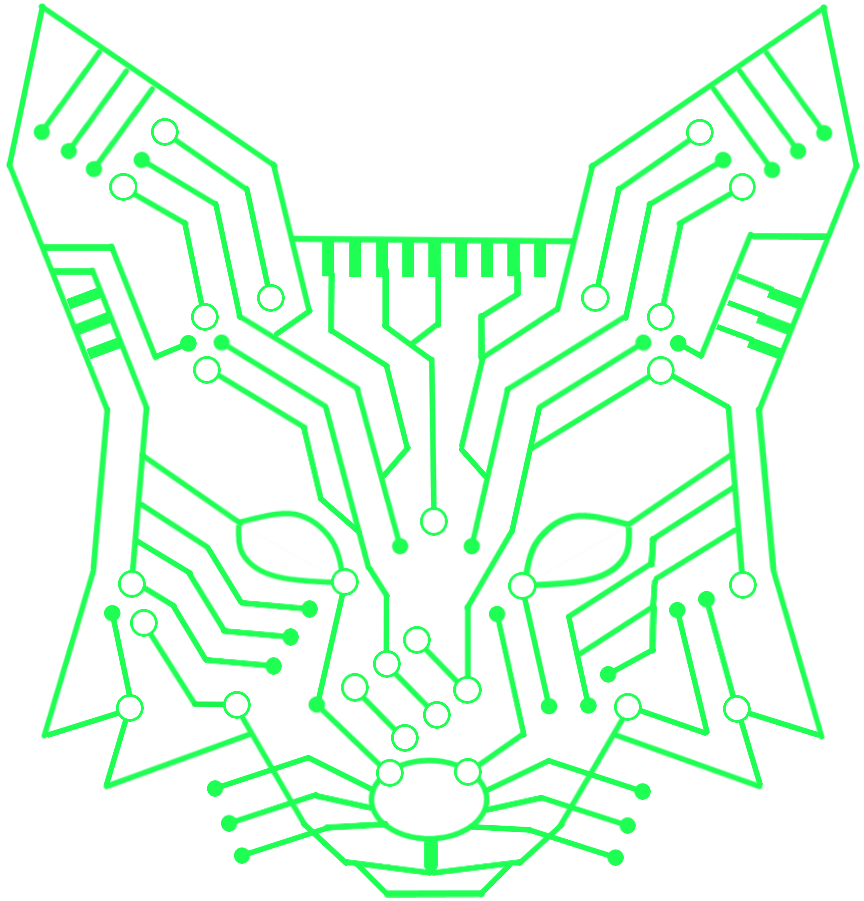
SearchEngine: a Holistic Approach to Matching

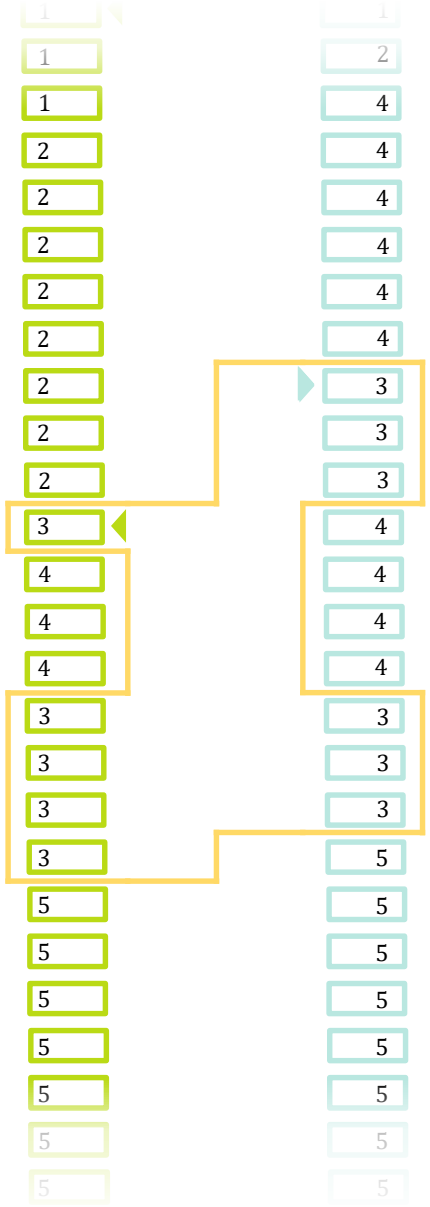
Thorsten Doherr | Leibniz Centre for European Economic Research, Germany | https://github.com/ThorstenDoherr/searchengine



ZEW

Leibniz Gemeinschaft

Blocking



Pairwise Comparisons

21 million IAB records

24 million creditreform records

≈ $500*10^{12}$ comparisons

Blocking

Segmentation of the solution space along arbitrary exclusion restrictions

For example:

- Address blocking (postal code, city)
- Spatial blocking after geocoding
- Overlapping Canopies, i.e. based on first 4 characters of any word in the firm name
- …
- Combination of methods
- Overlapping blocks to avoid false negatives

Comparisons

Scoring based on…

- string comparison functions
- word or token frequencies
- spatial distances
- …

Multiple scores or vectors require statistical methods like ML to handle curse of dimensionality

vs.

Searching

Index Based Search

Complexity increment close to $\log_2$

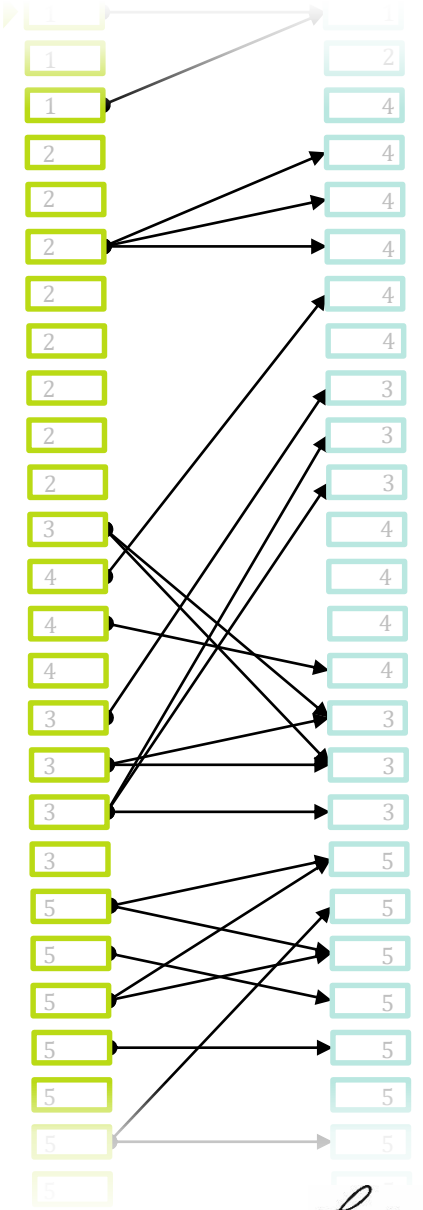
Search Heuristic

Word frequency based heuristic identifies candidates

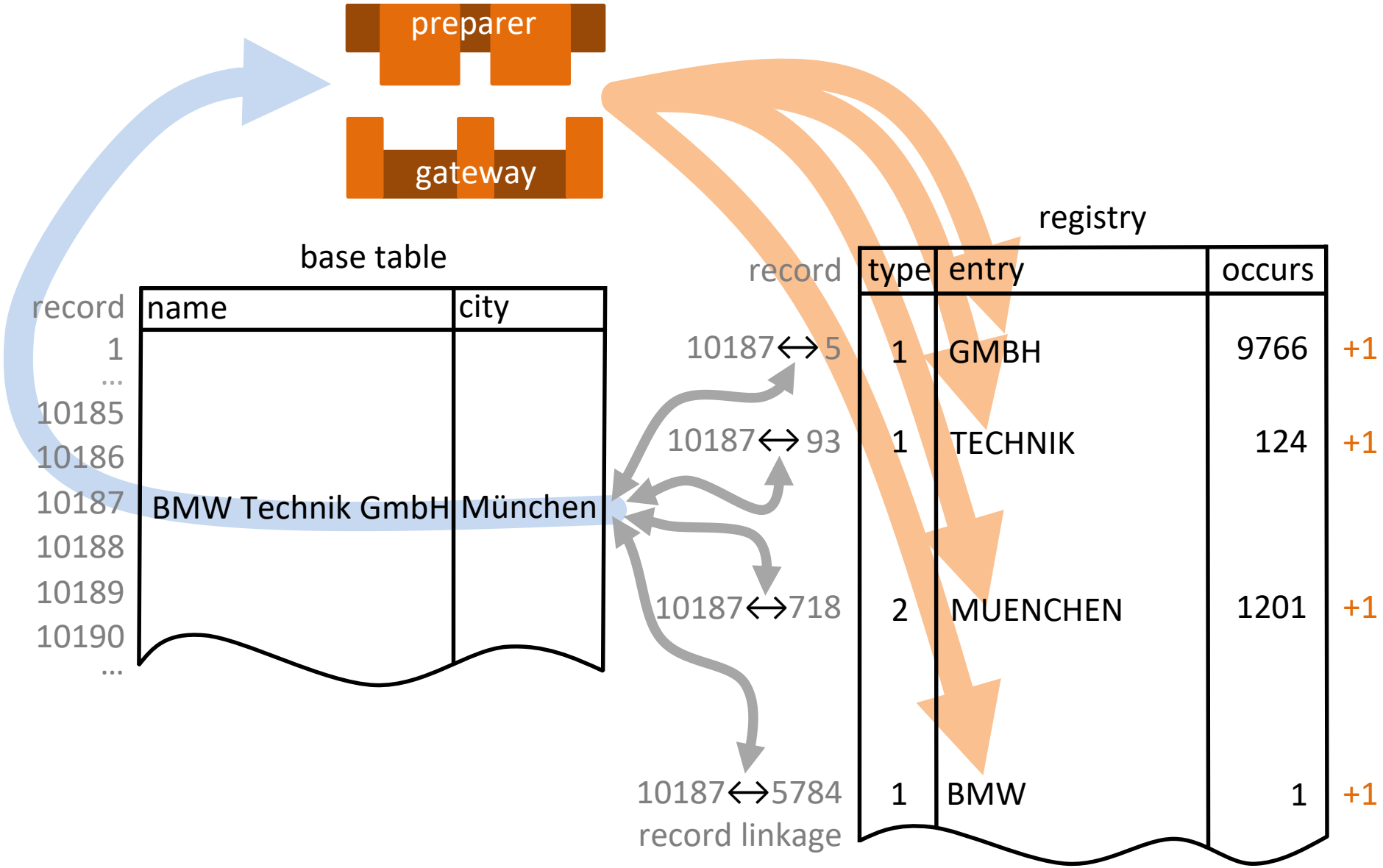
- Base table defines heuristic meta data and provides candidates
- Search table provides the search terms
- Individual blocking is not bound to exclusion restrictions
- Search strategy requires several runs to minimize false negatives

