Spelling Correction using Lucene FSTs

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Users mistype their queries

The Task

Goal 1: Spelling robustness - return correct results even if the user mistyped the query

Goal 2: Precision - return as few as possible irrelevant results

Difficulties

- User queries are corrected word by word
- Spelling robustness means more complex search queries and more irrelevant matches
- Include the word the user actually meant
- Include as few as possible additional words in the search query
- Results have to be delivered quickly

Agenda

- **Matching**
- Ranking

Lucene's FuzzyQuery (4.x)

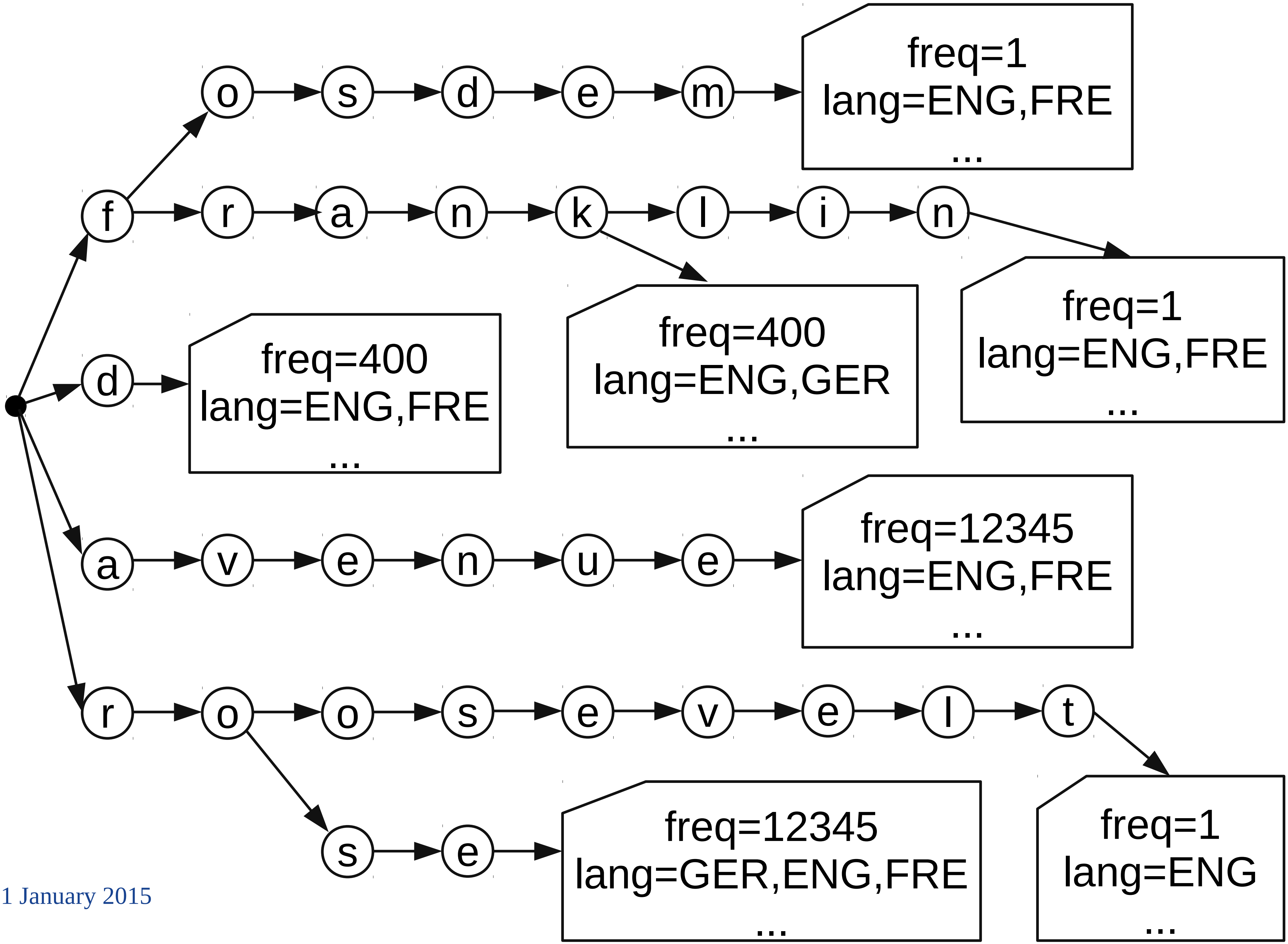
- Enables spelling robustness per term
- Searches for top-n terms per user term
- Requires an indexed field as dictionary
  - Dictionary comes for free
- Ranks terms by Levenshtein Distance

What is the Problem?

- By default 50 candidates per term
  - Slow query execution
  - Inaccurate
- High memory footprint due to CompiledAutomaton
- Candidates sorted by Levenshtein Distance
  - Limited customizability due to a lack of information

How do we solve it?

- Build a custom dictionary and store it in a Lucene FST (Finite State Transducer)
  - Meta information can be stored for each term
  - No automaton compilation needed
  - Flexibility for how to rank candidates


o
s
d
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m
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...
f
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...
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lang=ENG,FRE
...
d
freq=400
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...
a
v
e
n
u
e
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lang=ENG,FRE
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s
e
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e
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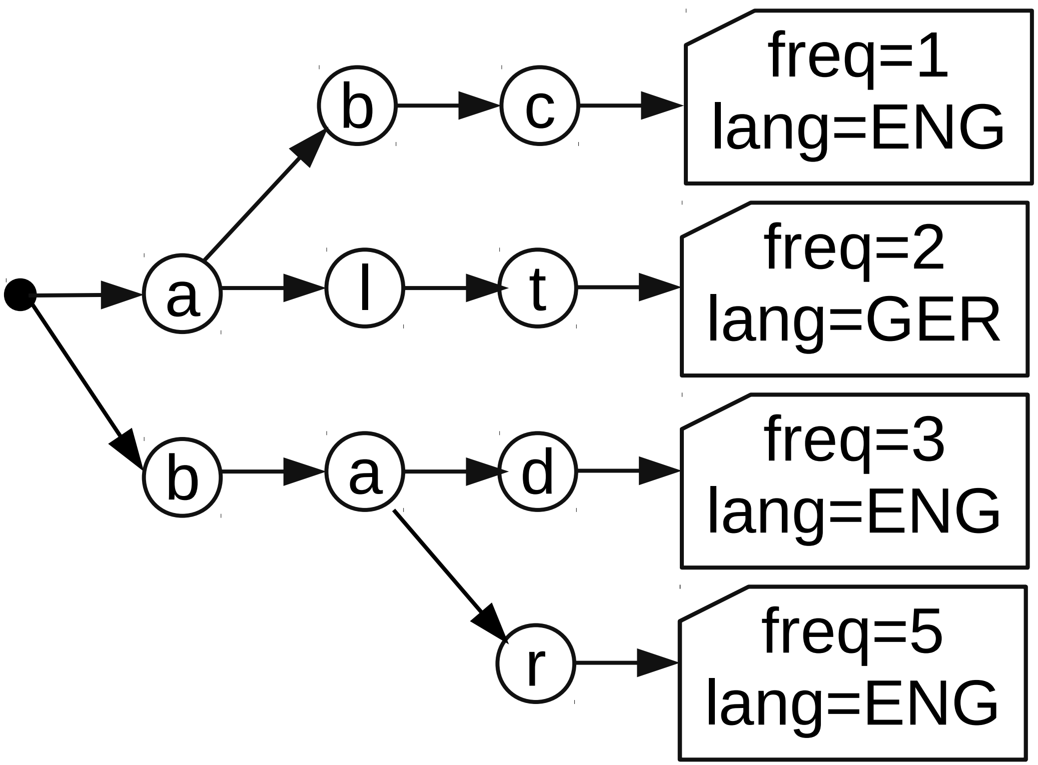
s
e
freq=12345
lang=GER,ENG,FRE
...
freq=1
lang=ENG
...

