Interpretable Natural Language Processing

Applied results and fundamental studies

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AGI IN RUSSIAN

https://agirussia.org

AIGENTS

https://aigents.com

Novosibirsk State University

*THE REAL SCIENCE

SingularityNET

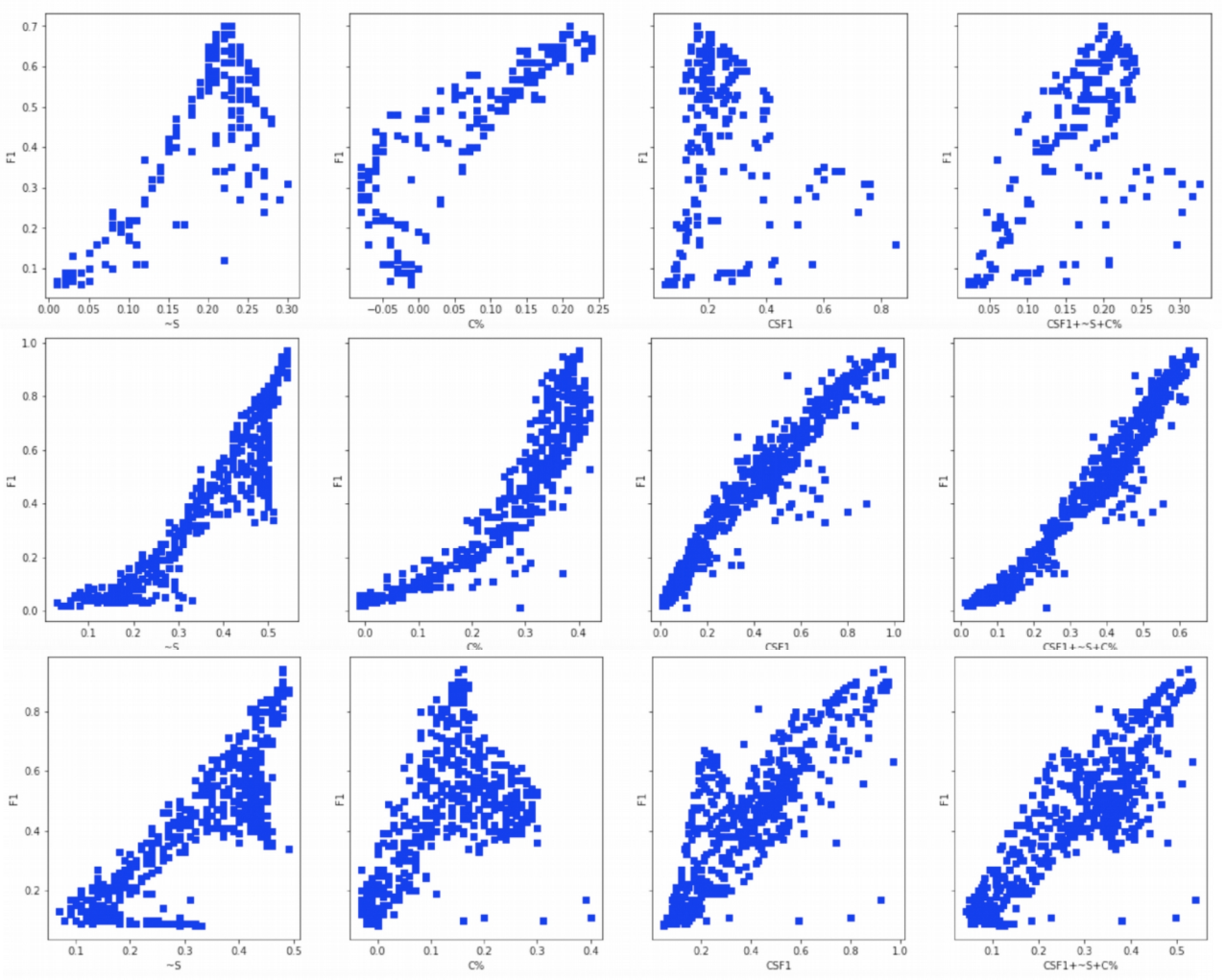
SingularityDAO

The riddle: find English, Chinese and Russian!

Language 1

Language 2

Language 3



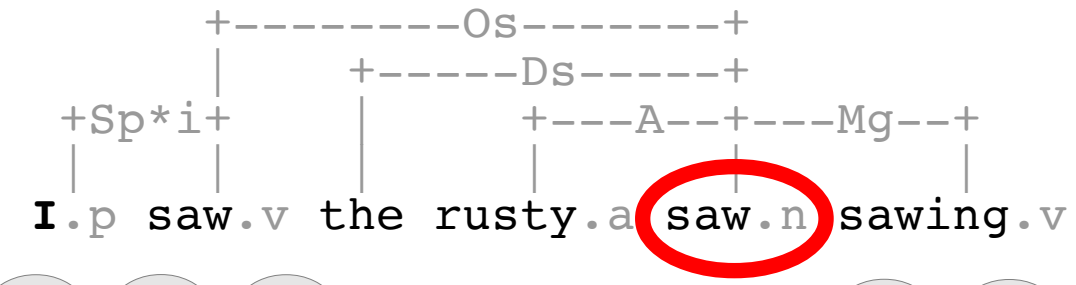
The plan

- Introduction
- Applications
  - Entity extraction and attribution
  - Mining for sentiment and cognitive distortions
  - Language parsing and segmentation
  - Language generation and question answering
- Fundamental studies
  - Language Learning for Grammar
  - Language Learning for Lexicon, Punctuation and Morphology

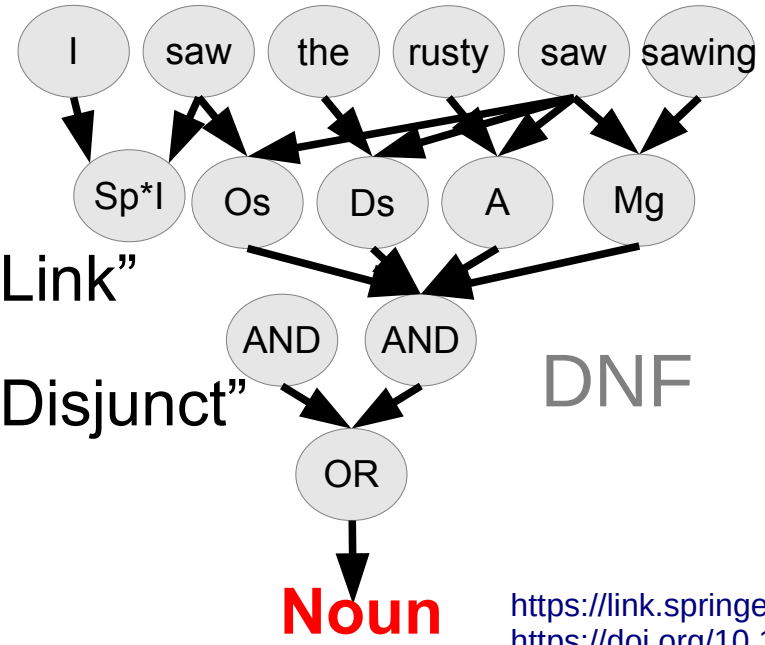
Introduction

Bridging the Symbolic-Subsymbolic gap in NLP

Formal Link Grammar



Deep Language Model

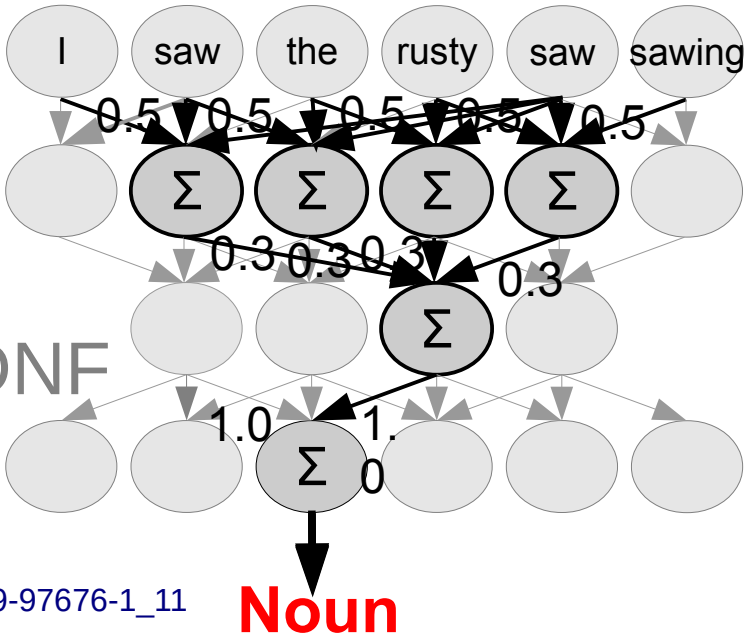


Explain

Transfer

DNF

Soft-DNF

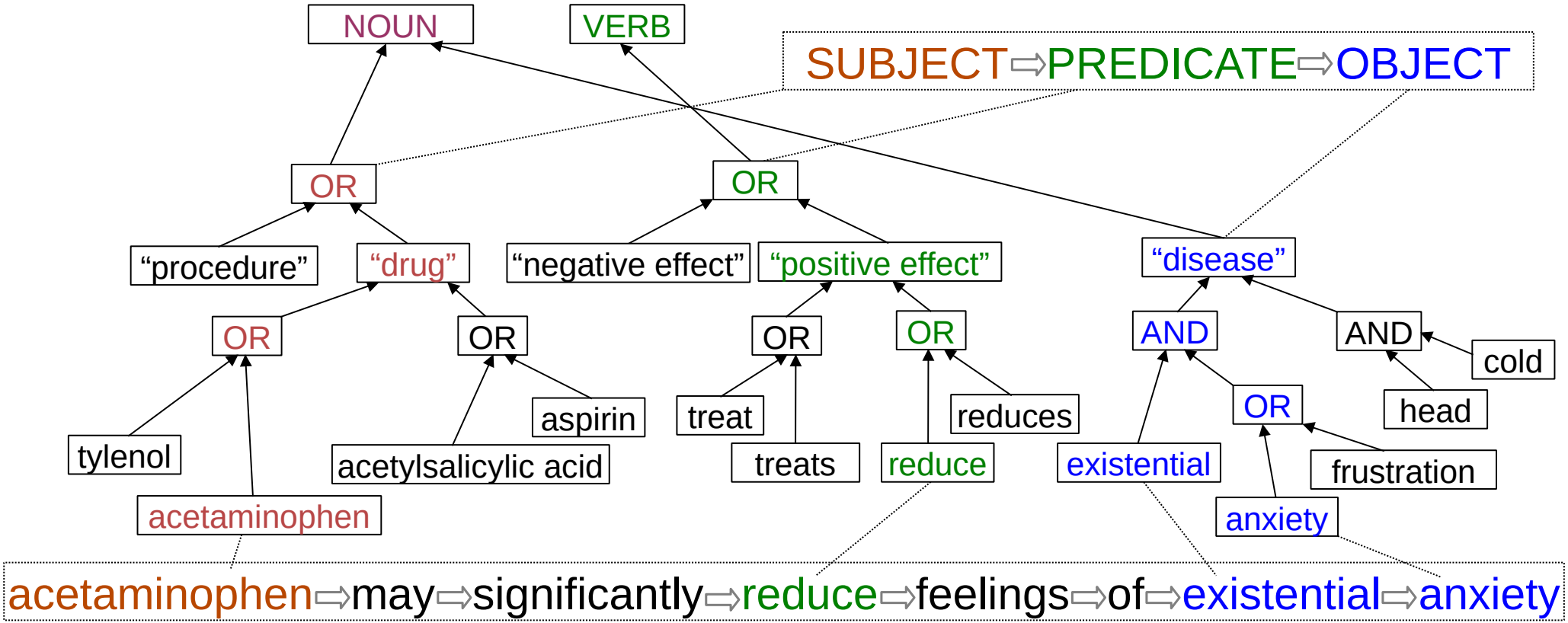


https://link.springer.com/chapter/10.1007/978-3-319-97676-1_11
https://doi.org/10.1007/978-3-030-27005-6_11

https://github.com/singnet/language-learning/

SingularityNET

Discovering NLP patterns (words, punctuation, phrases) for unsupervised language learning (Aigents® “Deep Patterns”)



https://ieeexplore.ieee.org/document/7361868
https://github.com/aigents/aigents-java

Applications

Aigents® "Deep Patterns" - Generalized Text Mining

Classification

Category: "Healthcare"

tylenol
acetaminophen
placebo

Here's the Tylenol twist: Before they began writing, half of each group received acetaminophen while the other half swallowed a placebo. Even among those people who wrote about death, the Tylenol takers set bail at roughly $300—a sign that acetaminophen may significantly reduce feelings of existential anxiety, explains study lead author Daniel Randles, a PhD candidate in UBC's department of... psychology.

