Automating travel booking requests

David S. Batista - November 2021

Team

Sebastian Mika
VP Data

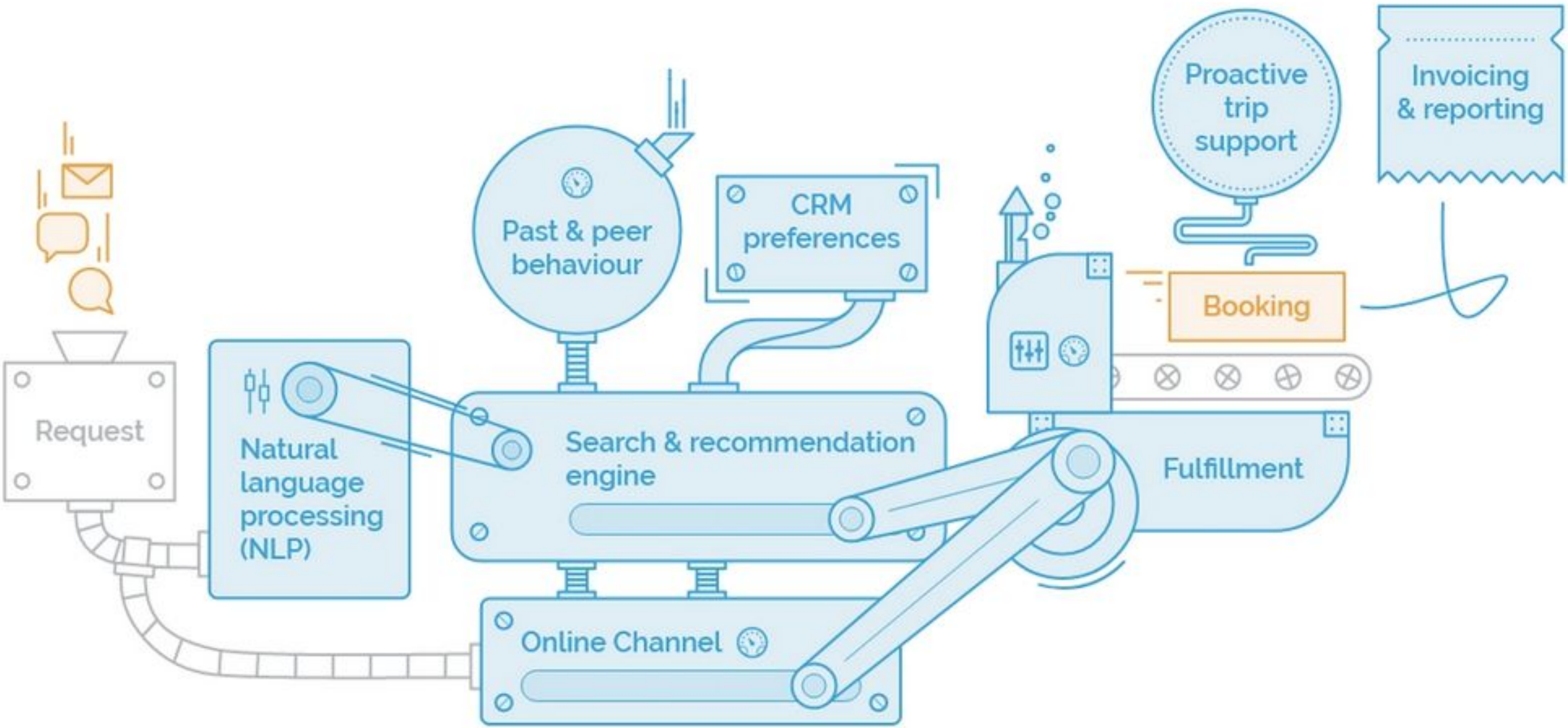
David Batista
Lead NLP Engineer

Sandip Mukherjee
ML Engineer

Scott Martens
Senior ML Engineer

+ team of 4 remote worker annotators

What is the Automation?



Hello Comtravo,

I need a train from Berlin to Munich, next Thursday around 9:00
and back to Berlin on Friday at 18:00.

Best Regard,
Mr Muster from Muster Inc.

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~~Hello Comtravo,~~

I need a train from **Berlin** to **Munich**, next **Thursday around 9:00** and back to **Berlin** on **Friday at 18:00**.

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Booking: 94.3% **Not a Booking: 5,7%**

