

# Using Contextual Information to Understand Searching and Browsing Behavior

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**TU/e**

RUSSIR 2015,  
Saint-Petersburg, Russia

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# Outline

- Research Problem and Questions
- What is Contextual Information?
- Searching and Browsing Behavior
- Training Context-Aware System
- Applications that Benefit from Contextual Information
- Conclusion & Open Questions





MS Beta

questions | x | 🔍

- questions
- questions to ask at an interview
- questions to ask your boyfriend
- questions to ask a girl
- questions to ask in an interview
- questions to ask a guy
- questions and answers
- questions aapke answers sai baba ke

[Advanced search](#) [Manage search history](#)

### [Ask.com - Official Site](#)

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Ask Jeeves UK - Ask Search

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# Questions?

# Main Research Problem

Great imbalance between richness of information on the web and the succinctness and poverty of search requests of web users

Queries are only a partial description of the underlying complex information needs

How to **discover, model and use** contextual information in order to understand and improve users' searching and browsing behavior on web?



# Understanding user needs





# Let's give it a try...



- Everything
- Images
- Videos
- News
- Shopping
- More

- Any time
- Latest
- Past 24 hours
- Past 2 days
- Past week
- Past month
- Past year
- Custom range...

my keys

About 129,000,000 results (0.17 seconds)

▶ [Where Are My Keys?](#) ☆ 🔍

Welcome to "Where are my keys?" the only site you are currently 20378 places where what was lost could be found.  
[www.them.ws/keys/index.php](http://www.them.ws/keys/index.php) - Cached - Similar

[Houses for sale - MyKeys.co.uk property portal](#)

Houses for sale across the UK from the MyKeys.co.uk property portal. Properties available from UK estate and letting agents.  
[www.mykeys.co.uk/](http://www.mykeys.co.uk/) - Cached - Similar

[Where are my keys? - Uncyclopedia, the content-free encyclopedia](#) ☆ 🔍

19 Dec 2010 ... One of the most important philosophical questions of our day, the location of my keys has plagued mankind for generations.  
[uncyclopedia.wikia.com/wiki/Where\\_are\\_my\\_keys%3F](http://uncyclopedia.wikia.com/wiki/Where_are_my_keys%3F) - Cached - Similar

[find my keys](#) ☆ 🔍

Get advice and support on how to find my keys, and other life goals.  
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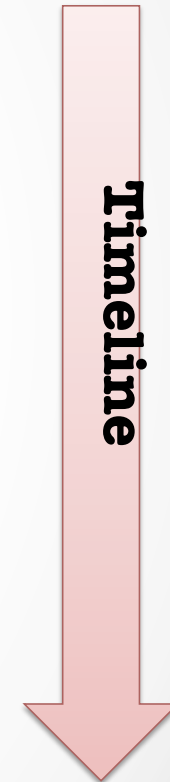
[lost keys](#)

[my keys san diego](#)

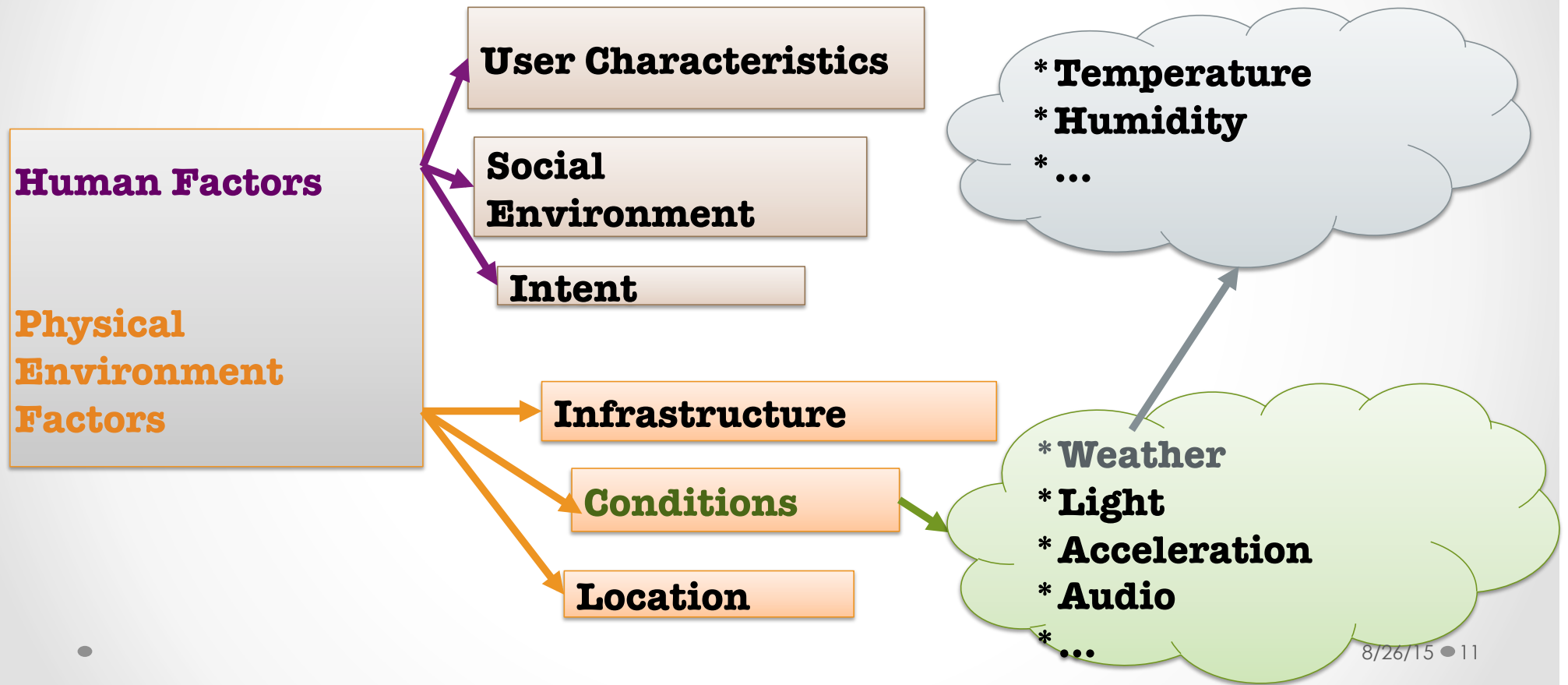
[See your ad here »](#)

# History of context definition and discovery

Context	Year
Location	1992
Taxonomy of explicit context	1999
Predictive features vs. contextual	2002
Hidden context: (clustering, mixture models)	2004
Contextual bandits	2007
History of previous interaction	2008
Independence of predicted class	2011
Two level prediction model	2012
Focus on Context Discovery	2012 -



# Explicit Context Taxonomy



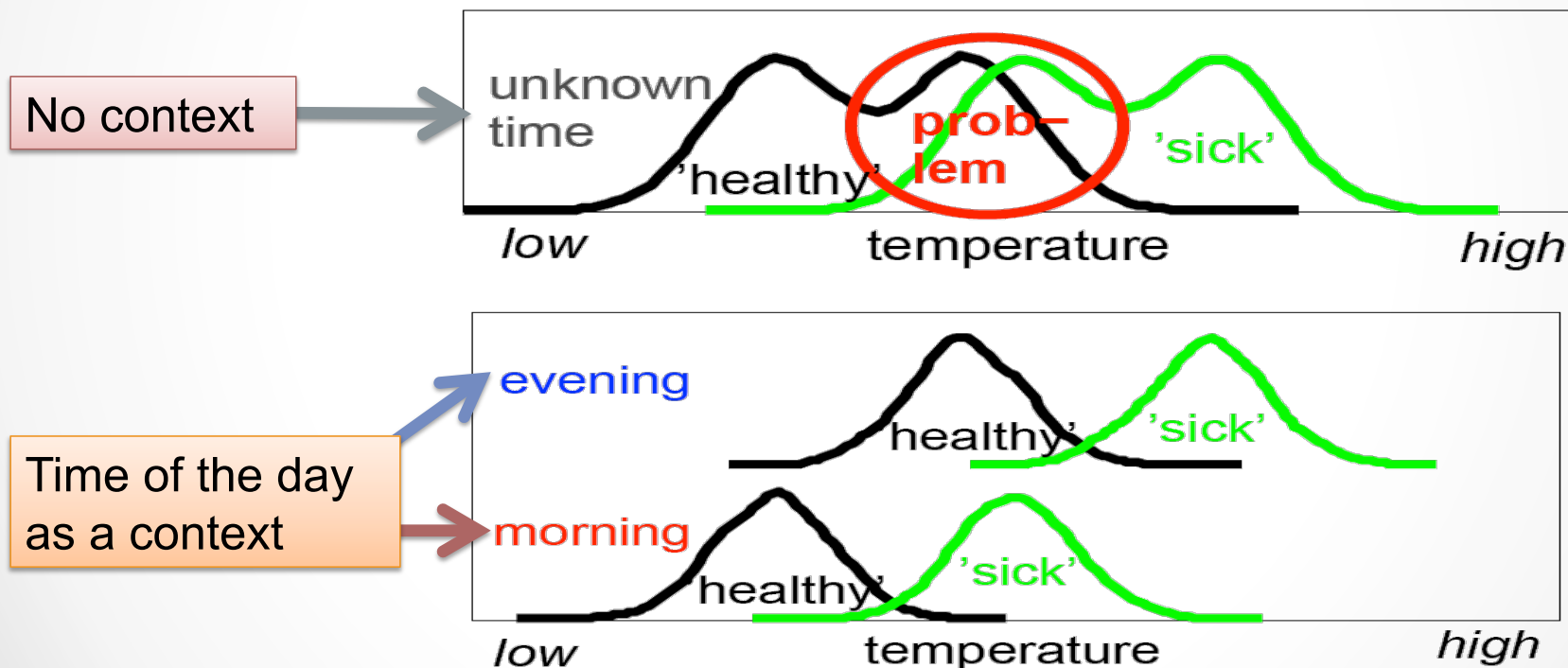
# Type of Context

- **User Context**
  - User Preferences
  - User profiles
  - Usage of user history
- **Document/Product Context**
  - Meta-data
  - Content features
- **Task Context**
  - Current activity
  - Location and etc.
- **Social Context**
  - Leveraging the social graph