Case/Relationship Extraction

IS

Entity (Case): "Treatment: Healing anxiety with Tylenol"

HAS

significantly
reduce
feelings
study

"acetaminophen may significantly reduce feelings of existential anxiety, explains study lead author Daniel Randles"

Property Attribution Entity Extraction

Brand: Tylenol
Substance: acetaminophen
Reliability: medium
Effect: positive
Diagnosis: Anxiety
Reporter: Daniel Randles

acetaminophen
may
reduce
anxiety
explains

acetaminophen may significantly reduce feelings of existential anxiety, explains study lead author Daniel Randles.

https://ieeexplore.ieee.org/document/7361868?arnumber=7361868
https://github.com/aigents/aigents-java

Aigents® “Deep Patterns” - Property Attribution

<set> := <disjunctive-set> | <conjunctive-set> | <M-skip-N-gram>
<disjunctive-set> := { <pattern> * }
<conjunctive-set> := (<pattern> *)
<N-gram> := [<pattern> *]
<pattern> := <token> | <regexp> | <variable> | <set>

Variables may have domain restrictions in ontology and/or refer to other patterns as subgraphs

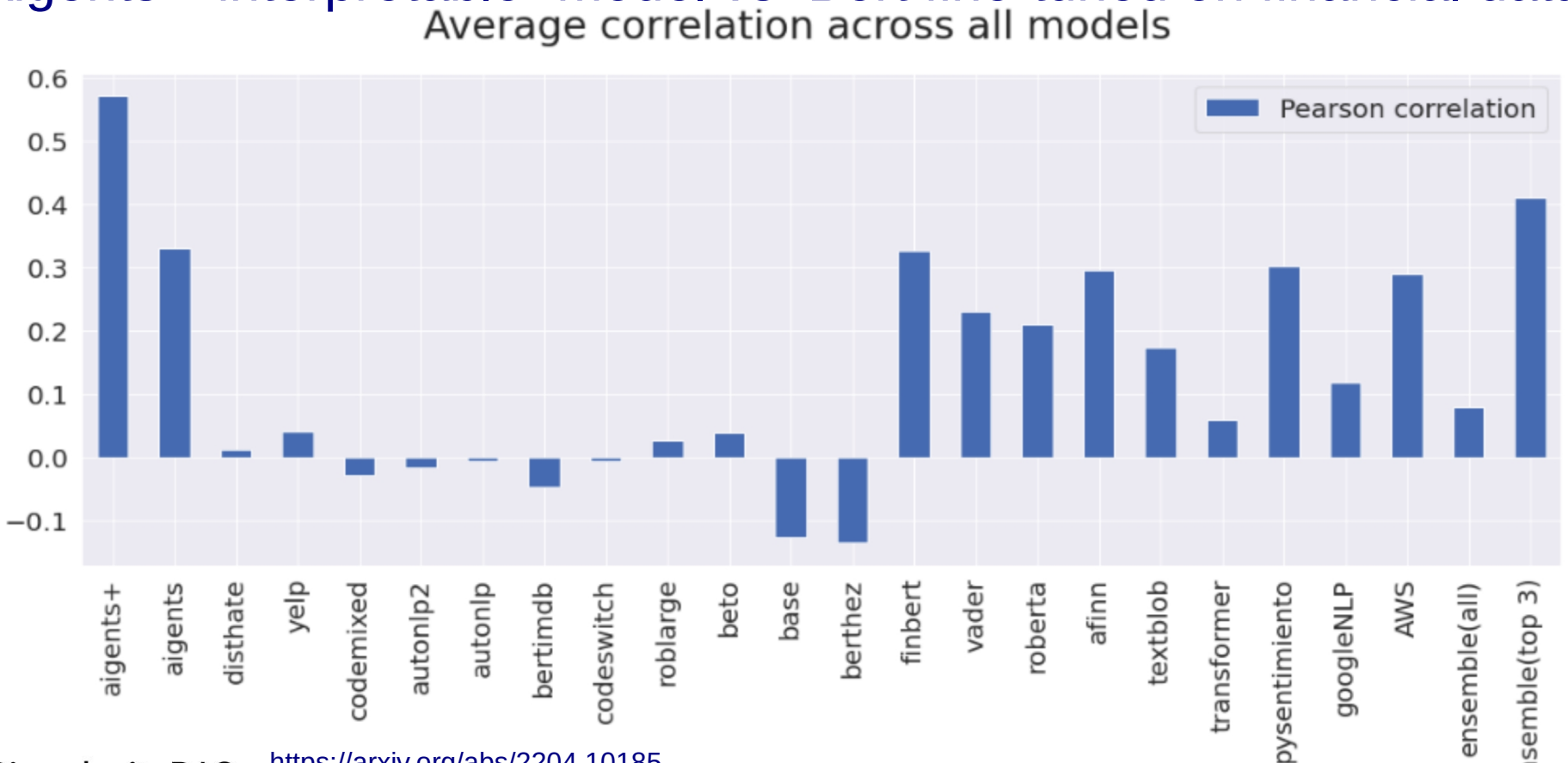
Example:

{[$description catheter] [$coating coating] [$inner-diameter
{diameter inner-diameter}] [$tip tip] [$pattern pattern]}
X
“Convey Guiding Catheter. Unique hydrophilic coating.
Small atraumatic soft tip. Ultra-thin 1 × 2 flat wire braid pattern”
=
{ **coating** : "hydrophillic", **description** : "convey guiding",
pattern : "ultra-thin 1 × 2 flat wire braid", **tip** : "soft" }

https://ieeexplore.ieee.org/document/7361868?arnumber=7361868
https://github.com/aigents/aigents-java

Sentiment Analysis – Models' Fight

Aigents® "interpretable" model vs. Bert fine-tuned on financial data



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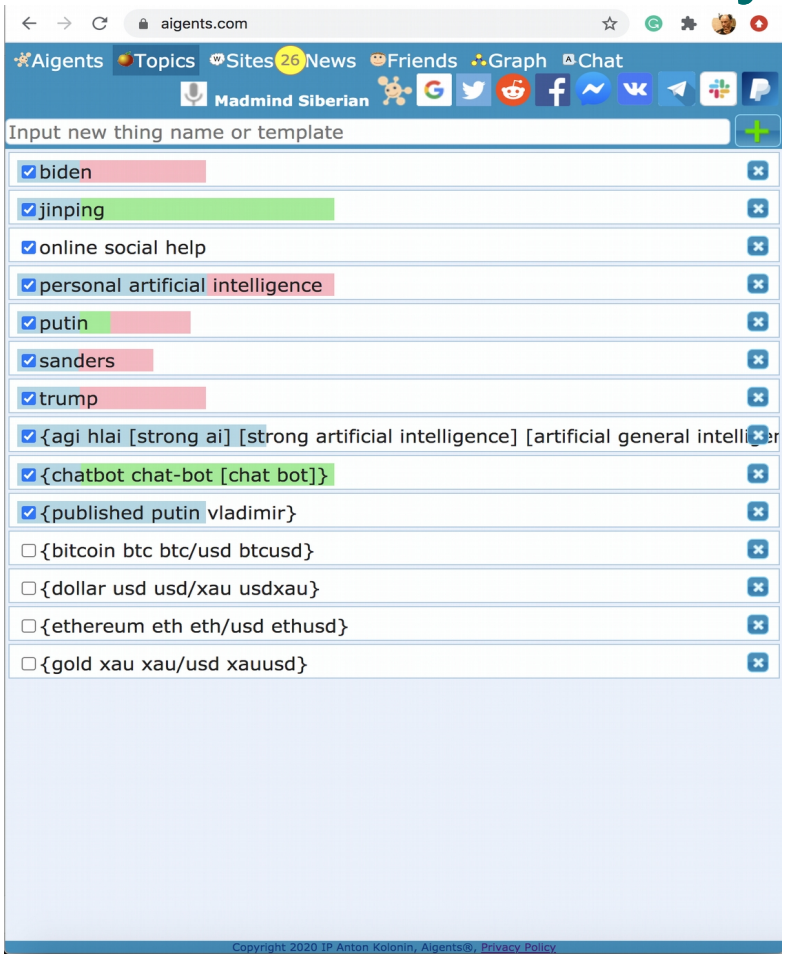
https://arxiv.org/abs/2204.10185

https://blog.singularitynet.io/aigents-sentiment-detection-personal-and-social-relevant-news-be989d73b381

N-M-skip-grams for Aigents® Sentiment Analysis

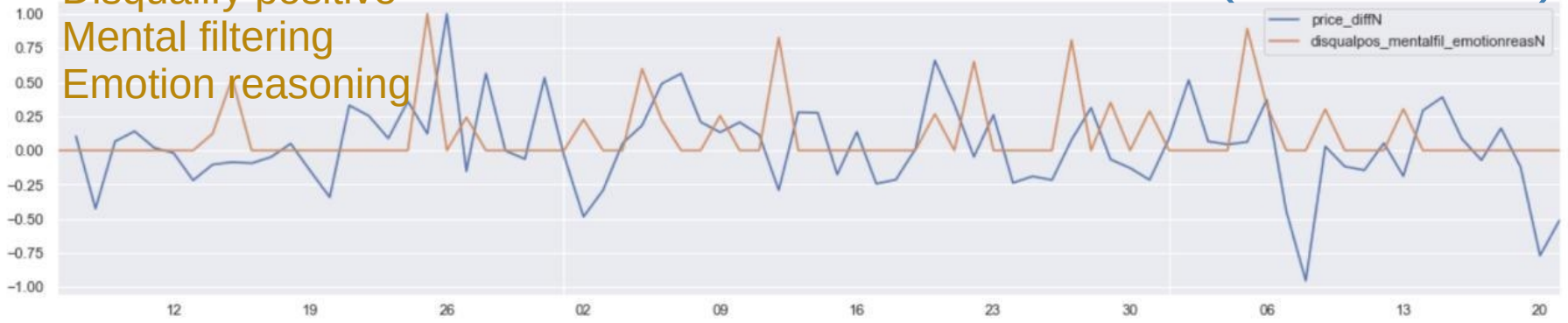


https://blog.singularitynet.io/aigents-sentiment-detection-personal-and-social-relevant-news-be989d73b381

Mining Cognitive Distortions for FinTech

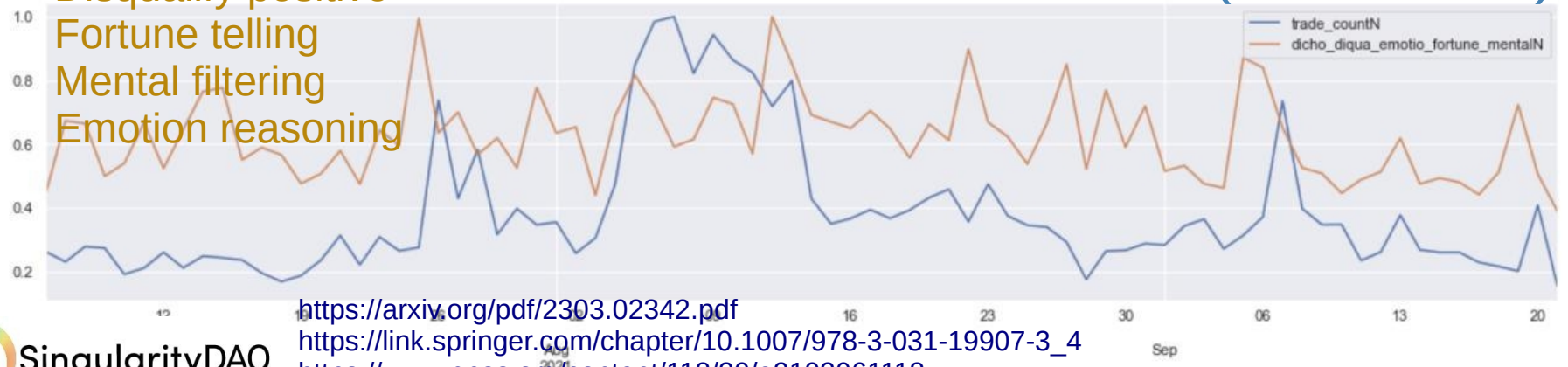
Price difference/derivative (BTC/USDT)