Trip 1

origin: Berlin
destination: Munich
dpt_time: Thursday around 9:00

Trip 2

origin: Munich
destination: Berlin
dpt_time: Friday at 18:00

Trip 1

origin: 08011155
destination: 08000261
dpt_time: Thursday around 9:00

Trip 2

origin: 08000261
destination: 08011155
dpt_time: Friday at 18:00

Trip 1

origin: 08011155
destination: 08000261
dpt_time: 2021-12-02T09:00

Trip 2

origin: 08000261
destination: 08011155
dpt_time: 2021-12-03T18:00

Trip 1

origin: 08011155
destination: 08000261
dpt_time: 2021-12-02T09:00

Trip 2

origin: 08000261
destination: 08011155
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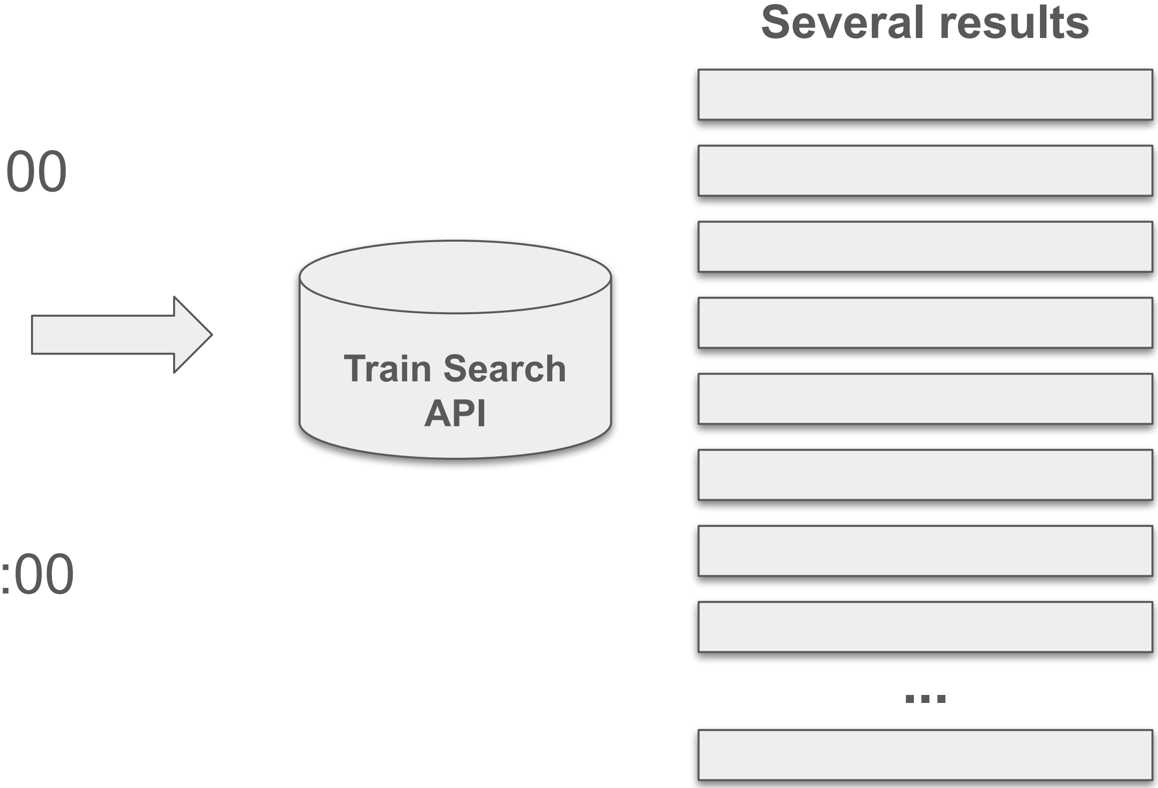
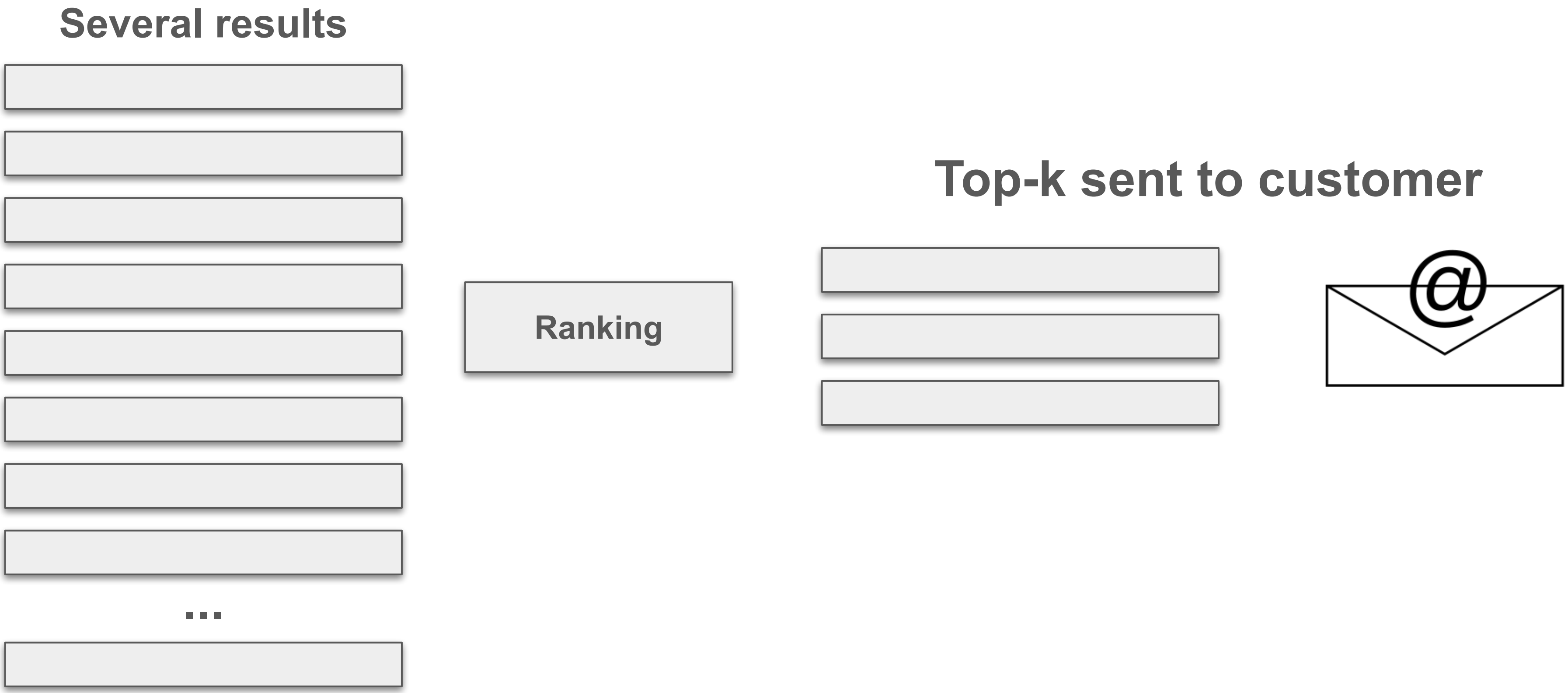