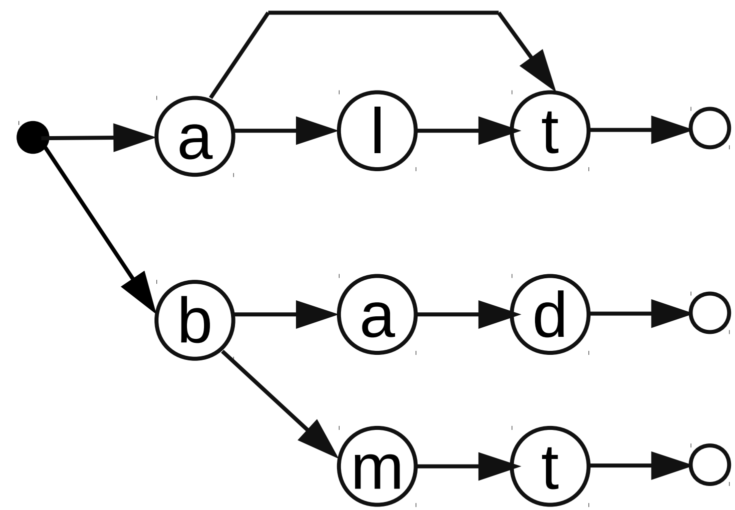
FST Based Solution

- Spelling corrections ordered using the meta information stored in the FST
  - Flexibility on what information to store
- Additional effort to build the FST
- FSTs are intersected with the automaton representing the user term

How Automaton Intersection Works

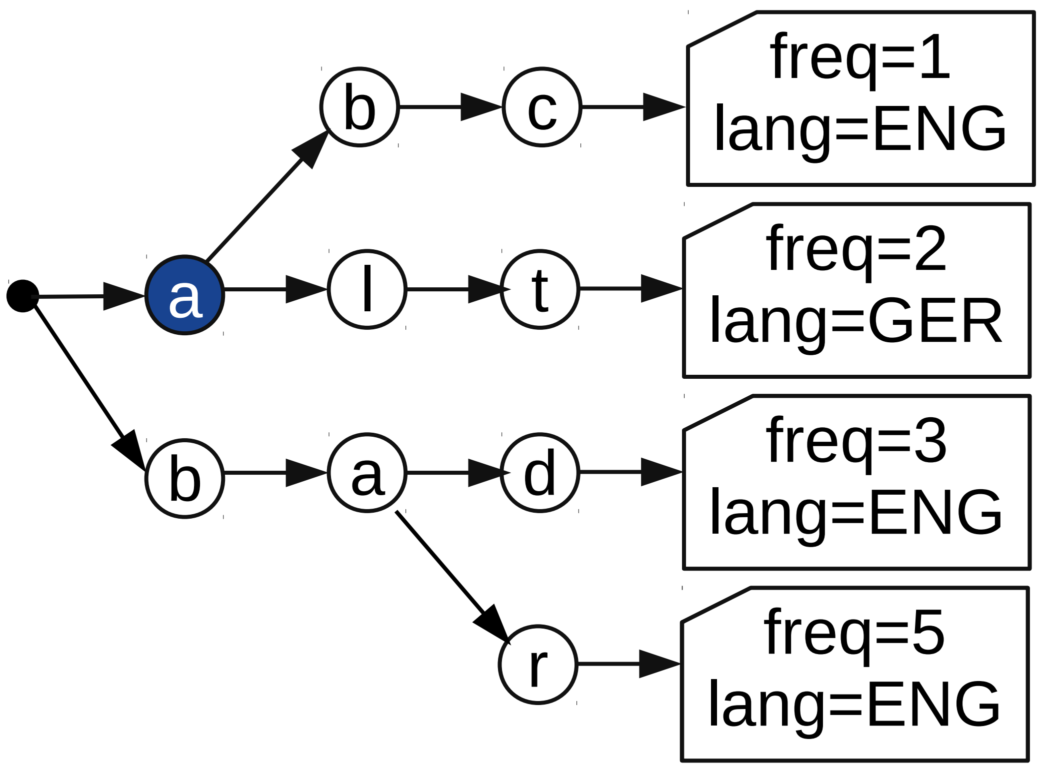


FST



Automaton

How Automaton Intersection Works



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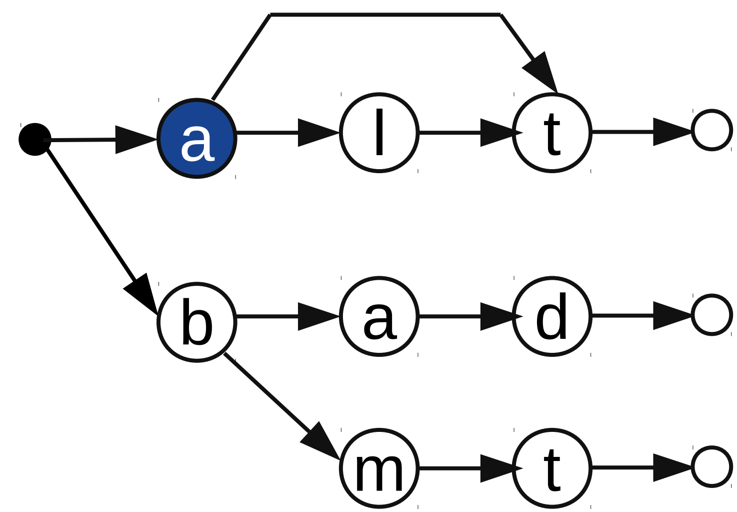

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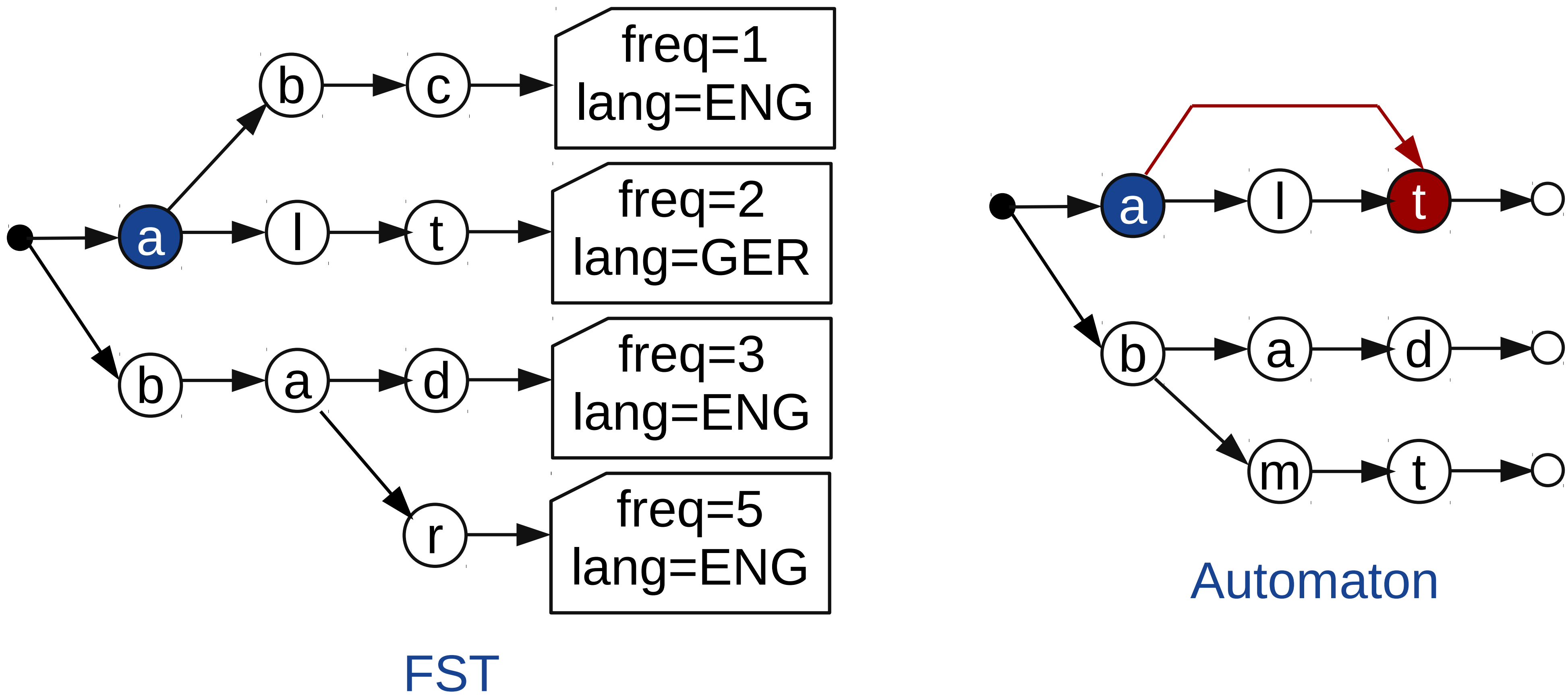

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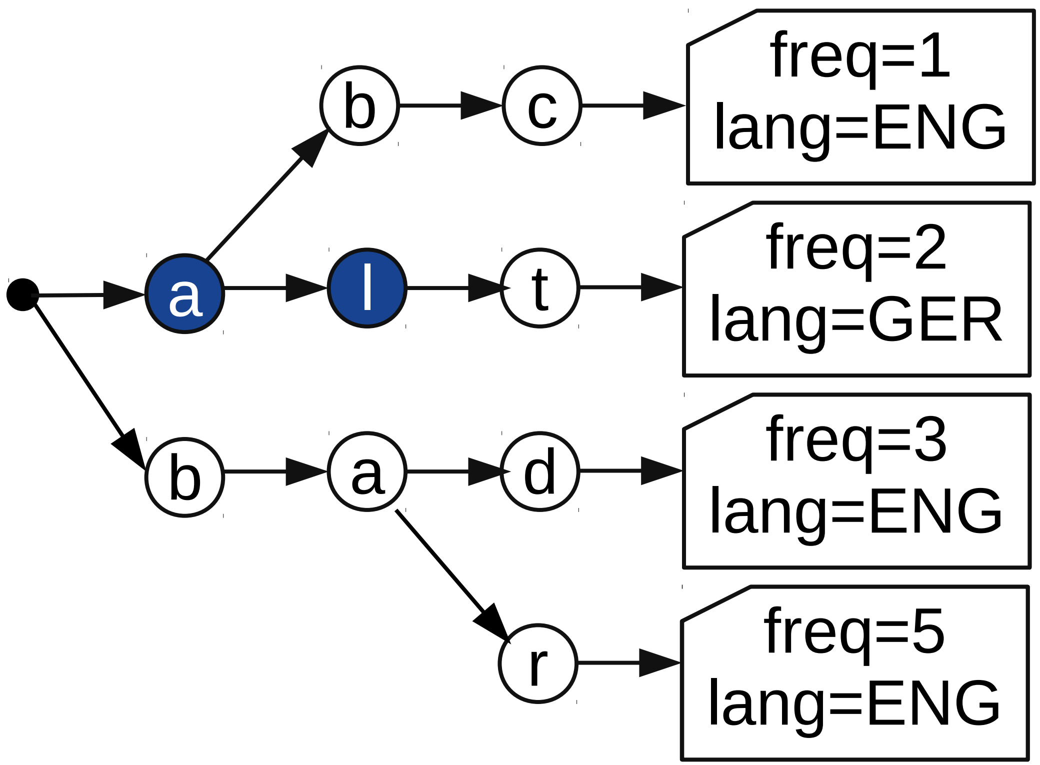