Disqualify positive
Mental filtering
Emotion reasoning



Trade count (BTC/USDT)

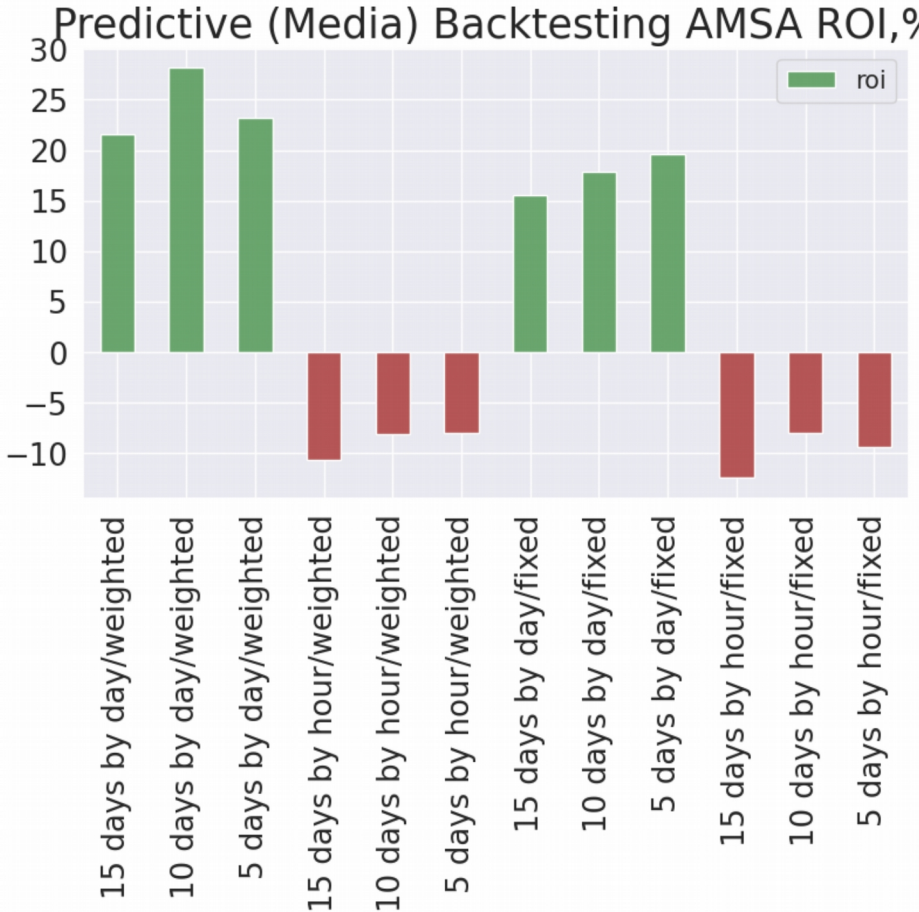
Dichotomy reasoning
Disqualify positive
Fortune telling
Mental filtering
Emotion reasoning

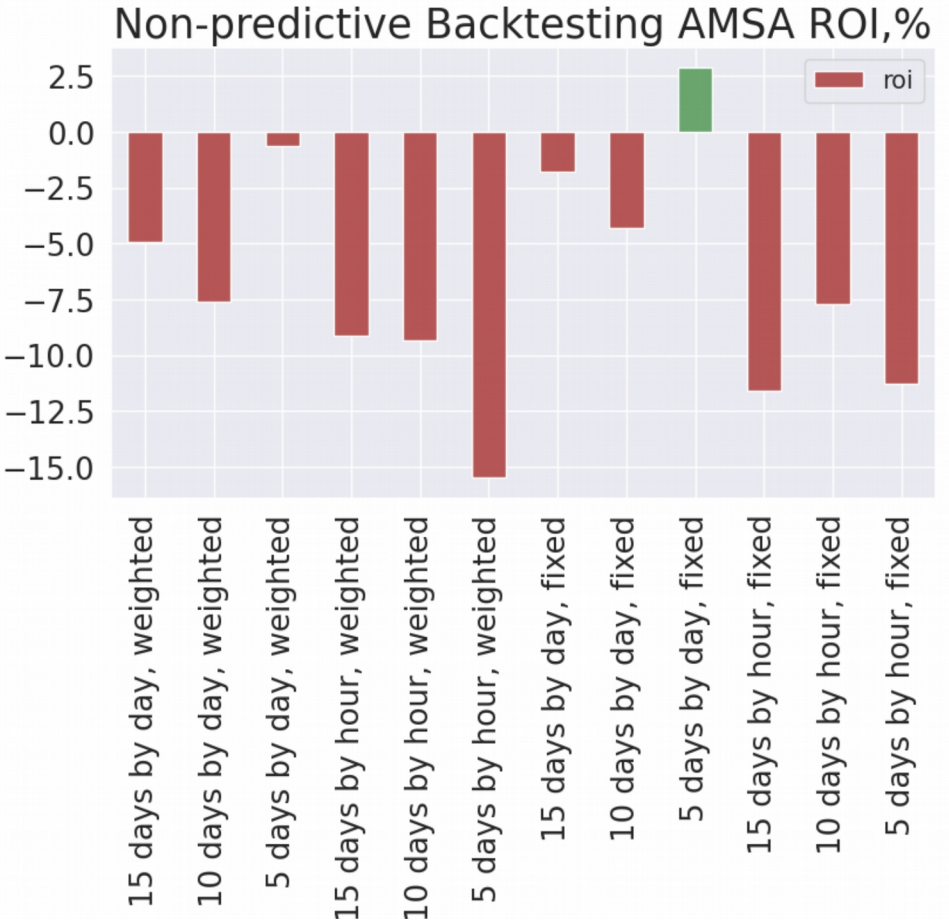


https://arxiv.org/pdf/2303.02342.pdf
https://link.springer.com/chapter/10.1007/978-3-031-19907-3_4
https://www.pnas.org/content/118/30/e2102061118

SingularityDAO

Applying Cognitive Distortions in Crypto-Trading





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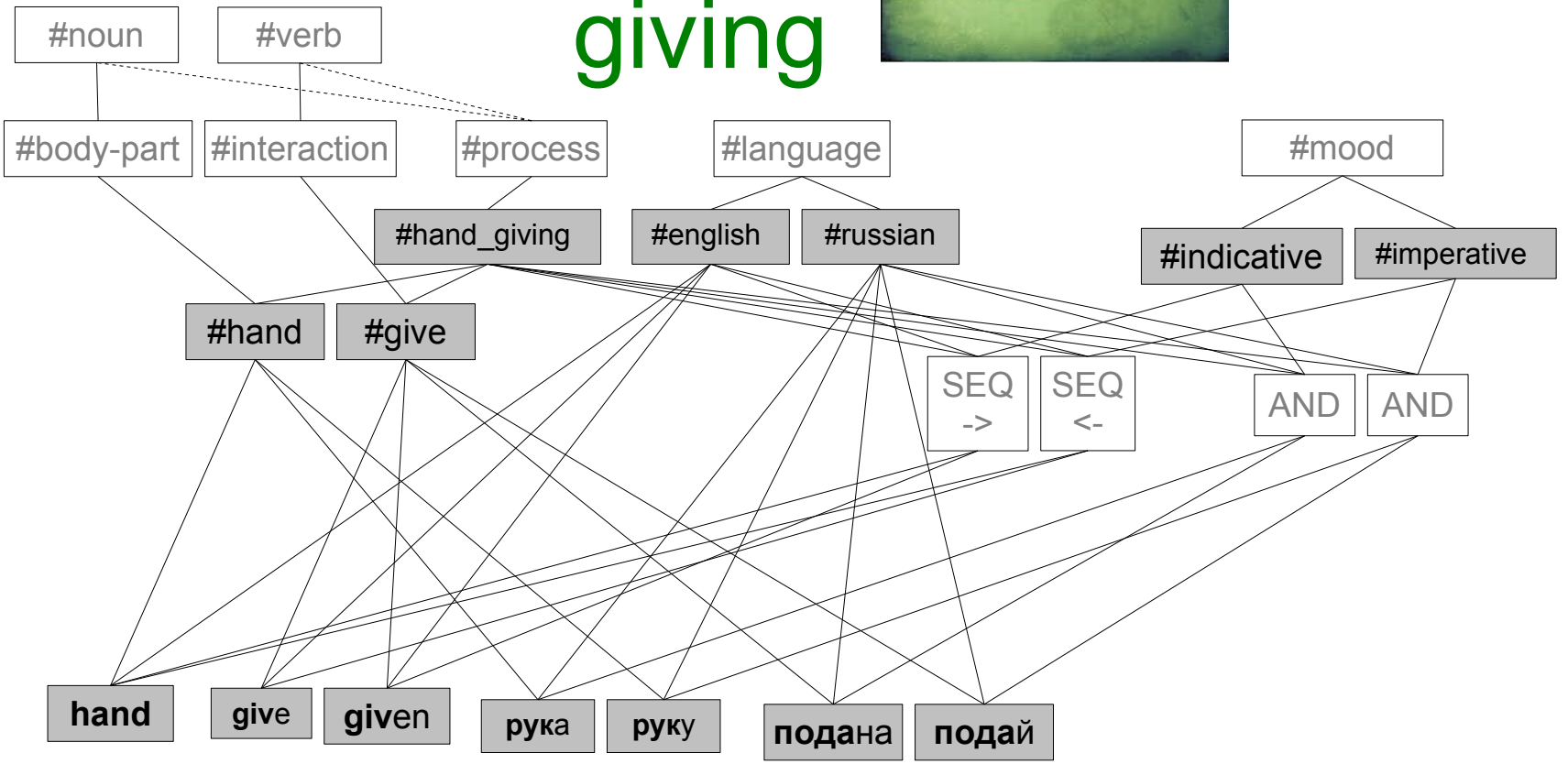
https://arxiv.org/abs/2303.02342