Holistic Approach

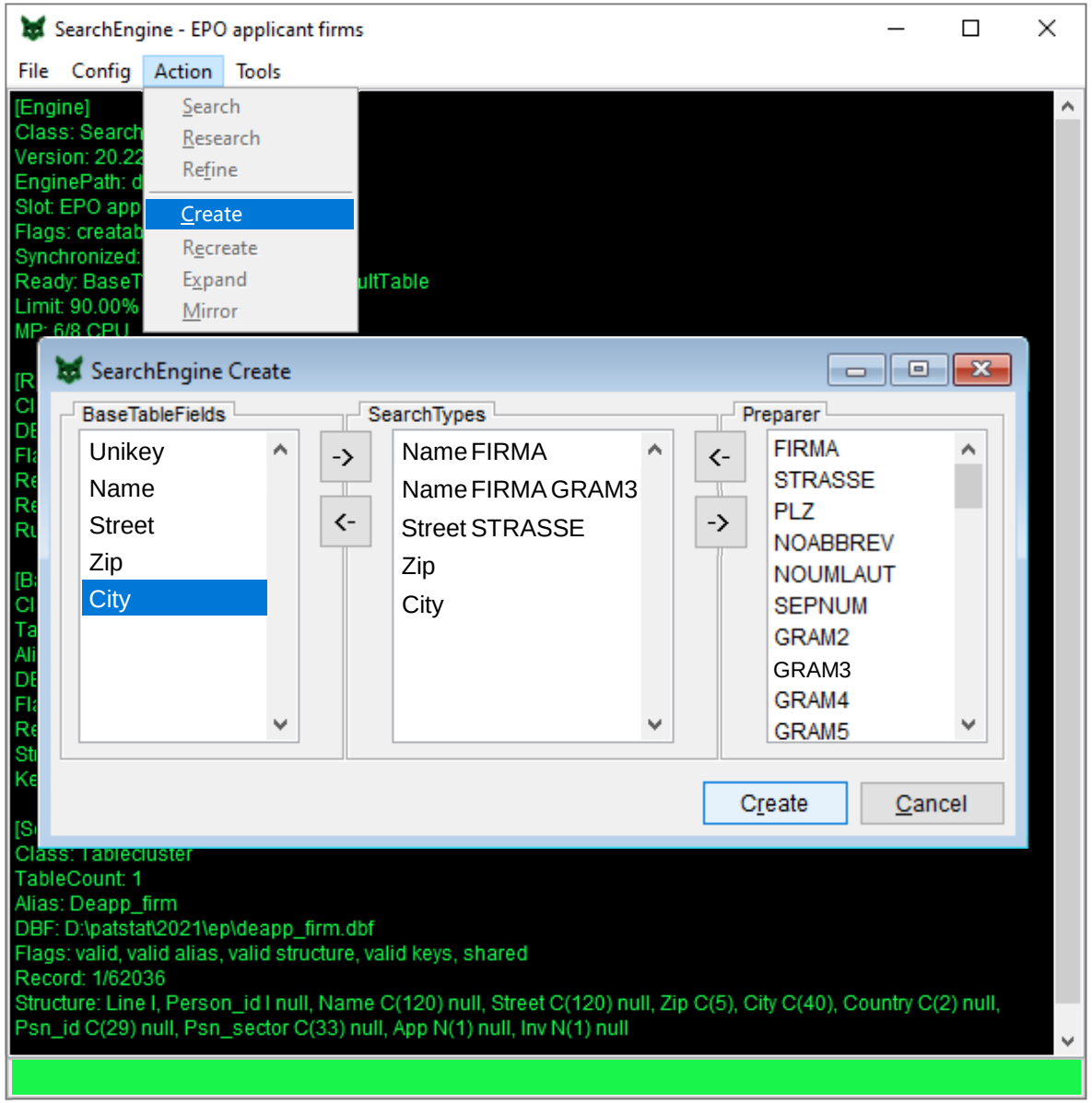
- Similarity between search record and candidates is already established
- Only filtering of false positives is required
- Meta data of the search heuristic is repurposed to create variation
- Training sample composition and ML integration is trivial



Components of the SearchEngine



Preparer Gateway



- Preparers are normalization/tokenization directives.
  In combination with search fields, they define search types.
  By default, all fields will be normalized:
  upper case, only alpha-numeric characters, word tokens

- FIRMA, STRASSE, PLZ are custom preparers defined in the "searchengine_firma_strasse.xml" file. They handle the idiosyncrasies of German firm names and addresses (legal forms, concatenated street types) and are not required for other languages.
  Languages allowing the (arbitrary) concatenation of words pose a challenge for word based algorithms.

- GRAMn preparers implement a computational linguistics method by creating overlapping tokens of size n, i.e.
  THORSTEN → THO HOR ORS RST STE TEN
  Other linguistic preparers implement SOUNDEX, METAPHONE and COLONE but only GRAM can handle erroneously concatenated/split words.
  These preparers destroy information for the sake of increased robustness against misspellings, therefor they will also be referred as destructive preparers → increased risk of false positives

Relative Identification Potential

1 name	2 street	3 zip	4 city
BMW FORSCHUNG UND TECHNIK GMBH	HANAUER STRASSE 46	80992	MUENCHEN

type	entry	occurs	$IP = \frac{1}{occurs}$	$share = \frac{IP}{\sum IP}$	$rIP = share * weight$
…	…	…			
1	BMW	552	→ 0.0018116	→ 76.863%	→ 53.804%
1	FORSCHUNG	1980	→ 0.0005051	→ 21.428%	→ 15.000%
1	TECHNIK	25552	→ 0.0000391	→ 1.660%	→ 1.162%
1	UND	1190073	→ 0.0000008	→ 0.036%	→ 0.025%
1	GMBH	3353864	→ 0.0000003	→ 0.013%	→ 0.009%
…	…	…	∑ 0.0023569	∑ 100.00%	∑ 70.000%
2	HANAUER	6851	→ 0.0001460	→ 90.511%	→ 9.051%
2	46	65931	→ 0.0000152	→ 9.494%	→ 0.941%
2	STRASSE	7410645	→ 0.0000001	→ 0.084%	→ 0.008%
…	…	…	∑ 0.0001613	∑ 100.000%	∑ 10%
3	80992	3905	→ 0.0002561	→ 100.000%	→ 10%
…	…	…	∑ 0.0002561	∑ 100.000%	∑ 10%
4	MUENCHEN	316874	→ 0.0000032	→ 100.000%	→ 10%
…	…	…	∑ 0.0000032	∑ 100.000%	∑ 10%

Relative Identity

1 name					2 street			3 zip	4 city	$\sum rIP$
BMW	FORSCHUNG	UND	TECHNIK	GMBH	HANAUER	STRASSE	46	80992	MUENCHEN	
53.8	15.0	0.0	1.2	0.0	9.1	0.0	0.9	10	10	100.00%

BMW FORSCHUNG UND TECHNIK GMBH	HANAUER STRASSE 46	80992	MUENCHEN	100.00%
BMW FORSCHUNG U TECHNIK GMBH	HANAUER STRASSE 46	80992	MUENCHEN	99.98%
BMW TECHNIK UND SERVICE GMBH	HANAUER STRASSE 48	80992	MUENCHEN	84.06%
BMW STIFTUNG HERBERT QUANDT	HANAUER STRASSE 46	80992	MUENCHEN	83.80%
BMW MAENNERCHOR MUENCHEN EV	DACHAUER STRASSE 371	80992	MUENCHEN	73.81%

Threshold: 70%

Not Commutative $(a \rightarrow b \neq b \rightarrow a)$

1 name				2 street			3 zip	4 city	$\sum rIP$
BMW	MAENNERCHOR	MUENCHEN	EV	DACHAUER	STRASSE	371	80992	MUENCHEN	
18.0	51.2	0.8	0.0	1.2	0.0	8.8	10	10	100.00%

BMW MAENNERCHOR MUENCHEN EV	DACHAUER STRASSE 371	80992	MUENCHEN	100.00%
MANNERCHOR RIESENFELD EV	ABBACH STRASSE 27 A	80992	MUENCHEN	71.23%

Threshold: 70%

Candidate Retrieval

1 BMW	1 FORSCHUNG	3 80992	4 MUENCHEN	2 HANAUER	1 TECHNIK	2 46	1 UND	1 GMBH	2 STRASSE
53.8	15.0	10.0	10.0	9.1	1.2	0.9	0.0	0.0	0.0
2150179	2172419	2179375	2188161	2182779	2186398	2187556	2188225	2188227	2188228

sort order

registry

type	entry	occurs
...	...	...
1	BMW	552
3	LENIN	552
...	...	...
1	FORSCHUNG	1980
...	...	...
3	80992	3950
...	...	...

$N_{registry}$

record	regindex: index
	...
2150179	4636758
2156731	4637310
	...
2172419	7854367
	7856347
	...
2179375	11241655
	11245605
	...

$N_{registry} + 1$

record	base: target
	...
4636758	10187
	15633
	27996
	...
	7267831
4637310	...

$\sum occurs$

70%

BUFFER	AGGREGATION	Σ	+21.2
	BMW, FORSCHUNG, 80992	78.8	100.0
	BMW, FORSCHUNG	68.8	90.0
	BMW, 80992	63.8	85.0
	BMW	53.8	75.0
	FORSCHUNG, 80992	25.0	46.2
	FORSCHUNG	15.0	36.2
	80992	10.0	31.2

fixed size

Efficiency Puzzle

The retrieval also stops early when the interim total of the collated RIDs exceeds $100-threshold$, because at least one of those words is necessary to push the Identity over the threshold. In this example retrieval actually stops already after “BMW”.

Identity Completion

1 BMW	1 FORSCHUNG	3 80992	2 HANAUER	1 TECHNIK	2 46	4 MUENCHEN	1 UND	1 GMBH	2 STRASSE
53.8	15.0	10.0	9.1	1.2	0.9	10.0	0.0	0.0	0.0
250179	2172419	2179375	2182779	2186398	2187556	2188161	2188225	2188227	2188228

sort order

BUFFER

15633

baseindex

record	index
	...
15633	124935
15634	124944
	...

$N_{base} + 1$

reg

record	target		
	...		
124935	2150179	BMW	53.8
	2179375	80992	10.0
	2182779	HANAUER	9.1
	2186398	TECHNIK	1.2
	2187556	46	0.9
	2188021	SERVICE	
	2188161	MUENCHEN	10.0
	2188225	UND	0.0
	2188227	GMBH	0.0
	2188228	STRASSE	0.0
124944	...		83.8

$\sum occurs$

Depth

The default value for the BUFFER is 262,144.
It can be increased to accommodate more homogenous databases or for specific search purposes, i.e. selection by legal form.
The higher the Depth of the BUFFER the higher the amount of bycatch to be rejected at the first stage.