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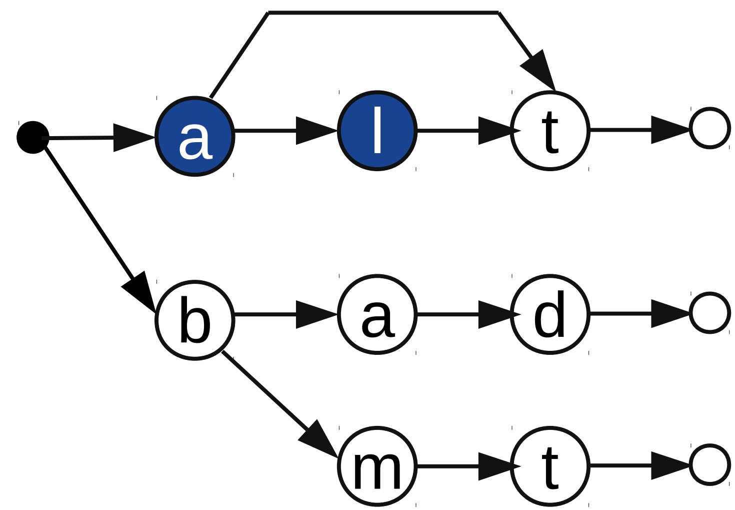

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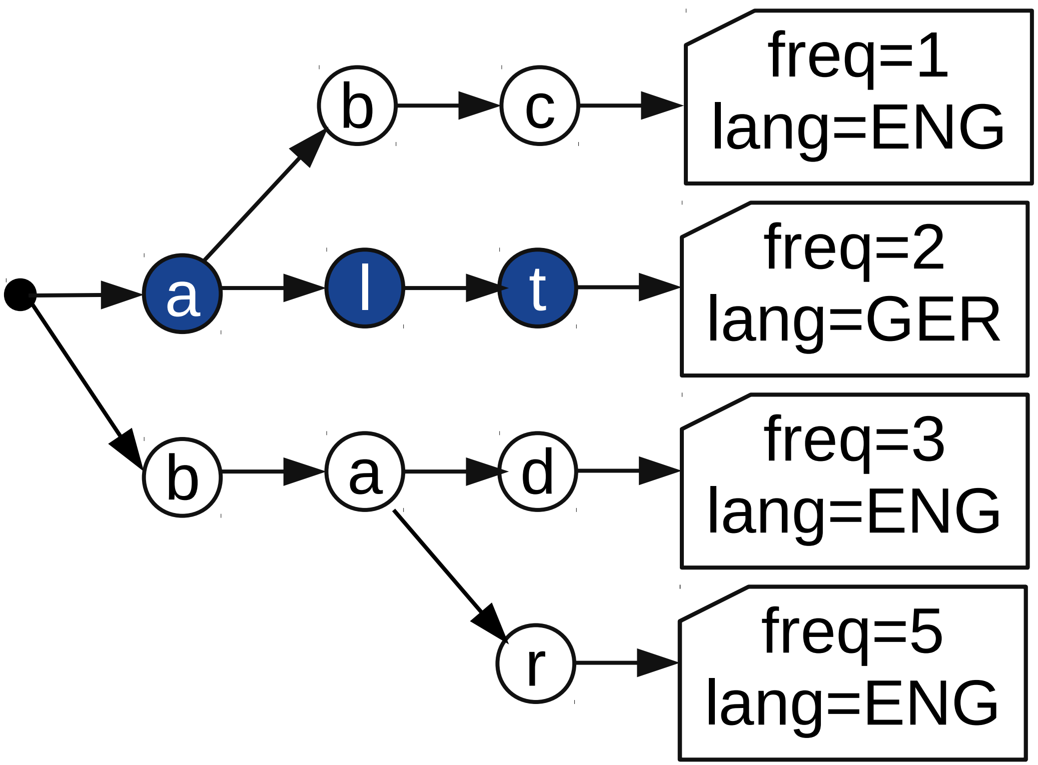

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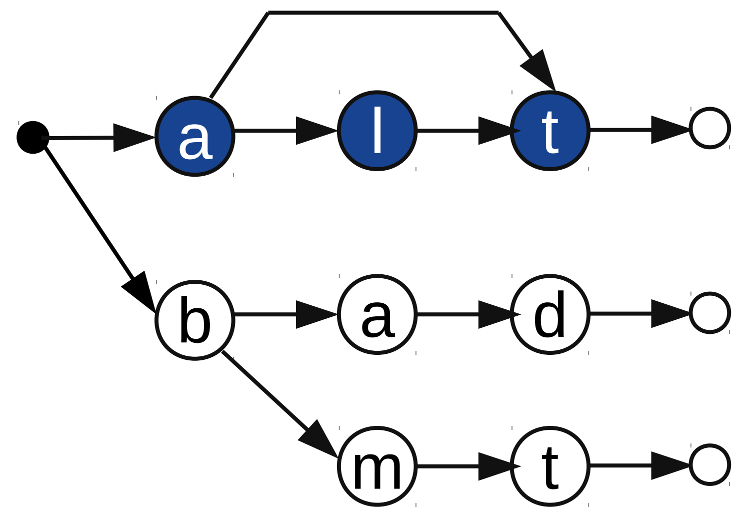

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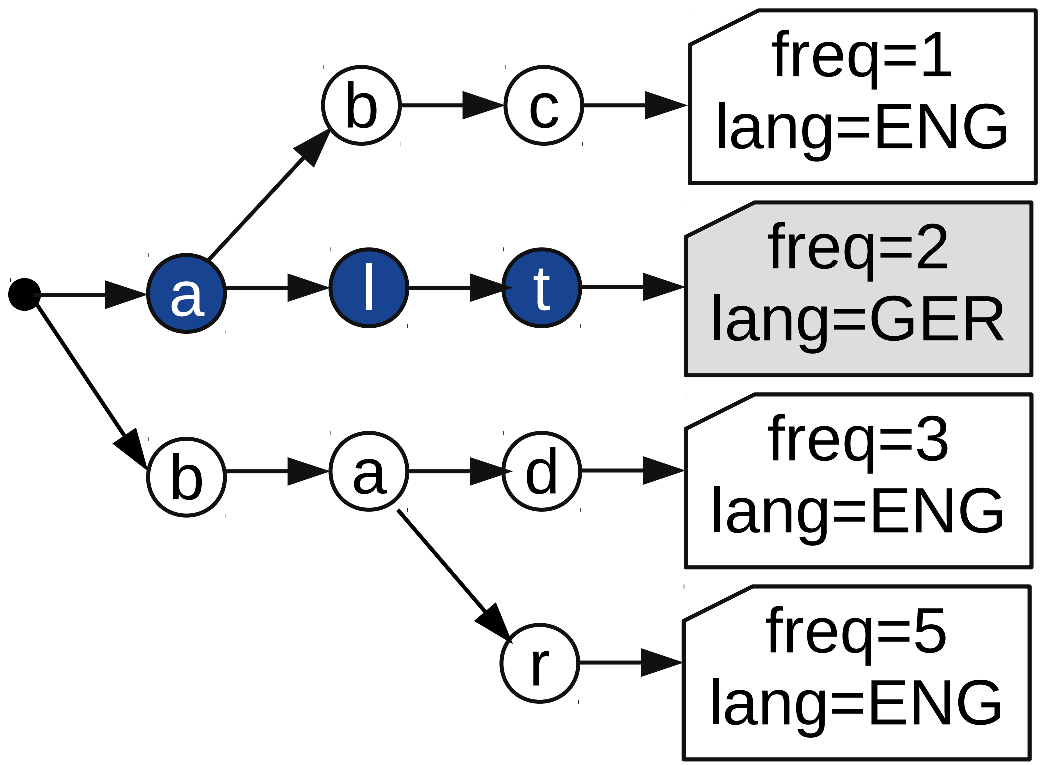

