Computational Lexical Semantics: Methods and Applications

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Plan

Plan

Similarity Measures

- **Similarity measure** is a numerical measure of the degree the two objects are alike
- **Dissimilarity measure** is a numerical measure of the degree to which the two objects are different.
- Both similarity and dissimilarity scores are scalars in range $[0; 1]$ or $[0; \infty]$.
- Two similar objects i and j will have a high similarity score s_{ij} and a low dissimilarity score d_{ij}.
- Similarity to dissimilarity and vice versa:
  - if $d_{ij} \in [0; 1]$, then $s_{ij} = 1 - d_{ij}$, where $s_{ij} \in [0; 1]$;
  - if $s_{ij} \in [0; 1]$, then $d_{ij} = 1 - s_{ij}$, where $d_{ij} \in [0; 1]$;
  - if $d_{ij} \in [0; \infty]$, then $s_{ij} = 1 - \frac{d_{ij} - \min_{i,j}(d_{ij})}{\max_{i,j}(d_{ij}) - \min_{i,j}(d_{ij})}$, where $s_{ij} \in [0; 1]$;
  - if $s_{ij} \in [0; \infty]$, then $d_{ij} = 1 - \frac{s_{ij} - \min_{i,j}(s_{ij})}{\max_{i,j}(s_{ij}) - \min_{i,j}(s_{ij})}$, where $d_{ij} \in [0; 1]$.

Semantic Similarity Measures

Definition

A semantic similarity measure quantifies semantic relatedness input terms c_i, c_j with the similarity score $s_{ij} = sim(c_i, c_j)$:

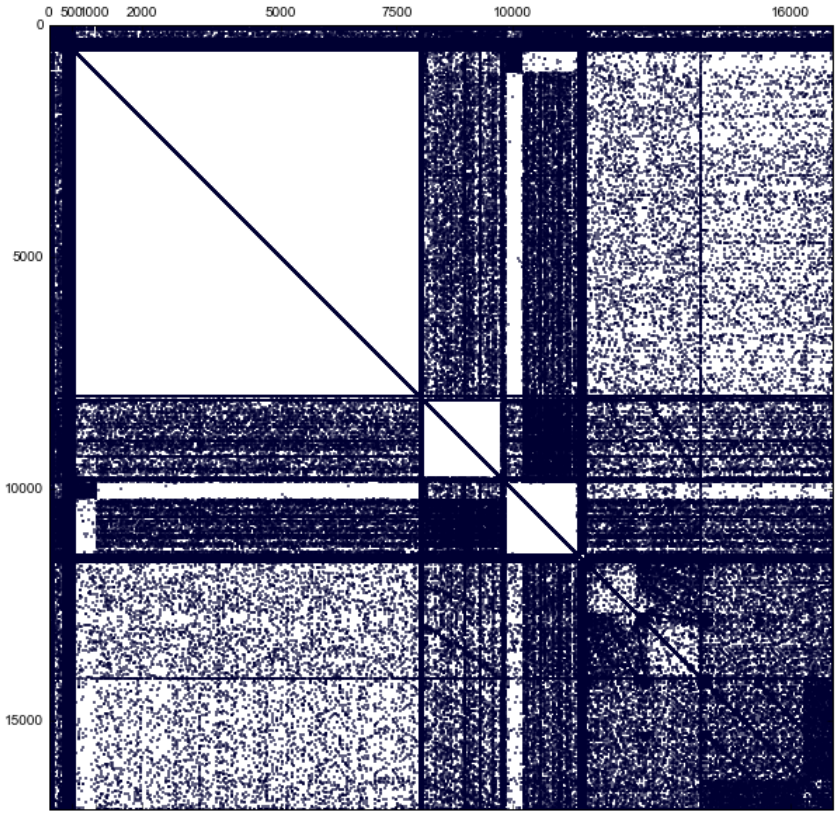
$$s_{ij} = \begin{cases} 1 & \text{if } \langle c_i, c_j \rangle \text{ is a pair of } syn, hyper, cohypo \\ 0 & \text{otherwise} \end{cases}$$