← Oblivious to surplus words of candidates

Weak Search Terms: Berlin GmbH, Berlin

identity	name	street	zip	city
80.00	CPB Cassetten-Produktion GmbH Berlin	Ballinstr. 16-18	12359	Berlin
80.00	SCHERDEL Berlin GmbH & Co. KG	Kanalstr. 66-74	12357	Berlin
80.00	Münchhoff GmbH Berlin	Nollendorfplatz 6	10777	Berlin
80.00	Elektron Berlin GmbH Fertigung elektrotechnischer Spezialartikel	Saatwinkler Damm 60	13627	Berlin
80.00	KMB Kabel-Maschinen-Berlin GmbH	Innungsstr. 56	13509	Berlin
80.00	Alois Dallmayr Kaffee Berlin GmbH u. Co. KG	Haberstr. 9-13	12057	Berlin
80.00	Mampe GmbH Berlin	Grenzallee 22-34	12057	Berlin
80.00	KBA - Berlin GmbH	Mertensstr. 127-131	13587	Berlin
80.00	Beiersdorf Manufacturing Berlin GmbH	Franklinstr. 1	10587	Berlin
80.00	Centro-Boden Berlin KG Wohn- und Gewerbebauten im Centrum GmbH & Co.	Joachimstaler Str. 14	10719	Berlin
80.00	Amcor Specialty Cartons Berlin GmbH	Haberstr. 5	12057	Berlin
80.00	Helmholtz-Zentrum Berlin für Materialien und Energie GmbH	Hahn-Meitner-Platz 1	14109	Berlin
80.00	LAROSÈ Hygiene-Service GmbH Berlin	Grünauer Str. 116-120	12557	Berlin
80.00	Hifi Elements Berlin GmbH	Hubertusstr. 7	12163	Berlin
80.00	FB Fernsehdienst in Berlin GmbH	Bismarckstr. 71	12157	Berlin
80.00	Klosterfrau Berlin GmbH	Motzener Str. 41	12277	Berlin
80.00	DG Leasing Berlin GmbH	Turmstr. 77	10551	Berlin
80.00	DG Leasing Berlin GmbH & Co. Miet + Leasing KG	Turmstr. 77	10551	Berlin
80.00	Henning Berlin GmbH & Co.	Potsdamer Str. 8	10785	Berlin
80.00	"Pia Rucci""""" Sportswear Bekleidungsvertriebs GmbH, Berlin	Lützowufer 12-13	10785	Berlin
80.00	Ideal Automotive Berlin GmbH	Zerpenschleuser Ring 22	13439	Berlin
80.00	Saarberg Handel Berlin GmbH	Quedlinburger Str. 11	10589	Berlin
80.00	Messe Berlin GmbH	Messedamm 22	14055	Berlin
80.00	BAO BERLIN International GmbH	Fasanenstr. 85	10623	Berlin
80.00	Metallbauzaun-Montagen Roden GmbH Berlin	Saatwinkler Damm 25- 26	13627	Berlin
80.00	tip AUTO-Berlin GmbH	Schulzendorfer Str. 23-24Hof	13347	Berlin
80.00	CVB Albert Carl GmbH Berlin	Oberlandstr. 22-25	12099	Berlin
80.00	Breuer Service Berlin GmbH Industrie- und Kraftfahrzeugreinigung	Alte Jakobstr. 135	10969	Berlin
80.00	Tyler Berlin GmbH	Flankenschanze 28	13585	Berlin
80.00	FRÜH - HERBST Anlagentechnik Berlin GmbH	Lankwitzer Str. 23-25	12107	Berlin
80.00	PFENNIGs Feinkostfabrik Berlin Albert Pfennig + Sohn GmbH & Co.	Ringbahnstr. 22-30	12099	Berlin
80.00	Wachschutz Berlin Werner Loesch GmbH & Co.	Odenwaldstr. 26	12161	Berlin
80.00	Kaiser Kabel GmbH Kabel- und Freileitungswerk Berlin	Gradestr. 100	12347	Berlin
80.00	KKB Küchenkomplettbau GmbH Berlin	Reuchlinstr. 10-11	10553	Berlin
80.00	Tetra Pak Berlin GmbH & Co TPB KG	Hennigsdorfer Str. 159	13503	Berlin
80.00	Häfele Berlin GmbH & Co. KG	Schichauweg 50	12307	Berlin
80.00	Van Houten Industrie Berlin GmbH	Grenzallee 4- 6	12057	Berlin
80.00	Möbelkiste GmbH u. Co. Handelsgesellschaft Berlin	Bundesallee 36	10717	Berlin
80.00	Kamps Berlin Geschäftsführungs GmbH	Bergiusstr. 26-28	12057	Berlin
80.00	Novetta Berlin KG NB-Nahrungsmittelgesellschaft mbH & Co.	Sonnenallee 221	12059	Berlin
80.00	Tyler Refrigeration Berlin GmbH & Co.	Urbanstr. 116	10967	Berlin
80.00	Greve-Chemotechnik Berlin GmbH	Lindenufer 39	13597	Berlin
80.00	Hilfswerk-Siedlung GmbH Evangelisches Wohungsunterne	irchblick 13	14129	Berlin
80.00	Werbedienst Berlin GmbH	ingbahnstr. 16-20	12099	Berlin
80.00	Berlin Los Angeles Platz Value Added I, GmbH & Co. K	os-Angeles-Platz 1	10789	Berlin
80.00	Kraft Jacobs Suchard Berlin GmbH & Co. KG	Nobelstr. 1- 21	12057	Berlin
	GmbH & Co. Berlin KG	Roedernallee 9	13407	Berlin

25000

Weak Search Terms…

- have few words with high frequencies
- are often affected by missing search fields
- contain redundancy, i.e. city name in firm name

This leads to…

→ bloated candidate lists of unrelated false positives
→ ambiguous candidates without variance in the identity
→ waste of time trying to find true positives

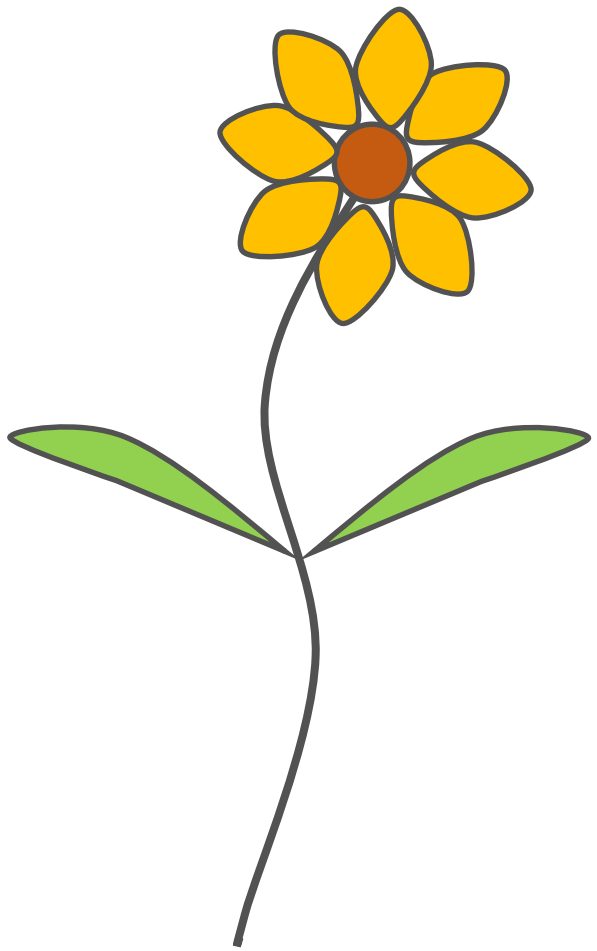
Potential solution

1. Sort candidates by identity in descending order
2. All candidates down to a cutoff point are deemed plausible, i.e. top 10 candidates
3. The identity of the candidate at the cutoff point becomes the new threshold for this search term to prevent arbitrary dismissal of candidates

! No variance in the identity → no cutoff

Jaccard P. (1902), `Lois de distribution florale dans la zone alpine´, Bulletin de la Société Vaudoise des Sciences Naturelles

Searched Flower

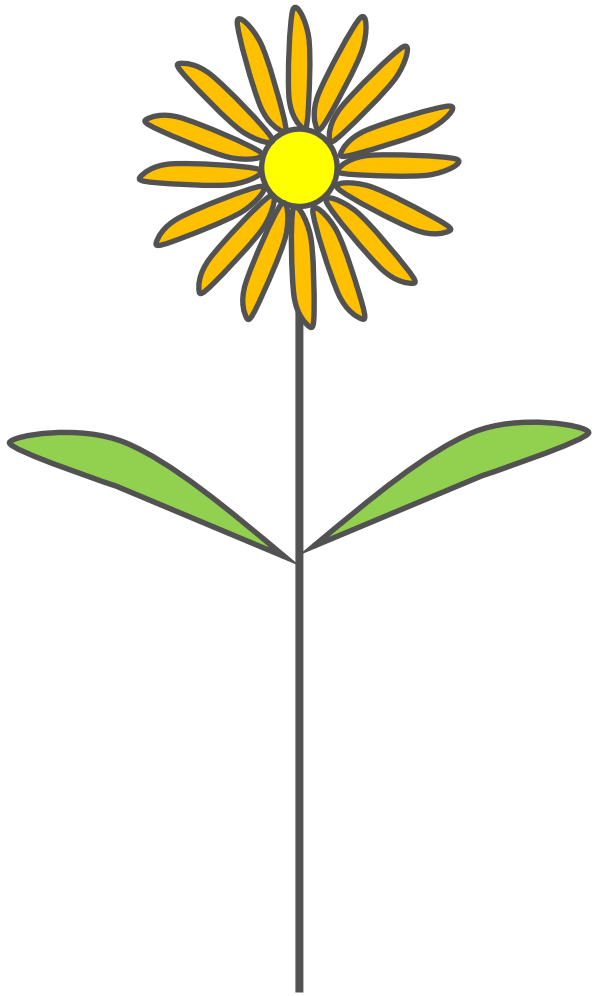


$$J(S,F) = \frac{|\{S \cap F\}|}{|\{S \cup F\}|}$$

$$\frac{4}{7} + 3$$

feedback

Found Flower



$$I_J(S,F,f) = I(S,F)(1-f) + J(S,F)f$$

$$f \in [0,1]$$

10% Feedback Effect on Berlin GmbH, Berlin

identity	name	street	zip	city
80.00	Berlin GmbH	Oudenarder Str. 31	13347	Berlin
80.00	Berlin			Berlin
80.00	C/O Berlin GmbH & Co. KG	Auguststr. 5a	10117	Berlin
80.00	C/O Berlin GmbH & Co. KG	Oranienburger Str. 35/ 36	10117	Berlin
80.00	KG Berlin	Kottmeierstr. 1- 3	12459	Berlin
80.00	Gesellschaft Berlin GmbH	Holzhauser Str. 52-56	13509	Berlin
80.00	Immobilien Berlin GmbH	Barstr. 29	10713	Berlin
80.00	Berlin Bau GmbH	Breite Str.	10178	Berlin
80.00	Berlin Bau - GmbH Berlin			Berlin
80.00	Berlin GbR			Berlin
78.51	AG Berlin	Schlüterstr. 36	10629	Berlin
78.37	Thomas Berlin	An den Bänken 3	12589	Berlin
78.15	DR Berlin UG	Saarbrücker Str. 36	10405	Berlin
78.09	Baugesellschaft Berlin GmbH	Pfalzburger Str. 15	10719	Berlin
77.97	SE Berlin Beteiligungs GmbH	Pichelswerderstr. 3-5	13597	Berlin
77.89	Bau und Immobilien Berlin GmbH	Lindenstr. 4	12621	Berlin
77.70	Walter Berlin GmbH	Bürgerstr. 25- 27	12347	Berlin
77.70	Walter Berlin GmbH	Brauhofstr. 4a	10587	Berlin
77.65	Immobilien Service Berlin	Lampesteig 10	13409	Berlin
77.51	Martin Immobilien Berlin GmbH	Hönower Str. 1	10318	Berlin
77.41	Jürgen Berlin Handelsgesellschaft mbH	Sagritzer Weg 12	13435	Berlin
77.29	In-Berlin e.V.	Kaiser-Friedrich-Str. 88	10585	Berlin
77.09	AM Berlin GmbH	Prenzlauer Allee 53	10405	Berlin
77.00	Joachim Berlin	Randowstr. 12	13057	Berlin
76.99	KG Beteiligungs-mbH Berlin			Berlin
76.85	Management Holding GmbH & Co. KG Berlin			Berlin
76.82	Beteiligungs-Management-Gesellschaft Berlin GmbH			Berlin
76.76	Marketing Service Berlin GmbH	Taubenstr. 19-23	10117	Berlin
76.68	Walter Immobilien Berlin	Hochkönigweg 44	12349	Berlin
76.57	Trockenbau Berlin	Küstriner Str. 7- 8	13055	Berlin
76.56	Grundstücksgesellschaft mbH Berlin	Kaiser-Friedrich-Str. 41	10627	Berlin
76.54	Ulrich Bau Berlin GmbH	Mühlenstr. 8a	14167	Berlin
76.51	Michael Berlin Ingenieurbüro	Rochowstr. 1b	10245	Berlin
76.49	Kurt Berlin GmbH	Baumschulenstr. 72	12437	Berlin
76.34	Immobilien Haus Berlin	Kleiststr. 3-6	10787	Berlin
76.14	Thomas-Haus Berlin e.V.	Peter-Lenne-Str. 4	14195	Berlin
76.07	Metallbau Berlin GmbH	Müggelseedamm 128	12587	Berlin
76.04	BERLIN VERLAG GmbH & Co.KG	Greifswalder Str. 207	10405	Berlin
76.04	BERLIN VERLAG GmbH & Co.KG	Greifswalder Str. 207	10405	Berlin
76.01	Claudia Berlin	Paul-Dessau-Str. 9	12679	Berlin
75.95	Bäckerei Berlin	Oranienstr. 67	10969	Berlin
75.93	Schneider Bau Berlin	Bismarckstr. 39	10627	Berlin
75.91	Auto-Service Berlin GmbH	Katzlerstr. 15	10829	Berlin
75.86	Büro-Service-GmbH Berlin	Malschweg 12	13593	Berlin
75.85	Immobilien Vertrieb Berlin e.V.	Kurfürstendamm 208	10719	Berlin
75.85	Metallbau Service Berlin GmbH	Heinersdorfer Str. 4	13129	Berlin
75.82	[illegible]Management-Gesellschaft Berlin mbH			Berlin

Containment of weak search terms

Cutoff

Defines the upper limit for a reasonable number of candidates, i.e. 10.

