughout the property.

5 people are looking right now

8.6 Excellent
1,256 reviews

Total price from:
€ 503

[Book now](#)

Sandman Hotel Vancouver City Centre

★★★



Featuring an indoor pool and hot tub, this central Vancouver hotel provides guestrooms with free WiFi. Robson Street shopping district is only 5 minutes' walk away.

2 people are looking right now

7.3 Good
1,475 reviews

Total price from:
€ 275

[Book now](#)

[Hotels in Vancouver](#)

Our recommendations for groups

Distance from... ▾

Lowest Price First

Review Score & Price

Stars ▾

...



EXchange Hotel Vancouver ★★★★★

[Vancouver – Show on map](#) (550 m from center) – [Subway Access](#)

In high demand! Booked 20 times in the last 24 hours

Recommended for 4 adults

2 × Double Room

FREE cancellation – no prepayment needed

Risk Free: You can cancel later, so lock in this great price today!

Price for 4 adults for 1 night: € 312

includes taxes and charges

Excellent
82 reviews **8.7**
Location **9.4**

Check out these 58 other properties outside Amsterdam



ibis budget Amsterdam City South ★★

[Amstelveen – Show on map](#)

[\(6.4 km from Amsterdam\)](#)

Booked 7 times in the last 6 hours

Recommended for 4 adults

2 × Twin Room

In high demand – only 7 rooms left on our site!

Price for 4 adults for 2 nights: € 576

+€ 13.76 taxes and charges

Very Good
7,352 reviews **8.0**

Recommender Systems.



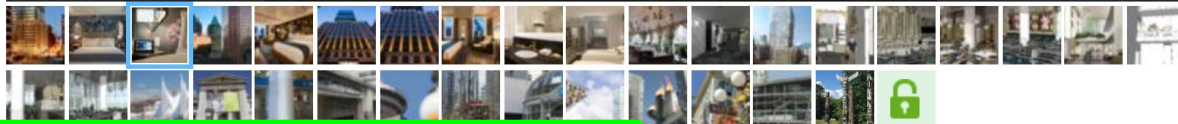
More
Filters

Attractions

Districts


Room Types / Policies


Deluxe Queen Room - Recommended for 4 adults



Recommended for 4 adults

2 x [Deluxe Queen Room](#) € 312
includes taxes and charges

Fits: 

FREE cancellation before Nov 22, 2018 
NO PREPAYMENT NEEDED – pay at the property

Group price for 1 night: € 312
includes taxes and charges

[Reserve](#)

Don't worry – clicking this button won't charge you anything!

Popular Filters

<input type="checkbox"/> Hotels	71
<input type="checkbox"/> Very Good: 8+	80
<input type="checkbox"/> Breakfast Included	45
<input type="checkbox"/> Airport Shuttle	9
<input type="checkbox"/> Free WiFi	135
<input type="checkbox"/> Hostels	9
<input type="checkbox"/> Wonderful: 9+	26

Recommended for You

<input type="checkbox"/> Fitness Center	39
<input type="checkbox"/> Gastown	32
<input type="checkbox"/> Free cancellation	121
<input type="checkbox"/> Good: 7+	114
<input type="checkbox"/> Non-smoking Rooms	128

Recommender Systems are Complex.



Target Item



What do we
want to
recommend?

Audience



Who are we
recommending
for?
When?

Framing



What is the
role of the
recs?

KPI



How do we
measure
effectiveness?

Data



What data are
we going to
use?

Feedback



How do we
define user
satisfaction?