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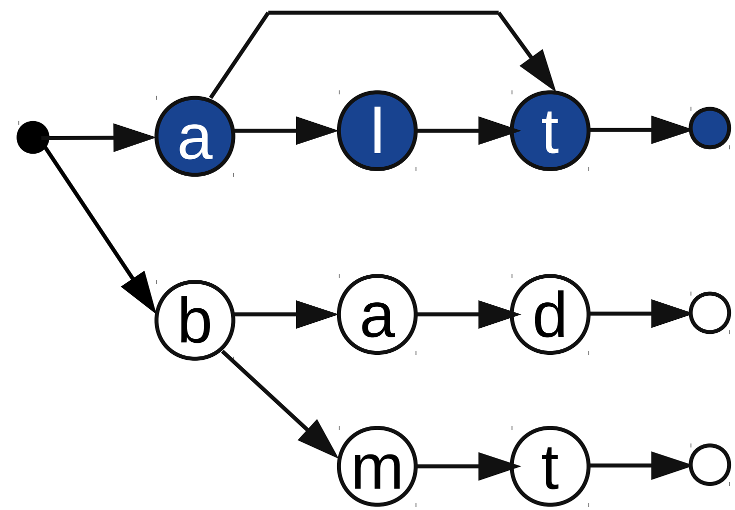

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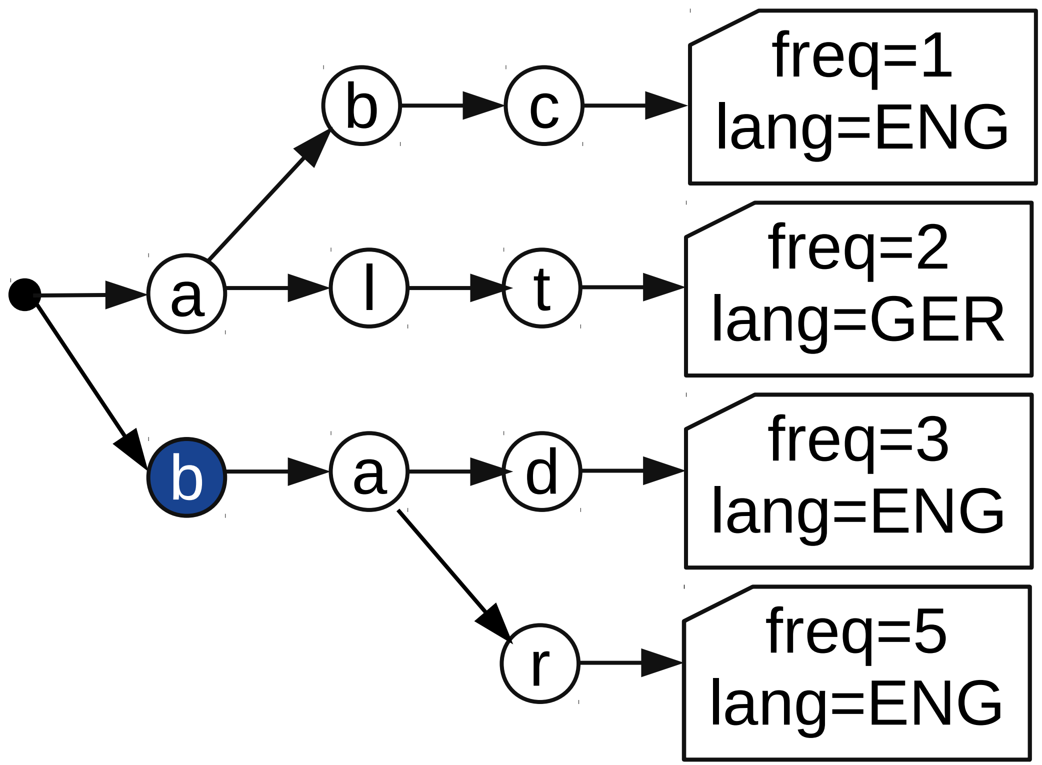

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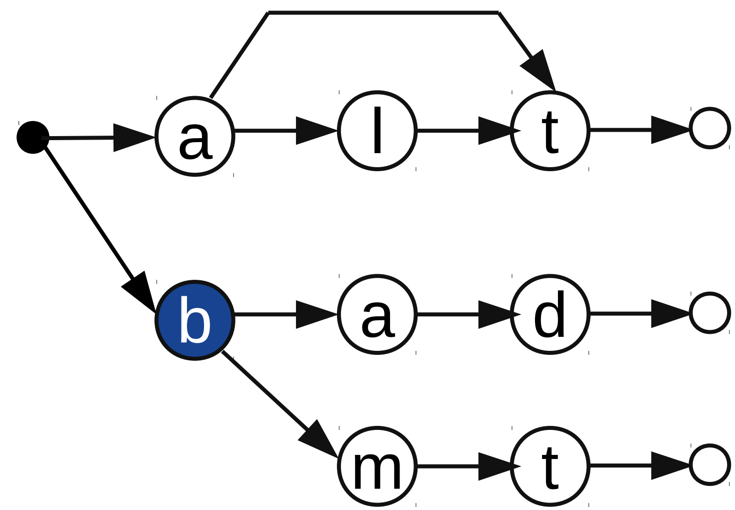

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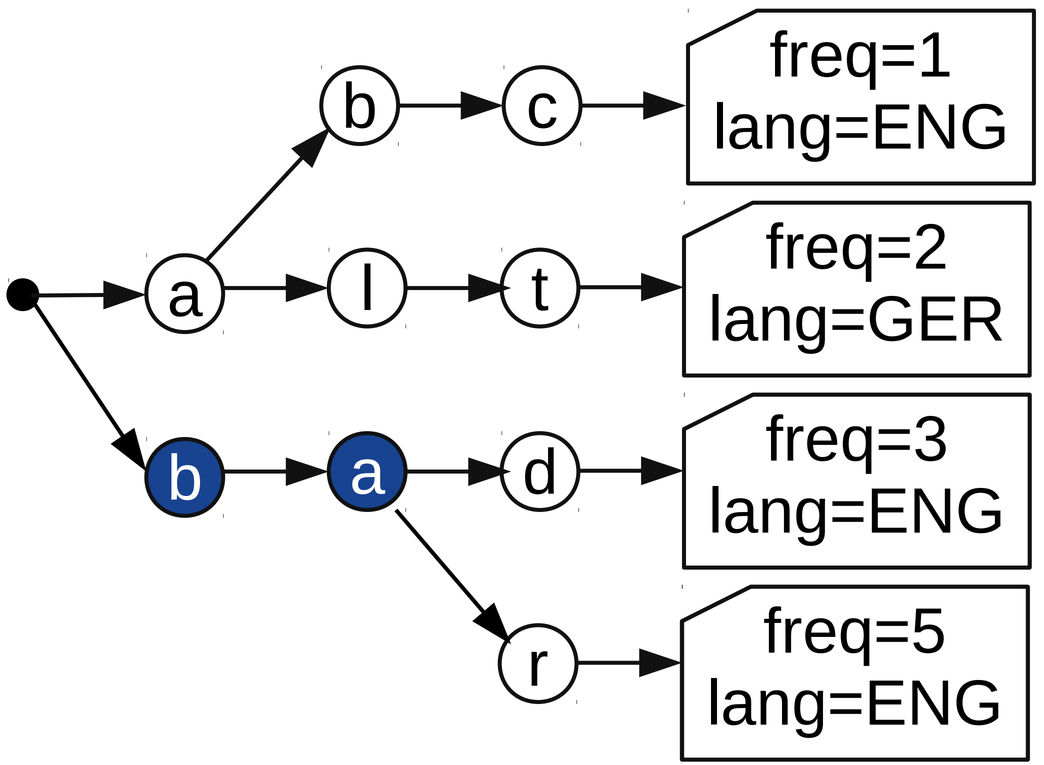

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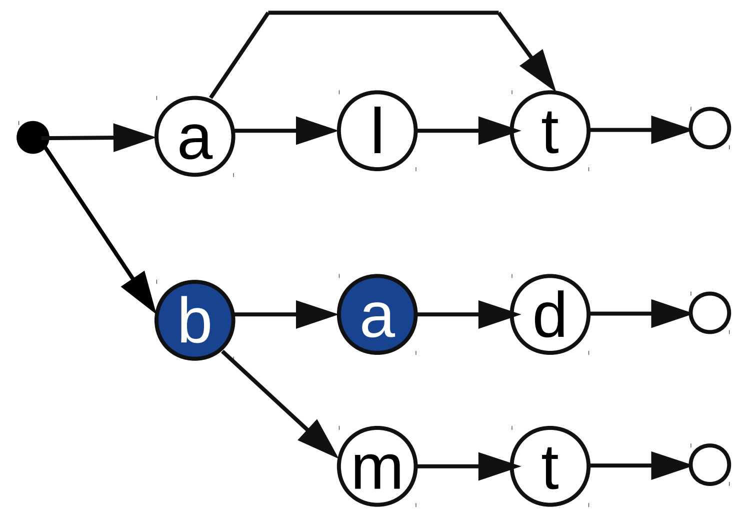