Properties

- Nonnegativity: $0 \leq s_{ij} \leq 1$;
- Reflexivity: $s_{ij} = 1 \Leftrightarrow c_i = c_j$;
- Symmetricity: $s_{ij} = s_{ji}$;

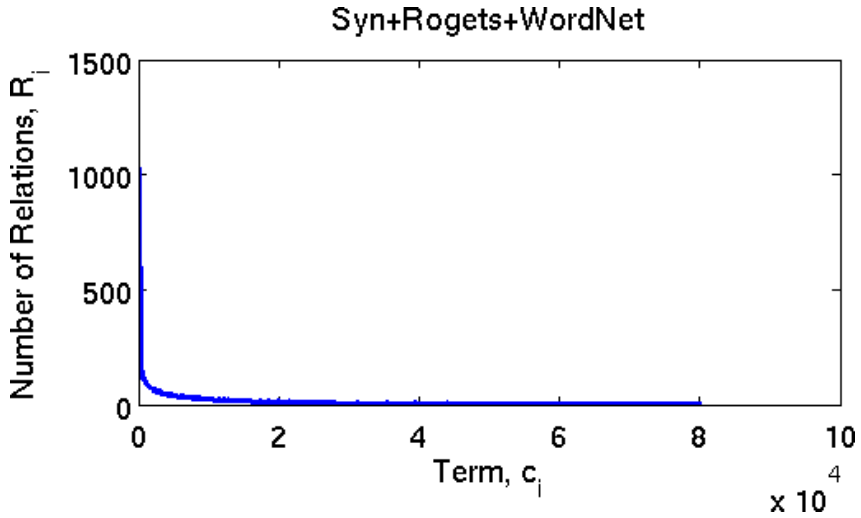
Word similarity matrix **S**

- **S** – word $*$ word similarity matrix;
- $s_{ij} \in \mathbf{S}$ – similarity of words w_i and w_j;
- $s_{ij} = sim(w_i, w_j), s_{ij} \in [0; 1]$.

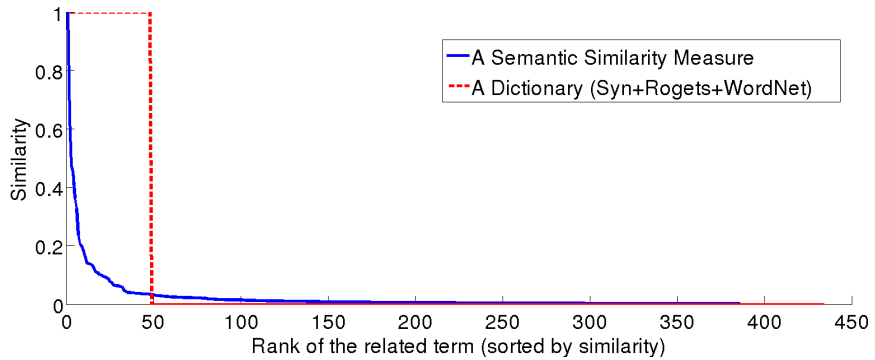


Semantic Similarity Measures

- Many dissimilar pairs, few similar pairs: $s_{ij} \sim exp(\lambda)$:



- Similarity distribution of the term "doctor":