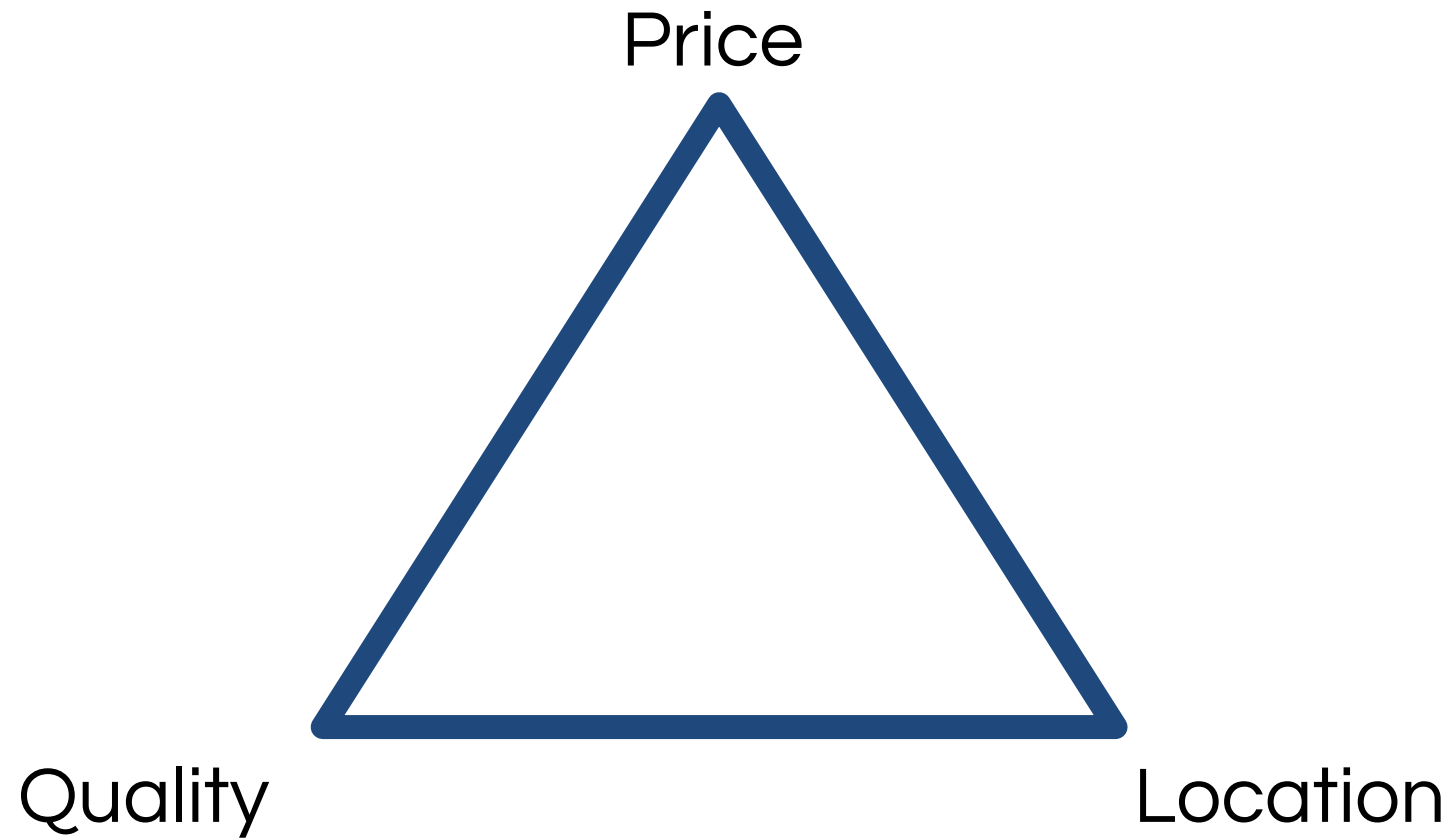


other ML?

Travel Preference



Travel Preference



Travel Context

Booking.com

Amsterdam

May 13 - May 14 (1 night) 2 adults

Traveling With Kids?
Add your kids to find the perfect property!

Rooms 1 Adults 2 Children 0

Travelling with children?
Find the perfect property for your family by filling this in

Are you travelling for work?
 Yes No

City Centre • In city

Parking WiFi

Search

Destination/hotel name:
Pefkohori

Are you travelling for work?
 Yes No

Check-in
Thursday 15 June 2017

Check-out
Friday 23 June 2017

8-night stay

Rooms 1
Adults 3
Children 0

Travelling with children?
Find the perfect property for your family by filling this in

Search

27% reserved

Pefkohori: 43 p
3 reasons to visit: th

Top picks for groups

Don't want to use a cred



Semantic Layer

Enables EVERYONE to introduce

- new features
- personalisation
- persuasion

User Interface Optimization



User Interface Optimization

Whatever accommodations you're looking for, we've got you covered.



Apartments
652,111 apartments



Resorts
21,210 resorts



Villas
332,918 villas

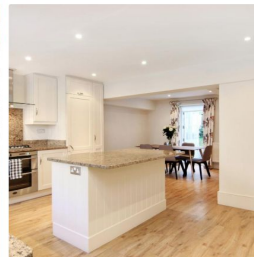
More than just hotels...discover pure comfort with homes & apartments



Annabel's Luxury Suites
Imerovigli
Starting from € 337.50
9.7 Exceptional · 6 reviews



Casa Portuguesa Prata
Lisbon
Starting from € 242.50
8.6 Excellent · 78 reviews

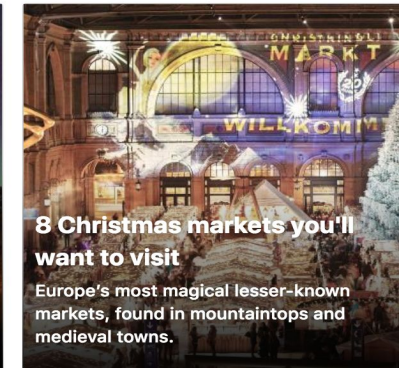
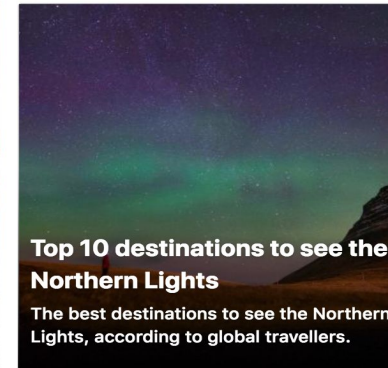
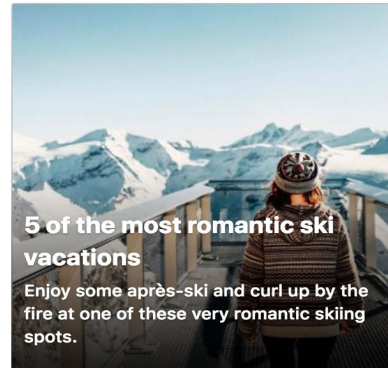


London Lifestyle Apartments - ...
London
Starting from € 341
7.7 Good · 16 reviews



MY CASA - 131 PROMENADE.
Nice
Starting from € 190
8.0 Very Good · 19 reviews

Get inspired for your next trip



Vancouver 🇨🇦
Top reasons to visit: scenery, sightseeing, nature

Still interested in your previous searches for Vancouver?

Nov 23 - Nov 24	2 rooms, 4 adults	×
Nov 23 - Nov 24	1 room, 1 adult	×

Amsterdam 🇳🇱
Top reasons to visit: museums, city walks, sightseeing

Still interested in your previous searches for Amsterdam?

Oct 19 - Oct 20	1 room, 2 adults	>
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Victoria 🇨🇦
244 properties

Whistler 🇨🇦
191 properties

Banff 🇨🇦
52 properties



What about Supply?



Content Curation

Guests Love...

- ★ **"beautiful hotel"**
6 related reviews
- ★ **"helpful staff"**
4 related reviews
- ★ **"absolutely loved"**
2 related reviews

Vancouver

Top reasons to visit:
scenery, sightseeing, nature

What Travelers Love About This Location

9.5

"excellent location. Friendly staff, great property"



Somnath
 United States of America

9.5

"The ambiance, location, newness, view from the upper floors and gym. They are all great !"



Keshmahinder
 Malaysia

8.7

"Great location to and from town."



Daniel
 Canada

Content Augmentation



Delta Hotels by Marriott Vancouver Downtown Suites

★★★★

Vancouver – [Show on map](#) (700 m from center) – [Subway Access](#)

Last booked: 11 hours ago

Wonderful **9.1**
305 reviews
Location 9.4



Recommended for 4 adults
An outstanding value on these dates.