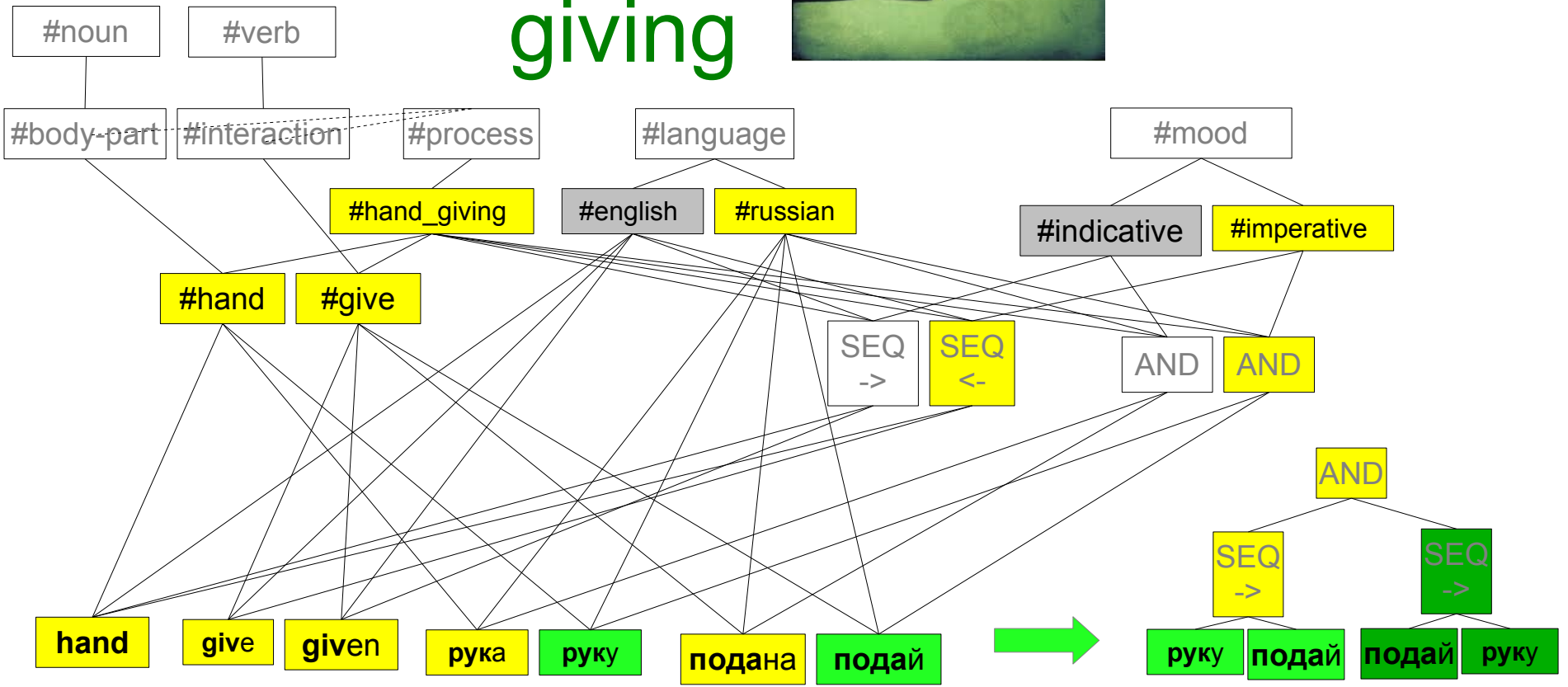
Grammar & Ontology Graph - Structure

Hand giving

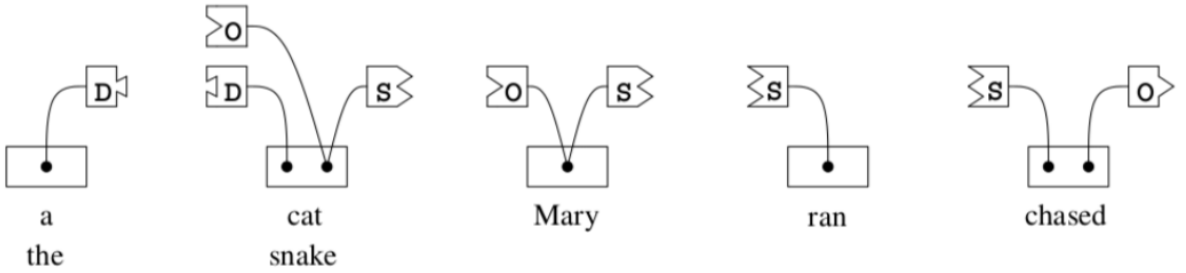


Grammar & Ontology Graph - Generation

Hand giving



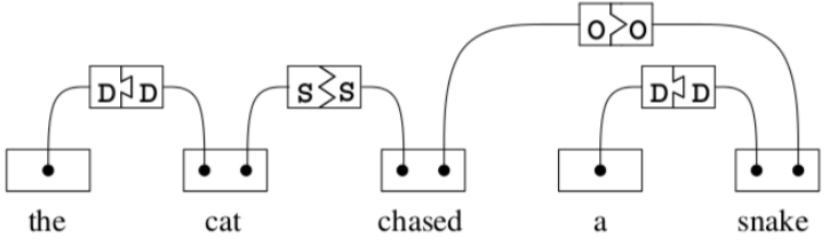
Link Grammar Connectors & Disjuncts



An illustration of Link Grammar connectors and disjuncts. The connectors are the jigsaw-puzzle-shaped pieces; connectors are allowed to connect only when the tabs fit together. A disjunct is the entire (ordered) set of connectors for a word. As lexical entries appearing in a dictionary, the above would be written as

```
a the: D+;
cat snake: D- & (S+ or O-);
Mary: O- or S+;
ran: S-;
chased S- & O+;
```

Note that although the symbols ‘‘&’’ and ‘‘or’’ are used to write down disjuncts, these are ***not*** Boolean operators, and do ***not*** form a Boolean algebra. They do form a non-symmetric compact closed monoidal algebra. The diagram below illustrates puzzle pieces, assembled to form a parse:



https://arxiv.org/abs/1401.3372
B. Goertzel, L. Vepstas, 2014

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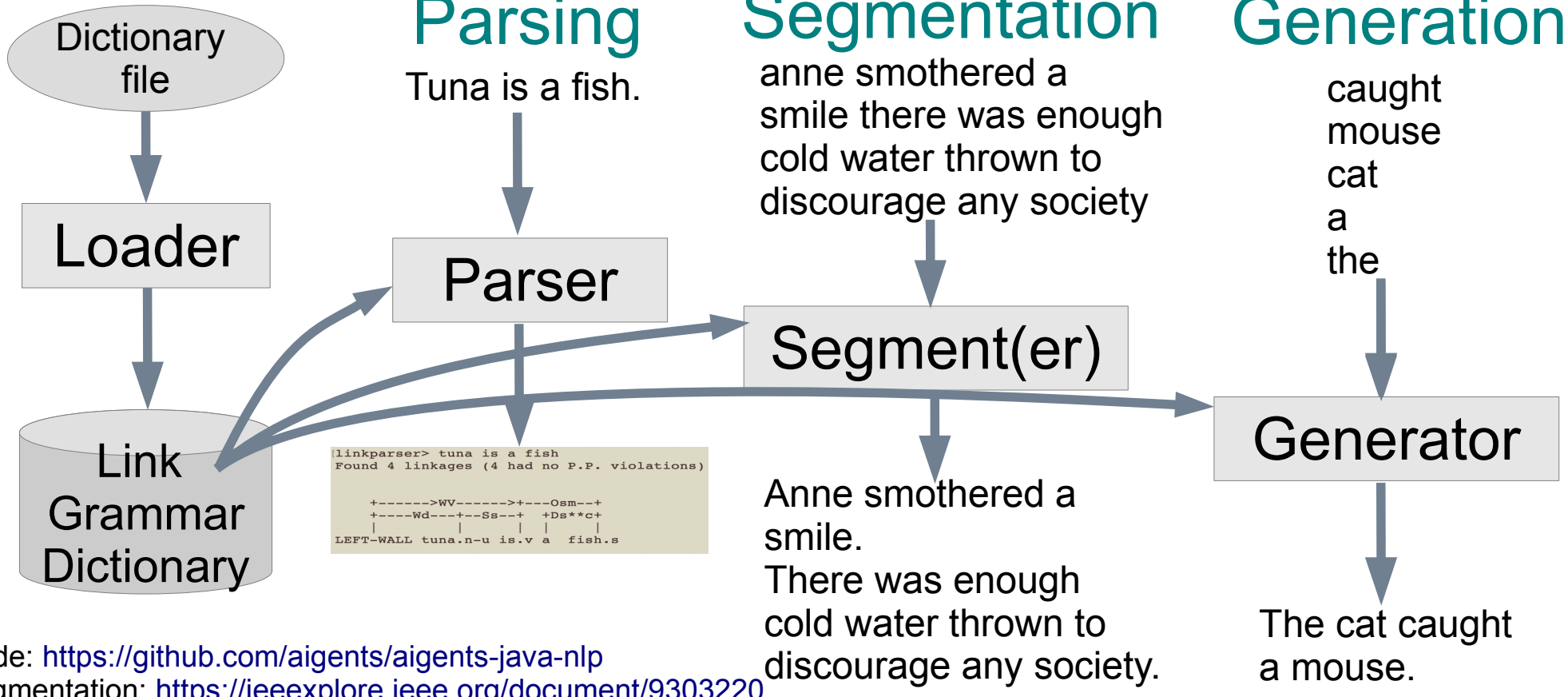
Link Grammar – not just for parsing only



Code: https://github.com/aigents/aigents-java-nlp
Segmentation: https://ieeexplore.ieee.org/document/9303220
Generation: https://arxiv.org/abs/2105.00830
V. Ramesh, A. Kolonin, 2020-2021

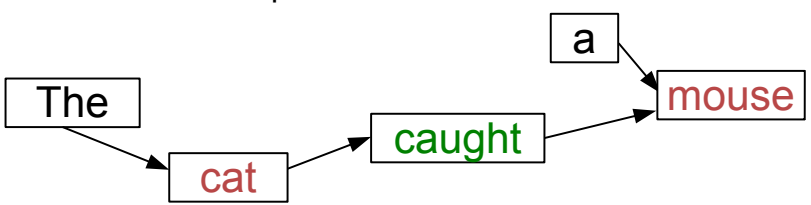
Grammatical Language Generation

Generator determines what sentences can be formed from a given list of words via valid Link Grammar rules:

1) Given a list of words, the Generator determines a subset of all orderings of those words that satisfies initial checks of the planarity and connectivity metarules.

2) For each ordering in the subset, the Generator determines if that ordering is valid; specifically, it ensures that every pair of consecutive words can be connected via links part of the Dictionary objects. To do so, the Generator uses the `connects()` function, which returns a boolean value indicating whether its two parameters left and right can be linked together.

Planarity metarule: links do not cross
Connectivity metarule: links and words of a sentence must form a connected graph that can be completely traversed via one path



Algorithm 2: CONNECTS

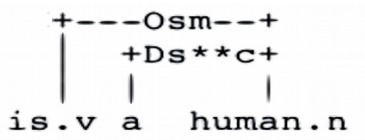
Input : A pair of strings $left$ and $right$, representing the two words to potentially be connected

Output: An boolean value indicating whether $left$ and $right$ can be connected via valid Link Grammar rules

Obtain $leftList$, the list of rules corresponding with $left$ (i.e. the rule when $left$ is a verb, the rule when $left$ is a gerund, etc.), from the global Dictionary variables $dict$ and $hyphenated$
Obtain $rightList$ in a similar manner

```
for leftRule in leftList do
    for rightRule in rightList do
        Split leftRule and rightRule into lists of Disjuncts ld and rd
        for l in ld do
            for r in rd do
                Replace all instances of '−' in l with '+' and vice versa
                if l = r then
                    return true
                else
                    continue
                end
            end
        end
    end
end
return false
```

`connects()` is not always applicable. For instance, when the determiner "a" is present in the phrase "is a human," the links are not "is" → "a" and "a" → "human" but rather "is" → "human" and "a" → "human" as shown in this Link Grammar parse:



https://arxiv.org/abs/2105.00830 V. Ramesh, A. Kolonin, 2021

Grammatical Language Generation - Results

Our algorithm was primarily tested on 92 sentences with words all part of SingularityNET's "small world" POC-English corpus. For this purpose, we have used the Link Grammar dictionary (automatically inferred from high quality Link Grammar parses created by SingularityNET's ULL pipeline) containing 42 total words and 5 total word clusters.

When tested on the same 92 sentences while using the complete Link Grammar dictionary for English, the algorithm achieved the following results. The decrease in "Single correct generated sentence" and increase in "Multiple sentences with one correct" is a direct result of the increased grammatical and semantic ambiguity from using Link Grammar instead of "small world" grammar. Since the "small world" grammar was created from the "small world" corpus itself, each of the words in the corpus contains only a subset of the grammatical or semantic contexts that Link Grammar does.

Our NLG architecture was also tested on 54 sentences part of Charles Keller's production of Lucy Maud Montgomery's "Anne's House of Dreams" as found in the Gutenberg Children corpus and performed as follows

Metric	Result
Single correct generated sentence	62/92
Multiple sentences with one correct	30/92
Multiple sentences with none correct	0/92
No generated sentences	0/92
Too many results*	0/92
Accuracy	1.000
Total runtime	18 min, 46 sec
Average runtime per sentence	0 min, 12 sec

Metric	Result
Single correct generated sentence	8/92
Multiple sentences with one correct	57/92
Multiple sentences with none correct	0/92
No generated sentences	0/92
Too many results*	27/92
Accuracy	0.707
Total runtime	115 min, 6 sec
Average runtime per sentence	1 min, 15 sec

* "Too many results" is defined as over 25 generated sentences.