Number of relations in semantic resources

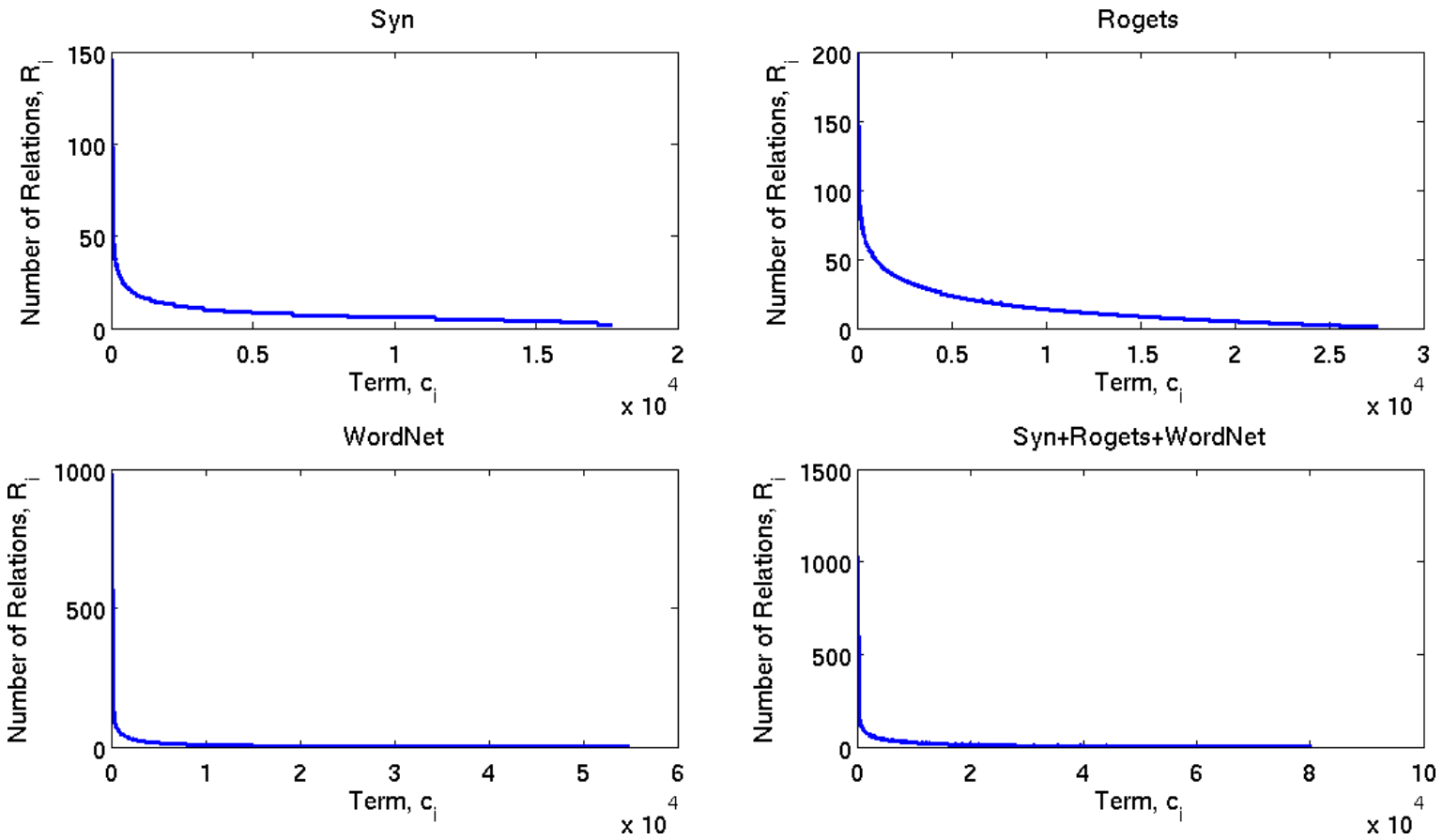


Figure: Number of relations (synonyms and hyponyms) per term in the dictionaries: a dictionary of synonyms, Roget's thesaurus, WordNet and a union of these three resources.

Evaluation of Semantic Similarity Measures

1. correlations with human judgments (**MC**, **RG**, **WordSim**);
2. semantic relation ranking (**BLESS**, **SN**);
3. semantic relation extraction;
4. using extracted relations in an application:
   - a short text classification system (**iCOP**);
   - a lexico-semantic search engine (**Serelex**).

Evaluation of Semantic Similarity Measures

1. **Correlations with human judgments**:
   - Criterion: Pearson correlation (ρ) ž Spearman correlation (r).
   - Datasets: MC, RG, WordSim.
2. **Semantic relation ranking**:
   - Criterion: Precision, Recall, F-measure.
   - Dataset: BLESS, SN.
3. **Semantic relation extraction:**
   - Criterion: Precision@k.
   - Data: annotation and/or dictionaries.
4. **Application-based evaluation:**
   - short text classification system (**iCOP**);
   - lexico-semantic search engine (**Serelex**).