2 x King Suite with Sofa Bed and

FREE cancellation – no prepay

RISK FREE. You can cancel later,
great price today!

Recommended Destinations for You:



Richmond



Prices in Richmond for your dates have been going up over the past 2 days.



Seattle



Prices in Seattle for your dates are the lowest we've seen in 40 days!

```
graph LR; A[Main problems] --> B[Recs & other ML]; B --> C[Modelling]; C --> D[Experimentation]; D --> E[Conclusion]
```

Main
problems

Recs
& other ML

Modelling

Experimentation

Conclusion

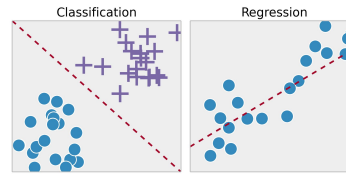
ML Problem Construction.



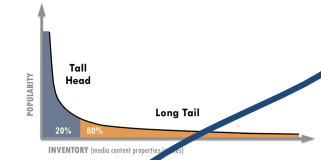
Idea

ML problem

Ground Truth Data

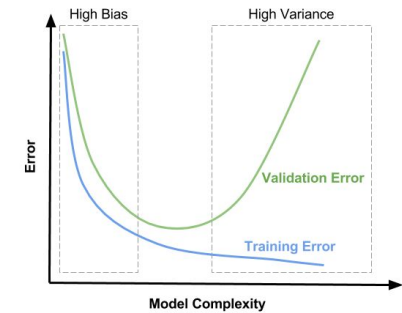
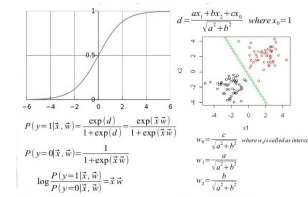
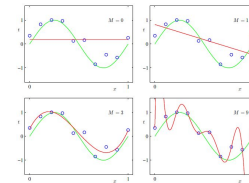
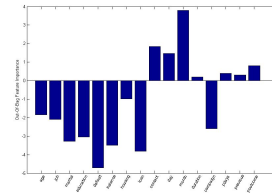


Year	Pop	City	State	State Capital	Area	Average Cost (\$)	Median Property Value (\$)
1990	100000	San Francisco	California	Sacramento	49	100000	100000
1991	100000	San Francisco	California	Sacramento	49	100000	100000
1992	100000	San Francisco	California	Sacramento	49	100000	100000
1993	100000	San Francisco	California	Sacramento	49	100000	100000
1994	100000	San Francisco	California	Sacramento	49	100000	100000
1995	100000	San Francisco	California	Sacramento	49	100000	100000
1996	100000	San Francisco	California	Sacramento	49	100000	100000
1997	100000	San Francisco	California	Sacramento	49	100000	100000
1998	100000	San Francisco	California	Sacramento	49	100000	100000
1999	100000	San Francisco	California	Sacramento	49	100000	100000
2000	100000	San Francisco	California	Sacramento	49	100000	100000
2001	100000	San Francisco	California	Sacramento	49	100000	100000
2002	100000	San Francisco	California	Sacramento	49	100000	100000
2003	100000	San Francisco	California	Sacramento	49	100000	100000
2004	100000	San Francisco	California	Sacramento	49	100000	100000
2005	100000	San Francisco	California	Sacramento	49	100000	100000
2006	100000	San Francisco	California	Sacramento	49	100000	100000
2007	100000	San Francisco	California	Sacramento	49	100000	100000
2008	100000	San Francisco	California	Sacramento	49	100000	100000
2009	100000	San Francisco	California	Sacramento	49	100000	100000
2010	100000	San Francisco	California	Sacramento	49	100000	100000
2011	100000	San Francisco	California	Sacramento	49	100000	100000
2012	100000	San Francisco	California	Sacramento	49	100000	100000
2013	100000	San Francisco	California	Sacramento	49	100000	100000
2014	100000	San Francisco	California	Sacramento	49	100000	100000
2015	100000	San Francisco	California	Sacramento	49	100000	100000
2016	100000	San Francisco	California	Sacramento	49	100000	100000
2017	100000	San Francisco	California	Sacramento	49	100000	100000
2018	100000	San Francisco	California	Sacramento	49	100000	100000
2019	100000	San Francisco	California	Sacramento	49	100000	100000
2020	100000	San Francisco	California	Sacramento	49	100000	100000



Feature & Model Selection

Algorithm Design



Model Construction Challenges.

- **User Base Impact**
 - class proportion of binary classifiers
- **Learning Difficulty**
 - Bayes error rate
 - Ranking VS random/popular

Model Construction Challenges.

-Data to Concept Matching

- e.g. "Multi-leg" destinations
- e.g. "nearby" destinations

Have you thought about staying further away?

Richmond

13.5 km from Vancouver
101 properties available

North Vancouver

5.5 km from Vancouver
14 properties available

*23% cheaper

Burnaby

11.6 km from Vancouver
28 properties available

*34% cheaper

Your searches and bookings

Brussels



14 Sept - 15 Sept

Amsterdam



15 Sept - 16 Sept

Extend your trip

Brussels

16 Sept - 17 Sept

Paris

16 Sept - 17 Sept

Berlin

16 Sept - 17 Sept

Offline VS Business.

Selection Bias



Offline VS Business.

Selection Bias - Family Trip



Offline VS Business.

Selection Bias

PROBLEM: high variance in the region of the feature space where **labels** are **missing**

Offline VS Business.

Selection Bias

PROBLEM: high variance in the region of the feature space where **labels** are **missing**

SOLUTIONS:

- more **data** reduces the production sample variance

Offline VS Business.