Activation

If the candidate list meets this threshold, Feedback will be applied. Usually, it should equal the Cutoff.

Feedback

Defines the magnitude of the feedback effect as discount on the Identity.

When Activation > 0 and Cutoff > 0:

→ Temporary Feedback effect to create variation for Cutoff

- Usually, 10% feedback suffices
- Effect will be undone before Threshold validation

Otherwise:

→ Permanent Feedback effect affecting Identity vs. Threshold

The interaction of these three settings prevents unnecessary, time consuming feedback calculations. Containment will keep candidates with the least amount of relevant noise.

3-Gram Search for “Blaupause”: BLA LAU AUP UPA AUS USE

identity	name
100.00	Blaupause Bootsbau GmbH
100.00	Blaupause KfK Verwaltungs GmbH
100.00	Projekt Blaupause e.V.
100.00	Alexander Schilder 'Blaupause'
100.00	blaupause e.V.
100.00	BLAUPAUSE e.V. - mobile und flexible Hilfen für Menschen mit einer Alkoholerkrankung
100.00	Blaupause - Initiative für mentale Gesundheit im Gesundheitswesen e.V.
100.00	Martin Alexander Rieger Blaupausen Medien Multimediaagentur
100.00	Blaupause UG Die Agentur für mehr
100.00	Blaupauser Zeichenbüro e.U.
100.00	Blaupauser Projektentwicklung GmbH
100.00	Blaupause Interior Design e.U.
100.00	Anja Thomä und Lena Dreesmann GbR "Blaupause"
100.00	Anja Thomä Blaupause papeterie
100.00	Barnimer Alternative e.V. Jugendclub Blaupause
100.00	Jens Naumann Jan Welsch Blaupause GbR
100.00	Agentur Blaupause 36 UG
91.10	Blaupark Living Ulm K20 Projekt GmbH
91.10	Ute Nißle-Klammt Blaupark-Apotheke
91.10	Blaupapier Immobilienverwertungsges.m .b.H.
91.10	Blaupapier GmbH
91.10	Blaupark Living Ulm K20 Projekt GmbH
91.03	Heike Hartung Plaupause
91.03	Plaupause - Bistro & Spätshop UG
89.68	Simon Huber Filmproduktion graupause
86.68	Seniorenzentrum Lopaupark GmbH
86.68	paupau GmbH
86.68	paupau Deli UG
86.68	Paulsen Baupartner GmbH
86.68	Karl Paul Kaupa Bettengeschäft
86.68	fraupaul e.U.
83.80	Bausen & Markwart Ausbaupartner GmbH
83.80	Baupartner BAUSTOFFSERVICE Schönhausen GmbH
83.80	Krause Baupartner

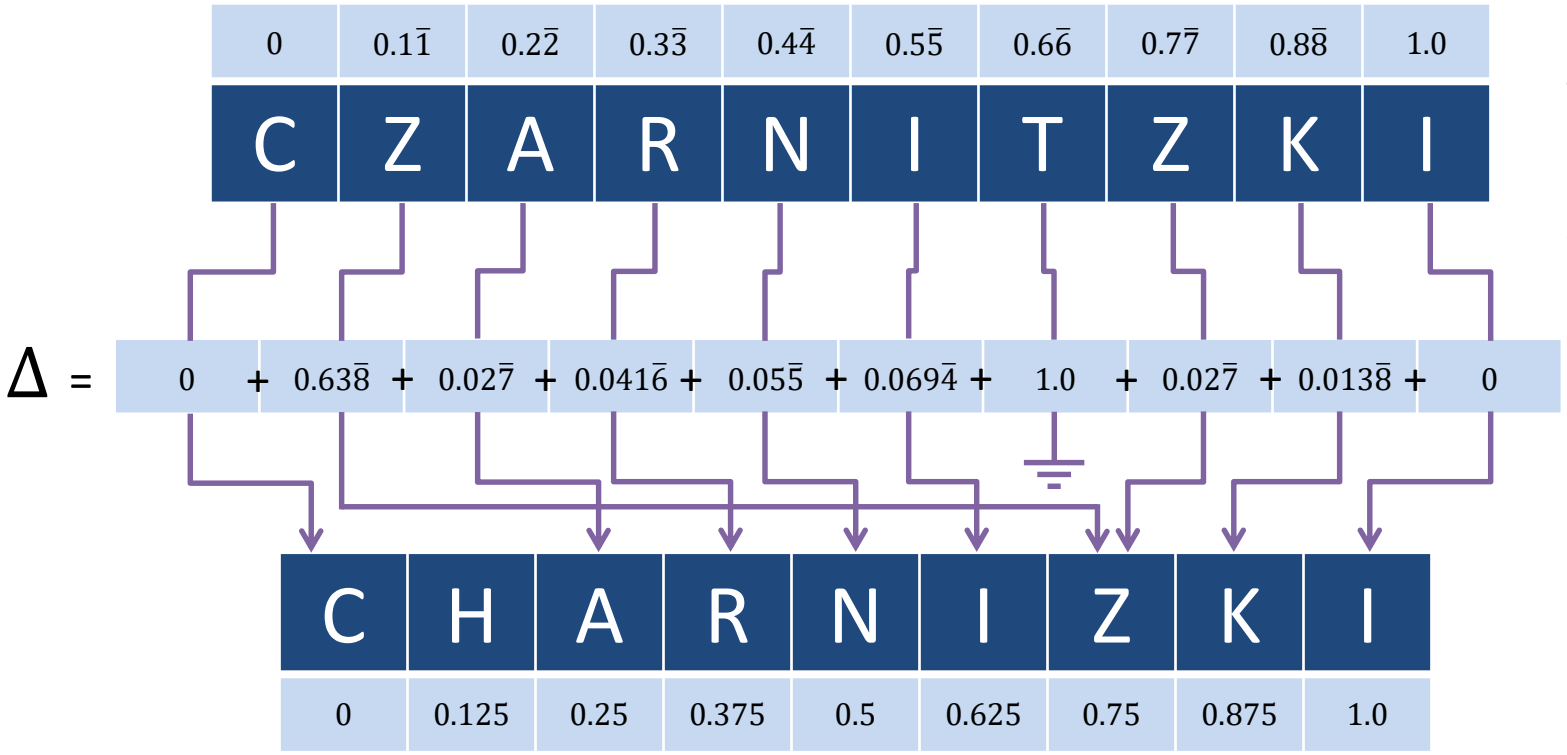
1580

Words responsible for retrieval:

blaupause
blaupausen
blaupauser
blaupark
blaupapier
plaupause
graupause
lopaupark
paupau
paulsen baupartner
paul kaupa
fraupaul
bausen ausbaupartner
baupartner baustoffservice schönhausen

Linguistic preparers destroy information for the sake of recalling misspelled terms at the expense of precision. The genuinely misspelled entries are drowned in a deluge of false positives. Usually, linguistic methods are applied in interactive environments, where results are eye-balled by humans discriminating between real misspellings and mechanical clutter. We have to replicate this visual screening via a flexible string distance function, which is independent of word positioning.

Least Relative Character Position Delta (LRCPD)



$$lrcpd(word1, word2) = 1 - \frac{\Delta(word1, word2)}{len(word1)} = 1 - \frac{1.875}{10} = 0.8125$$

Candidate Refinement (Visual Screening)

search = any search field affected by a destructive preparer
found = corresponding entry of the Candidate
run basic preparer over search and found
delta = 0
go through all words of search → word1
    max = 0
    go through all words of found → word2
        max = max(max, lrcpd(word1, word2))
        if max == 1 exit loop
    delta += max
delta = delta/wordcount(search)
remove all blanks from search and found
return max(delta, lrcpd(search, found))

- Refinement ignores word-positioning, is commutative and returns a percentage → easy integration
- Refinement is integrated into the Identity by replacing the components of search types affected by destructive Preparer

3-Gram Search for “Blaupause” after LRCPD-Refinement

identity	name
100.00	Blaupause Bootsbau GmbH
100.00	Blaupause KfK GmbH & Co. KG
100.00	Projekt Blaupause e.V.
100.00	Alexander Schilder 'Blaupause'
100.00	blaupause e.V.
100.00	BLAUPAUSE e.V. - mobile und flexible Hilfen für Menschen mit einer Alkoholerkrankung
100.00	Blaupause - Initiative für mentale Gesundheit im Gesundheitswesen e.V.
100.00	Blaupause UG Die Agentur für mehr
100.00	Blaupause Interior Design e.U.
100.00	Anja Thomä und Lena Dreesmann GbR "Blaupause"
100.00	Anja Thomä Blaupause papeterie
100.00	Barnimer Alternative e.V. Jugendclub Blaupause
100.00	Jens Naumann Jan Welsch Blaupause GbR
100.00	Agentur Blaupause 36 UG
88.89	Heike Hartung Plaupause
88.89	Plaupause - Bistro & Spätshop UG
85.00	Martin Alexander Rieger Blaupausen Medien Multimediaagentur
85.00	Blaupauser Zeichenbüro e.U.
85.00	Blaupauser Projektentwicklung GmbH

Refinement

and integration are subsequent processes following retrieval. They are optional. A second Threshold can be specified to filter candidates thereafter. Even the direction of the Refinement can be altered:

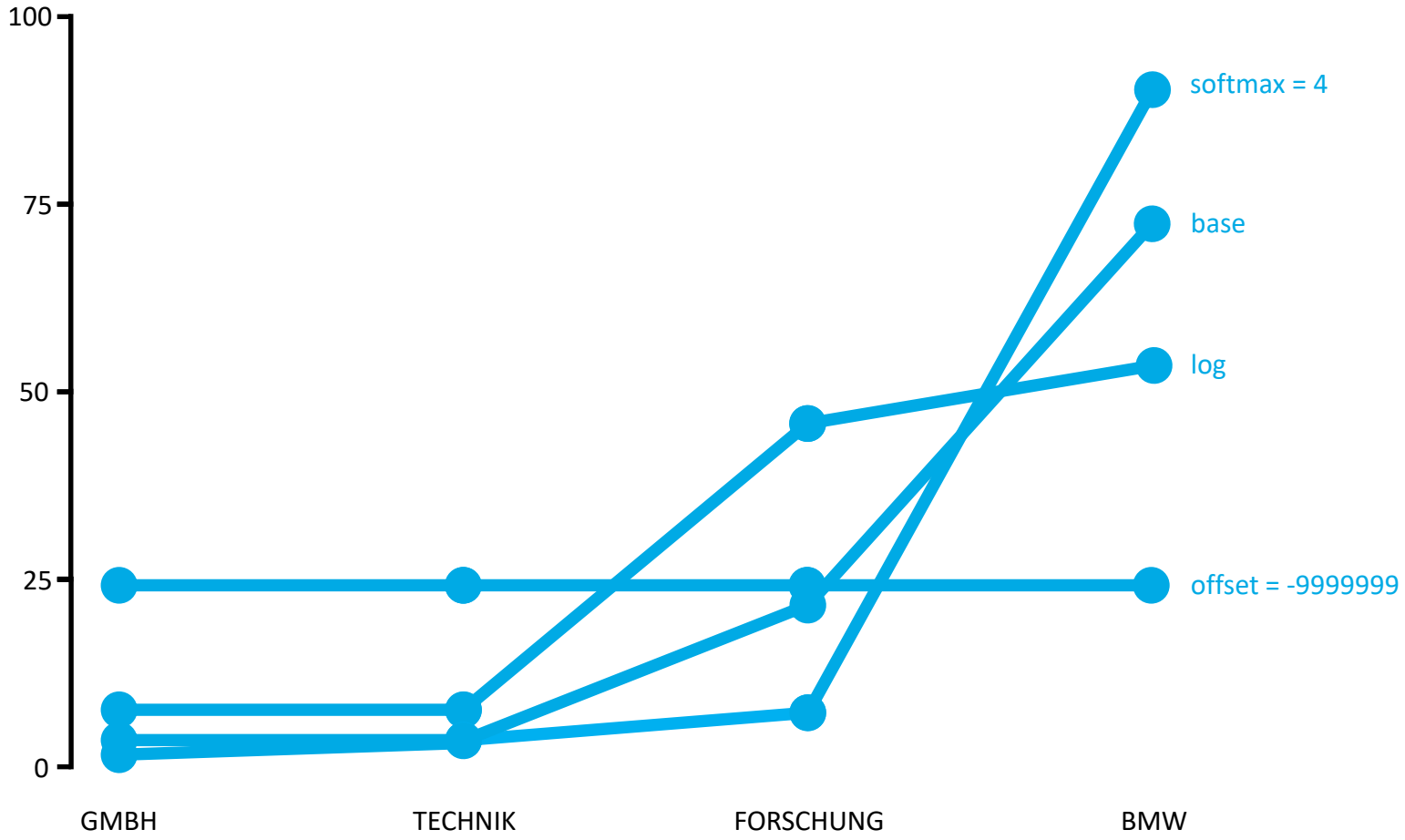
- Compare Searched with Found is the default direction and mimics the general SearchEngine behavior
- Dynamic compare compares in both directions and uses the lowest result → suitable for person names
- Compare Found with Searched reverses the default direction → more noise in the base table (rarely used)
- No automatic refine/research on destructive preparer skips the whole Refinement part (not advised but required for educational purposes)

Advice

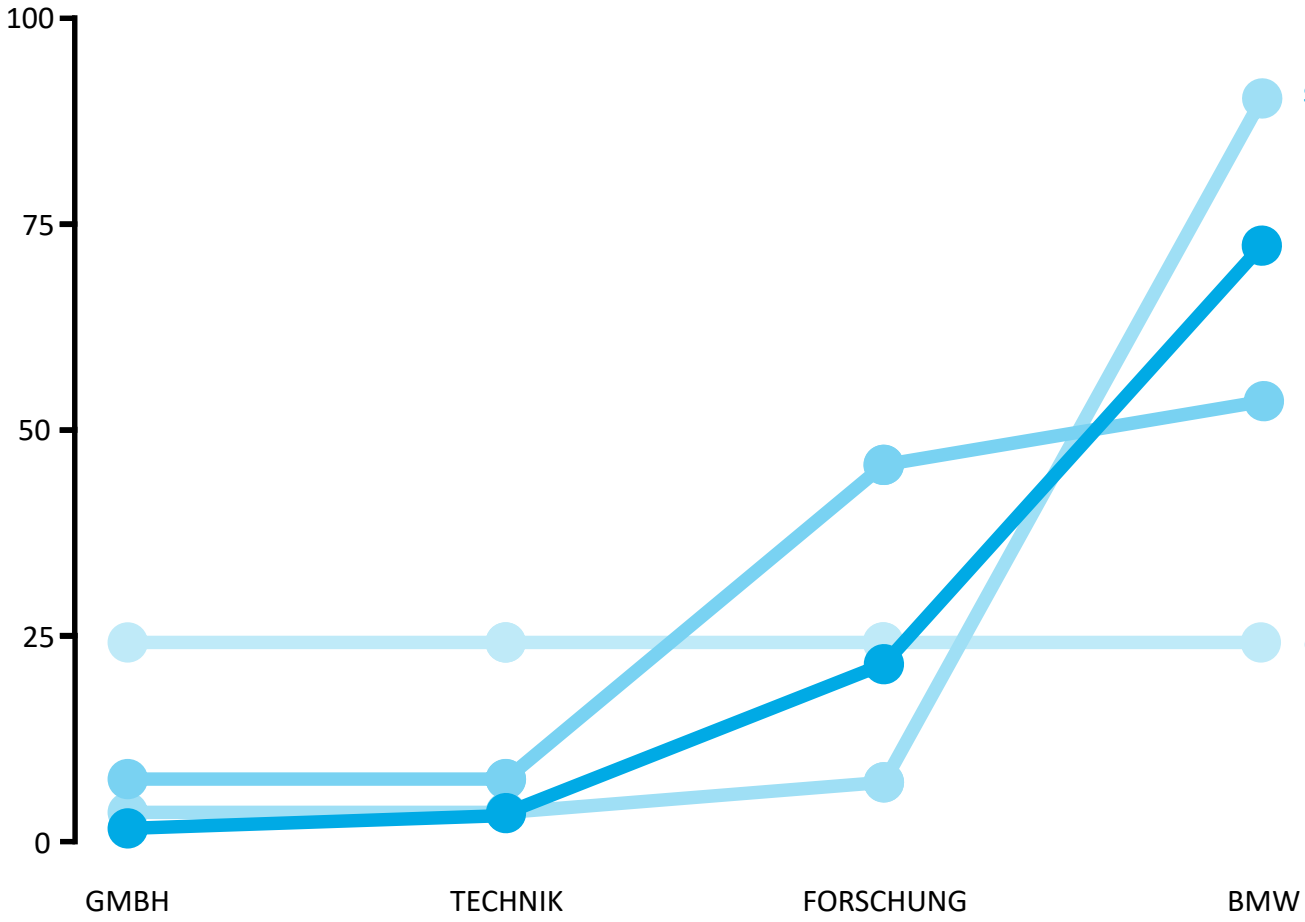
Refined components of the Identity lack the intrinsic frequency based heuristic. Every word has the same “Identification Potential”. This can be considered a tacit loss in information conveyed by the Identity. Plus, retrieval using destructive Preparer and the consecutive Refinement are slow.

Therefore search types using destructive preparers should be used sensibly and only after search steps based on conventional preparers to fill the gaps caused by misspellings.

Smoothing & Accentuating of the rIP



Smoothing & Accentuating of the rIP



softmax = 4 — experimental, keyword clustering for abstracts & titles
$0 < softmax \leq 1.5$: smoothing ($0.5 \approx$ log)
$1.5 < softmax \leq 30$: accentuating

base — high recall, moderate precision

log — high precision, moderate recall

offset = -9999999 — transformation into word based heuristic, outdated by log

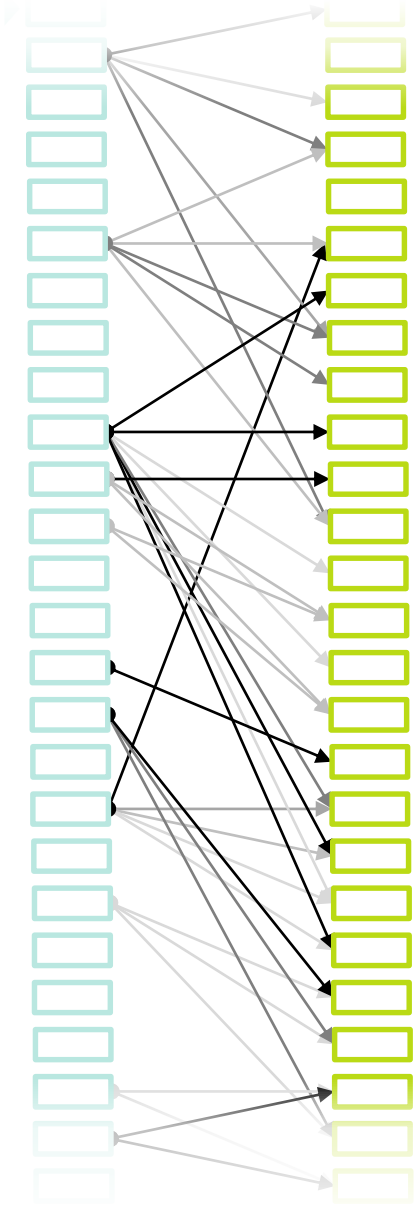
3-Gram Search for “Blaupause” with Log-Smoothing vs. Refinement

identity	name
100	Blaupause Bootsbau GmbH
100	Blaupause KfK GmbH & Co. KG
100	Projekt Blaupause e.V.
100	Alexander Schilder 'Blaupause'
100	blaupause e.V.
100	BLAUPAUSE e.V. - mobile und flexible Hilfen für Menschen mit einer Alkoholerkrankung
100	Blaupause - Initiative für mentale Gesundheit im Gesundheitswesen e.V.
100	Martin Alexander Rieger Blaupausen Medien Multimediaagentur
100	Blaupause UG Die Agentur für mehr
100	Blaupauser Zeichenbüro e.U.
100	Blaupauser Projektentwicklung GmbH
100	Blaupause Interior Design e.U.
100	Anja Thomä und Lena Dreesmann GbR "Blaupause"
100	Anja Thomä Blaupause papeterie
100	Barnimer Alternative e.V. Jugendclub Blaupause
100	Jens Naumann Jan Welsch Blaupause GbR
100	Agentur Blaupause 36 UG
83.54	Heike Hartung Plaupause
83.54	Plaupause - Bistro & Spätshop UG

identity	name
100.00	Blaupause Bootsbau GmbH
100.00	Blaupause KfK GmbH & Co. KG
100.00	Projekt Blaupause e.V.
100.00	Alexander Schilder 'Blaupause'
100.00	blaupause e.V.
100.00	BLAUPAUSE e.V. - mobile und flexible Hilfen für Menschen mit einer Alkoholerkrankung
100.00	Blaupause - Initiative für mentale Gesundheit im Gesundheitswesen e.V.
100.00	Blaupause UG Die Agentur für mehr
100.00	Blaupause Interior Design e.U.
100.00	Anja Thomä und Lena Dreesmann GbR "Blaupause"
100.00	Anja Thomä Blaupause papeterie
100.00	Barnimer Alternative e.V. Jugendclub Blaupause
100.00	Jens Naumann Jan Welsch Blaupause GbR
100.00	Agentur Blaupause 36 UG
88.89	Heike Hartung Plaupause
88.89	Plaupause - Bistro & Spätshop UG
85.00	Martin Alexander Rieger Blaupausen Medien Multimediaagentur
85.00	Blaupauser Zeichenbüro e.U.
85.00	Blaupauser Projektentwicklung GmbH

Why should “UPA” be much more relevant then “BLA”? Log-smoothing suppresses the undeserved dominance of specific n-grams.
Still, refinement should always be engaged for n-grams because the SearchEngine notoriously disregards positioning.
N-grams with and without smoothing complement each other, hence alternate both in dedicated search runs for best effect.