Panchenko A., **Similarity Measures for Semantic Relation Extraction.** PhD thesis. Université catholique de Louvain. 197 pages, 2013, (Chapter 1).

Correlations with human judgments

word, c_i	word, c_j	human, **s**	sim, **s**	human (rank), **r**	sim (rank), $\hat{\mathbf{r}}$
tiger	cat	7.35	0.85	1	3
book	paper	7.46	0.95	2	2
computer	keyboard	7.62	0.81	3	1
...	...	...	...	...	...
possibility	girl	1.94	0.25	64	65
sugar	approach	0.88	0.05	65	23

Datasets:

- WordSim353 – 353 word pairs (Finkelstein, 2002)
- MC – 30 word pairs (Miller Charles, 1991)
- RG – 65 word pairs (Rubenstein Goodenough, 1965)

Pearson correlation: $\rho = \frac{cov(\mathbf{s},\hat{\mathbf{s}})}{\sigma(\mathbf{s})\sigma(\hat{\mathbf{s}})}$

Spierman correlation:: $r = \frac{cov(\mathbf{r},\hat{\mathbf{r}})}{\sigma(\mathbf{r})\sigma(\hat{\mathbf{r}})}$

Correlations with human judgments

Table 1.4: Miller-Charles (MC) dataset and scores obtained with a similarity measure.

Word, c_i	**Word**, c_j	**Human Score**, s_k	**Score**, $\hat{s}_k$	**Human Rank**, r_k	**Rank**, $\hat{r}_k$
automobile	car	3.92	0.884	1	1
journey	voyage	3.84	0.592	2	8
gem	jewel	3.84	0.581	3	3
boy	lad	3.76	0.325	4	2
coast	shore	3.70	0.440	5	7
asylum	madhouse	3.61	0.190	6	5
magician	wizard	3.50	0.556	7	4
midday	noon	3.42	0.692	8	10
furnace	stove	3.11	0.296	9	9
food	fruit	3.08	0.300	10	13
bird	cock	3.05	0.145	11	16
bird	crane	2.97	0.190	12	12
implement	tool	2.95	0.260	13	6
brother	monk	2.82	0.174	14	21
crane	implement	1.68	0.016	15	14
brother	lad	1.66	0.219	16	11
car	journey	1.16	0.124	17	25
monk	oracle	1.10	0.057	18	17
cemetery	woodland	0.95	0.056	19	24
food	rooster	0.89	0.027	20	26
coast	hill	0.87	0.186	21	28
forest	graveyard	0.84	0.069	22	23
shore	woodland	0.63	0.076	23	22
monk	slave	0.55	0.101	24	18
coast	forest	0.42	0.145	25	19
lad	wizard	0.42	0.083	26	20
cord	smile	0.13	0.020	27	29
glass	magician	0.11	0.078	28	27
noon	string	0.08	0.026	29	15
rooster	voyage	0.08	0.005	30	30