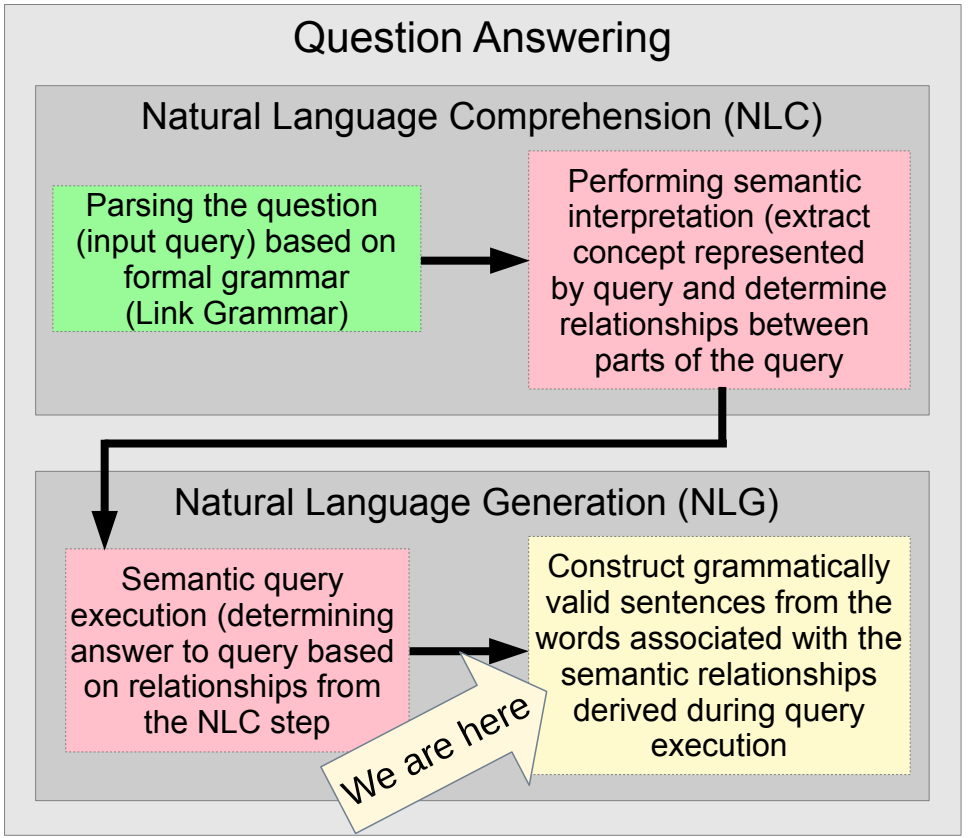
Metric	Result
Single correct generated sentence	1/54
Multiple sentences with one correct	53/54
Multiple sentences with none correct	0/54
No generated sentences	0/54
Accuracy	1.000
Total runtime	141 min, 51 sec
Average runtime per sentence	2 min, 37 sec

- POC-English – Proof-of-Concept corpus made of artificially selected sentences on limited number of topics ("small world").
- Gutenberg Children (GC) - compendium of books for children contained within Project Gutenberg (https://www.gutenberg.org), following the selection used for the Children's Book Test of the Babi CBT corpus https://research.fb.com/down-loads/babi/

https://github.com/aigents/aigents-java-nlp https://arxiv.org/abs/2105.00830 V. Ramesh, A. Kolonin, 2021

Grammatical Generation for Question Answering

Applications



Limitations

Grammatical ambiguity: same word may have different roles in a sentence

`"I saw the saw."`

First "`saw`" – verb, second "`saw`" – noun (different sets of grammar rules for each instance of "`saw`" – semantic/word sense disambiguation)

Subject-object ambiguity: a specific case of grammatical ambiguity which refers to the potential interchangeability of the subject and object in a sentence

`["mouse", "a", "the", "caught", "cat"]`

Result 1: `"The cat caught a mouse."`
Result 2: `"The mouse caught a cat."`

Both results are grammatically valid, but "The cat caught a mouse" is more contextually valid. Implementing grammatical and semantic disambiguation to solve these issues will be a product of our future work, along with extending the algorithm's generation capabilities to languages other than English (including those that require heavy morphology usage, such as Russian).

https://github.com/aigents/aigents-java-nlp https://arxiv.org/abs/2105.00830 V. Ramesh, A. Kolonin, 2021

Question Answering with Link Grammar

Context: Identity and Relationships

A mom is a human. A dad is a human. A mom is a parent. A dad is a parent. A son is a child. A daughter is a child. A son is a human. A daughter is a human. Mom is a human now. Dad is a human now. Mom is a parent now. Dad is a parent now. Son is a child now. Daughter is a child now. Son is a human now. Daughter is a human now. Mom was a daughter before. Dad was a son before. Mom was not a parent before. Dad was not a parent before.

Question: mom daughter
Answer: [Mom was a daughter before., Daughter was a mom before.]

Question: dad human
Answer: [Dad is a human.]

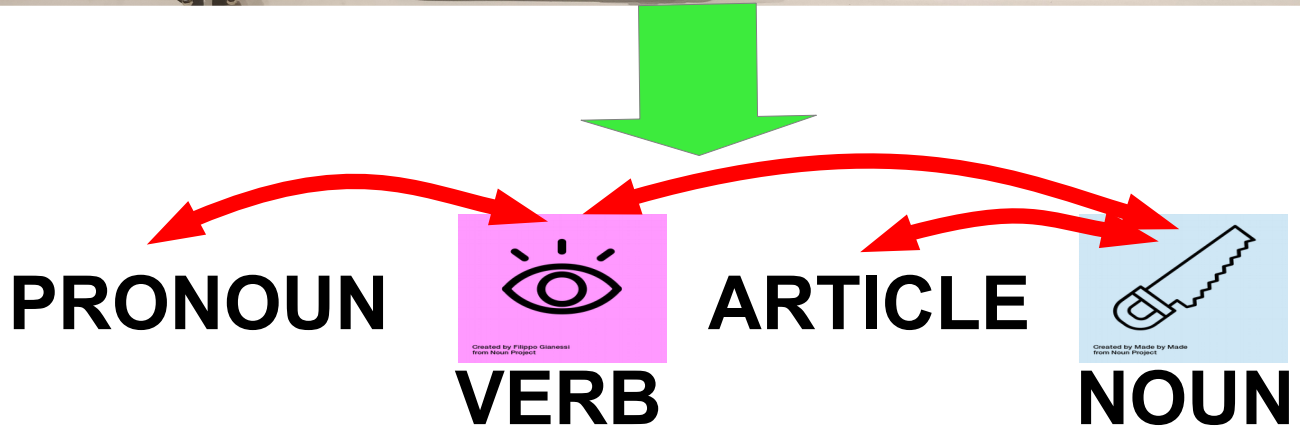
Table 1. Results when tested on 60 queries from SingularityNET's POC-English corpus.

Metric	Results				
	Ours	**BERT**	**ELECTRA**	**DistilBERT**	**RoBERTa**
BLEU	**0.878**	0.639	0.712	0.604	0.767
WVCS	**0.944**	0.606	0.741	0.595	0.799
WER	0.645	0.924	0.550	1.095	**0.150**
TER	**0.166**	0.381	0.342	0.457	0.245

https://www.youtube.com/watch?v=MKlOqO9FRq0
https://link.springer.com/chapter/10.1007/978-3-030-93758-4_22 V. Ramesh, A. Kolonin, 2021

Fundamental studies

Unsupervised Link Grammar Learning



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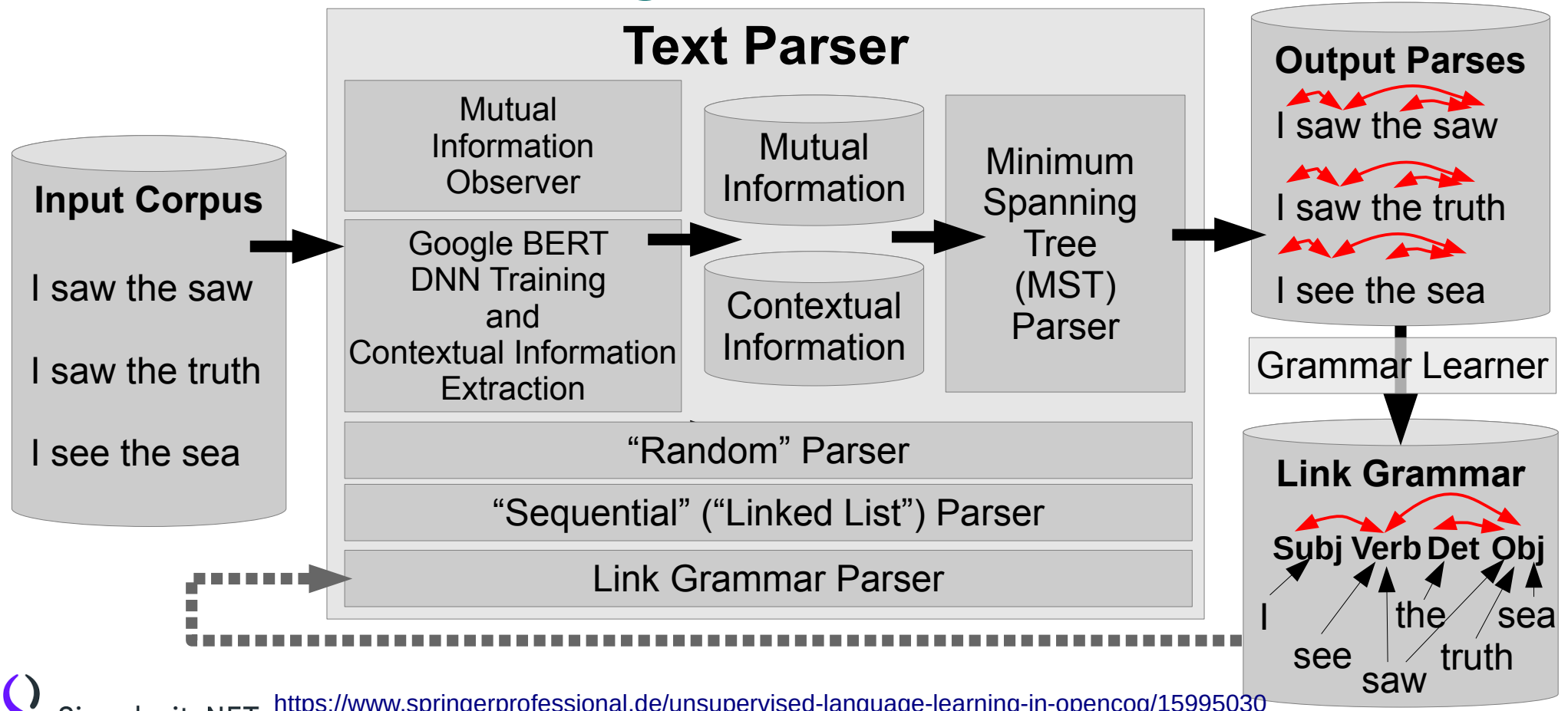
https://www.springerprofessional.de/unsupervised-language-learning-in-opencog/15995030
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