Unfocused Base Table vs. Focused Base Table



Firms are not in the Focus of the Data Collector

- Firms do not have a dedicated key
- Patent authorities and similar
- Scraped web data
- Focused on subordinate entities to firms, i.e. establishments, departments

Compound Search Strategy

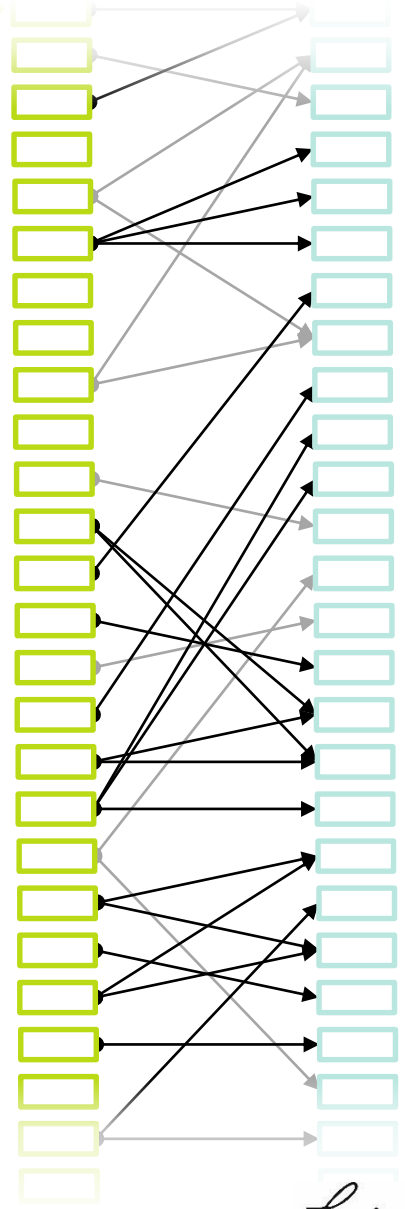
- Low threshold as all potential candidates need to be captured: the good, the bad and the ugly
- Merging: candidate list of subsequent search runs have to be merged with existing lists
- Prone to false positives
- Candidates of a search record have variable identities

Data Collector Curates Firm Data

- Firms have a dedicated key, i.e. bvdid, tax number
- Duplicates are avoided
- Orbis, Compustat, creditreform, authorities

Incremental Search Strategy

- Multiple incremental search runs
- Darwinian: only the best candidates are picked
- Completing: search records that already have candidates are omitted from subsequent search runs
- Search parameters are gradually relaxed between runs
- Candidates of a search record have uniform identities



Decision Space

Search Table providing Search Terms		Base Table providing Candidates/Heuristic
unfocused or focus on subordinate entities	vs.	curated, focused on the search topic
concise representation of the search topic	vs.	data littered with additional noise and clutter
small or specialized dataset	vs.	sufficiently large unbiased sample/population

General Workflow

- Preparing the Data (search and base table)
  - Harmonize idiosyncratic disparities between the datasets, like consistently using different kinds of abbreviations.
    “Univ” vs. “University” vs. “Uni”, “limited” vs. “ltd”, “Strasse” vs. “Str.” and so on
    Optionally: development of custom Preparers (there are already some in the “preparer” directory)
  - Removal of duplicate entries in the data especially in unfocused datasets, i.e. patent applicants. This removes unwanted distortions of the heuristic and redundancies. Keep a linkage to the original data!
  - The SearchEngine imports tab-delimited text files with column headers (not too fancy). Avoid unnecessary fields!
- Create the SearchEngine
  - Choose the base table according to the following priority list: more focused, more clutter, larger
  - Define search types by adding preparers to search fields. Usually, every search field has a conventional search type and only the most relevant field(s) will get an additional destructive search type including a n-gram preparer.
- Search Strategy for Firm Matching
  - Define a weight distribution according the relevancy of the search fields, ignoring additional destructive search types, e.g. 70% for relevant fields (firm name) and 30% for auxiliary fields (address). Define a containment by choosing a justifiable size for a large candidate list.
  - Incremental: complete search terms without candidates from earlier runs, gradually reduce retrieval restrictions, Darwinian (keep only the best)
    - Start with a high threshold requiring auxiliary fields using only conventional search types. You may even prelude with a run based on log smoothed conventional search types for the relevant fields followed by a non-smoothed version.
    - Switch to destructive search types by switching the corresponding weights and perform two search runs, one with log smoothing and one without smoothing of the destructive search types.
    - Lower the threshold forfeiting the necessity of auxiliary fields and repeat the search steps.
  - Compound: merge search runs based on a reasonably low threshold
    - Start with a conventional search run by setting the weights of the destructive search types to zero
    - Switch to destructive search types by switching the corresponding weights and perform two search runs, one with log smoothing and one without smoothing of the destructive search types.
- Concentrate on appropriate retrieval and less on identity refinement because the identity will be replaced by the meta vector carrying much more similarity indicators for the SearchEngine Machine Learning approach SEML.

Search Strategy Components

- Threshold
  - Interaction with the search type weights constitutes the search strategy
  - A threshold above the firm name weight enforces partial address similarity
  - If the threshold is below the firm name weight, similarity in the address increases the leeway
- Redistribution of search type weights
  - Increasing/decreasing the impact of search types on the relative Identity
  - The more weight on address search types, the higher the leeway for the firm name
  - A weight of zero deactivates a search type for strategies with dedicated misspelling steps:
    - Start with runs not capturing misspellings → associated search types (n-grams) has a weight of zero
    - Continue with misspelling runs → switch weight to linguistic search types, set conventional to zero
- Containment
  - Keep weak search terms at bay by assessing a sensible cutoff: maximum expected number of plausible candidates
- Capturing misspellings
  - Activating linguistic search types (n-grams) by assigning a weight > 0 and deactivating the corresponding conventional search type
  - Usually only relevant search fields like the firm name are equipped with linguistic preparer
- Smoothing of the rIP distribution
  - A smoothed distribution requires more words to match → dominant words lose dominance
  - Higher precision at the expense of recall
  - Some search contexts fare better with smoothing, i.e. street addresses or person names
  - N-grams covering misspellings may become dominant preventing matches → two search runs: one with and one without smoothing
- Strategies over multiple search steps
  - Incremental: exclude search records with candidates from subsequent search runs, Darwinian (keeping only the best candidates) → Focused Base Table
  - Compound: candidates of subsequent runs are merged (union of candidate sets) → Unfocused Base Table

Search Strategy: Establishment Panel vs. Company Panel (MUP)

- Data
  - Mannheimer Unternehmens Panel (MUP 2000-2021, German Company Panel)
    - Removing duplicates → firm name & address aggregates: 24 million
  - Betriebsdatenpanel (Establishment Panel 2000-2020)
    - Harmonizing street addresses due to systematic changes over years
    - Removing duplicates → establishment & address aggregates: 21 million

- SearchEngine
  - Base table: MUP
  - Search types: name FIRMA, name FIRMA GRAM3, street STRASSE, zip, city
  - Darwinian search mode: pick only the candidates with the highest Identity
  - Incremental: skip search records with candidates in subsequent search runs

- Strategy

run	description	threshold	establishments	candidates
1	name 70, name 3-gram 0, street 10, zip 10, city 10	85	9,393,950	14,531,161
2	name 0, name 3-gram 70 log, street 10, zip 10, city 10	85	294,805	356,327
3	name 0, name 3-gram 70, street 10, zip 10, city 10	85	32,075	39,234
4	name 70 -9999999, name 3-gram 0, street 10, zip 10, city 10	85	841,062	1,296,231
5	name 70, name 3-gram 0, street 10, zip 10, city 10	65	6,964,399	43,400,697
6	name 0, name 3-gram 70 log, street 10, zip 10, city 10	65	571,931	801,739
7	name 0, name 3-gram 70, street 10, zip 10, city 10	65	141,064	202,351
			18,239,286	60,627,740

Training Data

searched	found	identity	equal	name	street	zip	city	score	cnt	run
5935			1	Isotopen Technologien München AG	Rathausplatz 5	83435	Bad Reichenhall	2.65	5	
5935	684067	70.00		ITM Isotopen Technologien München AG	Theatinerstr. 23	80333	München	2.65	5	5
5935	19425145	70.00		ITM Isotopen Technologien München AG	Walter-Meissner-Str. 2	85748	Garching	2.65	5	5
5935	19425146	70.00		ITM Isotopen Technologien München AG	Lichtenbergstr. 1	85748	Garching	2.65	5	5
5935	21419919	70.00		ITM Isotopen Technologien München AG	Schleißheimer Str. 91a	85748	Garching	2.65	5	5
5935	21419920	70.00		ITM Isotopen Technologien München AG	Walther-von-Dyck-Str. 4	85748	Garching	2.65	5	5
3885			9	Universität Stuttgart	Keplerstrasse 7	70174	Stuttgart	0.04	4	
3885	16183176	100.00	1	Universität Stuttgart	Keplerstr. 7	70174	Stuttgart	0.04	4	1
3885	17625066	100.00		Akademische Motorsportgruppe an der Universität Stuttgart	Keplerstr. 7	70174	Stuttgart	0.04	4	1
3885	17706003	100.00		Vereinigung von Freunden der Universität Stuttgart	Keplerstr. 7	70174	Stuttgart	0.04	4	1
3885	17706007	100.00		Förderkreis Betriebswirtschaft an der Universität Stuttgart e.V.	Keplerstr. 7	70174	Stuttgart	0.04	4	1
40529			9	Klaus Sindel Rusi-Kosmetik-Pinsel-Brushes GmbH	Ansbacher Strasse 53	91572	Bechhofen	0.05	4	
40529	19723005	85.69		Hauck Pinsel GmbH	Ansbacher Str. 47a	91572	Bechhofen	0.05	4	9
40529	19700672	83.76		Johann Führ & Söhne Pinselfabrik GmbH	Ansbacher Str. 27-29	91572	Bechhofen	0.05	4	9
40529	19707191	82.98		Elco-Pinsel GmbH	Ansbacher Str. 86	91572	Bechhofen	0.05	4	9
40529	19773153	81.77		Ernst Bock & Sohn Pinselfabrik GmbH	Ansbacher Str. 68	91572	Bechhofen	0.05	4	9
25276			1	RHODIA AG	Engesserstrasse 8 Postfach 1320	7800	Freiburg	2.41	4	
25276	4371760	80.32		RHONE-POULENC RHODIA AG	Engesserstr. 8	79108	Freiburg	2.41	4	1
25276	5408910	80.32		RP Rhodia AG	Engesserstrasse 8		Freiburg	2.41	4	1
25276	5408911	80.32		RP Rhodia AG	Engesserstr. 8	79108	Freiburg	2.41	4	1
25276	15531543	80.32		Rhodia Acetow AG	Engesserstr. 8	79108	Freiburg	2.41	4	1
52085			1	Karlsruher Institut für Technologie	Körperschaft des öffentlichen Rechts,Kaiserstrasse 12	76131	Karlsruhe	0.15	3	
52085	16156922	90.02	9	Akademische Fliegergruppe am Karlsruher Institut für Technologie	Kaiserstr. 12	76131	Karlsruhe	0.15	3	1
52085	16156923	90.02	9	Akademische Fliegergruppe am Karlsruher Institut für Technologie e.V.	Kaiserstr. 12	76131	Karlsruhe	0.15	3	1
52085	16240255	90.02		KIT Karlsruher Institut für Technologie	Kaiserstr. 12	76131	Karlsruhe	0.15	3	1
20010			1	Dynamic Microsystems Semiconductor Equipment GmbH	Im Wiesengrund 17	78315	Radolfzell	0.09	2	
20010	16318610	82.32		DMS DYNAMIC MICRO SYSTEMS SEMICONDUCTOR EQUIPMENT GMBH	Im Wiesengrund 17	78315	Radolfzell	0.09	2	2
20010	16318611	82.32		DMS Dynamic Micro Systems Semiconductor Equipment GmbH	Im Wiesengrund 17	78315	Radolfzell	0.09	2	2
19904			1	KARL BROTZMANN COMSULTING GmbH	von Scheffel-Strasse 34	92224	Amberg	0.10	2	
19904	19376777	98.80		Karl Brotzmann Consulting GmbH	Von-Scheffel-Str. 34	92224	Amberg	0.10	2	3
19904	19776576	98.80		K a r l B r o t z m a n n C o n s u l t i n g GmbH	Von-Scheffel-Str. 34	92224	Amberg	0.10	2	3
22278			1	Eerec Technology GmbH Development & Design	Borntalstrasse 9	36460	Merkers/Thür.	0.11	2	
22278	7273363	81.58		EuRec Technology GmbH Development & Design	Borntalstr. 9	36460	Merkers-Kieselbach	0.11	2	2
22278	7273364	81.58		EuRec Technology GmbH Development & Design	Borntalstr. 9	36460	Merkers	0.11	2	2
33792			1	A L M Ü PRAZISIONSWERKZEUG GmbH	Ohmder Strasse 12	73119	Zell	1.74	1	
33792	15622884	98.70		ALMÜ Präzisions-Werkzeug GmbH	Ohmder Str. 12	73119	Zell	1.74	1	8
3092			1	Gesellschaft zur Förderung angewandter Optik, Optoelektronik, Quantenelektronik und Spektroskopie e.V.	Rudower Chaussee 29 (IGZ)	12489	Berlin	2.04	1	
3092	483360	82.25		OPTOSENS Optische Spektroskopie und Sensortechnik GmbH	Rudower Chaussee 29(IGZ)	12489	Berlin	2.04	1	7