Several results

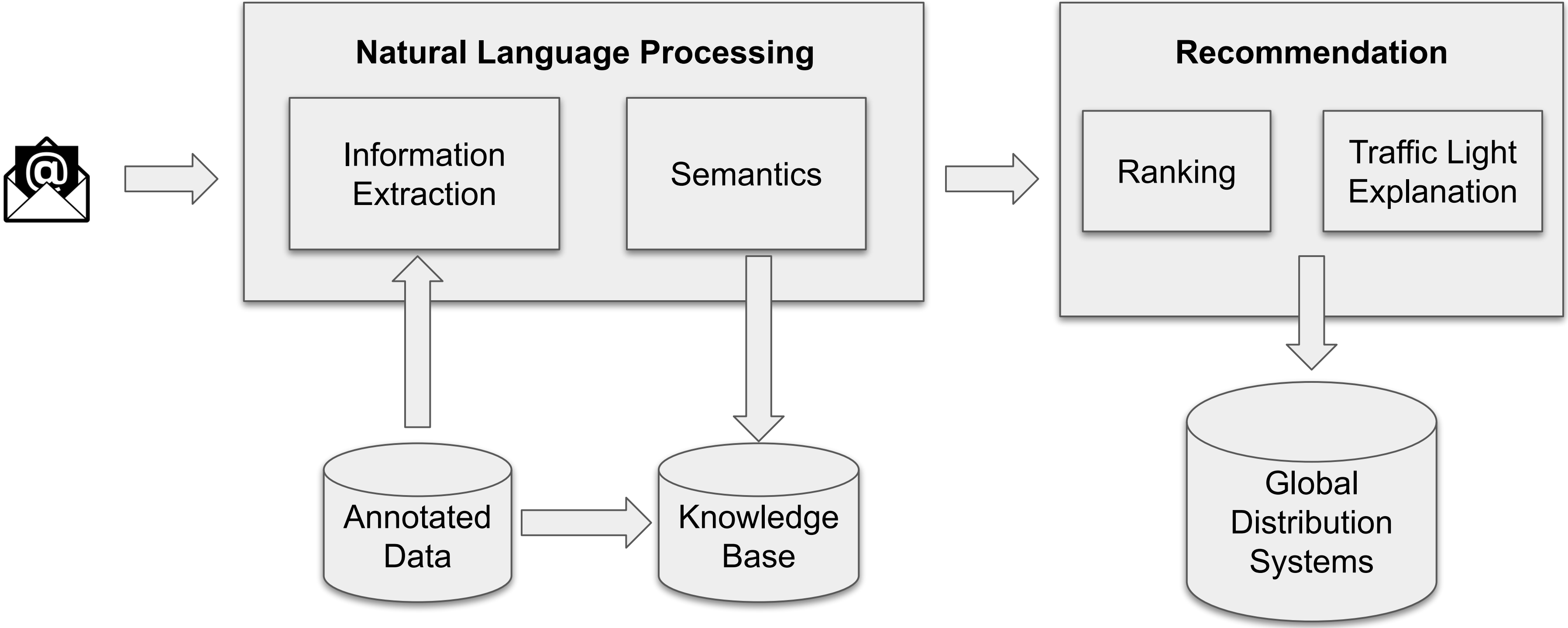
...

Ranking

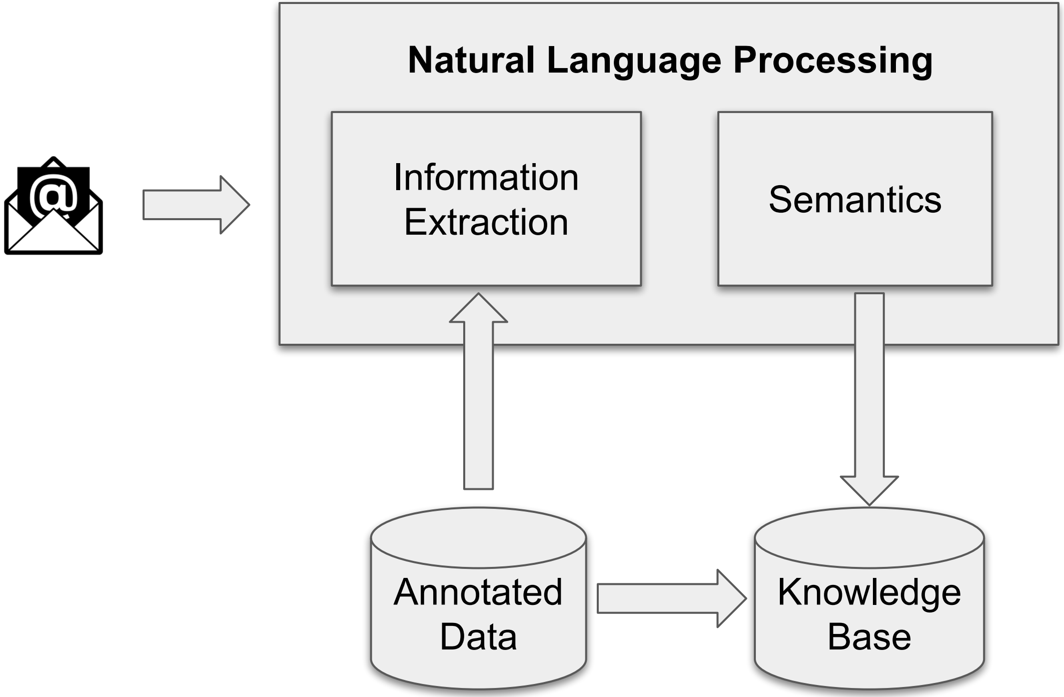
Top-k sent to customer

How does this all comes together?

Overview


Natural Language Processing
Information Extraction
Semantics
Recommendation
Ranking
Traffic Light Explanation
Annotated Data
Knowledge Base
Global Distribution Systems

Overview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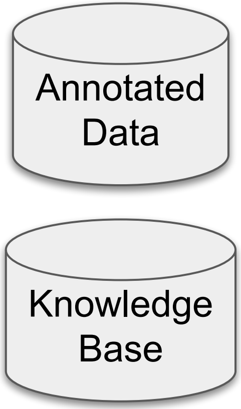
Annotated Data: surface strings

Annotated Data

- Named-Entities
  - Localities: airports, train stations, cities, full addresses
  - Temporal Expression: check-in/out, departure, time intervals
  - Airlines: *TAP, Lufthansa, EW*
  - Flight Numbers: “*LH123”, TP31”*
  - Train Types and Numbers:: “*ICE123”*
  - Hotel Names: *“Ibis”, “Motel One”, etc.*
  - Hotel Category/Stars: “*only 3 or 4 stars hotel please”*
  - Prices: “*between 80 and 120 EUR per night”*

- 40+ Named-Entity types

Annotated Data: semantics



Add semantics to the named-entities:

- time expressions → date format YY/MM/DD
- *‘Berlin’* - BER (airport), 8011160 (train station code), lat/lon
- *‘Adlon Hotel’* - #1234 (identifiers in hotel providers)

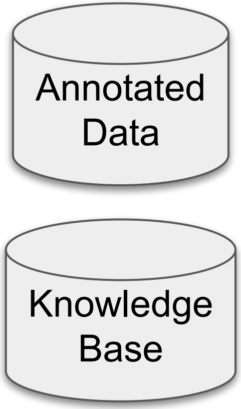
Knowledge Bases:

- Open source data : WikiData, GeoNames, DB Open Data
- Acquired data sets and payed APIs access

Annotators use the KB to “semantify” the named-entities:

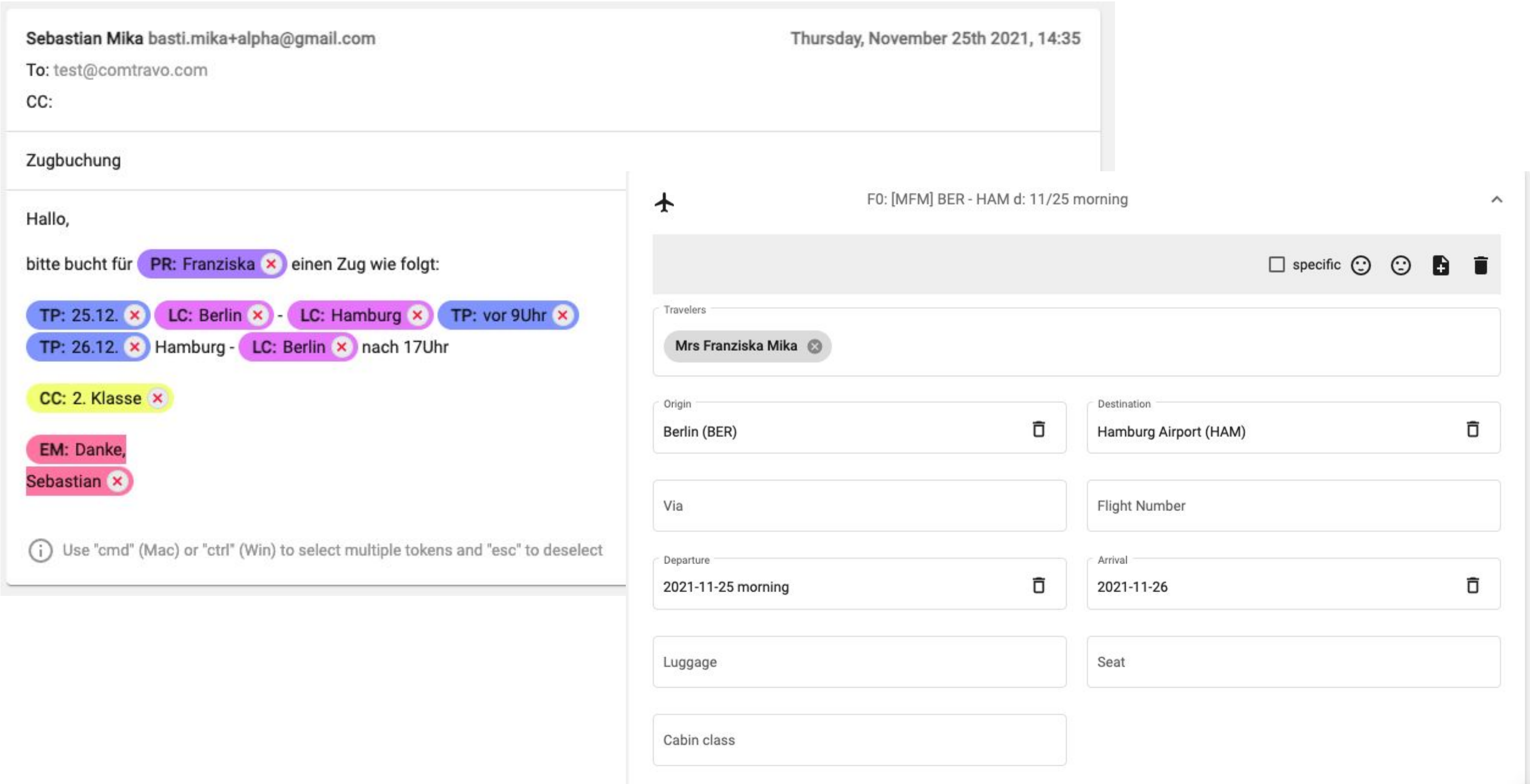
- real-world concepts, identifiers in the Knowledge Base
- geographic coordinates, etc.

Annotated Data: our own tool



Annotated Data

Knowledge Base



Sebastian Mika basti.mika+alpha@gmail.com

Thursday, November 25th 2021, 14:35

To: test@comtravo.com

CC:

Zugbuchung

Hallo,

bitte bucht für PR: Franziska ✕ einen Zug wie folgt:

TP: 25.12. ✕ LC: Berlin ✕ - LC: Hamburg ✕ TP: vor 9Uhr ✕
TP: 26.12. ✕ Hamburg - LC: Berlin ✕ nach 17Uhr

CC: 2. Klasse ✕

EM: Danke,
Sebastian ✕

ⓘ Use "cmd" (Mac) or "ctrl" (Win) to select multiple tokens and "esc" to deselect

F0: [MFM] BER - HAM d: 11/25 morning

□ specific

Travelers: Mrs Franziska Mika

Origin: Berlin (BER)

Destination: Hamburg Airport (HAM)

Via

Flight Number

Departure: 2021-11-25 morning

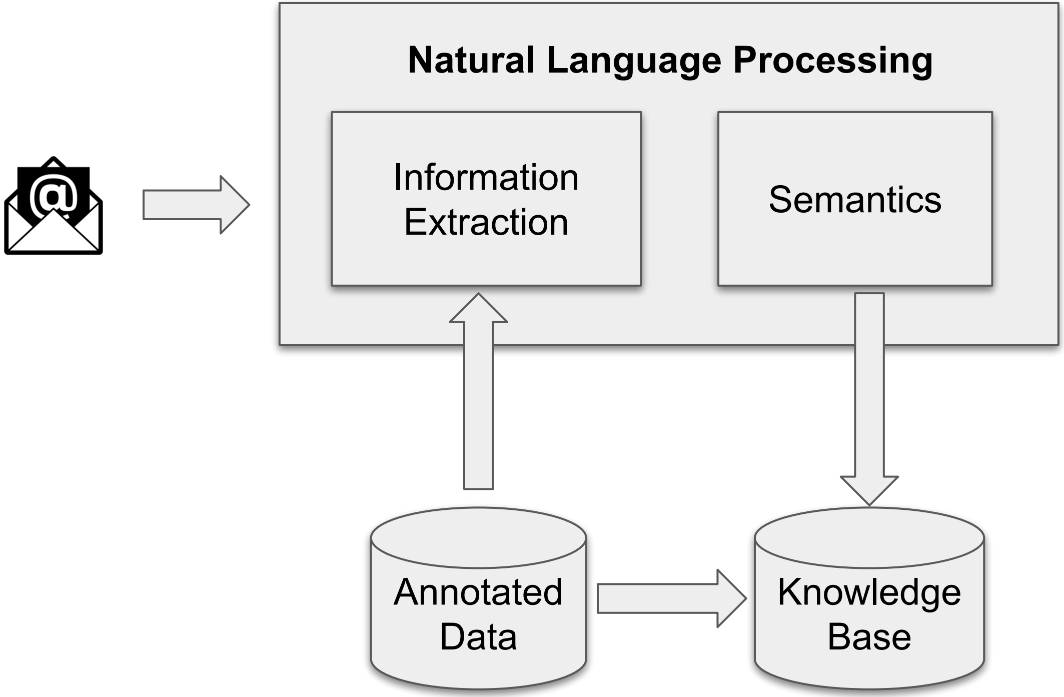
Arrival: 2021-11-26

Luggage

Seat

Cabin class

Overview



Natural Language Processing

Information Extraction

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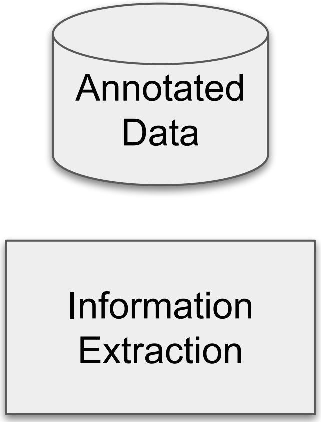
Natural Language Processing - Information Extraction