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# Example of Context: in Diagnostics

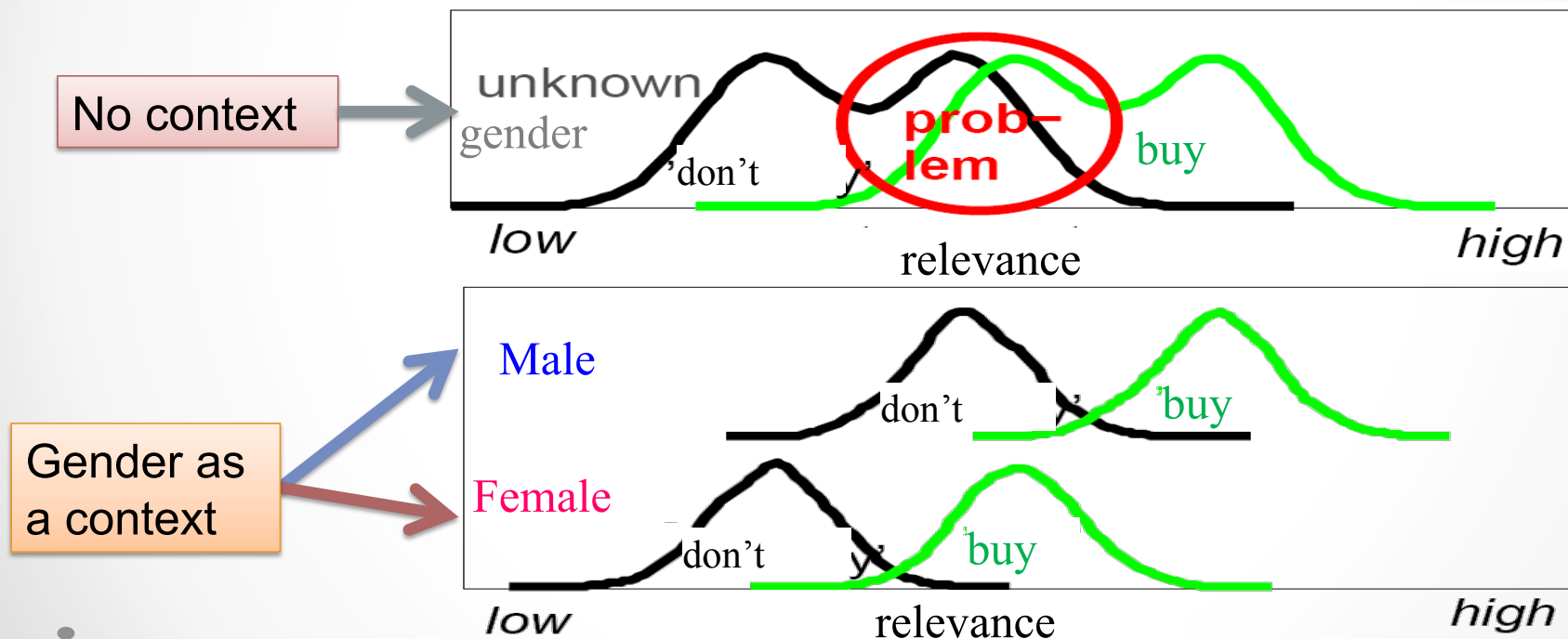
- Not predictive alone but a subset of features with the contextual attribute(s) becomes (much) more predictable



# Example of Context: in Marketing

$$P(\text{Purchase}|\text{gender}=\text{"male"})=P(\text{Purchase}|\text{gender}=\text{"female"})$$

Model<sub>Male</sub> ~ f(relevance); Model<sub>Female</sub> ~ f(perceived value);



# Types of User Behavior

- Searching – when users are issuing queries (users have particular information needs):
  - We are trying to improve search results (SERP) taking context into account
- Browsing – when users are surfing a website:
  - we are analyzing their movements utilizing context

**Contextual Information affects user behavior!**

# Web Predictive Analytics

- Web predictive analytics - aims to predict individual and aggregated characteristics indicating visitor behavior for purposes of understanding and optimizing web usage
- Application
  - Search engines (Bing, Yandex)
  - Recommender System (Booking.com, Yahoo News)
  - Computational Advertisement (Amazon.com)
- Tasks
  - Online shop's recommendations
  - Users' next action prediction
  - Users' intention predicting
  - Personalized search result page
  - ...



# Modeling User Behavior: What?

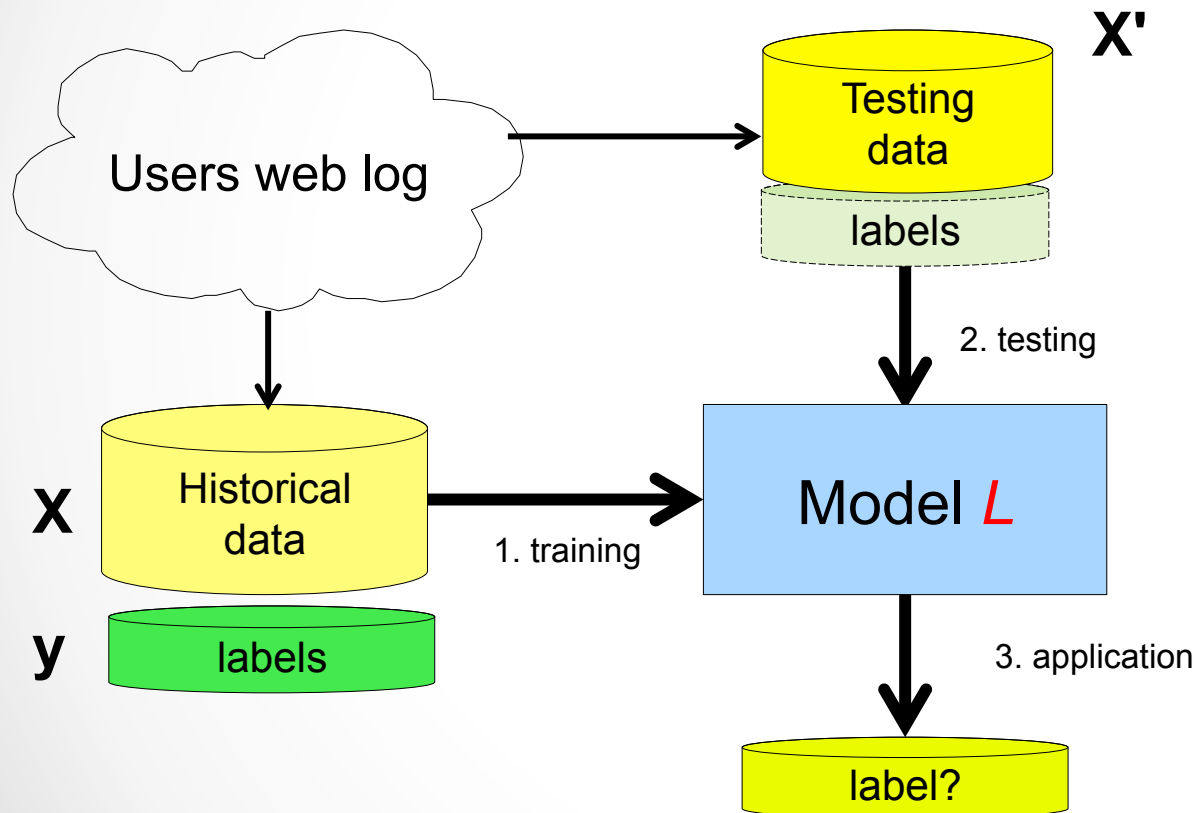
- Predicting Users Next Action
  - Click prediction on display advertising
  - Drop out prediction
  - User Trail prediction
- Predicting Information Needs
  - Navigational vs. explorative vs. purchase
  - Changes in user intent
  - Personalization based on context
  - Personalization based on changed context

# Modeling User Behavior: Why?

- Understanding How Satisfied are Users
  - redesign website
  - diversified search
  - search recommendations
- To better use advertisement budget
  - When serve ads?
  - What type of ads to serve?
  - brand awareness CPM or convergence CPC
- To `manipulate' user – is it worth giving a promotion?
  - personalize with intent of converging to a desired action
  - personalized suggestions based on user context

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# User Intent Modeling: How?