Selection Bias

PROBLEM: high variance in the region of the feature space where **labels** are **missing**

SOLUTIONS:

- more **data** reduces the production sample variance
- **propensity** modelled feature selection

```
graph LR; A[Main problems] --> B[Recs & other ML]; B --> C[Modelling]; C --> D[Experimentation]; D --> E[Conclusion]
```

Main
problems

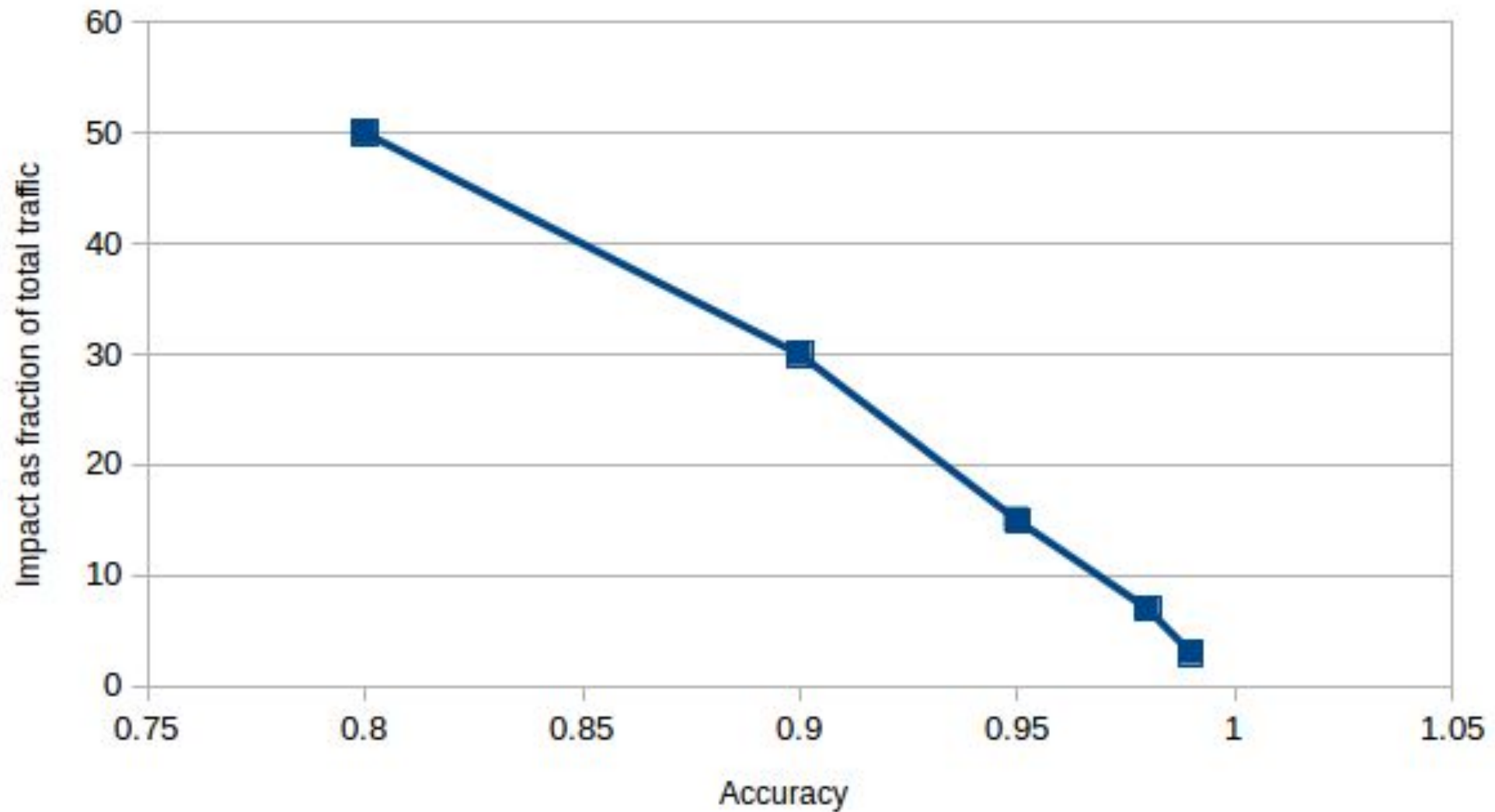
Recs
& other ML

Modelling

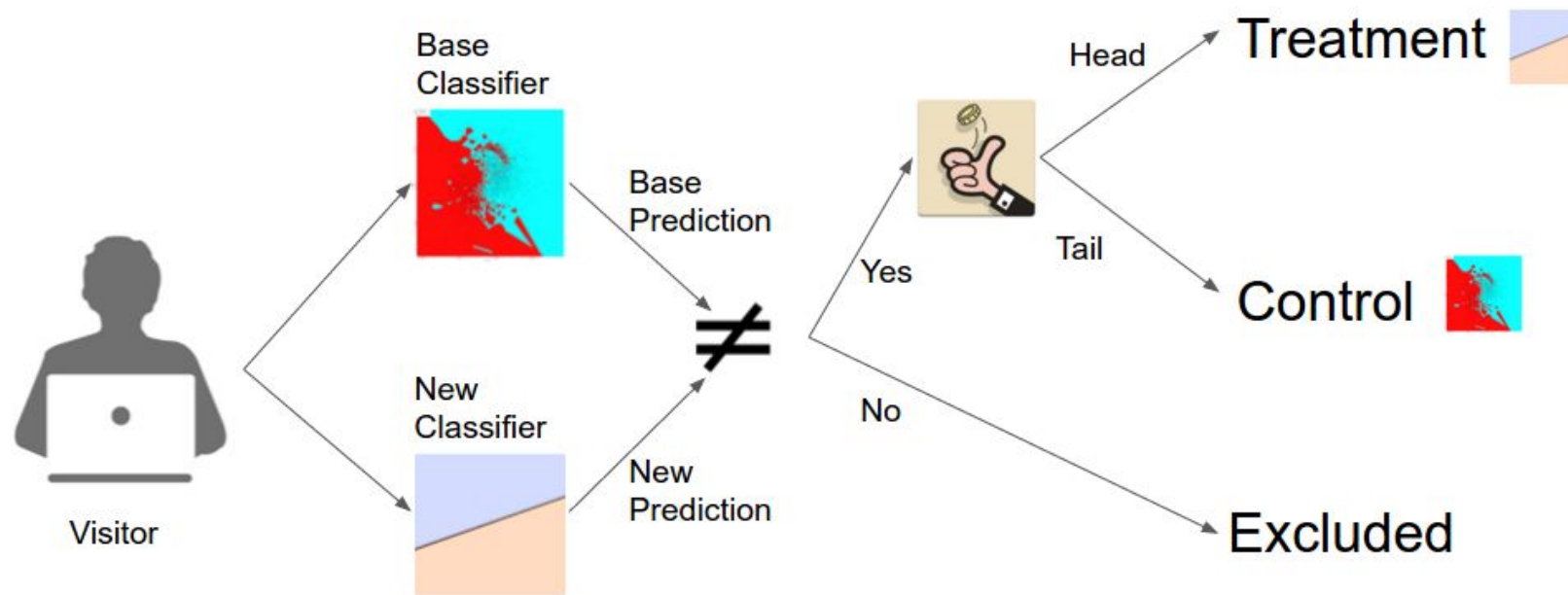
Experimentation

Conclusion

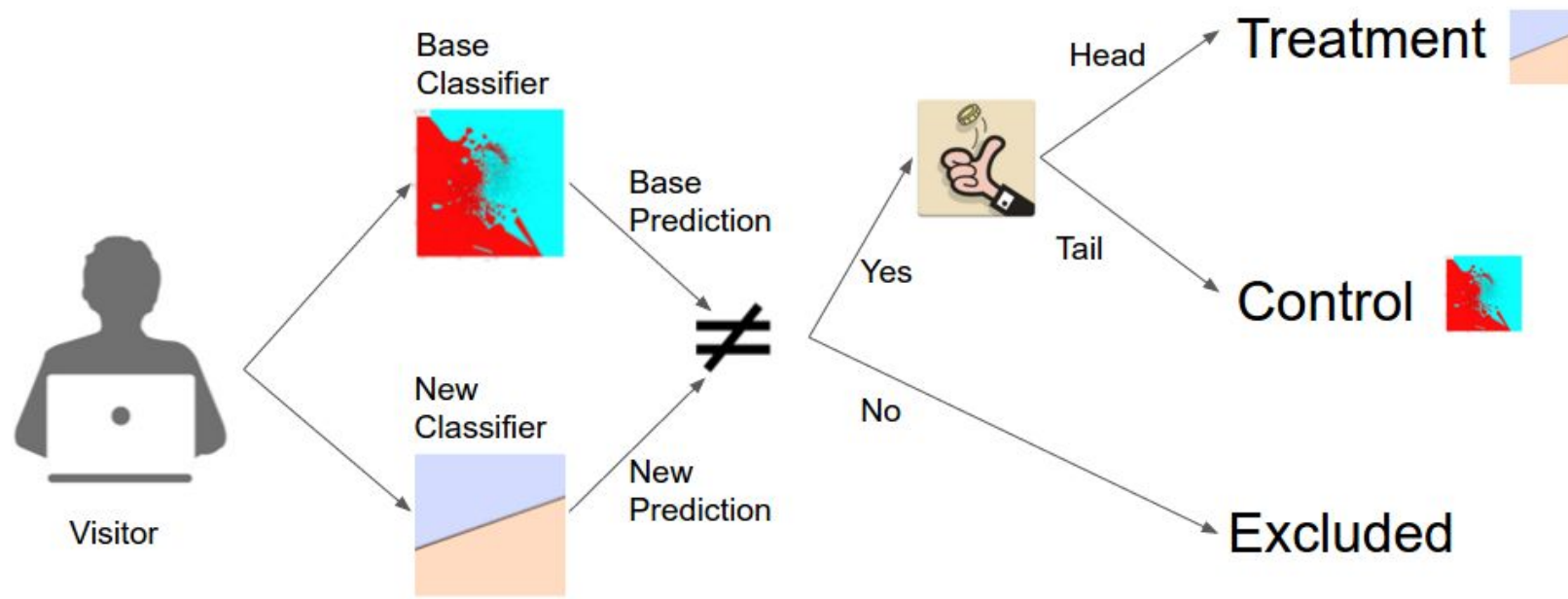
Correlated Models.



Correlated Models.