Annotated Data

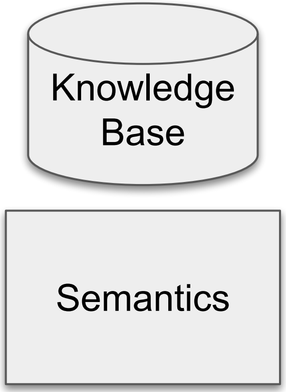
Information Extraction

- **Document level classifier**: is this email a booking ?
    - `DistilBert`

- **Named-Entity recognition**: supervised model + pattern-based rules
    - `BERT: Transformer`
        - Language Model pre-trained model on Wikipedia
        - Fine-tuned on our annotated data

    - Regex based
        - triggered after the model predictions
        - specific entities - low annotated samples
        - important clues in the message we need to get

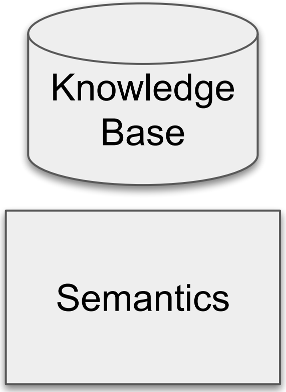
Natural Language Processing - Semantics



- ***‘Berlin’***
  - *BER* - IATA code for the Berlin airport
  - 8011160 - IBNR code for Berlin Central Train station
- ***‘Park Inn’***: associate an identifier from booking.com, HRS, etc.
- **Options**: room type, luggage, rebookable, cancelable

- Cleaning/Adjusting the output of the tagger
- Analyzing relationships between tagged entities
- Querying Knowledge Bases + Reasoning
- Using pre-computed priors from the KB + our internal data

Natural Language Processing - Semantics


Knowledge Base

Semantics

Need a hotel for two nights in ***Frankfurt***

Frankfurt am Main	Hessen	0.93
Frankfurt (Oder)	Brandenburg	0.2
..	..	..

Need a flight to ***New York****,* ***JFK*** *departing from either* ***Düsseldorf*** *or* ***Cologne***

Time Expressions: ct-parse

- https://github.com/comtravo/ctparse
- rules, regular expression, supervised modeling ~ **PCFG**
- Normalization of English and German time expressions

Natural Language Processing - Outcome

Please book me two nights from the 2nd of December to the 4th in the Quality Hotel am Tierpark

check-in	02.12.2021	🟢
check-out	04.12.2021	🟢
location	Tierpark	🟡
hotel	Quality Hotel	🟡

Natural Language Processing - Outcome

I need a train on Wednesday 1st of December from Frankfurt to Hamburg, please first train of the day.

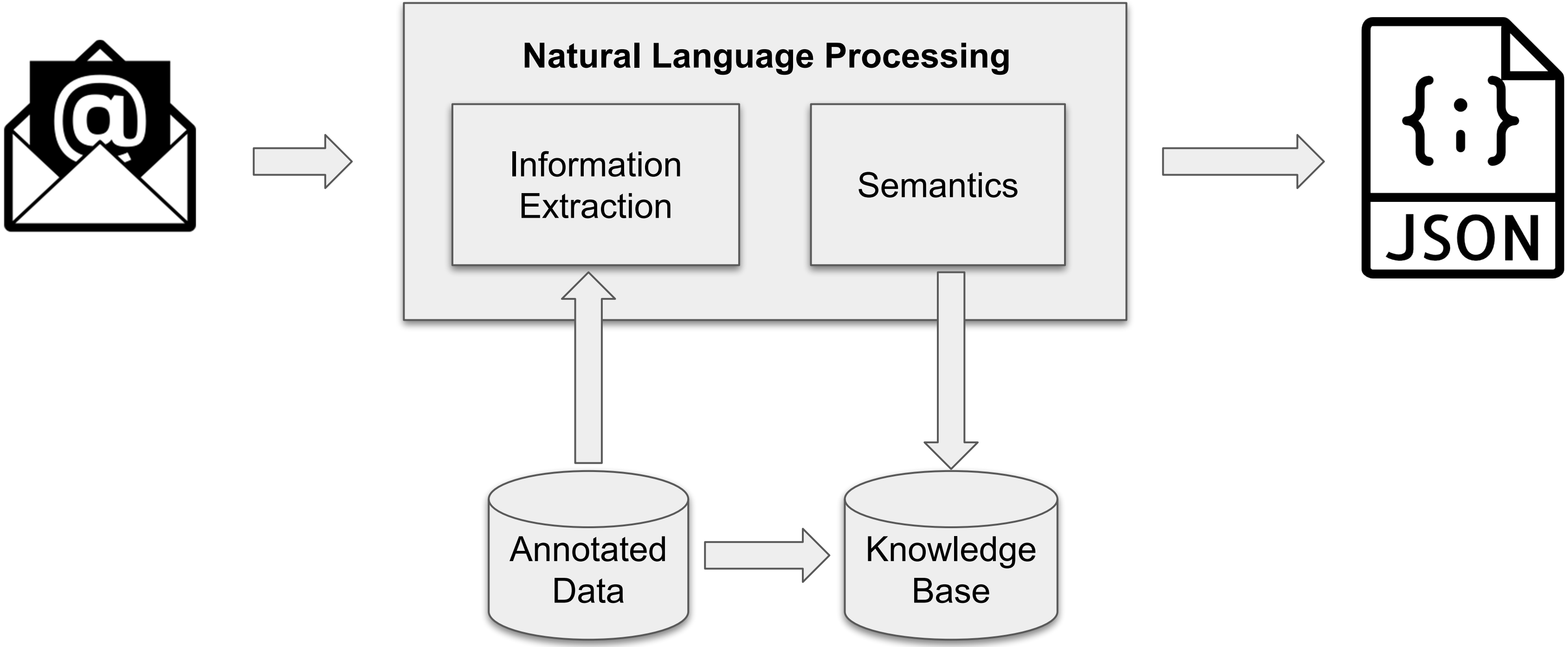
dpt_time	01.12.2021	🟡
origin	800321	🟢
destination	800123	🟢