Correlations with human judgments

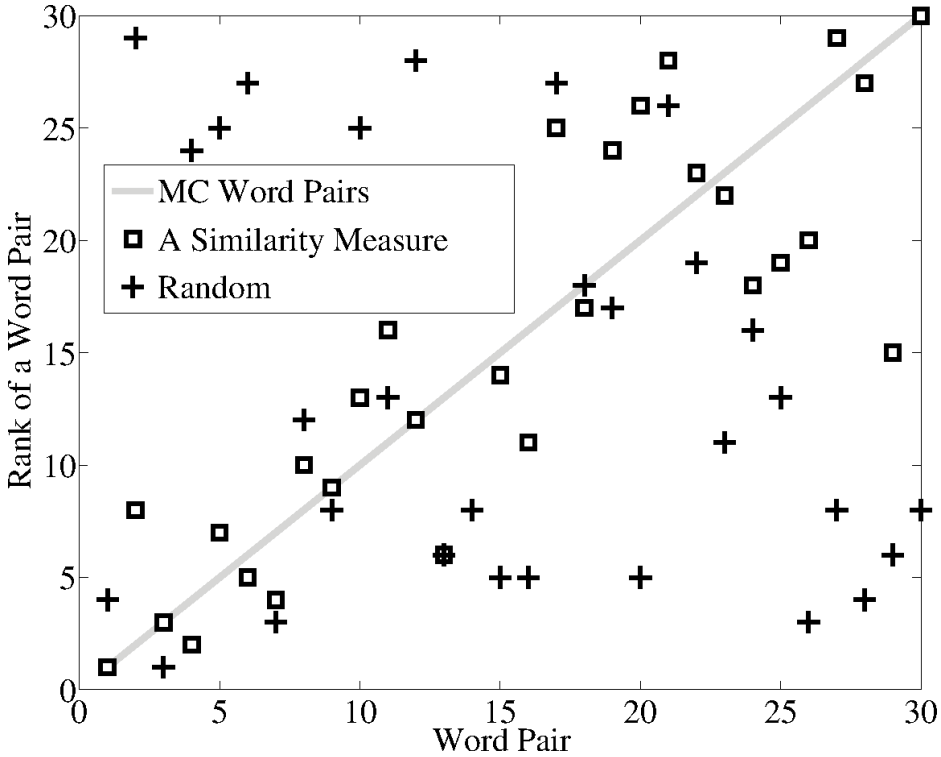


Figure: Spearman correlation on the Miller-Charles (MC) dataset. ρ of a similarity measure is 0.843 ($p<0.001$) and ρ of a random measure is -0.173 ($p=0.360$).

Semantic Relation Ranking and Classification

слово, c_i	**слово,** c_j	**тип отношения,** t
judge	adjudicate	syn
judge	arbitrate	syn
judge	asessor	syn
...	...	...
judge	pc	random
judge	fare	random
judge	lemon	random

Datasets:

- BLESS (Baroni and Lenci, 2011) – 26554 relations (hyper, coord, mero, event, attri, random)
- SN (Panchenko, 2012) – 14682 relations (syn, random)
- RT, AE, AE2 (Panchenko et al., 2015)

Semantic Relation Ranking and Classification

- Precision $P(k = 50) = \frac{1}{7} \approx 0.86$

word, c_i	**word,** c_j	**relation type**	s_{ij}
aficionado	enthusiast	syn	0.07197
aficionado	fan	syn	0.05195
aficionado	admirer	syn	0.01964
aficionado	addict	syn	0.01326
aficionado	devotee	syn	0.01163
aficionado	foundling	random	0.00777
aficionado	fanatic	syn	0.00414
aficionado	adherent	syn	0.00353
aficionado	capital	random	0.00232
aficionado	statute	random	0.00029
aficionado	blot	random	0.00025
aficionado	meddler	random	0.00005
aficionado	enlargement	random	0.00003
aficionado	bawdyhouse	random	0.00000