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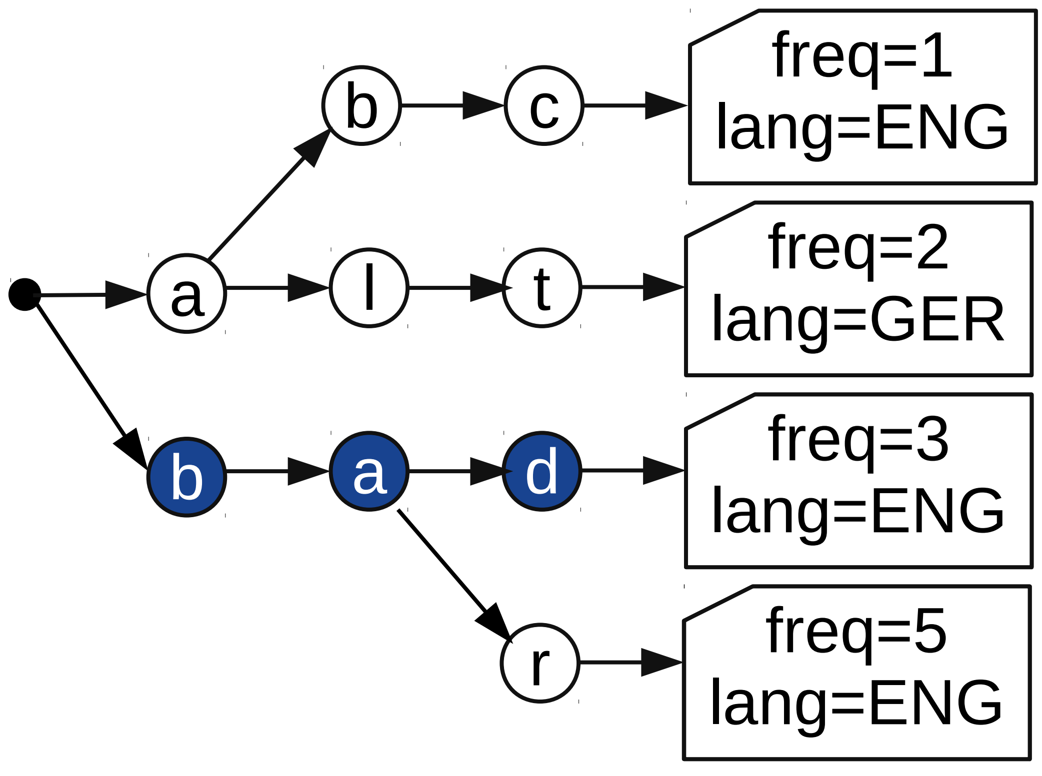

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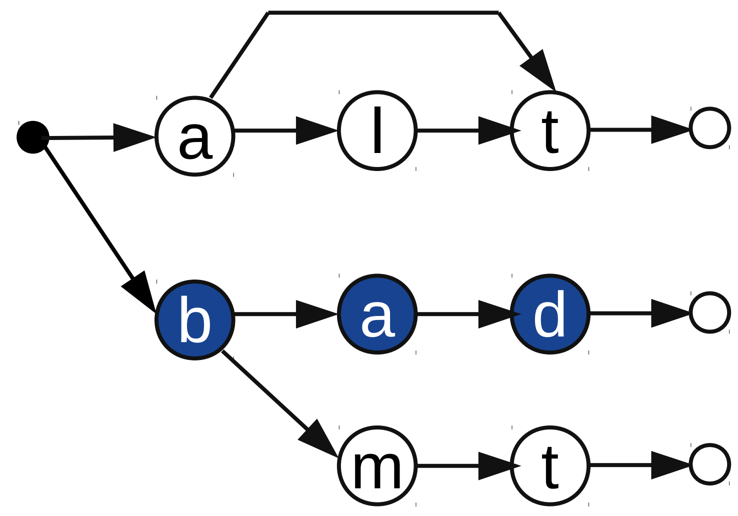

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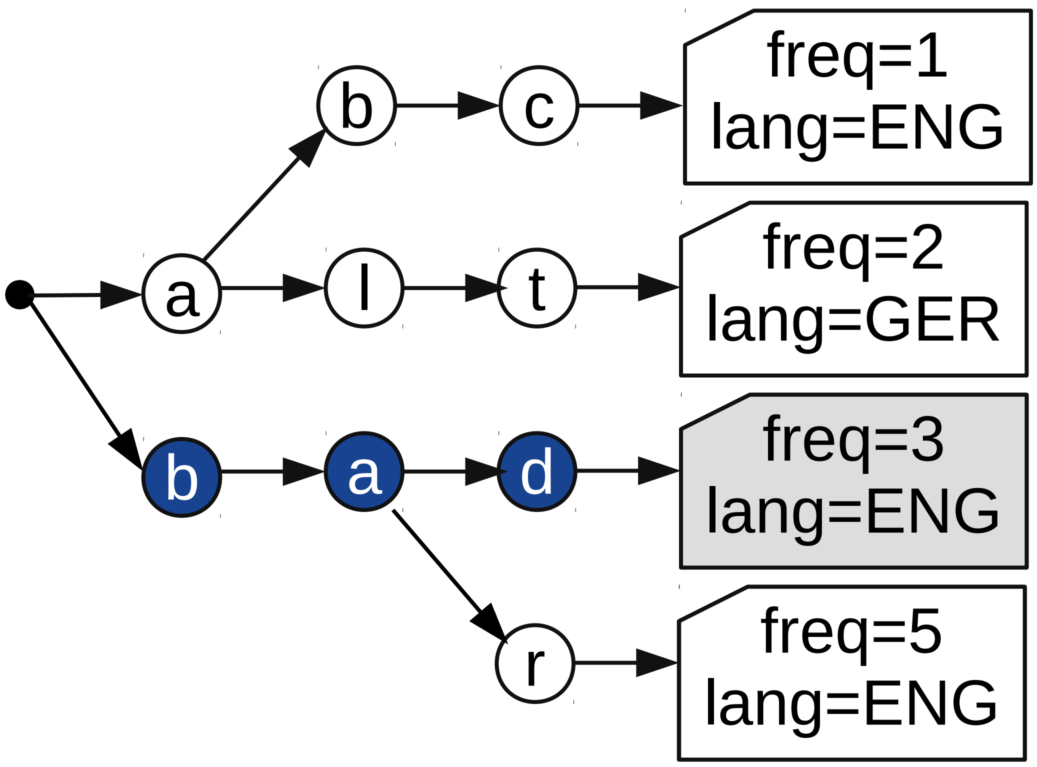
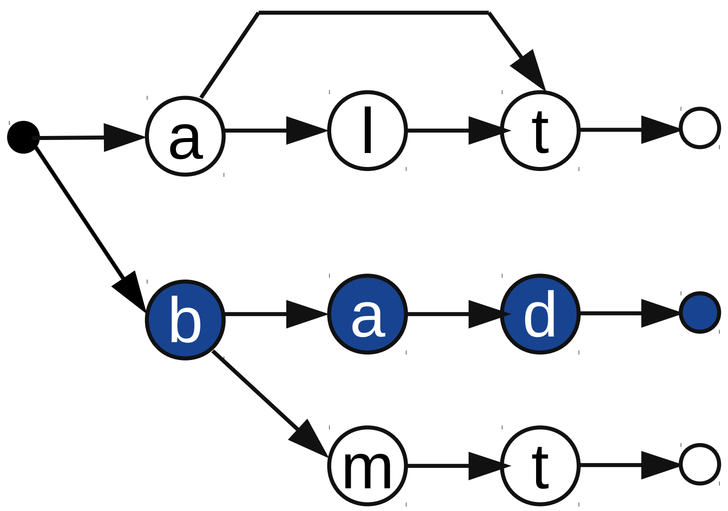
How Automaton Intersection Works