Natural Language Processing - Outcome

I need a flight on the 11th of December from Berlin to Lisbon.

dpt_time	11.12.2021	🟢
origin	BER	🟢
destination	LIS	🟢

Natural Language Processing



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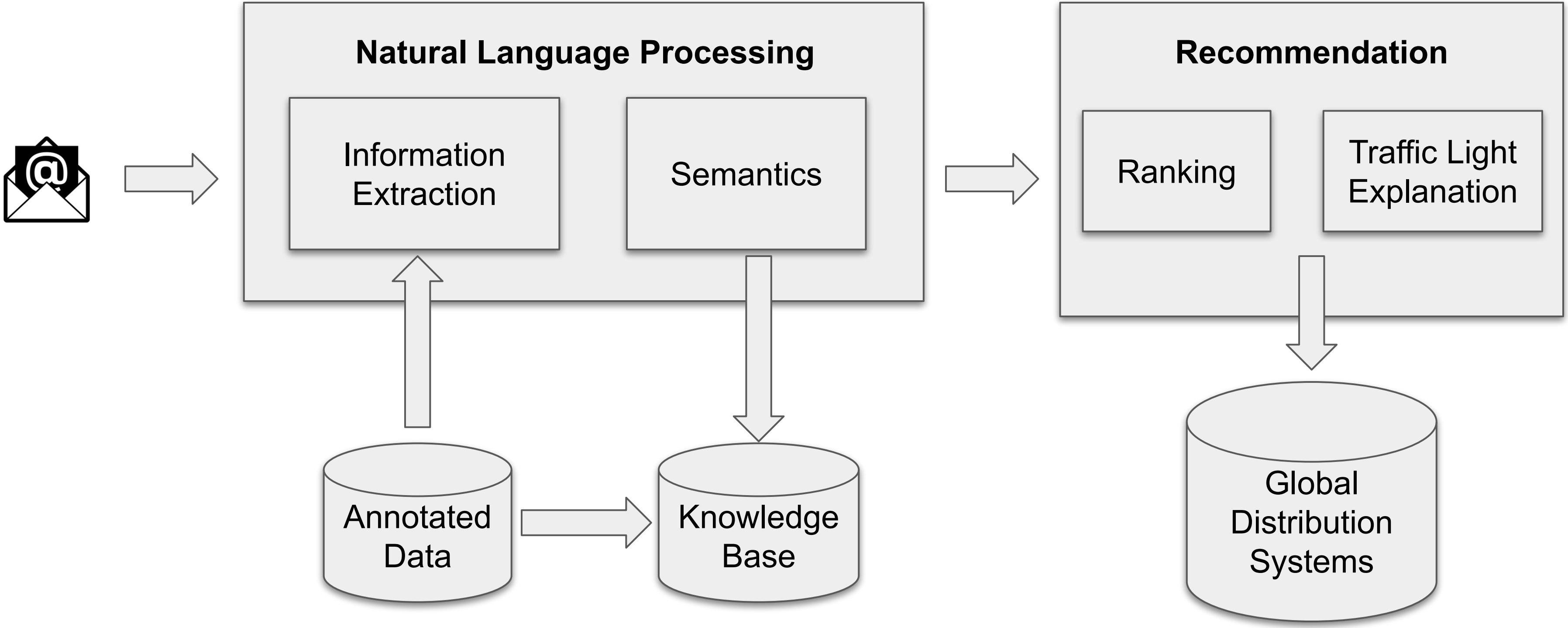
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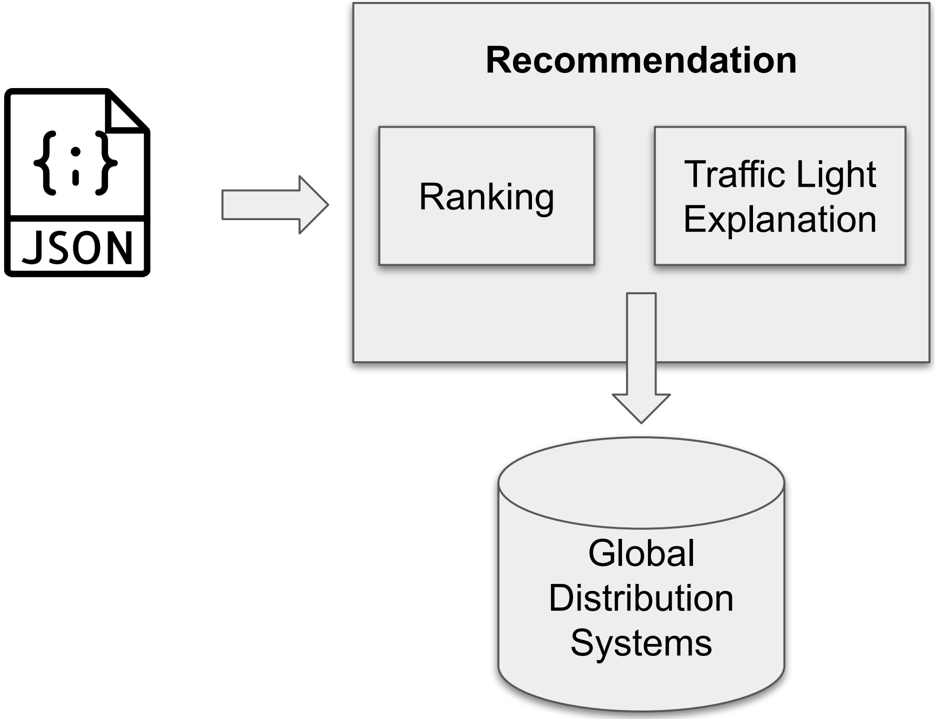
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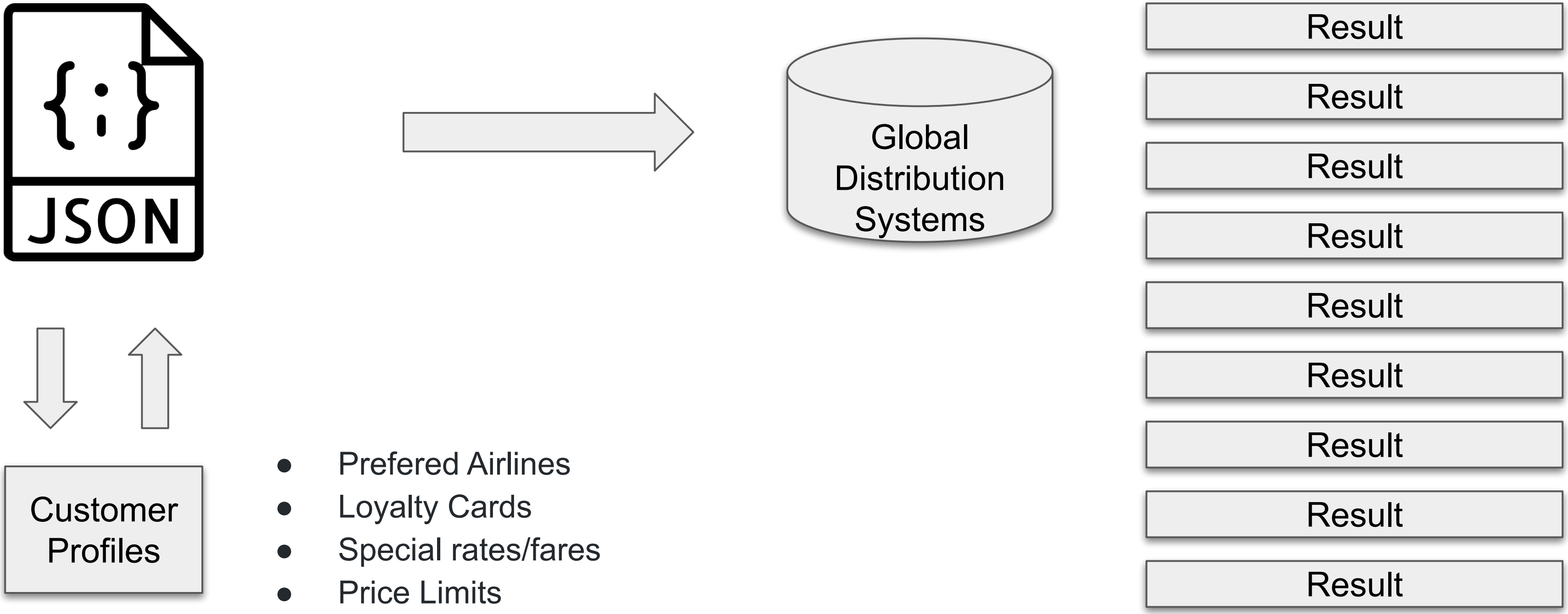
Recommendation - Search