Semantic Relation Ranking and Classification: BLESS

Target, c_i	Relatum, c_j	Relation Type, t	Score, $\hat{s}_k$
hawk	bird	hyper	1
hawk	dove	cohypo	1
hawk	eagle	cohypo	1
hawk	falcon	cohypo	1
hawk	owl	cohypo	1
hawk	vulture	cohypo	1
hawk	sparrow	cohypo	0.99999
hawk	swoop	event	0.99997
hawk	raptor	hyper	0.99996
hawk	swan	cohypo	0.99987
hawk	nest	event	0.99976
hawk	woodpecker	cohypo	0.99973
hawk	feather	mero	0.99964
hawk	crow	cohypo	0.99952
hawk	pigeon	cohypo	0.99948
hawk	fly	event	0.99946
hawk	goose	cohypo	0.999
hawk	pheasant	cohypo	0.99868
hawk	predator	hyper	0.9985
hawk	wing	mero	0.99836
hawk	beak	mero	0.99824
hawk	soar	event	0.99733
hawk	robin	cohypo	0.99644
hawk	penguin	cohypo	0.99451
hawk	roost	event	0.99013
hawk	creature	hyper	0.97707
hawk	animal	hyper	0.97269
hawk	head	mero	0.97016
hawk	claw	mero	0.96007
hawk	gray	attri	0.96
hawk	hunt	event	0.95608
hawk	plumage	mero	0.95465
hawk	hover	event	0.93882
hawk	catch	event	0.92227
hawk	vertebrate	hyper	0.91701
hawk	eye	mero	0.88698
hawk	wild	attri	0.88417
hawk	grey	attri	0.8643
hawk	young	attri	0.79082
hawk	foot	mero	0.78725
hawk	plume	mero	0.76141
hawk	passenger	random	0.66433
hawk	spot	event	0.65185
hawk	sit	event	0.65024
hawk	big	attri	0.6362
hawk	circle	event	0.58847
hawk	brown	attri	0.55922
hawk	chordate	hyper	0.54453
hawk	other	random	0.54346
hawk	sea	random	0.53117
hawk	windmill	random	0.51327
hawk	see	event	0.51181
hawk	first	random	0.49451
hawk	eat	event	0.45854
hawk	strong	attri	0.42262
hawk	aggressive	attri	0.34521

Target, c_i	Relatum, c_j	Relation Type, t	Score, $\hat{s}_k$
hawk	reverse	random	0.34406
hawk	include	random	0.32461
hawk	large	attri	0.29802
hawk	further	random	0.29732
hawk	star	random	0.27972
hawk	prism	random	0.2759
hawk	talon	mero	0.27262
hawk	rump	mero	0.2581
hawk	dark	random	0.24776
hawk	aim	random	0.24598
hawk	lay	event	0.24087
hawk	paint	random	0.23446
hawk	old	attri	0.22896
hawk	pinion	mero	0.21244
hawk	experienced	random	0.20552
hawk	crate	random	0.20478
hawk	live	event	0.19195
hawk	inhabit	event	0.18192
hawk	christmas	random	0.18135
hawk	conference	random	0.16068
hawk	trim	random	0.15775
hawk	limestone	random	0.14231
hawk	breathe	event	0.13926
hawk	die	event	0.13781
hawk	binding	random	0.11747
hawk	convict	random	0.11744
hawk	sign	random	0.11432
hawk	kerb	random	0.11242
hawk	nominate	random	0.11112
hawk	jacaranda	random	0.10915
hawk	strengthen	random	0.10065
hawk	everytime	random	0.090728
hawk	present	random	0.088429
hawk	difficulty	random	0.080802
hawk	elapse	random	0.08037
hawk	practical	random	0.07223
hawk	no-one	random	0.071844
hawk	educational	random	0.06702
hawk	economic	random	0.065984
hawk	judicial	random	0.065793
hawk	concern	random	0.065013
hawk	contextual	random	0.064861
hawk	feign	random	0.063987
hawk	localise	random	0.063514
hawk	neutron	random	0.06142
hawk	msm	random	0.060879
hawk	genesis	random	0.060742
hawk	improvisation	random	0.059412
hawk	employer	random	0.059407
hawk	triathlon	random	0.056394
hawk	idealism	random	0.055417
hawk	fia	random	0.054996
hawk	co-operative	random	0.047968
hawk	ira	random	0.044595
hawk	mindfulness	random	0.042337
hawk	shortcoming	random	0.031764

Semantic Relation Ranking and Classification

- Based on the number of correctly classified or ranked semantic relations.
- R – set of non-random relations, e.g. not like $\langle animal, random, bishop \rangle$
- $\hat{R}(k)$ set of extracted relations at k nearest neighbours

Evaluation metrics

- Precision: $P(k) = \frac{|R \cap \hat{R}(k)|}{|\hat{R}(k)|}$,
- Recall: $R(k) = \frac{|R \cap \hat{R}(k)|}{|R|}$,
- F1-measure: $F(k) = 2 \cdot \frac{P(k) \cdot R(k)}{P(k) + R(k)}$,