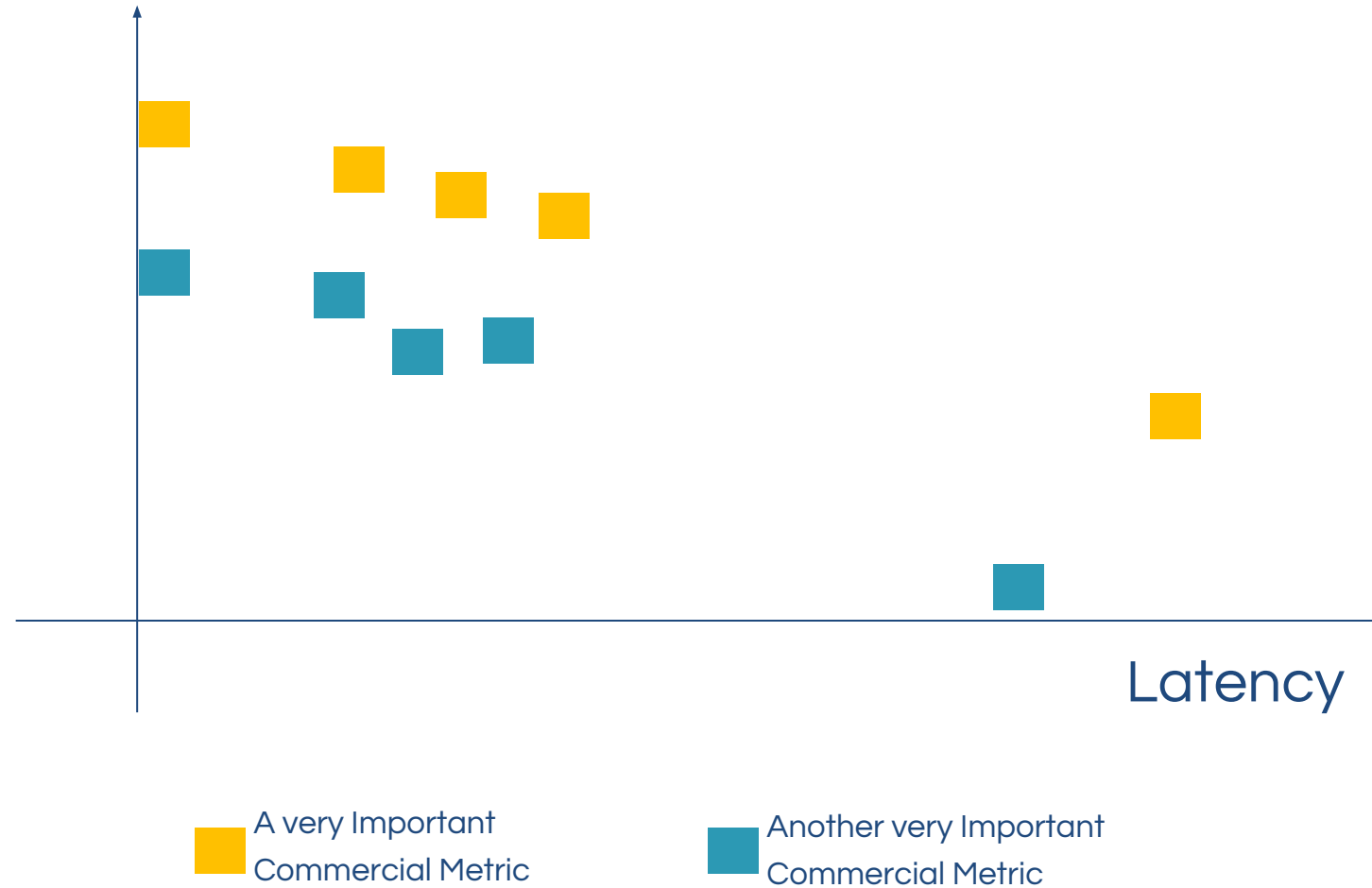


Correlated Models.



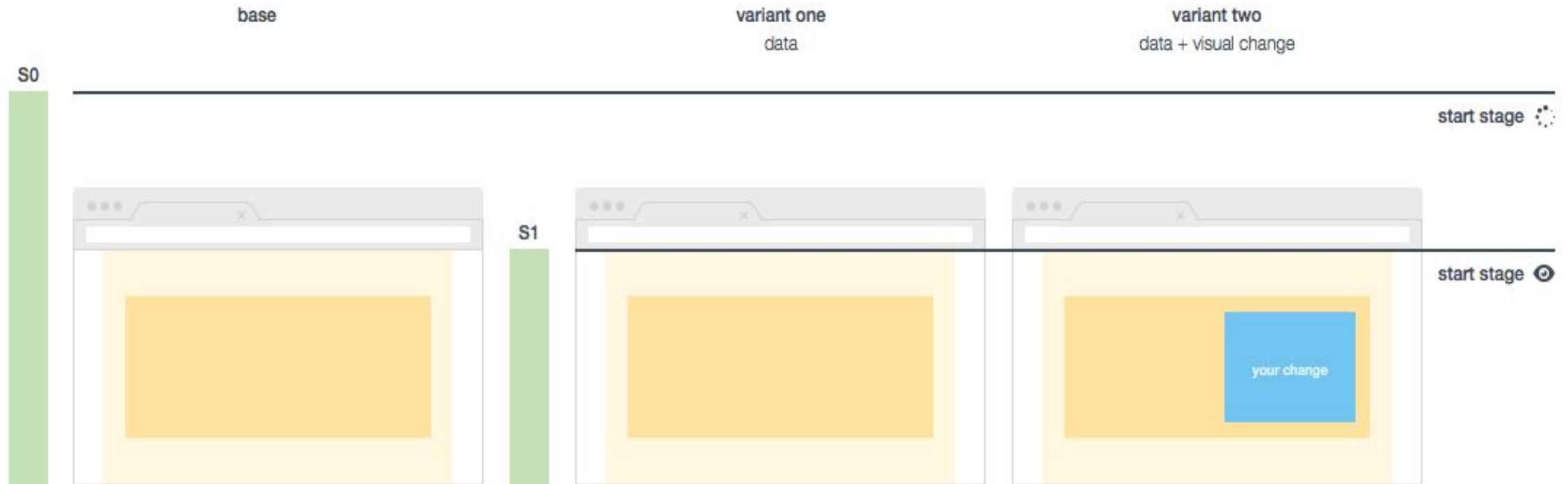
- Larger Outer Spaces (e.g. multiclass / ranking)
- Observation space (experiment per user - prediction per search)
- Per-prediction impact (same model in different features)

Latency is Critical.