Text Parsing for Link Grammar



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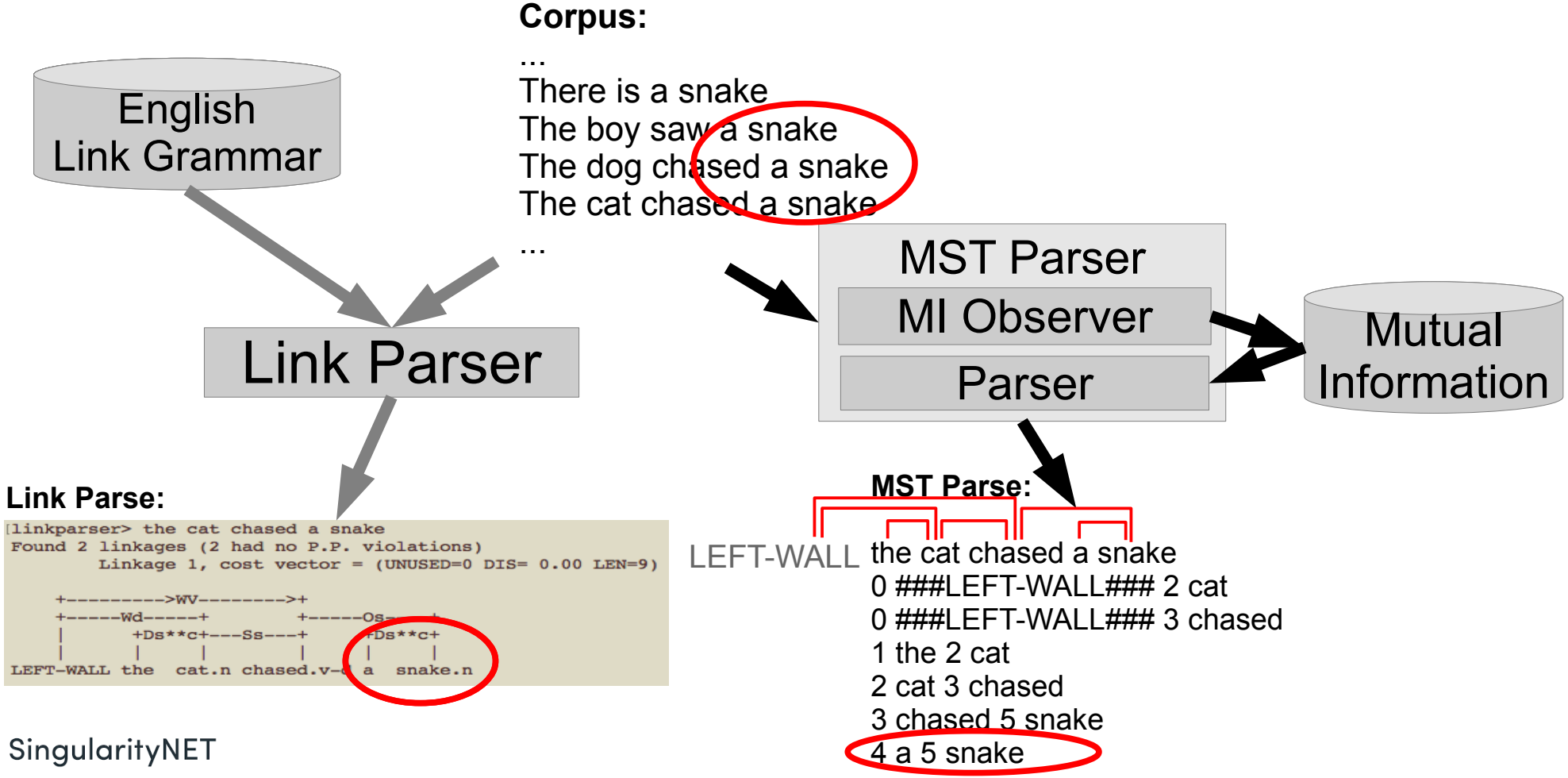
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

MST Parses vs. Link Parses



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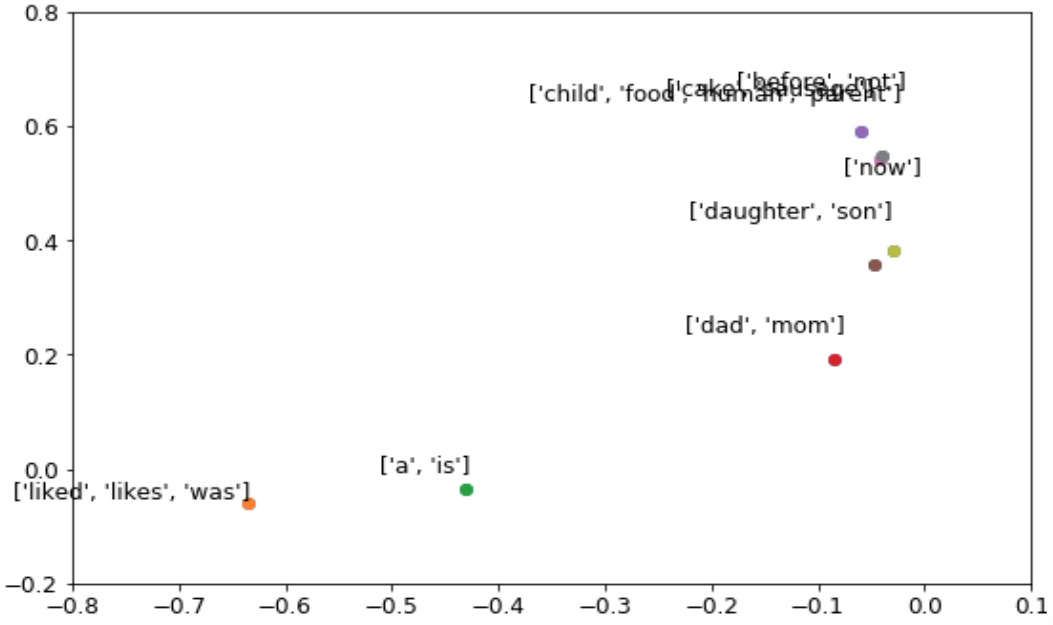
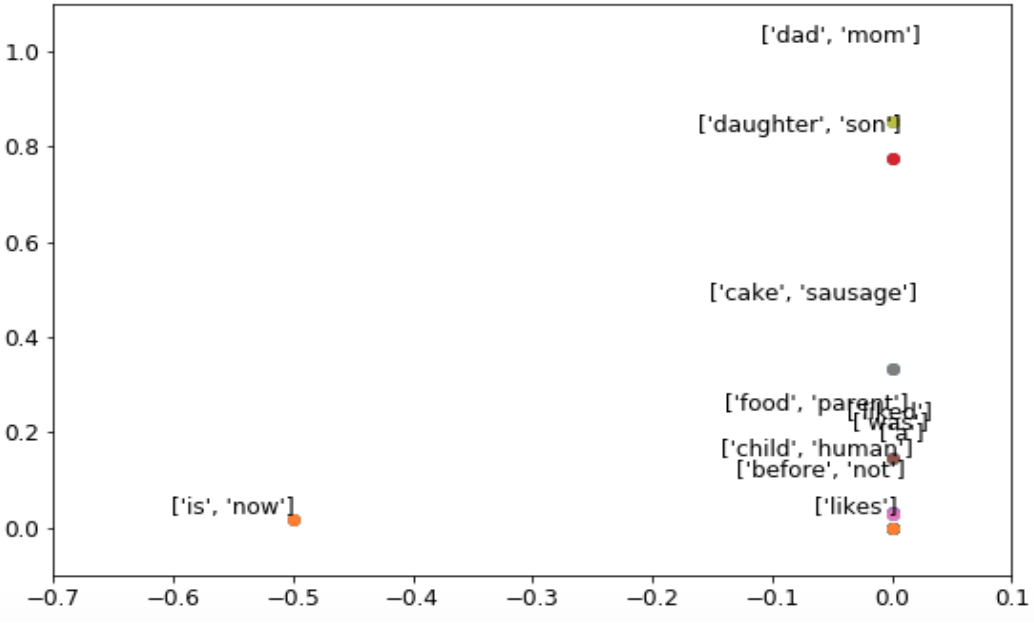
Learning Grammatical and Semantic Categories in Vector Spaces of Connectors and Disjuncts

POC-English (Connectors)



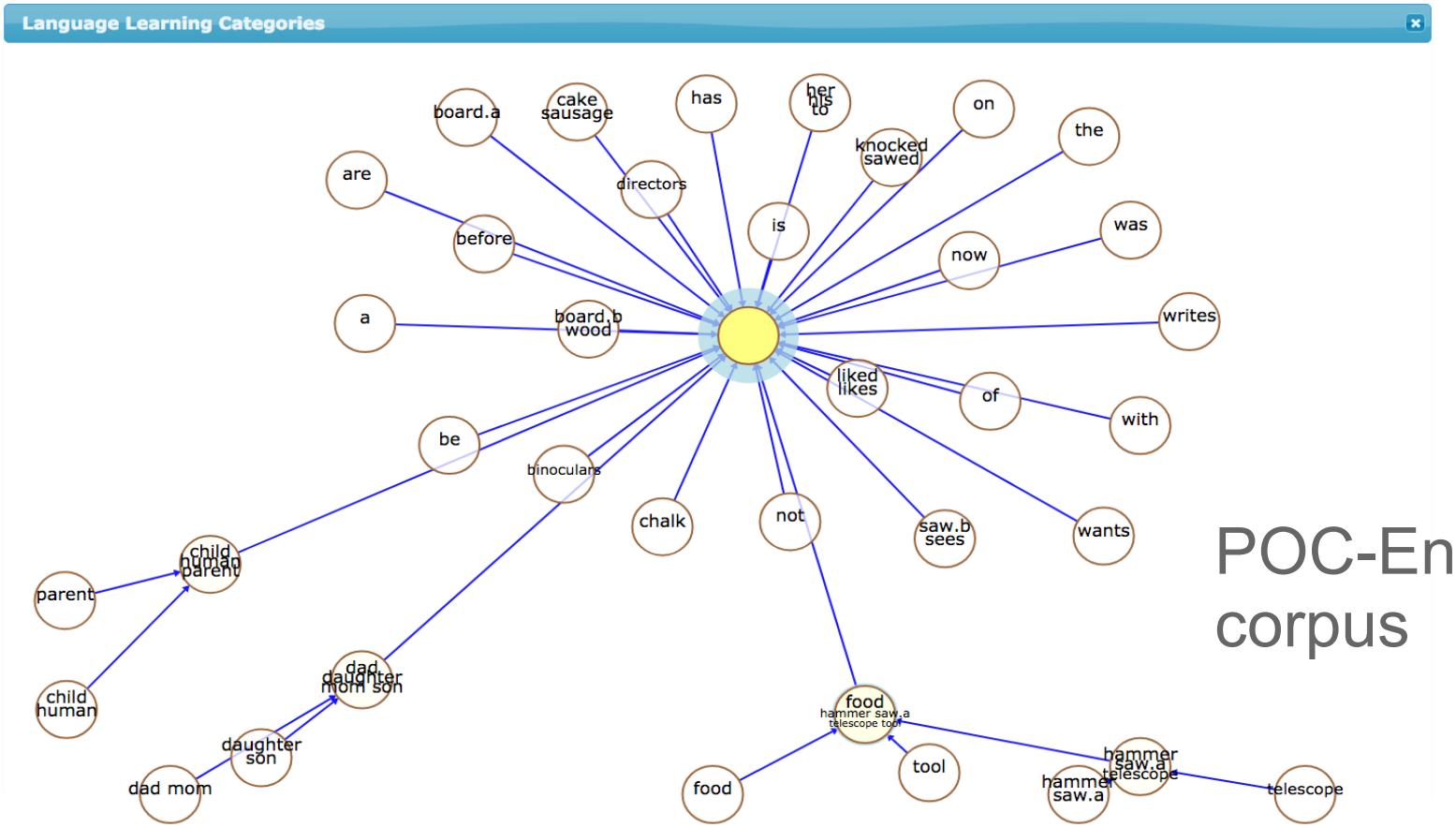
POC-English (Disjuncts)



https://github.com/singnet/language-learning
https://www.youtube.com/watch?v=cwgtcOfA3KI
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