**Training:**

$$y = L(X)$$

**Application:**

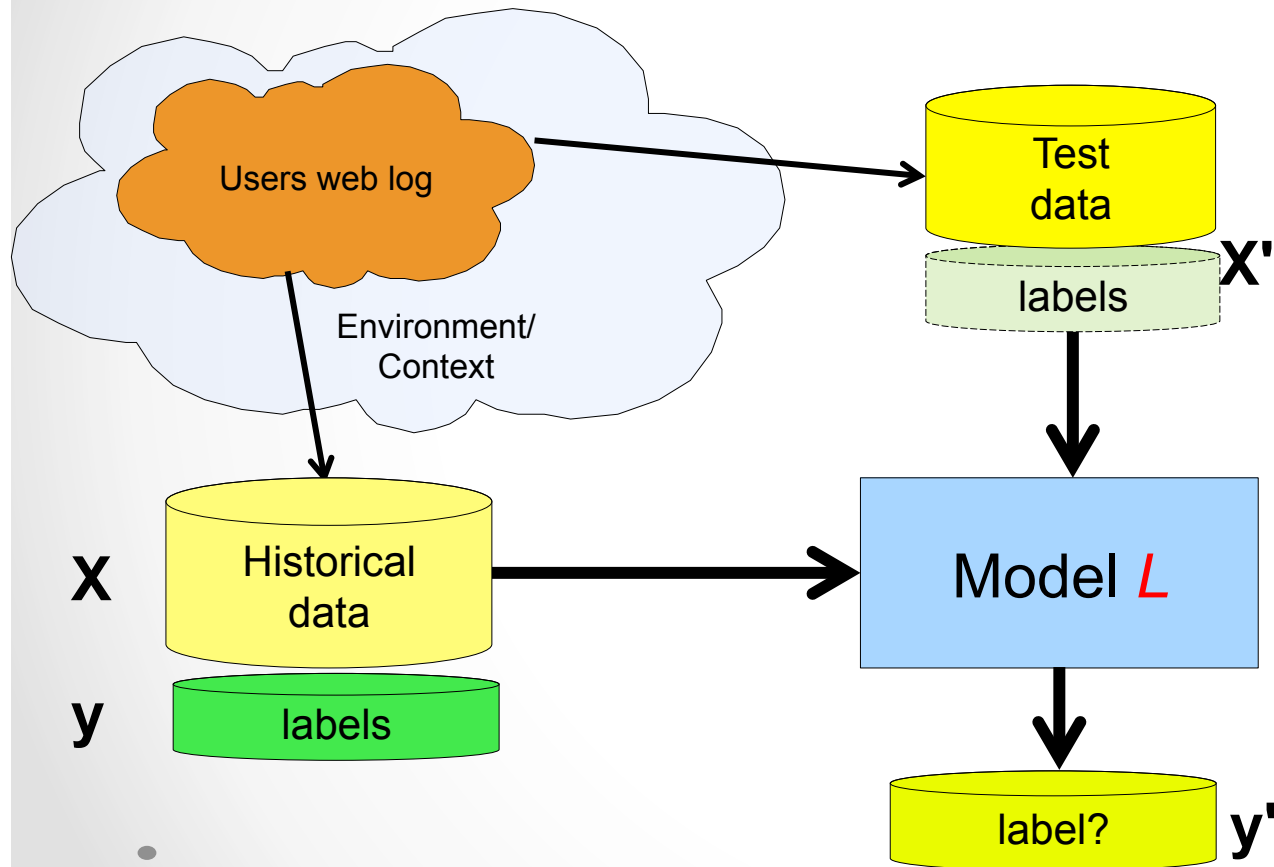
use  $L$  for an unseen data

$$y' = L(X')$$

**Formulations:**

- ① Classification
- ② Regression
- ③ Clustering
- ④ Scoring

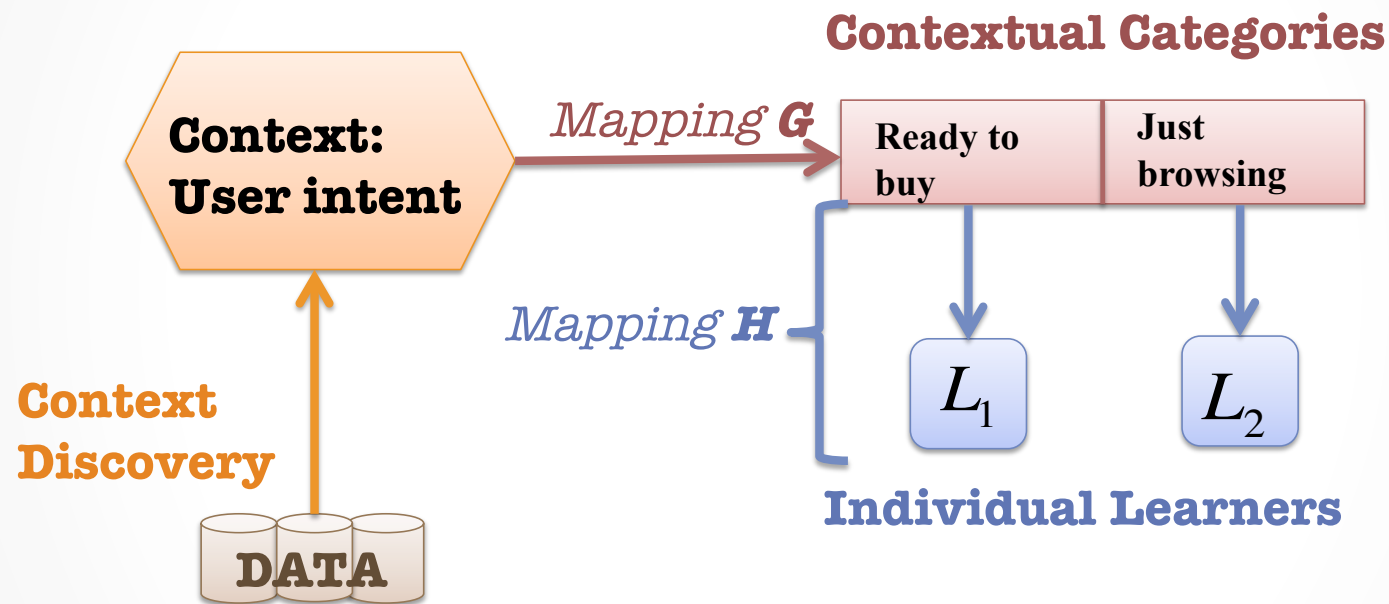
# Context-Awareness in Web Predictive Analytics



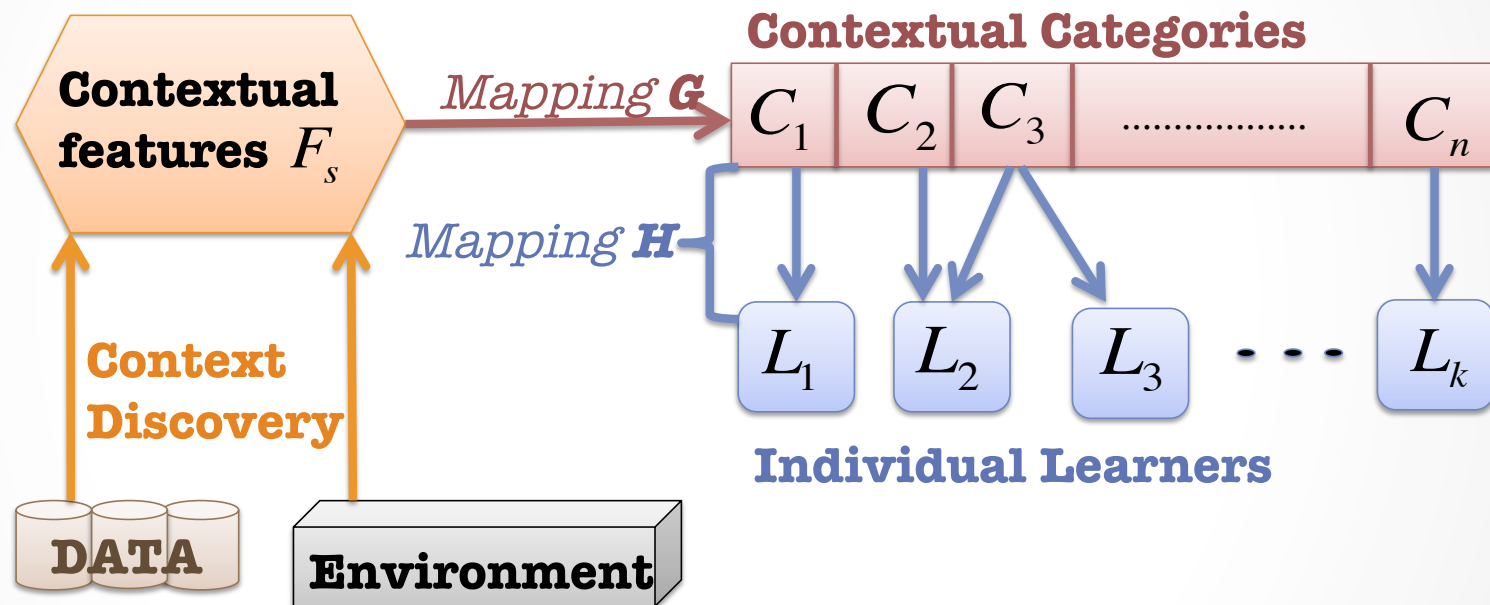
## Strategies:

- ① ?
- ② ?
- ③ ?
- ④ ?