FST



Automaton

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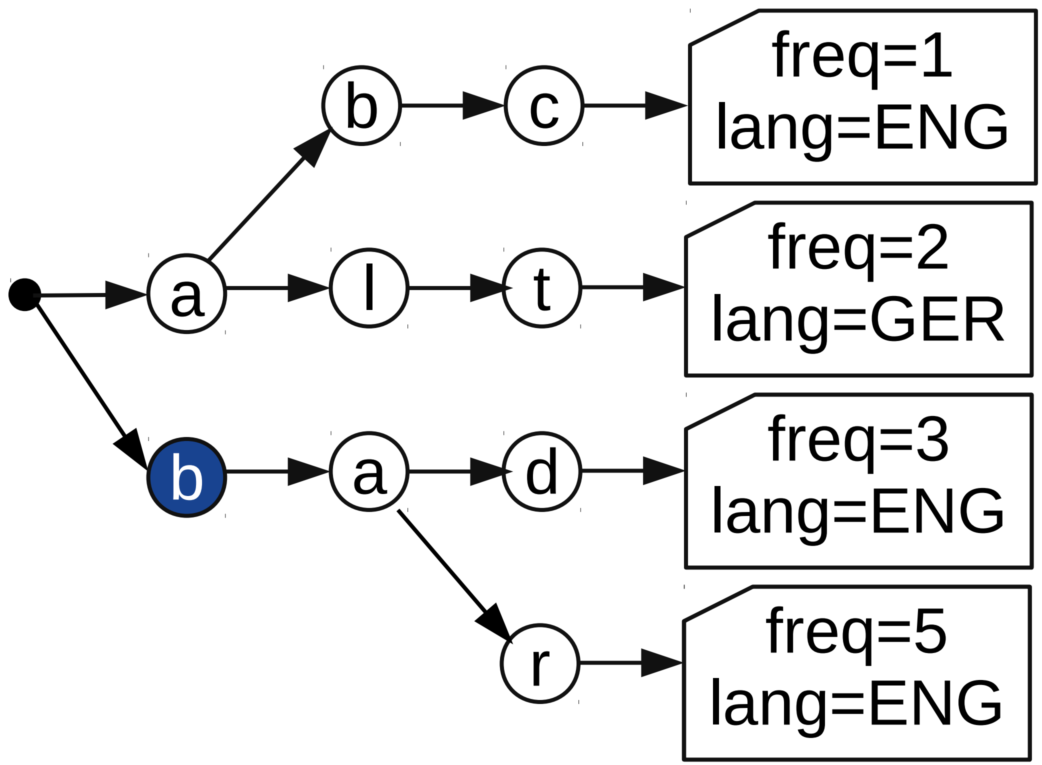

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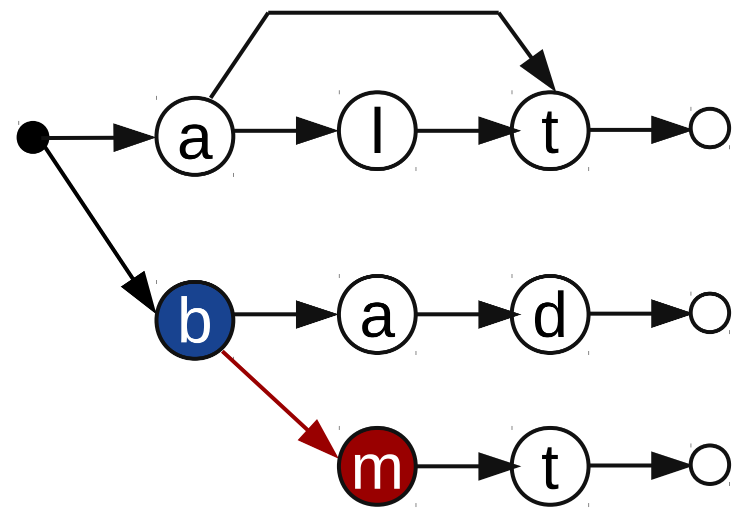


Automaton

Implementation

- Intersecting FST with plain Automaton inspired by lucene-suggest's FSTUtil
  - Optimizations to reduce object allocations
  - No prefix matching
- Each match triggers a hit collector
- Terms scored by their meta information and Levenshtein distance

Performance (“Avenue Franklin D. Roosevelt”)

FuzzyQuery

- Building automatons
  - <1ms
- Compiling automatons
  - 2ms
- Finding terms
  - 23ms
- Total
  - 26ms

FST Intersection

- Building automatons
  - <1ms
- Compiling automatons
  - Not needed
- Finding terms
  - 12ms
- Total
  - 13ms

Agenda

- Matching
- **Ranking**

Term Similarity

- Levenshtein distance

  minimum number of single-character insertions, deletions or substitutions

  Berlin → Belgien

  Berlin → Belin → Belgin → Belgien

Term Similarity

- Phonetic algorithms

  words encoded by their pronounciation

- Metaphone (Double Metaphone, Metaphone 3) for English and Germanic languages

Tchaikovsky → XKFS

Chaikowski → XKFS or XKSK

Chaykovsky → XKFS

Choosing best spelling corrections

Features that we store:

- Term frequency
- Term geo location

Features that we compute:

- Edit distance
- Phonetic distance
- Common typos
- First letter rule

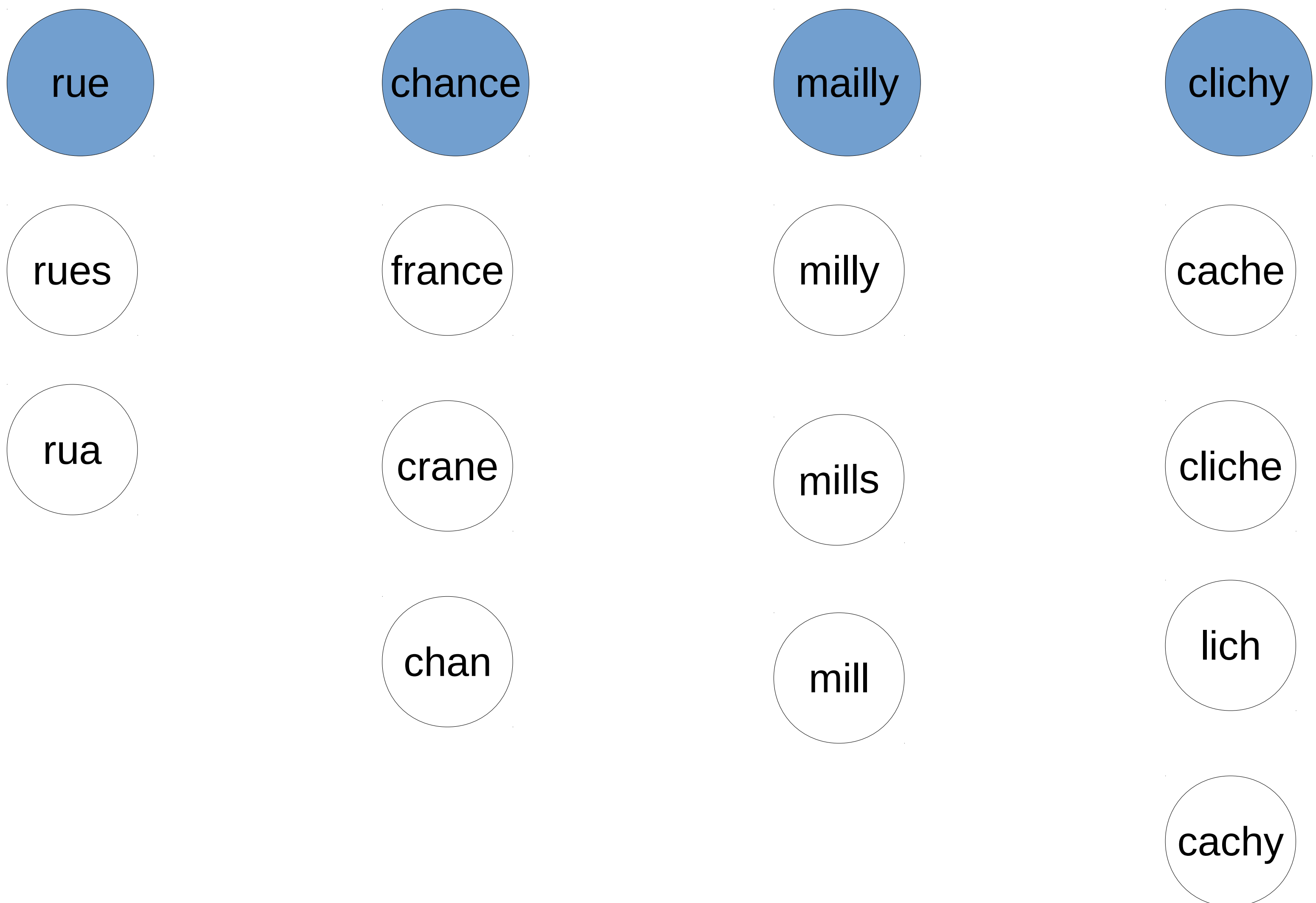
Choosing best spelling corrections

- Ranking function to score spelling candidates
- Linear weighted function over all the features