SingularityNET

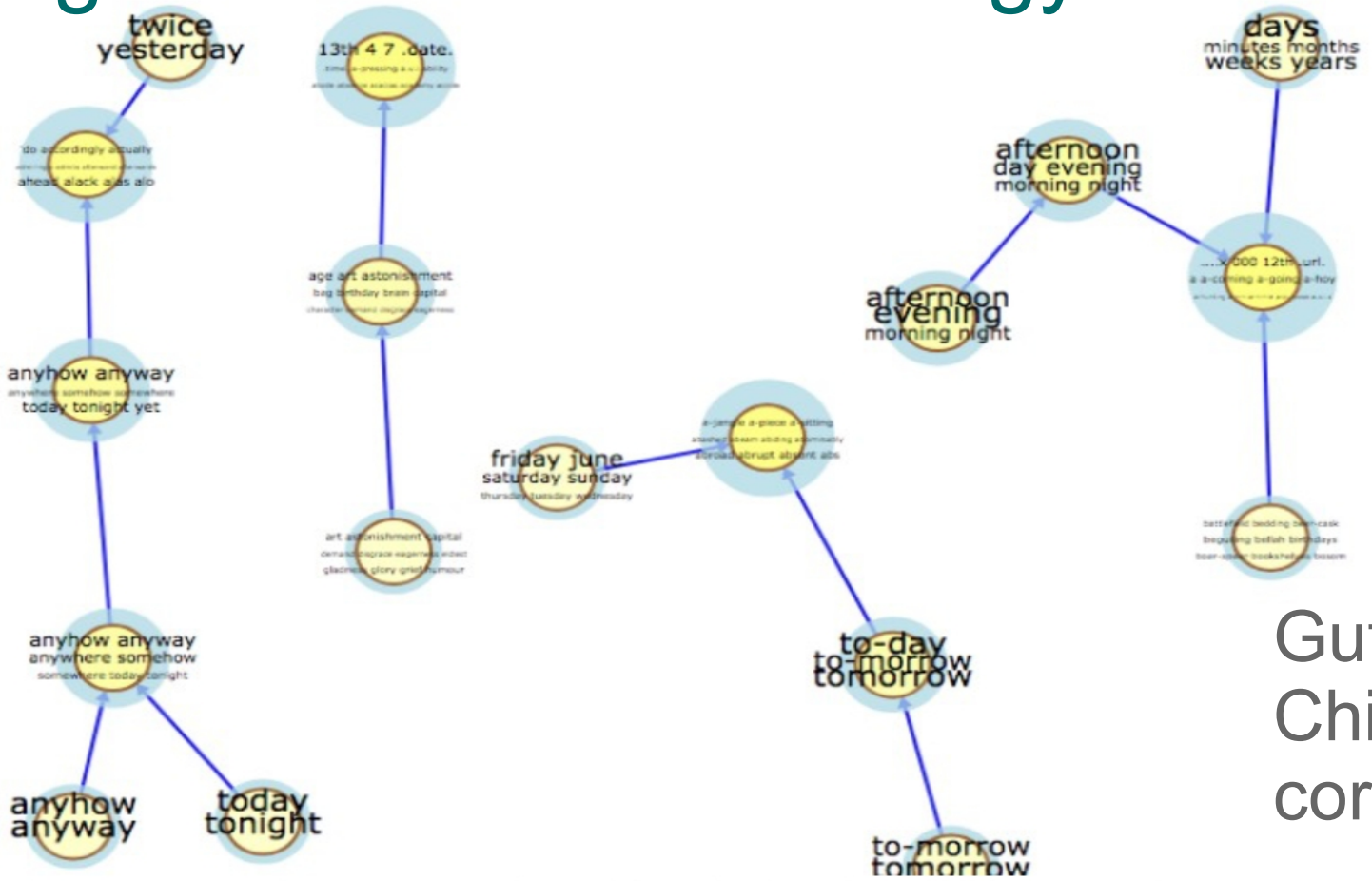
Learning Grammar and Ontology from Parses



POC-English corpus

https://www.springerprofessional.de/unsupervised-language-learning-in-opencog/15995030
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

Learning Grammar and Ontology from Parses



Gutenberg Children corpus

SingularityNET

https://www.springerprofessional.de/unsupervised-language-learning-in-opencog/15995030

https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

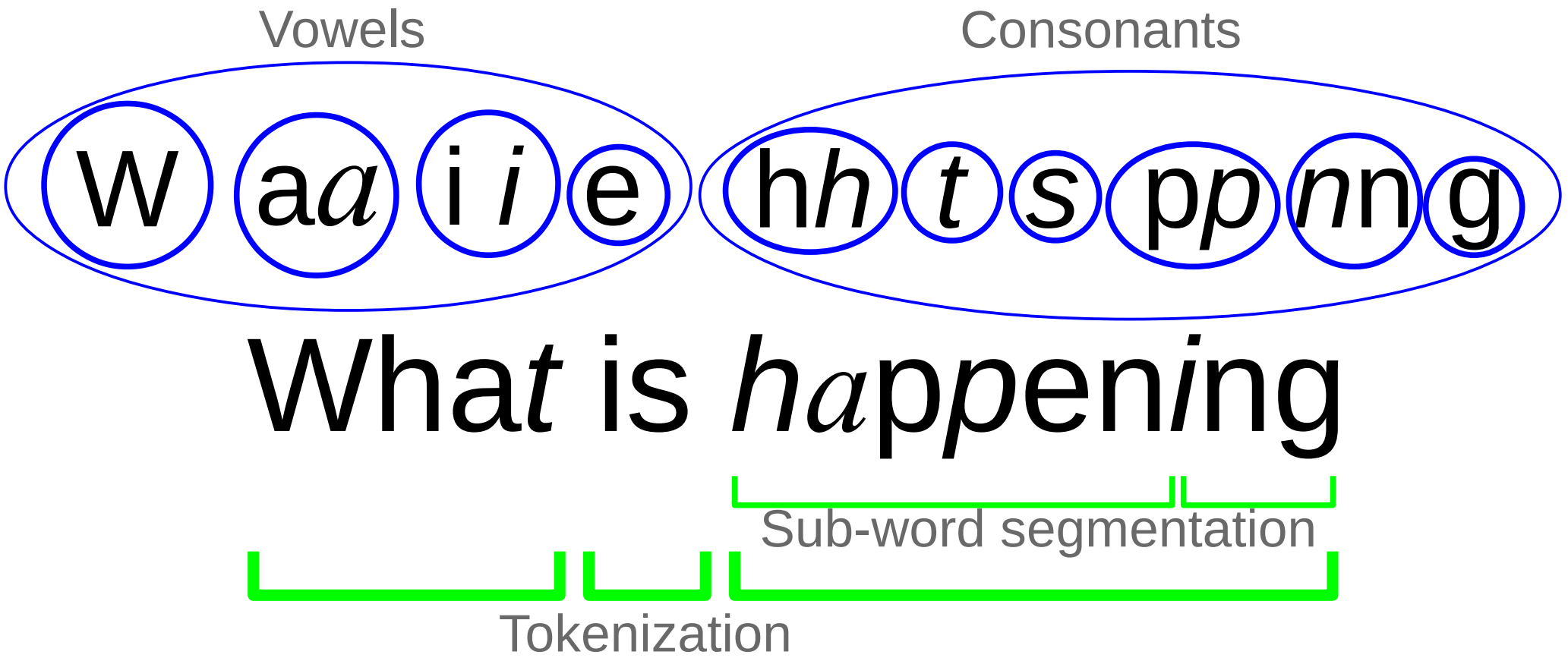
Grammar Learning F1 Across the Corpora

Corpus	Parses	Parses F1	Clustering	Parse-Ability	Grammar F1
POC-English	Manual	1.00	ILE	100%	1.00
POC-English	Manual	1.00	ALE-400	100%	1.00
POC-English	MST	0.71	ILE	100%	0.72
POC-English	MST	0.71	ALE-400	100%	0.73
Child-Directed Speech	LG-English	1.00	ILE	99%	0.98
Child-Directed Speech	LG-English	1.00	ALE-400	99%	0.97
Child-Directed Speech	MST	0.68	ILE	71%	0.45
Child-Directed Speech	MST	0.68	ALE-400	82%	0.50
Gutenberg Children	LG-English	1.00	ILE	63%	0.65
Gutenberg Children	LG-English	1.00	ALE-500	69%	0.66
Gutenberg Children	MST	0.52	ILE	93%	0.50
Gutenberg Children	MST	0.52	ALE-500	99%	0.53

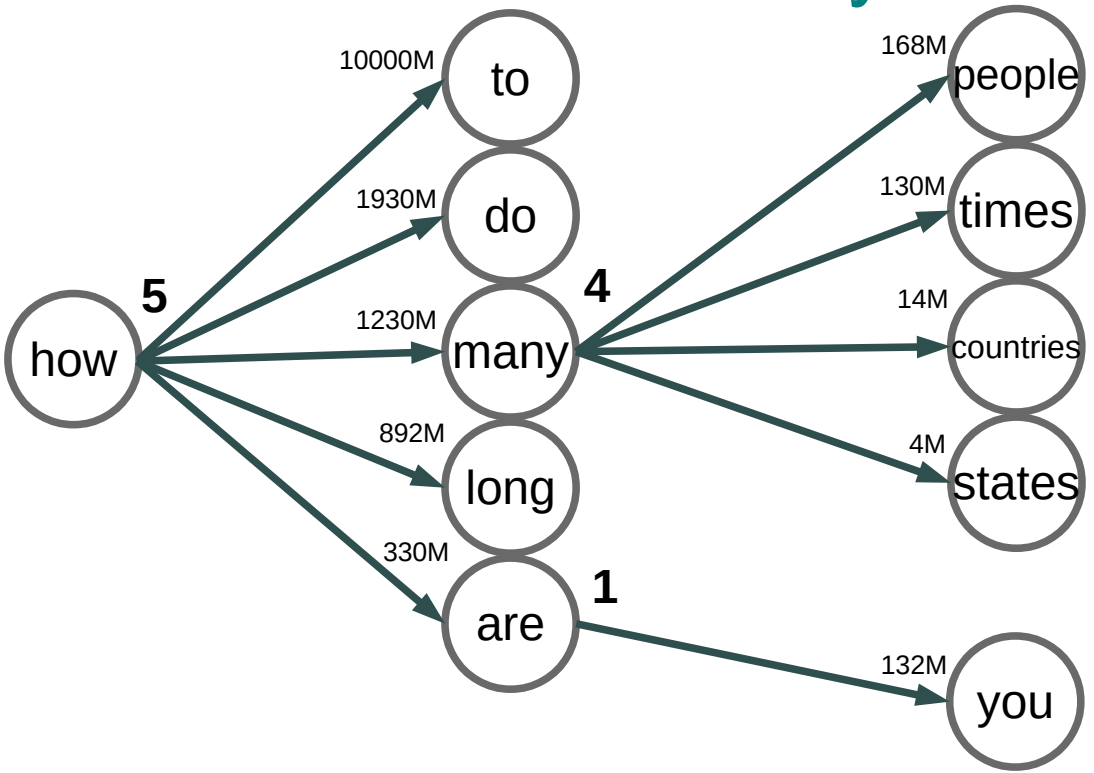
SingularityNET

https://www.springerprofessional.de/unsupervised-language-learning-in-opencog/15995030
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348

Learning for Lexicon, Punctuation and Morphology Clustering and Segmentation



Unsupervised Learning for Text Segmentation based on Probability and Uncertainty Measures



Metrics/Indicators:

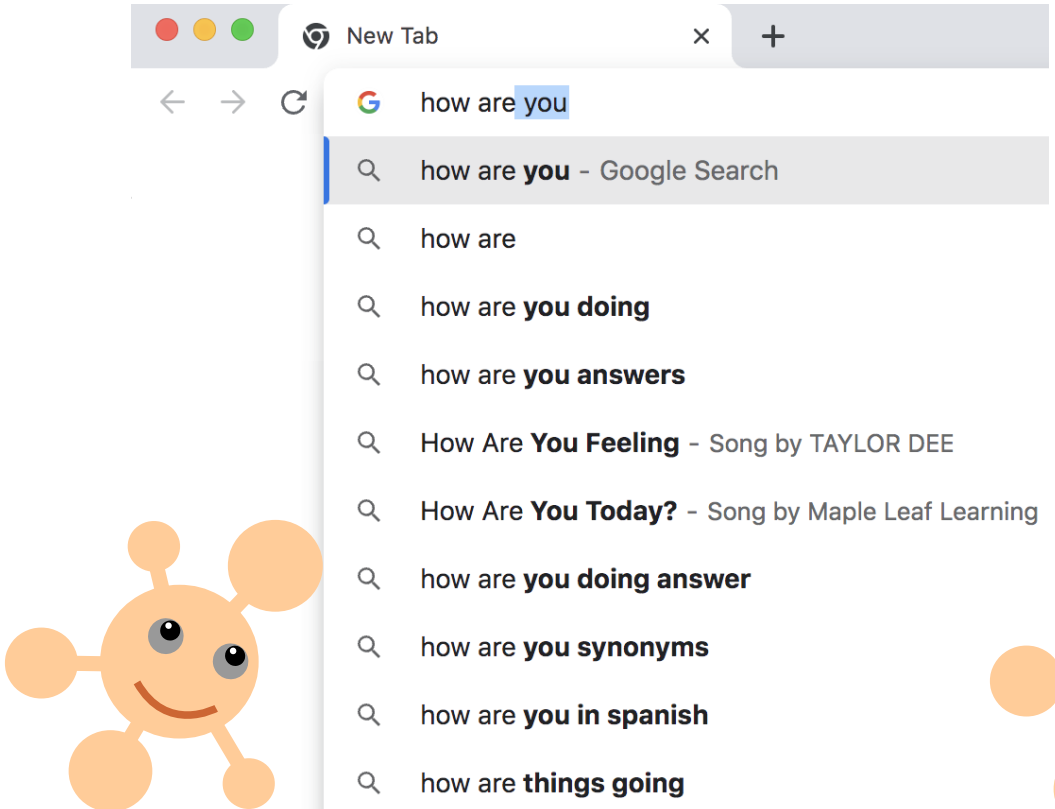
Mutual Information[1]
Conditional Probability[1,2]
Transition Freedom[2,3]