- Prefered Airlines
- Loyalty Cards
- Special rates/fares
- Price Limits

Recommendation - Ranking

From hundreds of results, how to select the best ones ?

Multiple Objectives:

- the cheapests train tickets
- but also for the shortest trip time
- the lowest possible number of changeovers

NOTE: assume that each objective is a quantity we want to minimize

Pareto Efficiency/Optimality: finds solutions in a multi-objective setting

Recommendation - Pareto Efficiency

- No single objective can be further improved without hurting others objectives
- A and B are pareto efficient while C is not
- Pareto-efficient solutions are not unique: pareto frontier

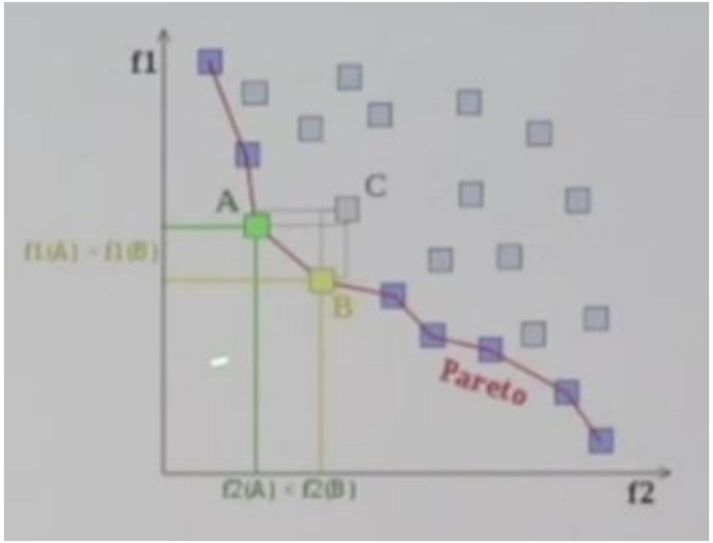
Formally:

Two results, r_i, r_j with *K* objectives $f_1, \cdots, f_k$

$$r_i = (f_1^i, \cdots, f_k^i), r_j = (f_1^j, \cdots, f_k^j)$$

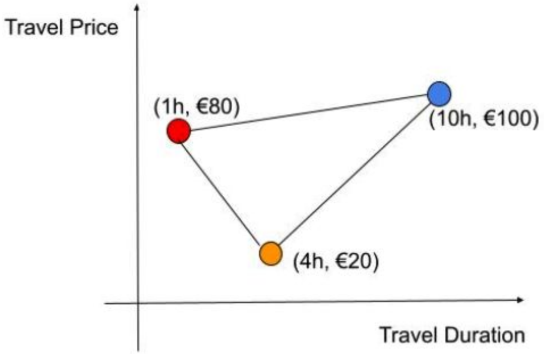
r_i dominates r_j iff $f_1^i \leq f_1^j, \cdots, f_k^i \leq f_k^j$

r_i is Pareto-efficient iff there exists no r_j which dominates r_i



Recommendation - Pareto Efficiency

	Name	Price	Duration
🔴	Train 1	80 euros	1 hour
🟠	Train 2	20 euros	4 hours
🔵	Train 3	100 euros	10 hours



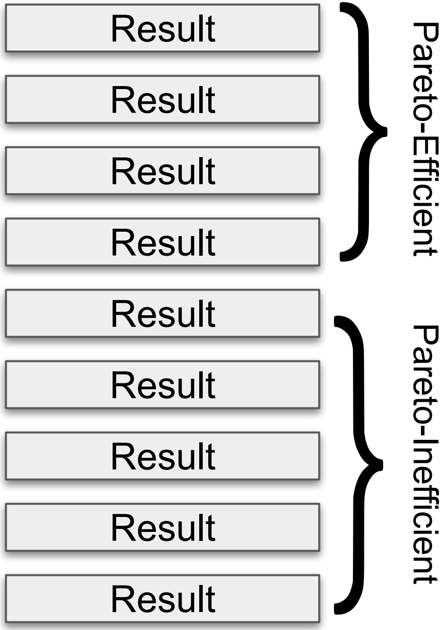
Recommendation - Pareto Ranking - Algorithm

Simple Cull Algorithm

- for every result item X
  a. compare X with every other result item
  b. if there is at least one result item which is better than X
     i. X is marked as **Pareto-Inefficient**
     ii. otherwise X is marked as **Pareto-Efficient**

- Each item will either be **Pareto-Efficient** or **Pareto-Inefficient**

Recommendation - Outcome



- Rank both sets - using a predefined precedence between objectives

- Select top-*k* and inspect them, how good are the selected results?