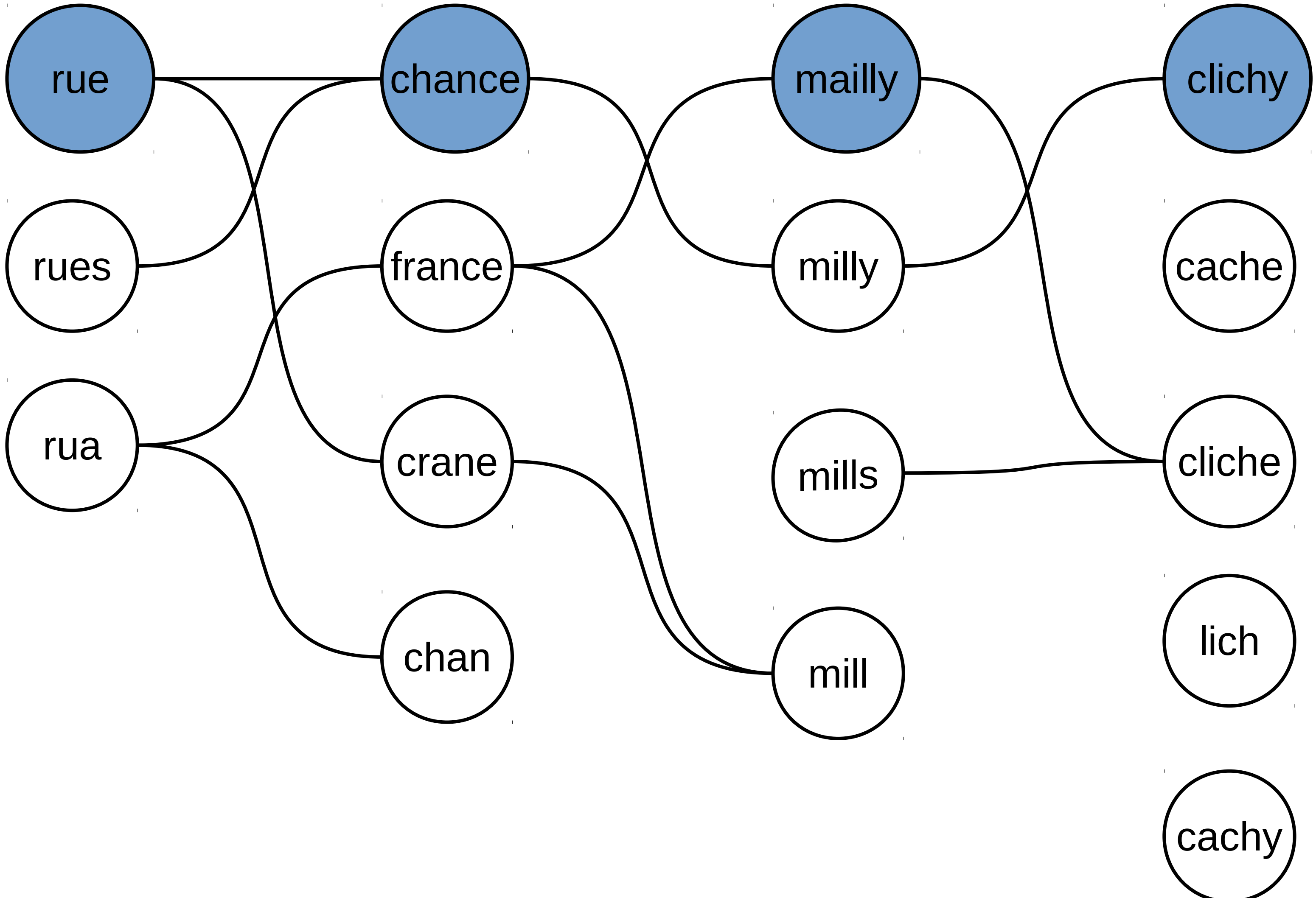
$$f(t) = \sum_{i \in features} w_i * f_i$$

- Train weights
- Take top-n spelling corrections (n << 50)

Terms and spelling corrections (“Rue Chance Mailly Clichy”)



Term co-occurence ("Rue Chance Mailly Clichy")

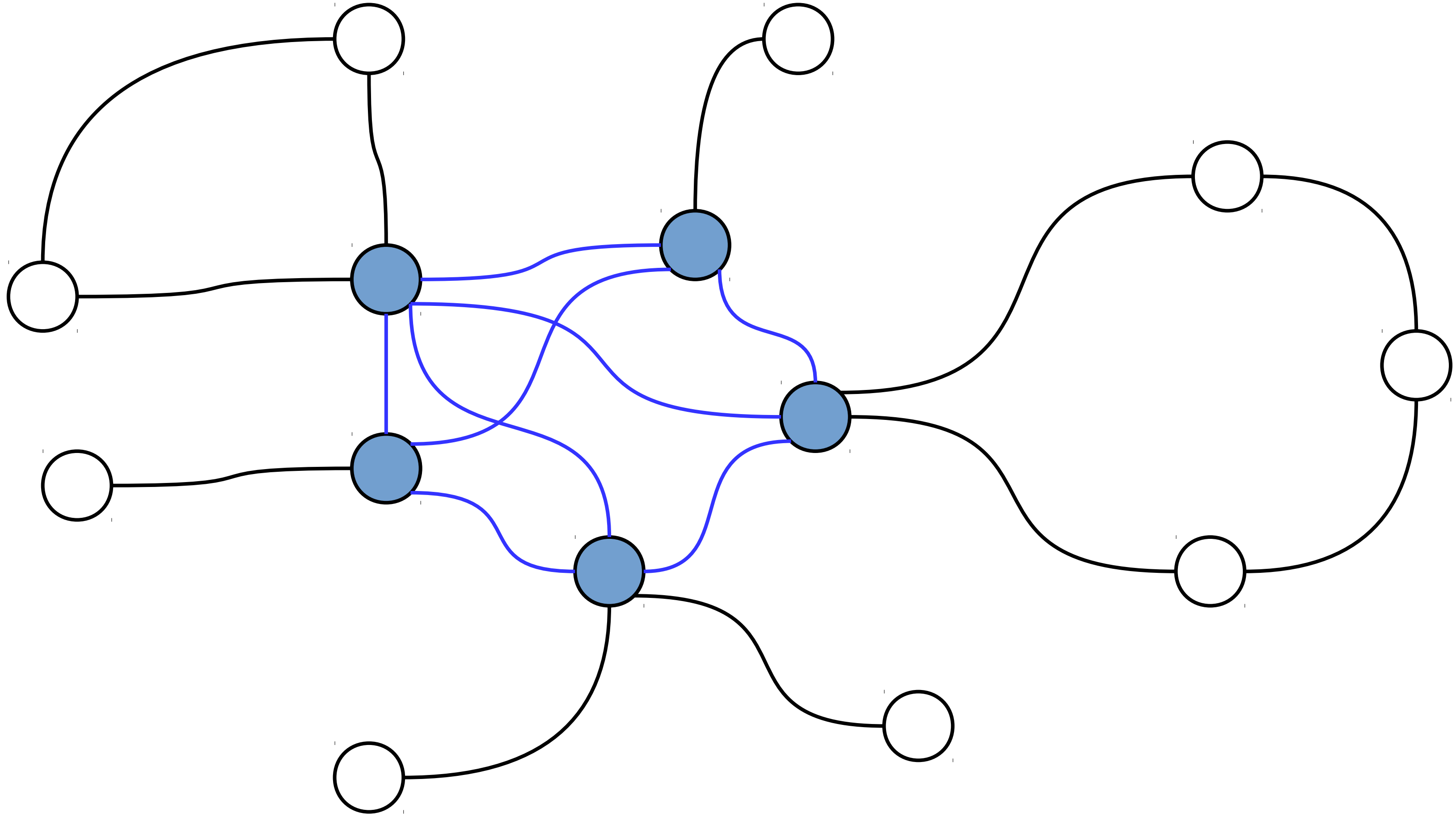


Term co-occurence

Features that we store:

- Term co-occurence likelihood
- Same language
- Same context

Dense subgraph



Densest at most k subgraph problem

- Extract the subgraph with at most k vertices and maximal density
- NP-complete
- Various definitions of density
- Various approximation algorithms available