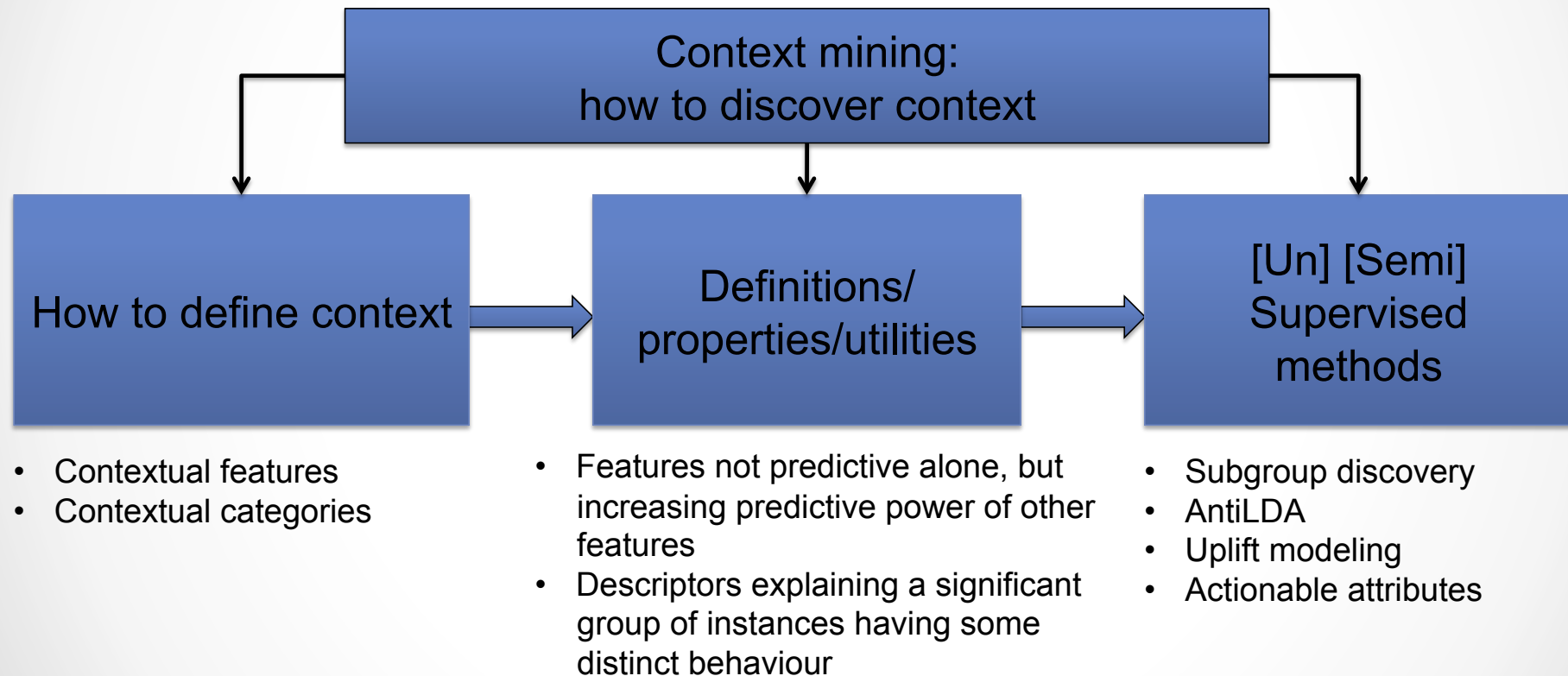
# Defining Useful Context



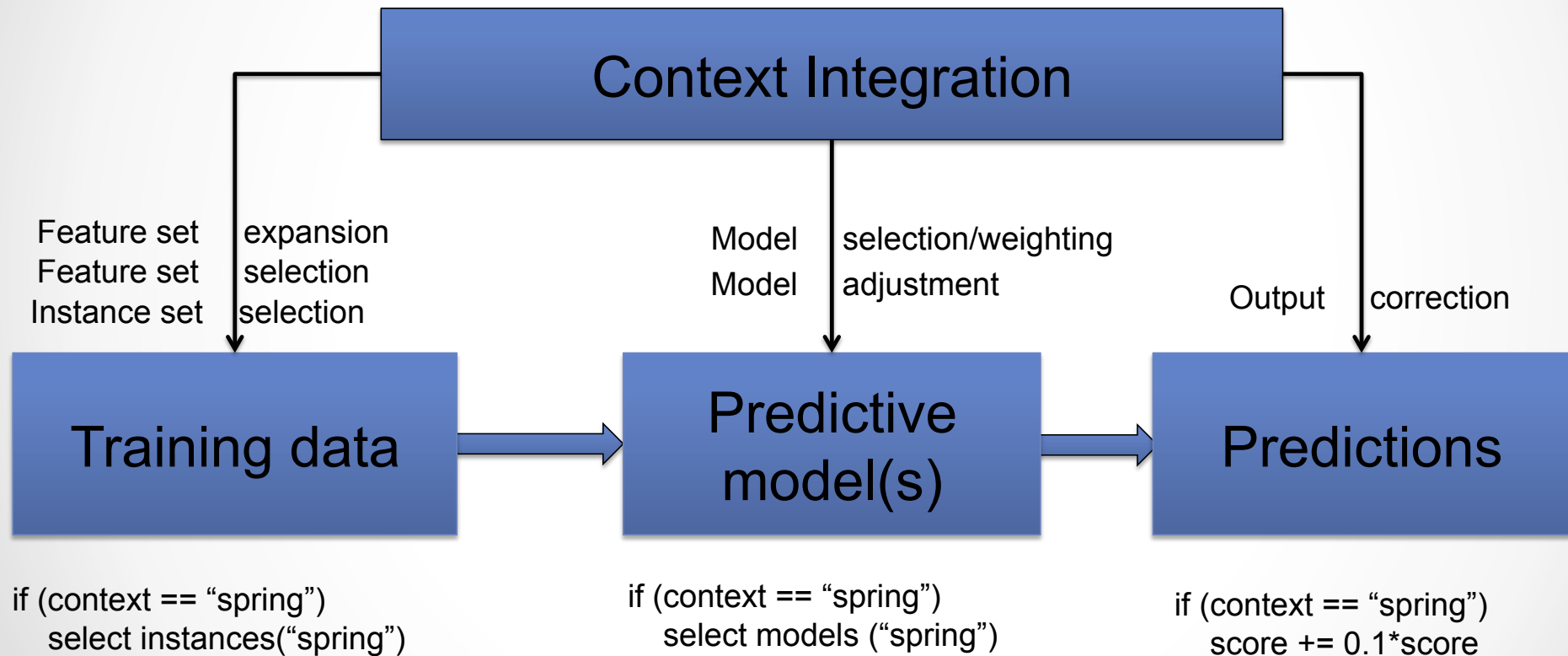
# Defining Useful Context



# Strategies for Context Discovery

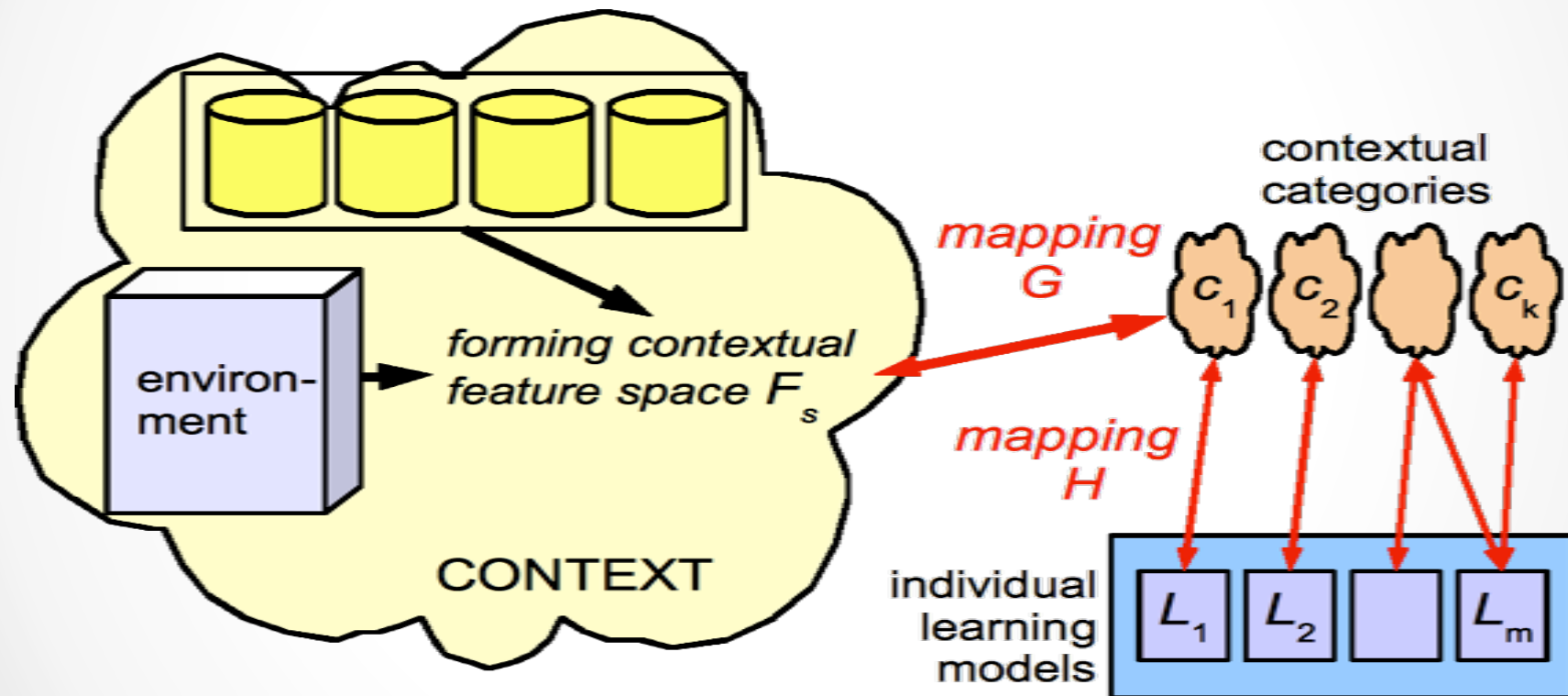


# Strategies for Context Integration

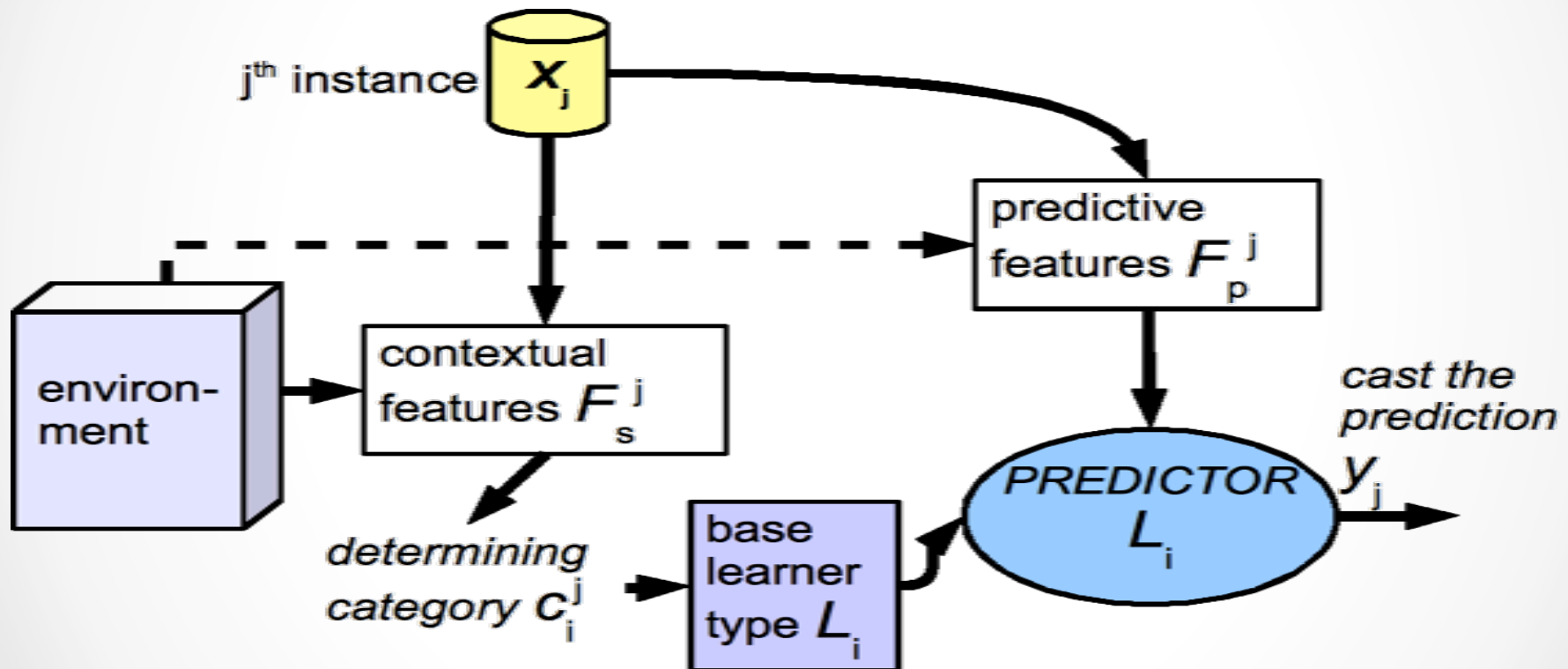




# Learning Classifiers and Contexts

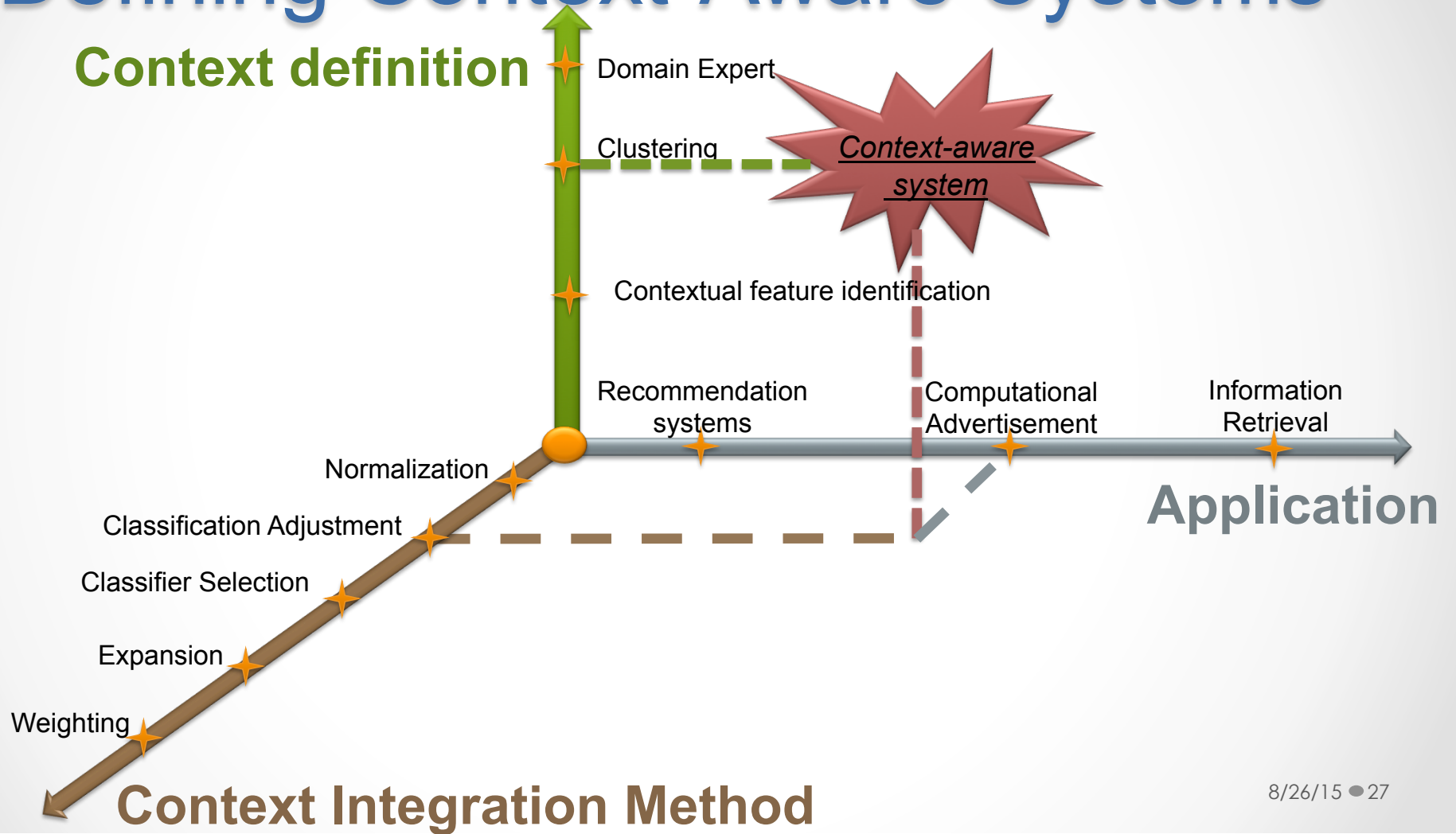


# Context-Aware Prediction



# Defining Context-Aware Systems

## Context definition



# Booking.com

Booking.com



\$ (CLP)



Recently Seen

My Lists



1

Sign in

Manage booking



[Find Deals](#) [Explore Destinations](#) [Homes and Apartments](#) [Booking.com for Business](#) [Book Faster with Our Apps](#)

## Find the Best Deals

713,000+ hotels, apartments, villas and more...