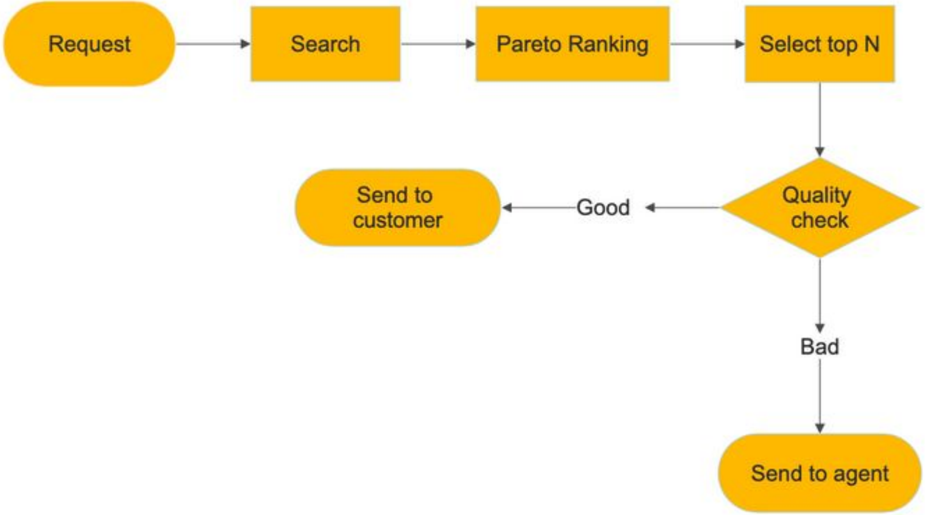
- We relax a bit the constraints to avoid not having any results, e.g:
  - a specific Hotel
  - a flight before 12:00

- Compare each of the top-*k* against the customer requests:
  - 🟢 if all preferences/objectives fulfilled
  - 🟡 otherwise

Recommendation - Outcome

- Combine Outcomes from
  - Natural Language Processing
  - Recommendation

- Depending on this outcomes we either:
  - Email the customer with top-*k* options
  - Shift handling to a travel agent:
    - detailing the reason(s)



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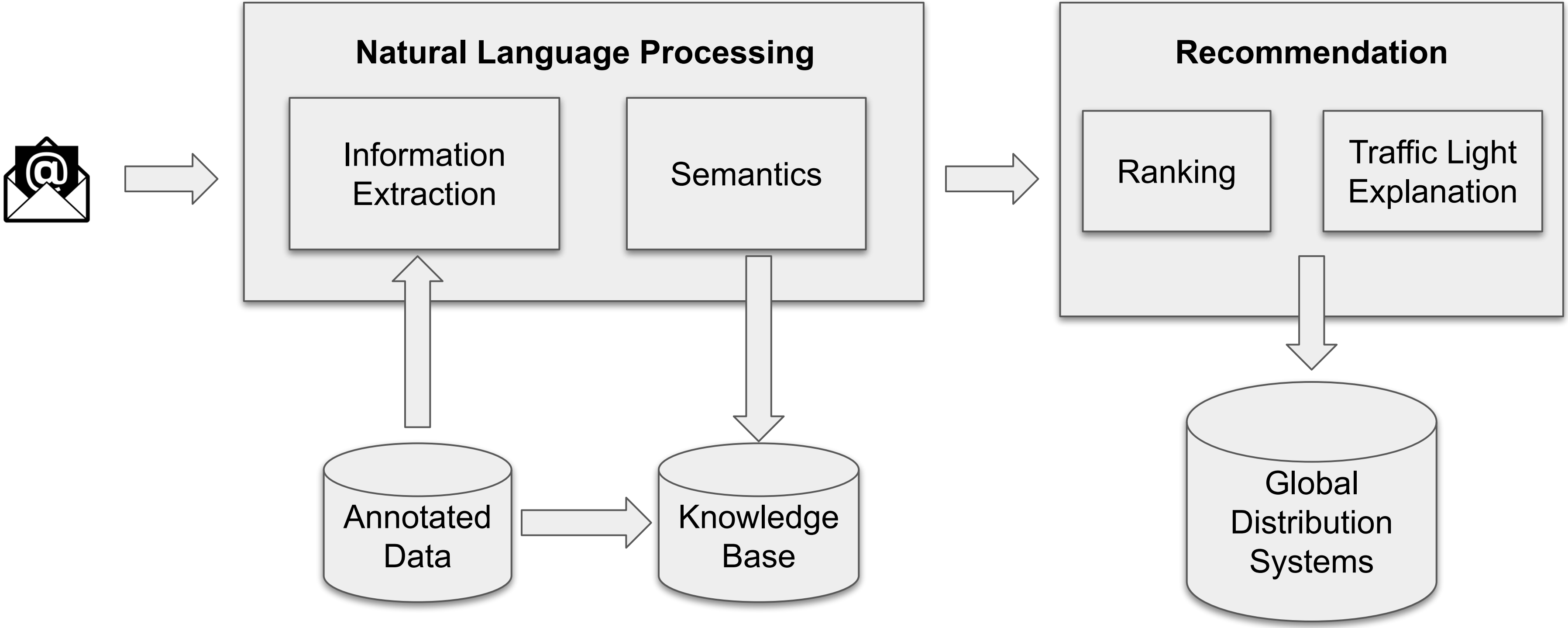

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Lessons learned: best practices

- Annotated data:
  - Training and evaluation of models
  - New annotations every week
  - Periodically run checks, statistical analysis

- Logging:
  - logs each relevant step in the pipeline
  - Events to S3 + ETL runs periodically indexing everything on Elasticsearch
  - input to search APIs and returns results algorithm did

- Error analysis:
  - Have an established process
  - Can be a framework to inspect all the logs referring every booking request