Choosing density function

- Classical definition

$$f(S) = \frac{number\ of\ edges}{number\ of\ nodes}$$

- For weighted graphs

$$f(S) = \frac{number\ of\ edges}{\sum node\ weights}$$

- Our case

$$f(S) = f\left(\sum_{S} w_s, \sum_{E} w_e, N\right)$$

Choosing minimum degree vertex

- Classical definition number of edges

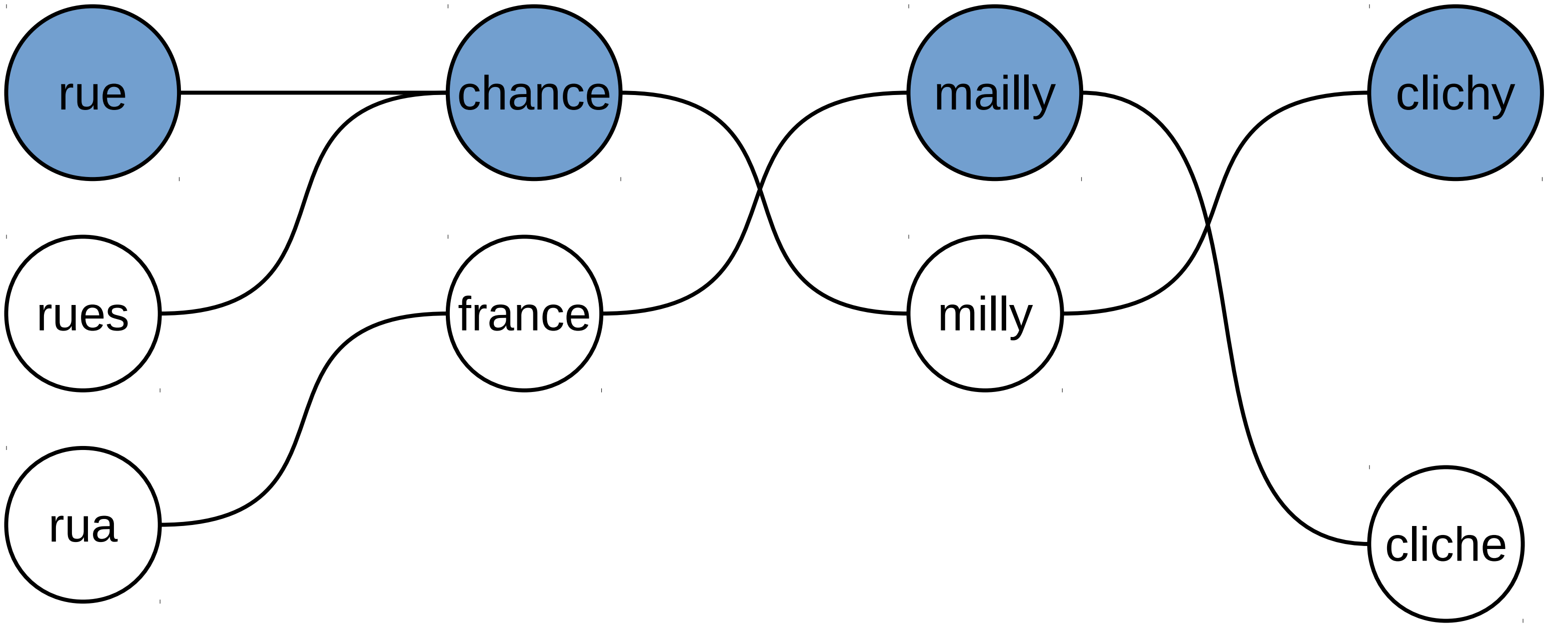
- For weighted graphs averaged number of edges

Greedy 2-approximation algorithm

```
Graph(E, V)
density function f(V), minimum degree vertex selection function min(S)
S = V
while (S not empty) {
    v = min(S)
    remove v from S
    compute f(S)
}
return max f(S)
```

M Charikar. Greedy approximation algorithms for finding dense components in a graph. 2000

Final Result



Conclusions

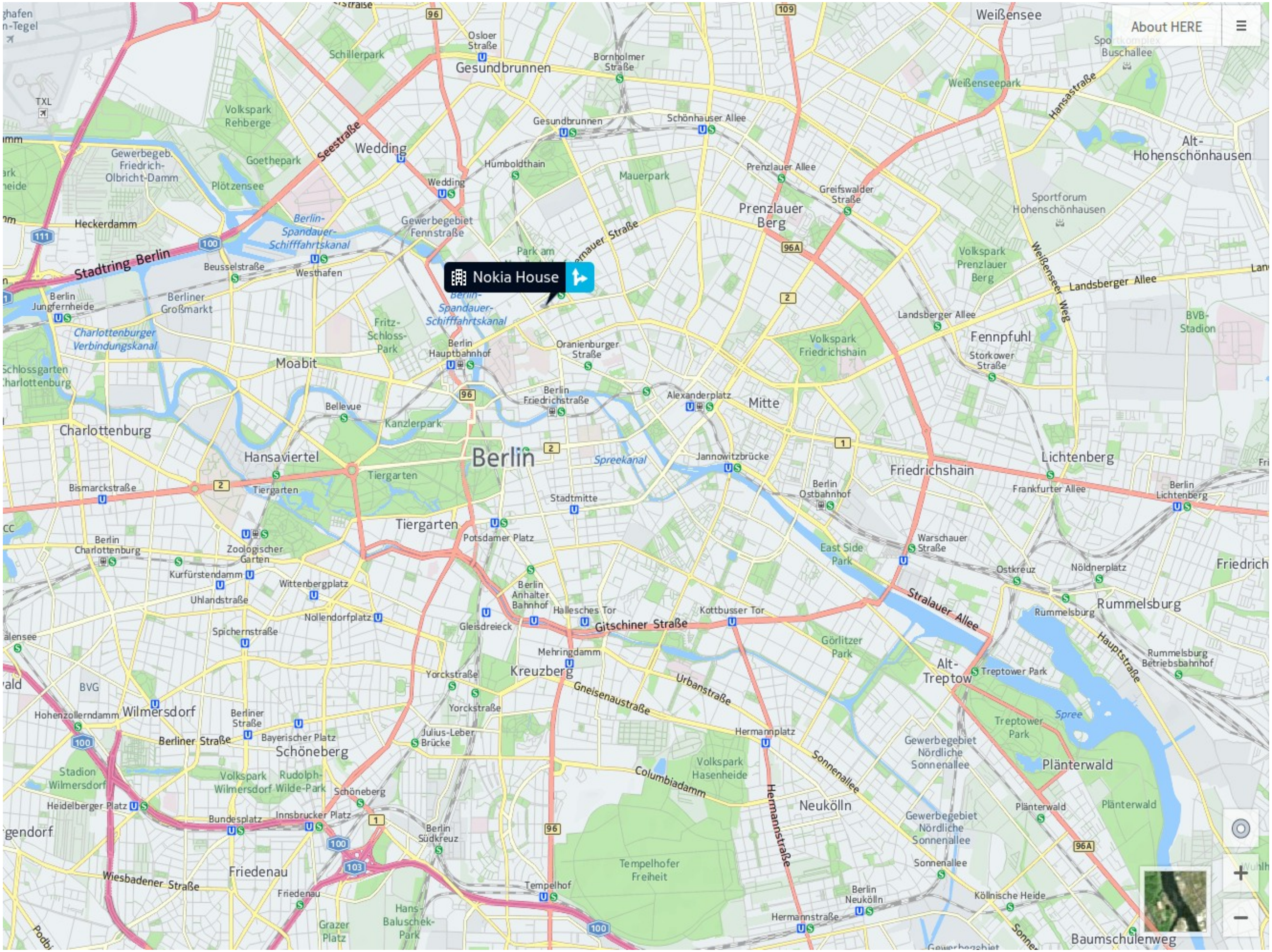
Using FST + Automaton has many advantages:

- performance
- meta information stored for each term
- flexible term ranking

Using ranking/filtering techniques

- minimizes number of terms actually searched for
- comes at a cost of time

Do you have any questions?



Nokia House
About HERE
Weißensee
Gesundbrunnen
Osloer Straße
Bornholmer Straße
Schillerpark
Weißenseepark
Sportkomplex Buschallee
Hansastraße
Volkspark Rehberge
Seestraße
Wedding
Goethepark
Gewerbegeb. Friedrich-Olbricht-Damm
Plötzensee
Humboldthain
Schönhauser Allee
Prenzlauer Allee
Mauerpark
Greifswalder Straße
Prenzlauer Berg
Alt-Hohenschönhausen
Sportforum Hohenschönhausen
Heckerdamm
Stadtring Berlin
Berlin-Spandauer-Schifffahrtskanal
Gewerbegebiet Fennstraße
Park am
Bernauer Straße
Beusselstraße
Westhafen
Berlin Jungfernheide
Berliner Großmarkt
Charlottenburger Verbindungskanal
Volkspark Prenzlauer Berg
Weißenseer Weg
Landsberger Allee
Fennpfuhl
Storkower Straße
BVB-Stadion
Fritz-Schloss-Park
Berlin Hauptbahnhof
Oranienburger Straße
Volkspark Friedrichshain
Schlossgarten Charlottenburg
Moabit
Bellevue
Kanzlerpark
Berlin Friedrichstraße
Alexanderplatz
Mitte
Charlottenburg
Hansaviertel
Berlin
Spreekanal
Jannowitzbrücke
Friedrichshain
Lichtenberg
Tiergarten
Bismarckstraße
Stadtmitte
Berlin Ostbahnhof
Frankfurter Allee
Berlin Lichtenberg
Potsdamer Platz
Berlin Charlottenburg
Zoologischer Garten
Kurfürstendamm
Wittenbergplatz
Uhlandstraße
East Side Park
Warschauer Straße
Ostkreuz
Nöldnerplatz
Berlin Anhalter Bahnhof
Hallesches Tor
Kottbusser Tor
Gitschiner Straße
Stralauer Allee
Rummelsburg
Nollendorfplatz
Gleisdreieck
Spichernstraße
Görlitzer Park
Mehringdamm
Yorckstraße
Kreuzberg
Gneisenaustraße
Urbanstraße
Alt-Treptow
Treptower Park
Hauptstraße
Rummelsburg Betriebsbahnhof
BVG
Hohenzollerndamm
Wilmersdorf
Berliner Straße
Bayerischer Platz
Schöneberg
Julius-Leber-Brücke
Hermannplatz
Treptower Park
Spree
Gewerbegebiet Nördliche Sonnenallee
Plänterwald
Stadion Wilmersdorf
Volkspark Wilmersdorf
Rudolph-Wilde-Park
Columbiadamm
Volkspark Hasenheide
Sonnenallee
Neukölln
Hermannstraße
Heidelberger Platz
Bundesplatz
Innsbrucker Platz
Berlin Südkreuz
Tempelhofer Freiheit
Wiesbadener Straße
Friedenau
Tempelhof
Berlin Neukölln
Köllnische Heide
Hans-Baluschek-Park
Grazer Platz
Baumschulenweg