Valparaíso

Check-in Date



Day

Month

Check-out Date



Day

Month

I don't have specific dates yet

Traveling for:  Work  Leisure



Guests 2 adults, 0 children

Search



Subscribe for a 10% discount

Unlock Member Deals and customized inspiration



**FREE cancellation on most rooms!**

Instant confirmation when you reserve

Just Booked

Still planning a trip to this destination?

## Valparaíso



156 properties

[Find somewhere to stay in Valparaíso »](#)

Try San Pedro de Atacama for your next trip

## San Pedro de Atacama



117 properties

# Booking.com

- World largest online travel agent
- > 220 countries
- > 81.000 destinations
- > 710.000 bookable hotels worldwide
- > 30.000.000 unique users
- >> 100.000 unique visitors per day

# Destination Finder

Try adding countries, regions, continents or specific travel interests

Check-in Date    Check-out Date    Guests    [Search](#)

✓ FREE cancellation on most rooms!

Show me: Destinations

[View map](#)

✓ Top reasons to visit: **food, shopping, and culture**



**Buenos Aires**  
Capital of Argentina

✓ Top reasons to visit: **shopping, food, and great for wine**




**Santiago**  
Capital of Chile

✓ Top reasons to visit: **museums, shopping, and sightseeing**



**Paris**  
Capital of France

✓ Top reasons to visit: **beach, food, and shopping**



Less than 1 hour away

✓ Top reasons to visit: **museums, culture, and shopping**



✓ Top reasons to visit: **shopping, museums, and sightseeing**



# Destination Finder

The screenshot displays a web application for finding travel destinations. At the top, a search bar contains the text "wi". Below the search bar is a vertical list of categories, each with an icon and a count of destinations:

- Great for Wine: 1905 destinations
- Wild Swimming: 1085 destinations
- Wildlife: 612 destinations
- Swimming Pools: 484 destinations
- Winter sports: 300 destinations
- Shopping for wine: 216 destinations
- Windsurfing: 120 destinations
- Walking with Kids: 88 destinations

Below the categories, there are three destination cards:

- Buenos Aires**: Capital of Argentina. Includes an airplane icon.
- Santiago**: Capital of Chile. Includes an airplane icon.
- Paris**: Capital of France. Includes an airplane icon.

Each destination card features a "View map" button and a list of top reasons to visit, marked with a green checkmark:

- Buenos Aires**: Top reasons to visit: beach, food, and shopping. Includes a "Less than 1 hour away" badge with a car icon.
- Santiago**: Top reasons to visit: museums, culture, and shopping.
- Paris**: Top reasons to visit: shopping, museums, and sightseeing.

At the top right, there is a search bar with a "Search" button. Below it, a "View map" button is visible. The interface uses a clean, modern design with a light blue and white color palette and yellow accents.

# Destination Finder

Great for Wine Food Add more

Check-in Date Check-out Date Guests [Search](#)

FREE cancellation on most rooms!

Sort by: Relevance Show me: Destinations

[View map](#)

Best places in the world for "Great for Wine" and "Food" – based on traveler recommendations

4555 recommendations for "Food" and 1040 for "Great for Wine"

**Buenos Aires**  
Capital of Argentina

16533 recommendations for "Food" and 2665 for "Great for Wine"

**Paris** Capital of France

22848 recommendations for "Food" and 2254 for "Great for Wine"

**Rome** Capital of Italy

16298 recommendations for "Food" and 1140 for "Great for Wine"

**US\$129**  
Double Room

12045 recommendations for "Food" and 151 for "Great for Wine"



# How Do We Get Endorsements?

- Only users who stayed at a hotel in a destination can endorse it
- Free text endorsements since 2013
- Since 2014 free text endorsements standardized to 256 canonical tags
- Used NLP techniques to extract the canonical base