Meta Vector Components

Heuristic

Absolute Identification Potential: $aIP(w) = 1 - ln(occ(w, st_w))/ln(maxocc(st_w))$
Report only the n largest aIP in descending order for…
…matching words in search term and candidate
…words exclusive to the candidate
…words exclusive to the search term (requires auxiliary registry of the search table)
for all search types, i.e.: name = 5, name GRAM3 = 15, street = 3, zip = 1, city = 2

Visual

Asymmetric string distances based on maximizing word-by-word comparisons between search term and candidate and vice versa for all search fields (independent of the positioning of words).

Overlap

Similarities between search field components, i.e. city name repeats in firm name

Descriptive

Candidate block statistics

- Number of candidates for the same search record
- Number of distinct identities among those candidates
- Percentile rank position within candidates
- Standard deviations of the string distances (calculated externally)

- Relatively slim parameter set per observation (around 110 variables)
  - Low risk of over-specification: having too many variables for too little data
- No semantics
  - "second hand metal wares" and "scrapyard" are not identified as tantamount

→ Lenient labeling required (use post-processing with core data to settle ambiguities)

SEML (SearchEngine Machine Learning): Establishments vs. Company Panel

- SEML components
  - `brain.ado` – Neural Network module for Stata
  - `seml_train.do`
    - Iterates hidden neuron setups: [25], [50], [100], [25x25], [50x50], [100x100]
    - Reports the best performing NN pertaining out-of-sample prediction
  - `seml_think.do` – implements the winning NN setup on the whole meta data
  - BYOD – bring your own device, i.e. Tensor Flow, Keras, Random Forest, …
- Training sample
  - 2,000 establishments paired with 5,523 candidates
  - 569 pairings retained for out-of-sample prediction
- Confusion matrix

Probit	True	False
Positive	180	10
Negative	367	12
Recall	93.75%	97.35%
Precision	94.74%	96.83%
Accuracy	96.13%	

NN[25x25]	True	False
Positive	184	3
Negative	374	8
Recall	95.83%	99.20%
Precision	98.40%	97.91%
Accuracy	98.07%	

- Quality assessment
  - only 58% overlap between companies and establishments due to structural disparities, i.e. self-employment vs. owner operated firms

Search Strategy: German EPO Firm Applicants vs. Company Panel (MUP)

- Preparation
  - Mannheimer Unternehmens Panel (MUP 2000-2021, German Company Panel)
    - Removing duplicates → firm & address aggregates: 24 million
  - German EPO Applicants (Patstat 2021)
    - Removing person owned patents with less than 10 patents
    - Removing duplicates → firm & address aggregates: 62,036
- SearchEngine
  - Base table: MUP
  - Search types: name FIRMA, name FIRMA GRAM3, street STRASSE, zip, city
  - Darwinian search mode: pick only the candidates with the highest Identity
  - Incremental: skip search records with candidates in subsequent search runs
- Strategy

run	description	threshold	applicants	candidates
1	name 70, name 3-gram 0, street 10, zip 10, city 10	79	56,603	108,775
2	name 0, name 3-gram 70, street 10, zip 10, city 10	79	682	977
3	name 0, name 3-gram 70 log, street 10, zip 10, city 10	79	275	385
4	name 70 -9999999, name 3-gram 0, street 10, zip 10, city 10	79	167	358
5	name 70, name 3-gram 0, street 10, zip 10, city 10	65	3,078	8,251
6	name 70 log, name 3-gram 0, street 10, zip 10, city 10	65	69	134
7	name 0, name 3-gram 40, street 20, zip 20, city 20	80	17	20
8	name 0, name 3-gram 40 log, street 20, zip 20, city 20	80	34	53
9	name 0, name 3-gram 40, street 20, zip 20, city 20	zealous	35	61
			60,960	119,014

SEML: German EPO Applicants vs. Company Panel

- Training sample
  - 3,264 applicants paired with 6,535 candidates
  - − 677 pairings retained for out-of-sample prediction
  - + completely scrutinized search runs 4 & 6 to 9 due to marginal representation
- Confusion matrix

Probit	True	False
Positive	575	13
Negative	70	19
Recall	96.80%	84.34%
Precision	97.79%	78.65%
Accuracy	95.27%	

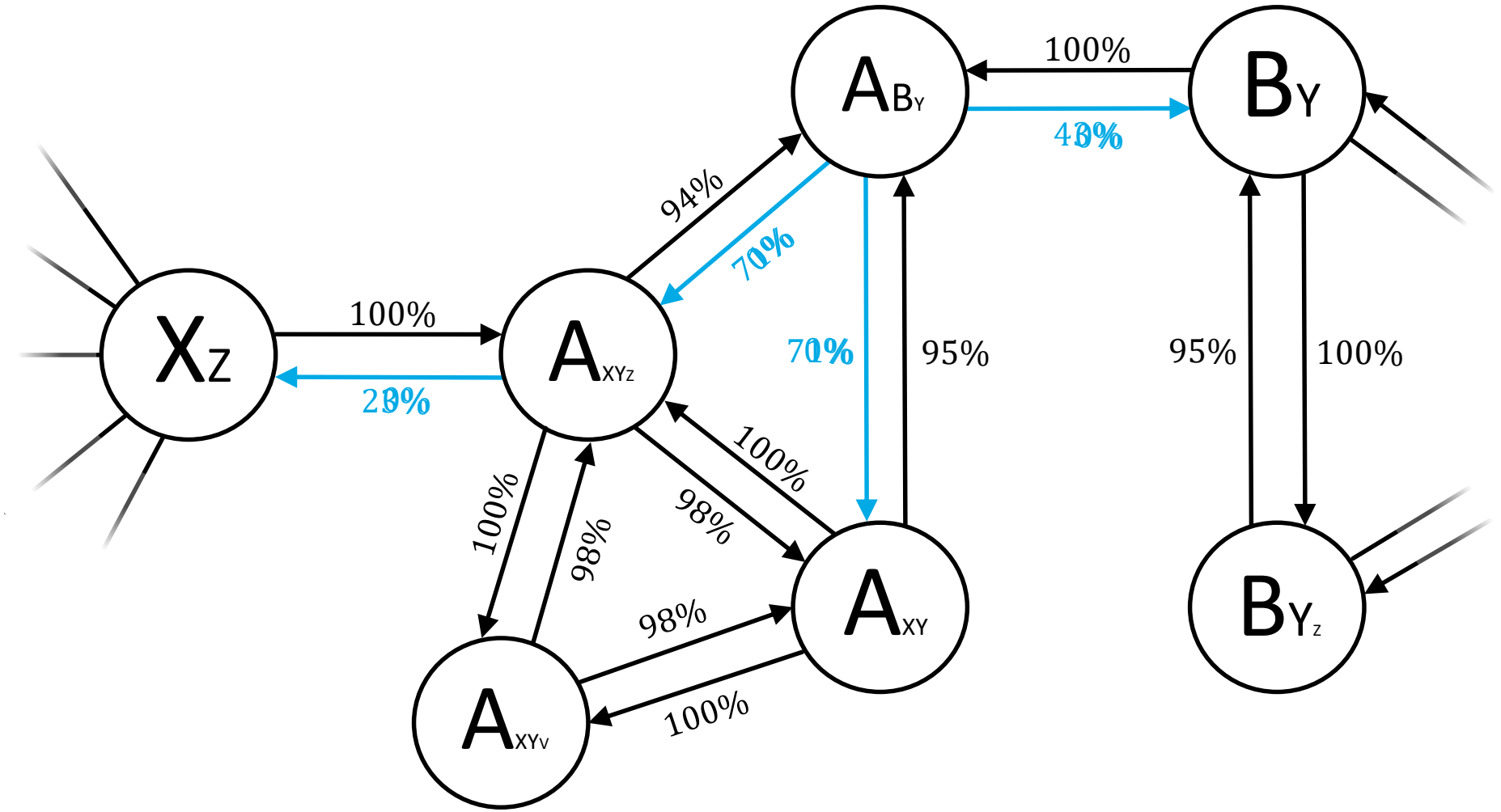
NN[25]	True	False
Positive	590	5
Negative	78	4
Recall	99.33%	93.98%
Precision	99.16%	95.12%
Accuracy	98.67%	

- Quality assessment
  - 59,630 of 62,036 applicants assigned covering 98.81% of all German firm patents