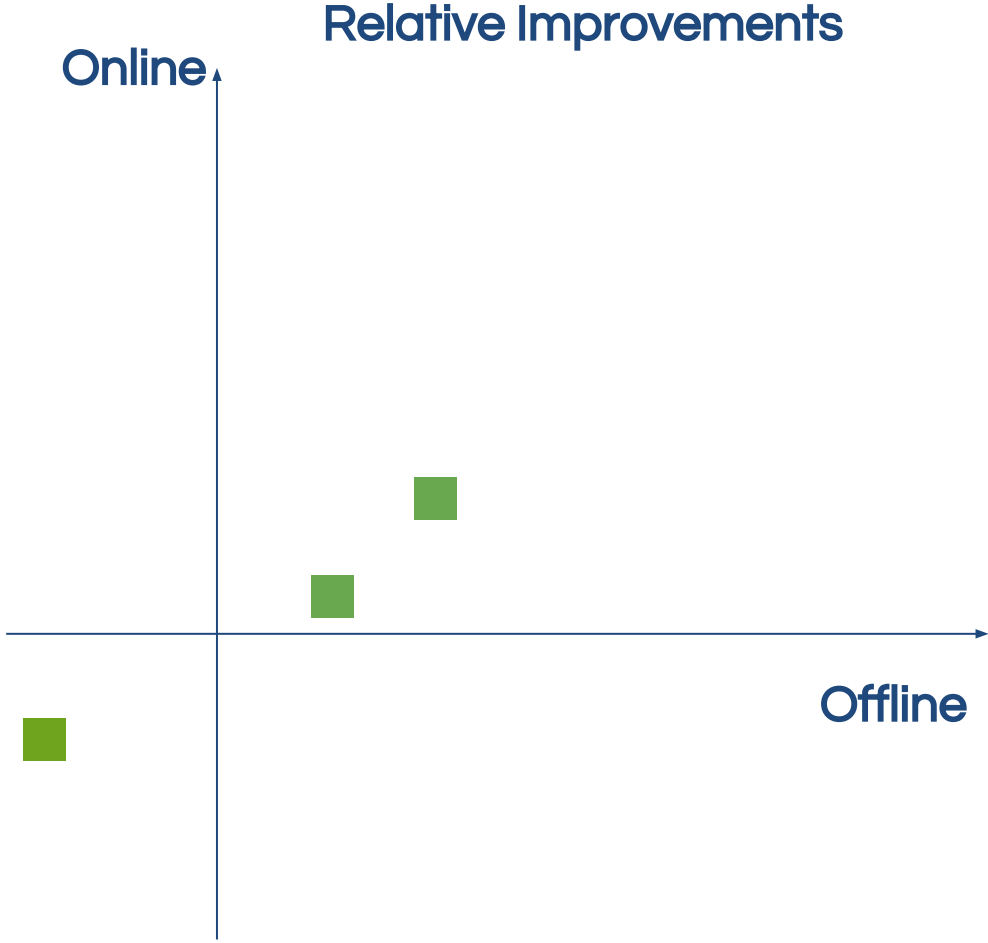


Performance Impact.