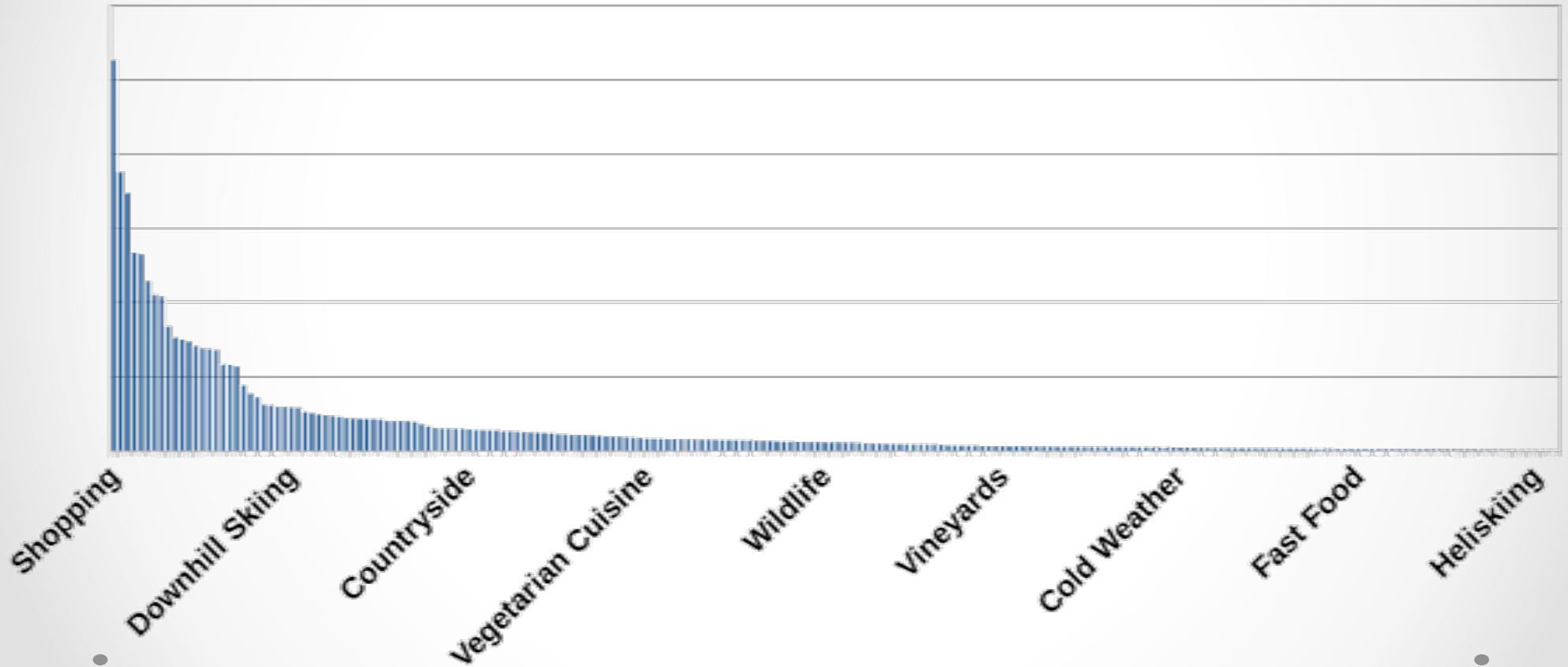
## **More Numbers:**

- > 13.000.000 total unique endorsements
- > 60.000 destinations

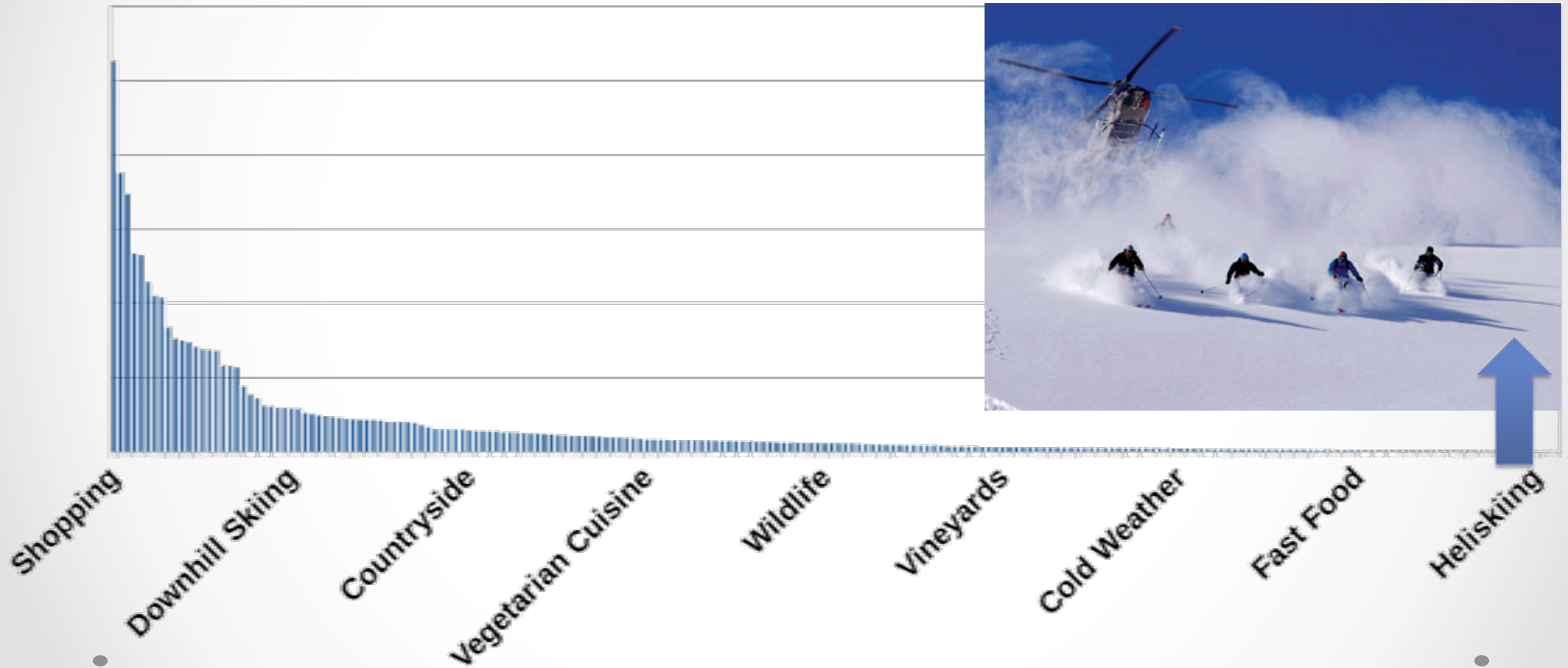
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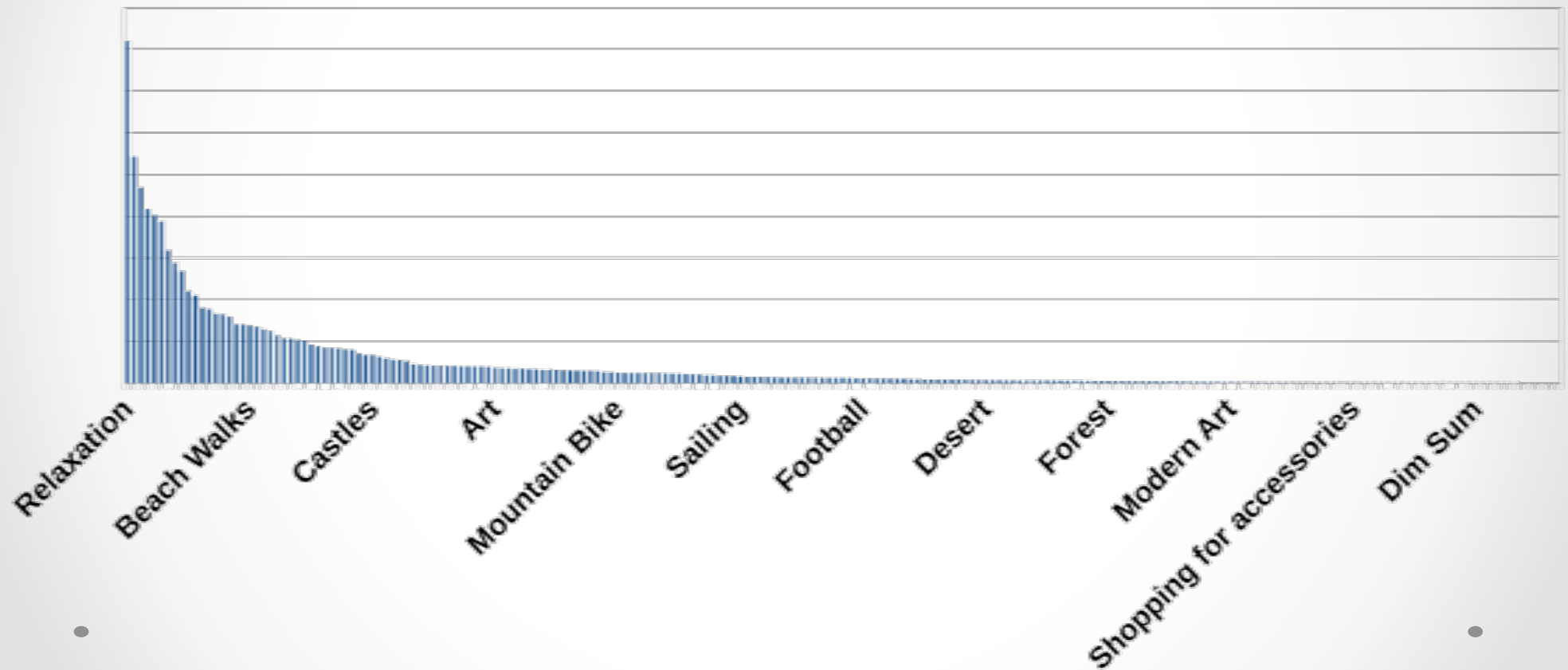
# Endorsement Histogram