Entity Resolution: Search Table = Base Table

searched	found	identity	equal	name	zip	city	street	country
203346				SCHERING AKTIENGESELLSCHAFT PATENTE	13342	BERLIN	MUELLERSTRASSE 178 POSTFACH 65 03 11	
203346	203346	100.00		SCHERING AKTIENGESELLSCHAFT PATENTE	13342	BERLIN	MUELLERSTRASSE 178 POSTFACH 65 03 11	DE
71132				HOECHST SCHERING AGR EVO GMBH	13342	BERLIN	GERICHTSTRASSE 27	
71132	71132	100.00		HOECHST SCHERING AGR EVO GMBH	13342	BERLIN	GERICHTSTRASSE 27	DE
71132	66486	95.00		HOECHST SCHERING AGR EVO GMBH	13347	BERLIN	GERICHTSTRASSE 27	DE
71132	73565	90.00		HOECHST SCHERING AGR EVO GMBH	13509	BERLIN	MIRAUSTRASSE 54	DE
323602				SCHERING AG	13342	BERLIN	MUELLERSTRASSE 170 178	
323602	323602	100.00		SCHERING AG	13342	BERLIN	MUELLERSTRASSE 170 178	DE
323602	389129	99.57		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13342	BERLIN	MUELLERSTRASSE 170 178	DE
323602	199658	99.29		SCHERING AKTIENGESELLSCHAFT	13342	BERLIN	PATENTE MUELLERSTRASSE 178 POSTFACH 65 03 11	DE
323602	203346	99.29		SCHERING AKTIENGESELLSCHAFT PATENTE	13342	BERLIN	MUELLERSTRASSE 178 POSTFACH 65 03 11	DE
323602	402998	95.00		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 170 178	DE
323602	180193	94.73		SCHERING AG	13353	BERLIN	MUELLERSTRASSE 178	DE
323602	303857	94.73		SCHERING AG	13353	BERLIN WEDDING	MUELLERSTRASSE 178	DE
323602	397563	94.73		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 178	DE
323602	264	94.57		SCHERING AKTIENGESELLSCHAFT	13342	BERLIN		DE
323602	71132	94.57		HOECHST SCHERING AGR EVO GMBH	13342	BERLIN	GERICHTSTRASSE 27	DE
323602	171208	94.29		SCHERING AKTIENGESELLSCHAFT	13353	BERLIN	MUELLERSTRASSE 178	DE
323602	435123	94.29		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13353	BERLIN	PATENTS LICIENSING MUELLERSTRASSE 178	DE
402998				BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 170 178	
402998	402998	100.00		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 170 178	DE
402998	397563	99.73		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 178	DE
402998	435123	99.40		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13353	BERLIN	PATENTS LICIENSING MUELLERSTRASSE 178	DE
402998	389129	94.68		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13342	BERLIN	MUELLERSTRASSE 170 178	DE
518249				BAYER PHARMA AG	13353	BERLIN	MUELLERSTRASSE 178	
518249	518249	100.00		BAYER PHARMA AG	13353	BERLIN	MUELLERSTRASSE 178	DE
518249	397563	100.00		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 178	DE
518249	402998	100.00		BAYER SCHERING PHARMA AG	13353	BERLIN	MUELLERSTRASSE 170 178	DE
518249	435123	98.76		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13353	BERLIN	PATENTS LICIENSING MUELLERSTRASSE 178	DE
518249	441578	98.76		BAYER PHARMA AKTIENGESELLSCHAFT	13353	BERLIN	MUELLERSTRASSE 178	DE
518249	543908	94.52		BAYER PHARMA AKTIENGESELLSCHAFT	13353	BERLIN	MUELLER STRASSE 178	DE
518249	389129	93.76		BAYER SCHERING PHARMA AKTIENGESELLSCHAFT	13342	BERLIN	MUELLERSTRASSE 170 178	DE

Intransitive Similarity Network: Directed Graph



Search

- Required: high threshold, i.e. 90%
- Connections in both directions enable transitivity
- Connections in one direction cause intransitivity

Mirroring

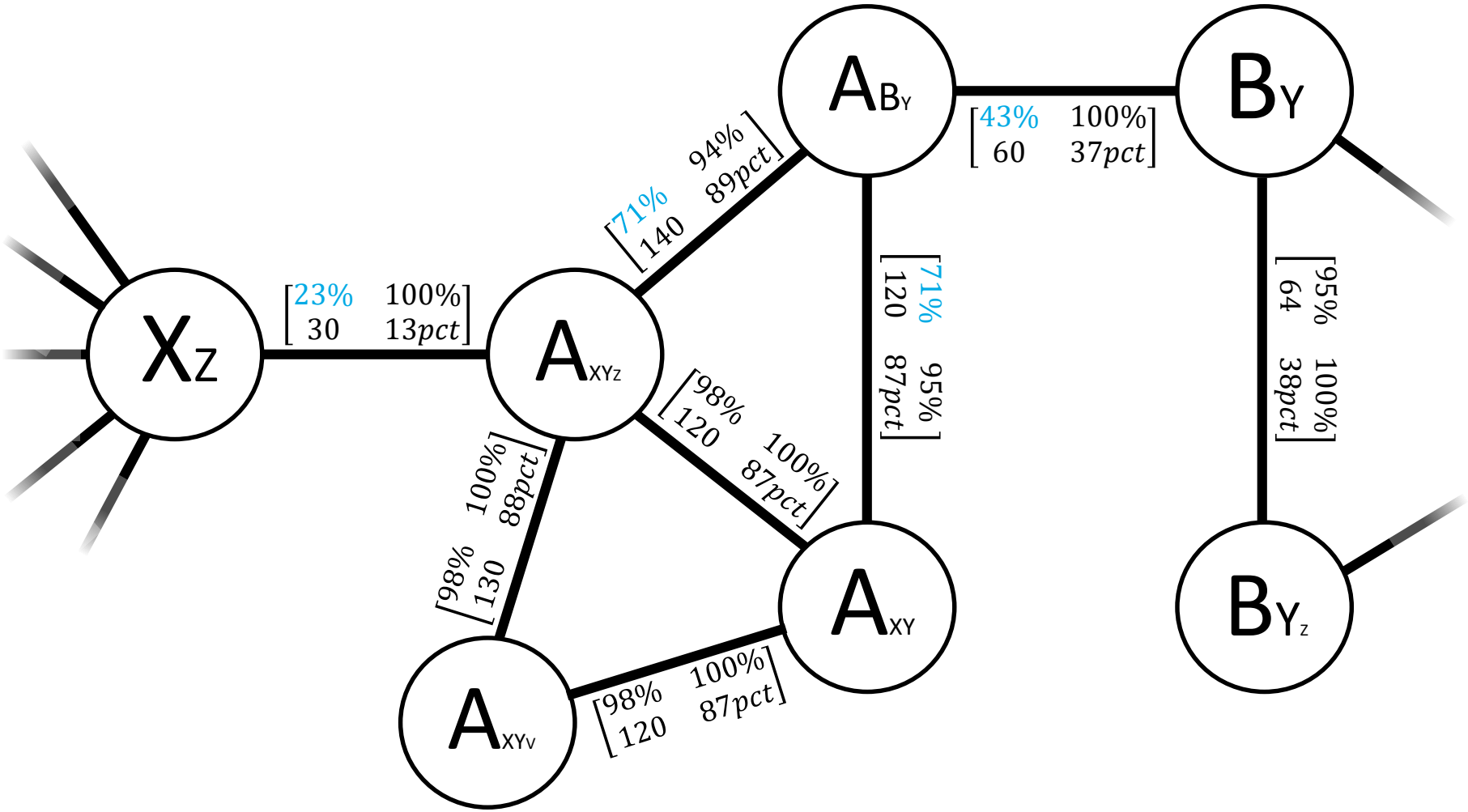
- Creates a dummy run n for all reversed connections not yet established
- Mirrored connections always have Identity zero

Research

- Reevaluates Identity for selected runs given current settings
- Apply on dummy run n
- Log-smoothing on critical search types is advised as retrieval is of no concern

$$A_{BY} \rightarrow ABY$$

Intransitive Similarity Network: Undirected Graph



quality attributes

$$\begin{bmatrix} min & max \\ s & p \end{bmatrix}$$

min, max of the identities
of both directions

s = Score
The score of a word is its associated weight divided by its frequency. The score of a search term is the sum off all word scores.
The minimum score of both involved search terms is used.

p = Score Percentile
The score has an arbitrary value range while the percentile stays within [0,100].

Nested Cascaded Traversal

It is like Spelunking!

- Choose an entrance to an unexplored cave (starting node).
- Shine with your flashlight into all tunnels (connections) branching out from the current room (node). Avoid all tunnels that appear too derelict according to safety guidelines (rules imposed on the quality attributes).
- Mark every passed room and tunnel to not run in circles or getting lost while backtracking from a dead end.
- If you have explored too many rooms, your expedition is abandoned and a new one with stricter guidelines enters the cave entrance.

Separates cascaded rules. Current rule is active unless the threshold of the subsequent rule is breached. Each new rule has to be more restrictive than the previous one to guarantee non-overlapping clusters.

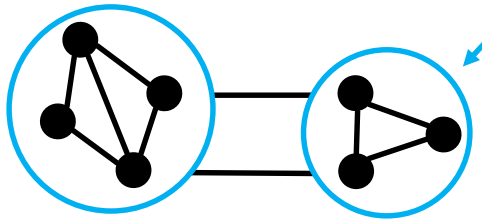
Comma

Separates cascades. Consolidates the clusters into hyper-nodes. The quality attributes of connections between encased nodes of different hyper-nodes are aggregated to the respective maximum forming a hyper-network.

Semicolon

$$min \geq 90 \text{ or } p \geq 70 \text{ and } min \geq 70 \; @ \; 0 \; , \; min \geq 90 \; @ \; 21 \; ; \; min \geq 90 \; @ \; 4$$

Hyper-Network



Rule

Imposes restrictions on the validity of connections based on the quality attributes. During traversal, these imply the boundaries of the resulting cluster.

Cluster Threshold

Forces the activation of the associated Rule when the intermediate cluster size attains the number. Resets the traversal to the starting node under the new regime.

The threshold refers to hyper-nodes. In this example, three unobserved transitions between hyper-nodes are condoned until the rule kicks in to enforce transitivity.

- First cascade establishes transitive clusters of high coherence
- Optional second cascade for audaciously intransitive transitions exploiting the tendency of thickets being less contained than plausible clusters (most of the time)

Clustering German EPO Applicants by Name

2. Cascade	1. Cascade	name
17840	17840	HANS KNOELL INSTITUT FUER NATURSTOFF FORSCHUNG
17840	17840	HANS KNOELL INSTITUT FUER NATURSTOFF FORSCHUNG E V
17840	17840	HANS KNOELL INSTITUT LEIBNIZ INSTITUT FUER NATURSTOFF FORSCHUNG
17840	25877	LEIBNIZ INSTITUT FUER NATURSTOFF FORSCHUNG UND INFEKTIONSBIOLOGIE E V HANS KNOELL INSTITUT
17840	25877	LEIBNIZ INSTITUT FUER NATURSTOFF FORSCHUNG UND INFEKTIONSBIOLOGIE E V HANS KNOELL INSTITUT HKI
17840	25877	LEIBNIZ INSTITUT FUER NATURSTOFF FORSCHUNG UND INFEKTIONSBIOLOGIE HANS KNOELL INSTITUT
17840	25876	LEIBNIZ INSTITUT FUER NATURSTOFF FORSCHUNG UND INFEKTIONSBIOLOGIE

2. Cascade	1. Cascade	name
13887	13887	FISCHER FORTUNA GMBH
13887	13887	FORTUNA MASCHINENBAU HOLDING AG
13887	13887	FORTUNA SPEZIALMASCHINEN GMBH
13887	13887	FORTUNA WERKE MASCHINENFABRIK GMBH
13887	15891	DR SCHICK GMBH
13887	15891	GEORG SCHICK DENTAL GMBH
13887	14322	FORTUNA VERTRIEB DR G SCHICK GMBH

SearchEngine

https://github.com/ThorstenDoherr/searchengine

Brain – Neural Network for Stata

https://github.com/ThorstenDoherr/brain

ssc install brain

Thank you for your attention
Time for questions