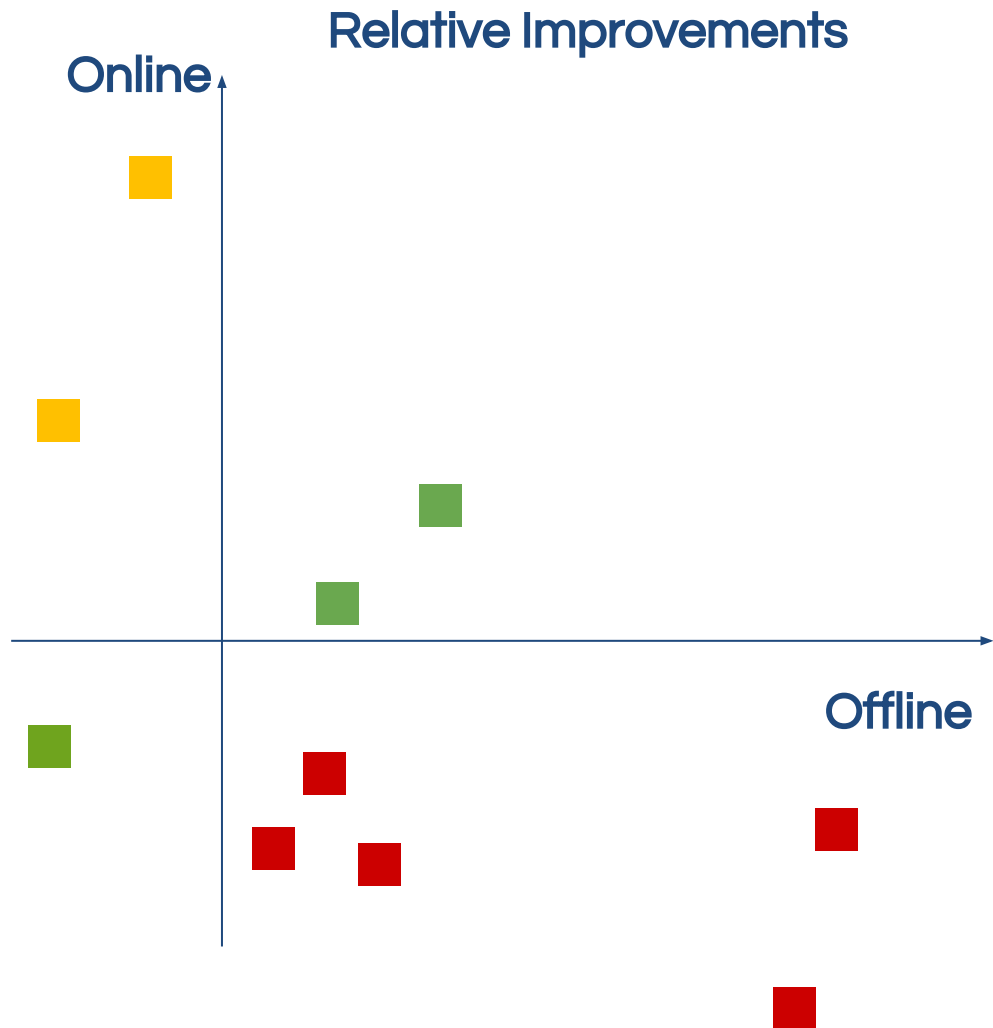
Blocked experimentation



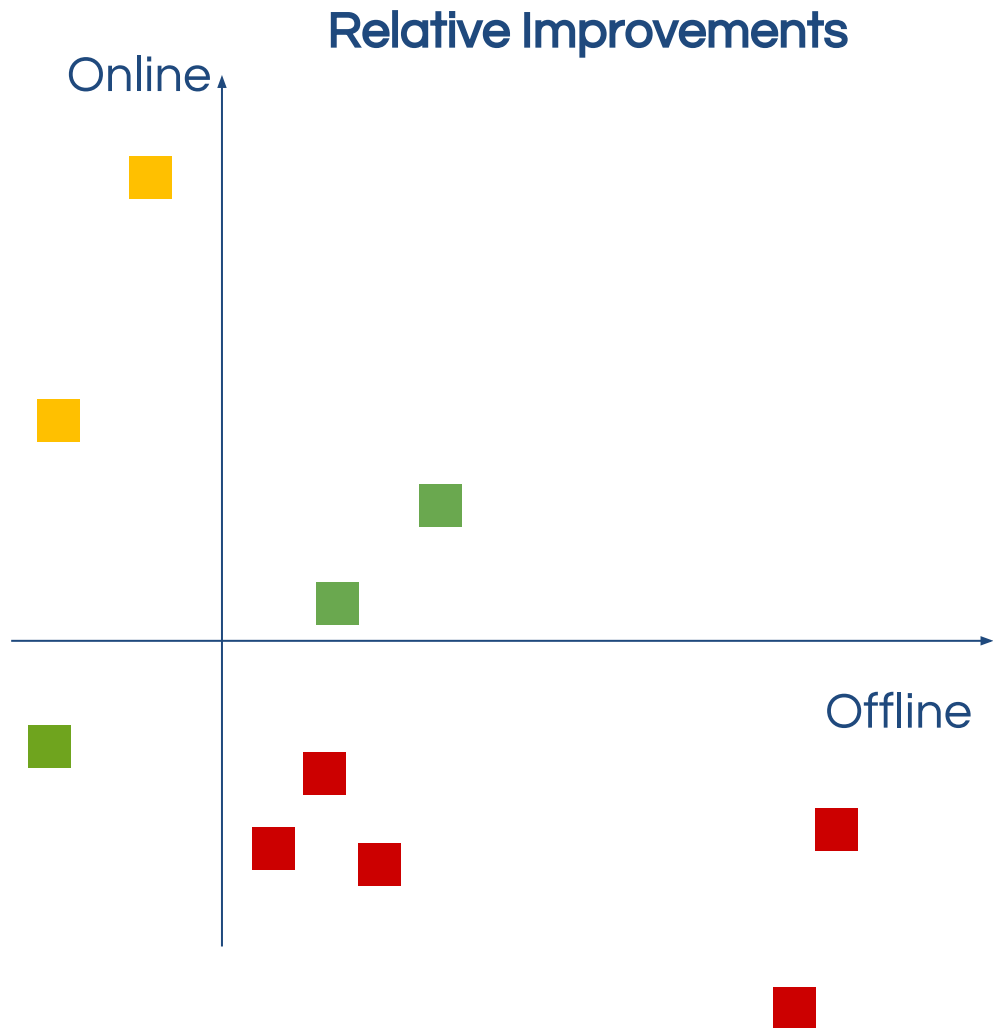
Offline metrics are just a Health Check.



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Offline metrics are just a Health Check.



Run Experiments



Evaluate Systems as a whole

Including the model, the UI, and the audience



Expose wrong intuitions

More clicks is better, is it?



Show Improvement Direction

Analysing experiment results we can get concrete ideas about what to do next



Discover Causal Effects

Experiments are the ultimate piece of evidence for causality

```
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```

Main
problems

Recs
& other ML

Modelling

Experimentation

Conclusion

What Matters?

89% of properties are reserved in Amsterdam

There is also availability in these nearby destinations

Hoofddorp

Schiphol

Badhoevedorp



Amsterdam is 88% unavailable for your dates on our site. Have you considered staying nearby?

[Schiphol](#)

43% cheaper

11.4 km away, 8 properties

[Badhoevedorp](#)

64% cheaper

8.3 km away, 4 properties

[Hoofddorp](#)

57% cheaper

17.2 km away, 13 properties

[Lijnden](#)

60% cheaper

9.3 km away, 1 property

[Amstelveen](#)

53% cheaper

8.1 km away, 5 properties

[Zaandam](#)

54% cheaper

8.9 km away, 8 properties

 [Schiphol Airport](#)

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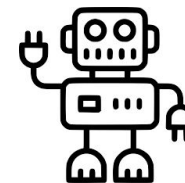
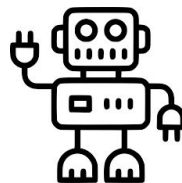
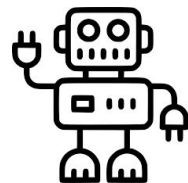
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Impact



Time

Not only ML Matters.

Work closely with **User Researchers, Designers and Copywriters**

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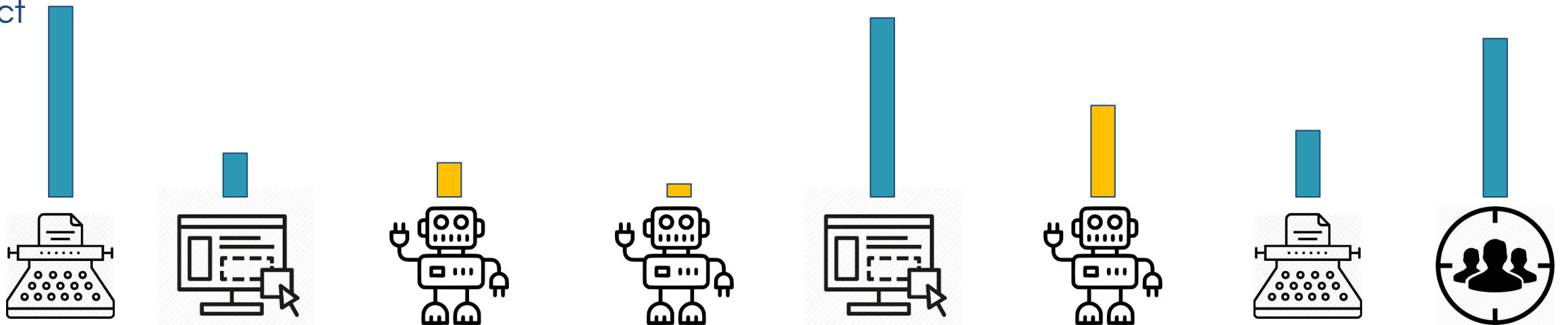
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[Schiphol Airport](#)

54% cheaper

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Impact



Time



ML & Experimentation
can **help** bridge the gap
UX - Data

Thank you!
Questions?

booking.ai

Themis Mavridis

themistoklis.mavridis@booking.com

Booking.com