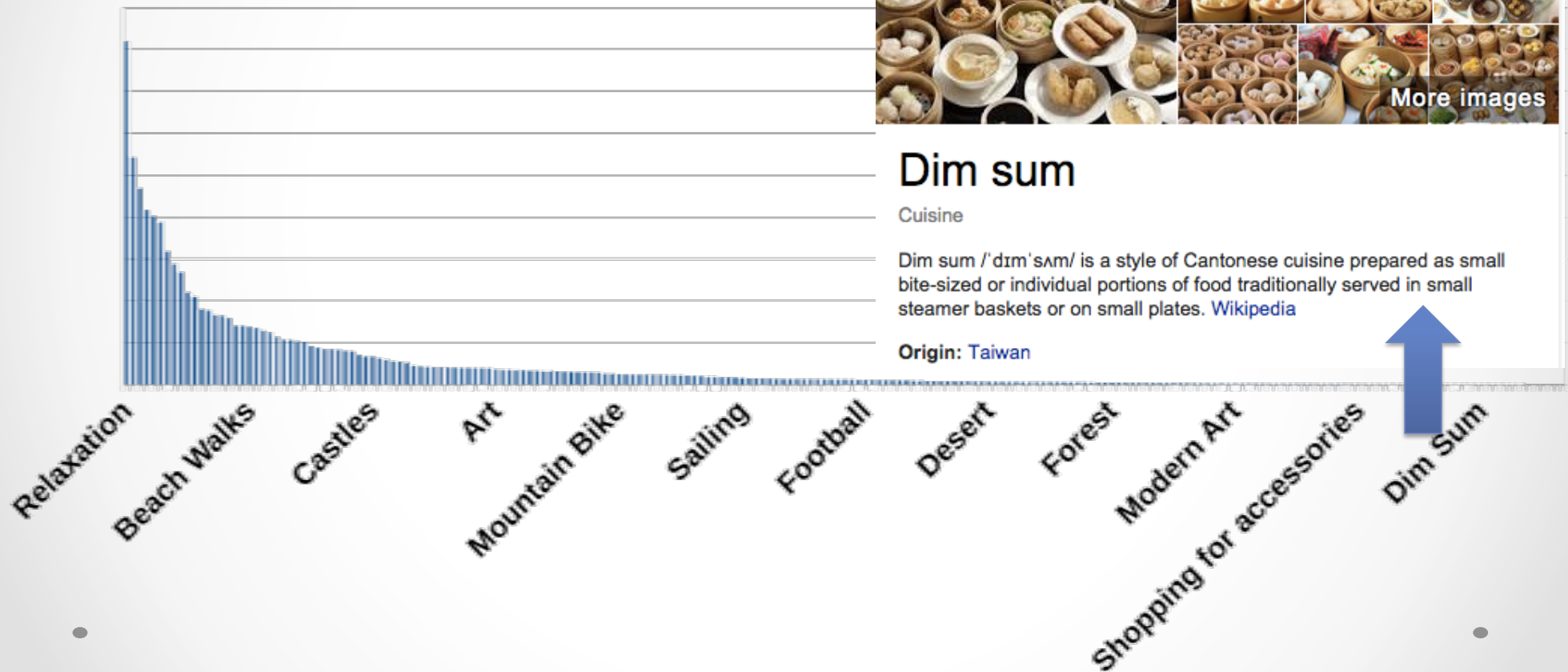
# Endorsement Histogram



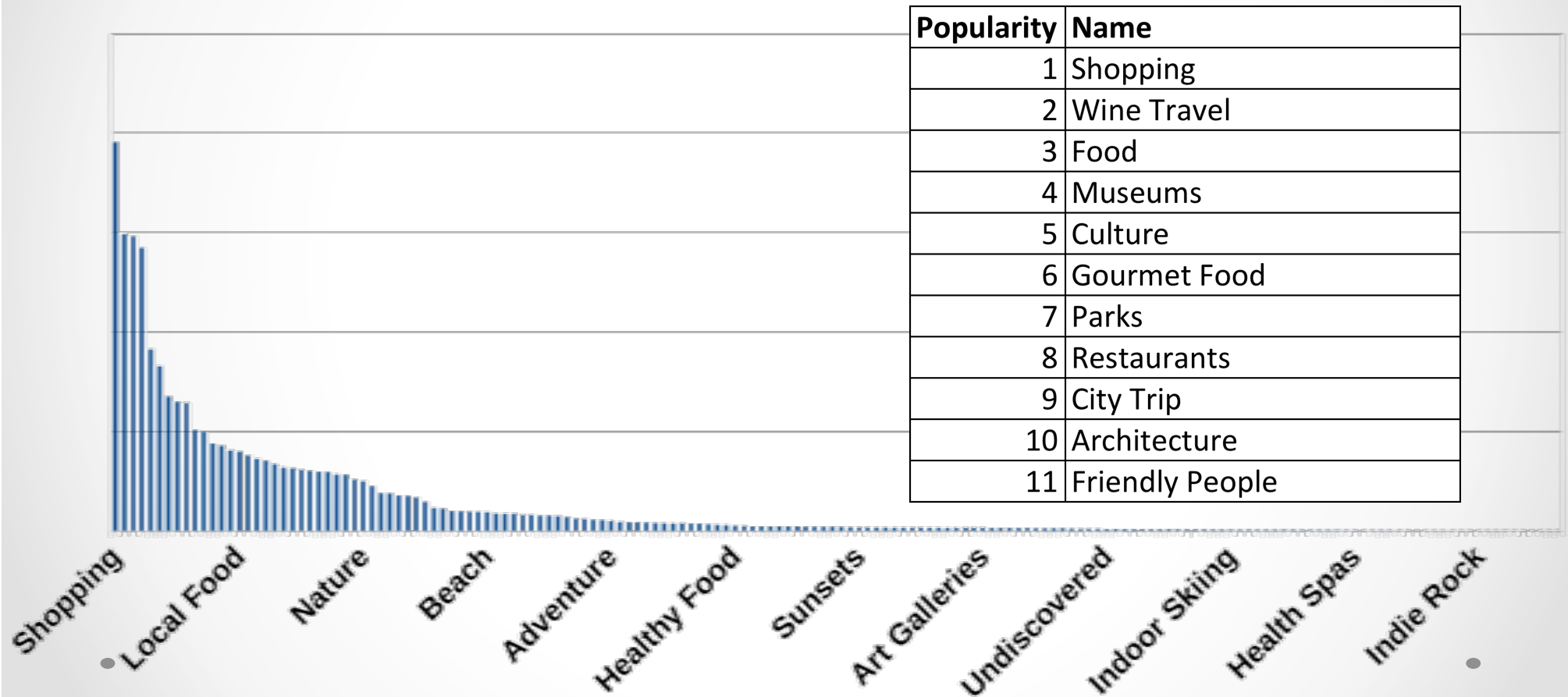
# Endorsement-Destination Histogram



# Endorsement-Destination Histogram



# Endorsements for Santiago



# Destination Finder

Booking.com

Not sure where to go?  
Add your interests and let us do the rest

Beach Keep adding more

**Problem:**  
How to Optimize ranking of recommended destinations?

Nice, France

Newquay, United Kingdom

Barcelona, Spain

3165 guests have endorsed this place for "Beach"

£45 Single Room

1183 guests have endorsed this place for "Beach"

Malaga, Spain

Marbella, Spain

Booking.com

# Problem Setup

- Challenge:
  - Recommender or Information Retrieval System?
- **Information Retrieval:**
  - Users have information need which is expressed as a query
  - System has to satisfy this information needs
- **Recommender:**
  - System predicts what users might be interested

We have both:  
1) Users search for activities  
2) Users don't know where they want to go



# Why is It Hard?

## Problem Characteristics:

- **S** - Sparsity: new or rare **users/destinations**
- **V** - Volatility: **users' interests/endorsements of destinations** change over time
- **I** - Identity: a failure to match data from the same **users**
- **P** - Personas: **users** have different interests at different, possibly closely points in time

**Continuous Cold Start Problem!**



# Ranking Destinations for 'Beach'

- Keep it simple!!! We care about performance!
- Naïve Bayes:

$$P(\text{Miami, Beach}) = P(\text{Miami}) * P(\text{Miami} | \text{Beach})$$

$$P(\text{Miami} | \text{Beach}) = \frac{\# \text{ 'Beach' endorsements for Miami}}{\# \text{ 'Beach' endorsements}}$$

# What and How to Compare?

- Booking.com Baseline
- Random
- Most Popular Destination
- Naïve Bayes

Objection:  
Increase User Engagement  
(Clickers per SERP)



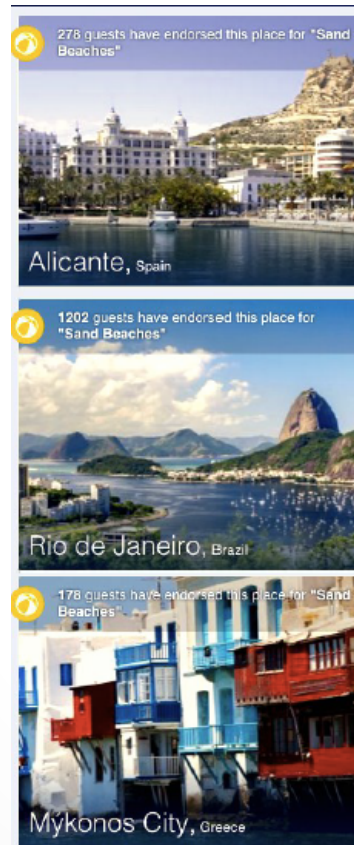
# A/B Testing Setup

- 50/50 traffic split
- Experiments run for  $N$  full weeks according to desired power and significance levels
- Hypothesis tests are performed according to targeted metrics (G-test in our case)

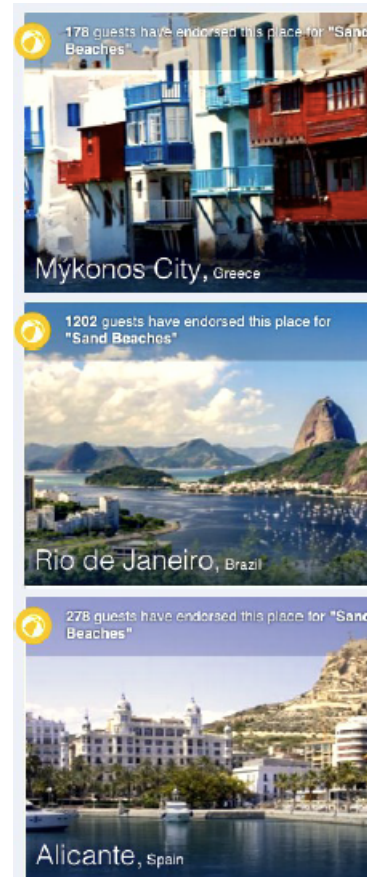


# A/B Testing

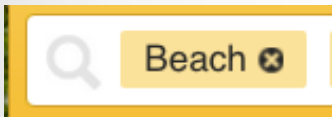
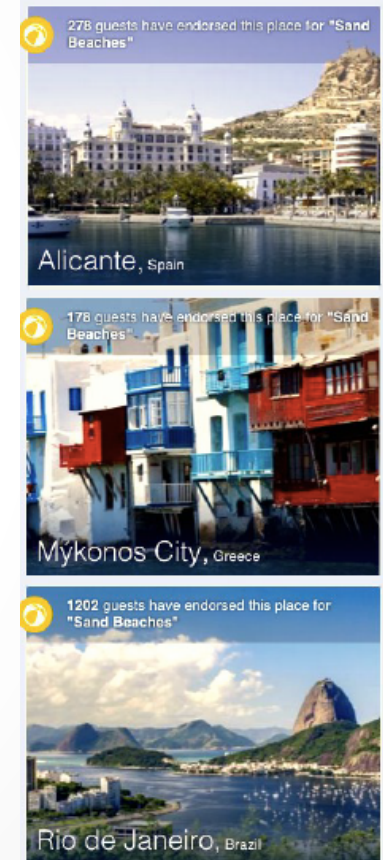
Version A



Version B



Version C



# A/B Testing

<u>Ranker</u>	<u># Users</u>	<u>Engagement</u>
Baseline	9928	<b>Amount of clickers</b>
Random	10079	
Popularity	9838	
Naïve Bayes	9895	

# A/B Testing

<u>Ranker</u>	<u># Users</u>	<u>Engagement</u>
Baseline	9928	25.61% +/- 0.72%
Random	10079	24.46% +/- 0.71%
Popularity	9838	25.50% +/- 0.73%
Naïve Bayes	9895	26.73% +/- 0.73%

# A/B Testing

<u>Ranker</u>	<u># Users</u>	<u>Engagement</u>
Baseline	9928	25.61% +/- 0.72%
Random	10079	24.46% +/- 0.71%
Popularity	9838	25.50% +/- 0.73%
Naïve Bayes	9895	26.73% +/- 0.73%



**Back to Question Why Is It Hard**

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# Conclusion and Future Work

- Interesting application
- Surprise 1: Keep simple baseline in production system
- Surprise 2: Random performed not bad => effect serendipity

For the Future:

- Improve the ranking by taking contexts into account

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# Thank you!

- **C**ontext identification and integration it into prediction models
- **A**ccurately predicting users' desired actions and understanding behavioral patterns of users in various web-applications
- **P**ersonalization and adaptation to diverse customer needs and preferences
- **A**ccounting for the practical needs within the considered application areas