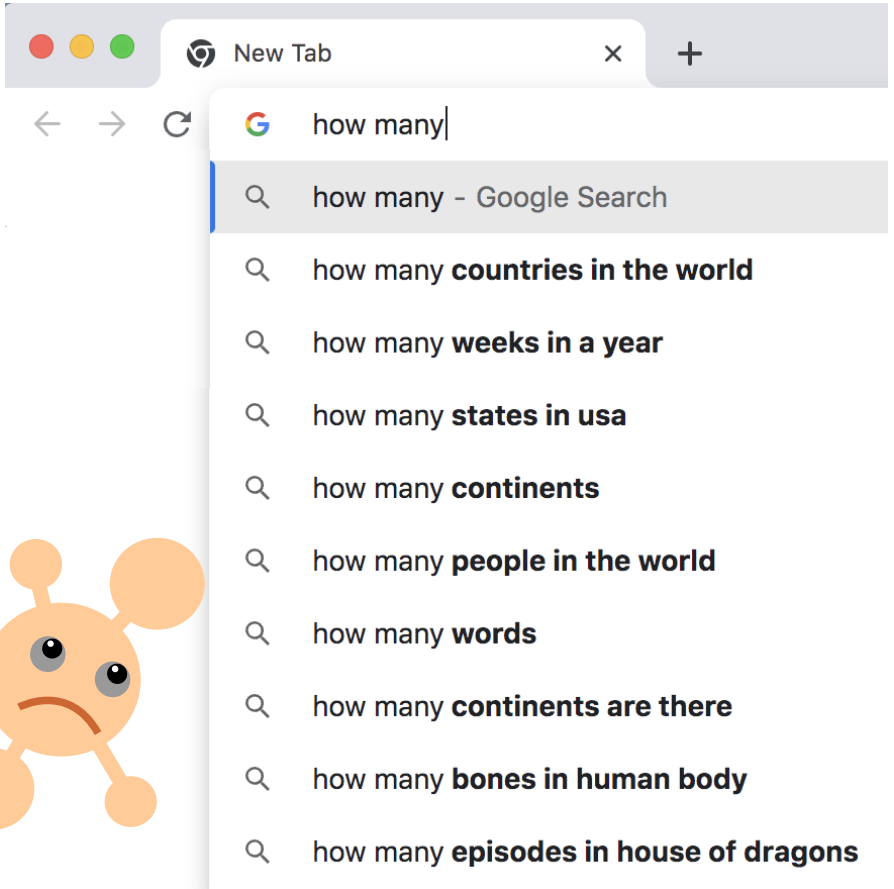
[1] https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=6983&context=etd

[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2655800/

[3] **Karl Friston. The free-energy principle: a unified brain theory?** https://www.nature.com/articles/nrn2787

Minimizing Uncertainty





https://aclanthology.org/2022.emnlp-main.239/
https://arxiv.org/pdf/2303.02427.pdf

Unsupervised Text Segmentation (Tokenization)

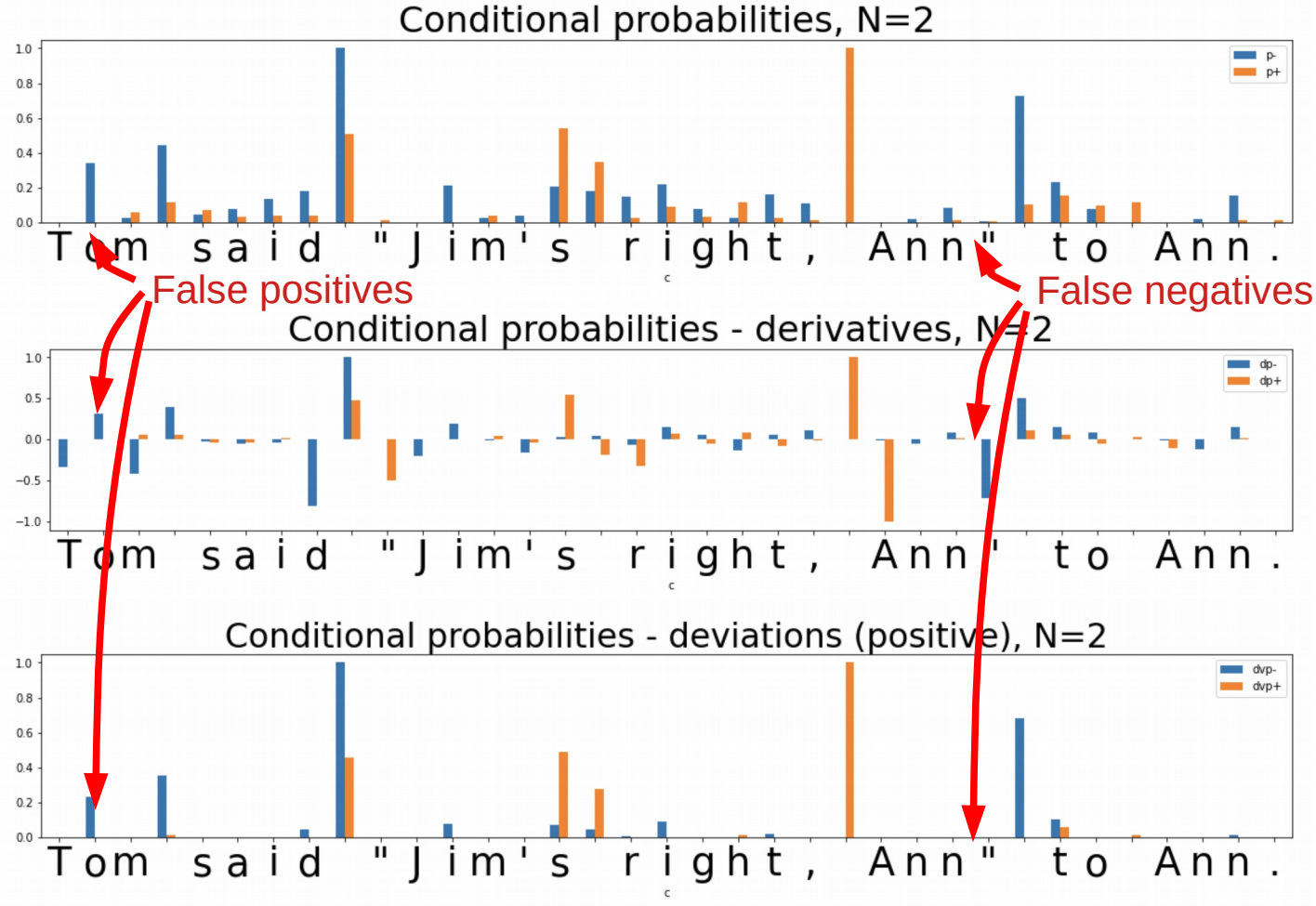
Metrics/Indicators:

Ngram (Character) Conditional Probability

(of Transition)

$P(Ngram_{n+1})/P(Ngram_n)$

P(“m ”)/P(“m”)

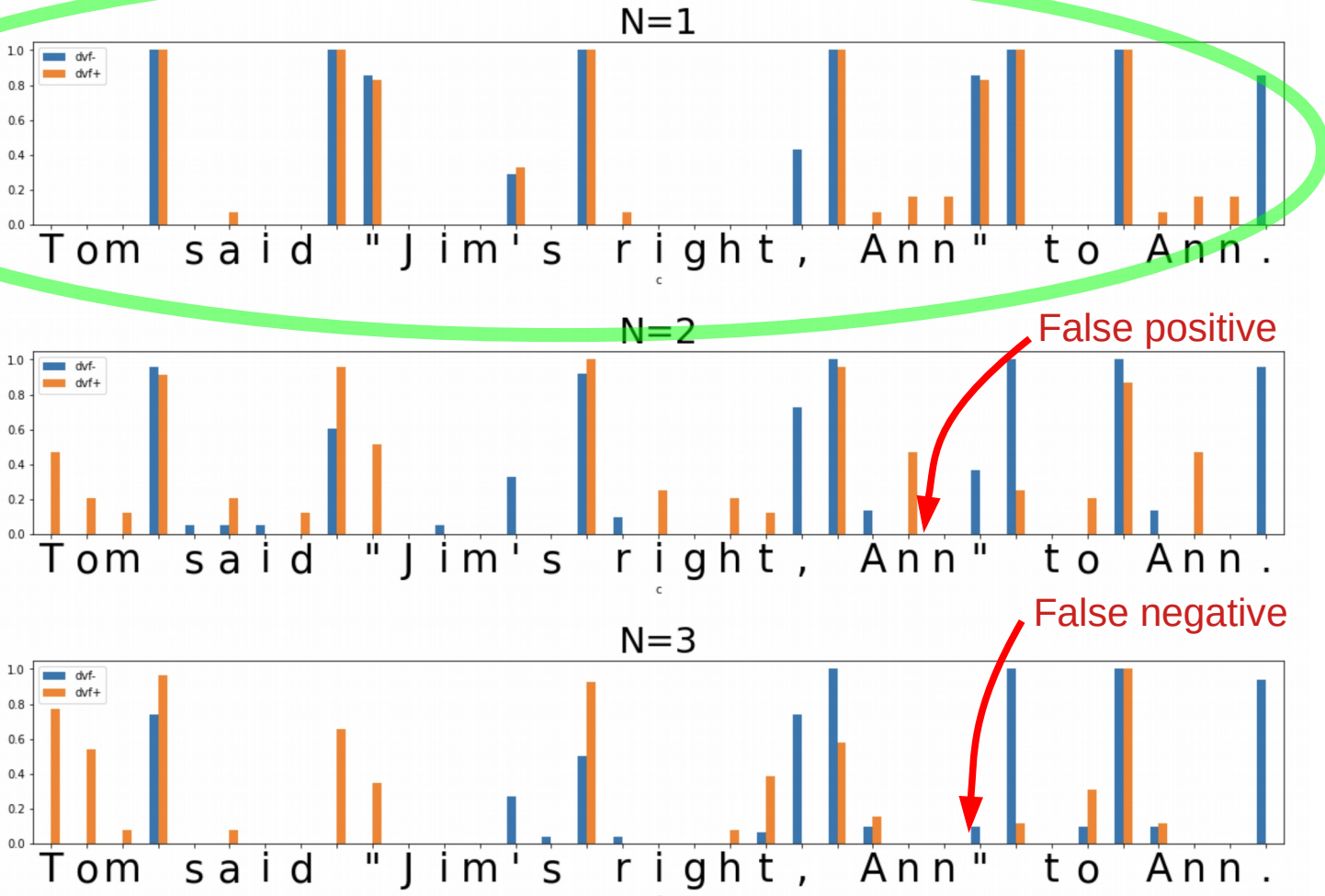


Unsupervised Text Segmentation (Tokenization)

Metrics/ Indicators:

Transition
Freedom
Deviation

(varying “N” of N-gram)



Unsupervised Text Segmentation (Tokenization)

English

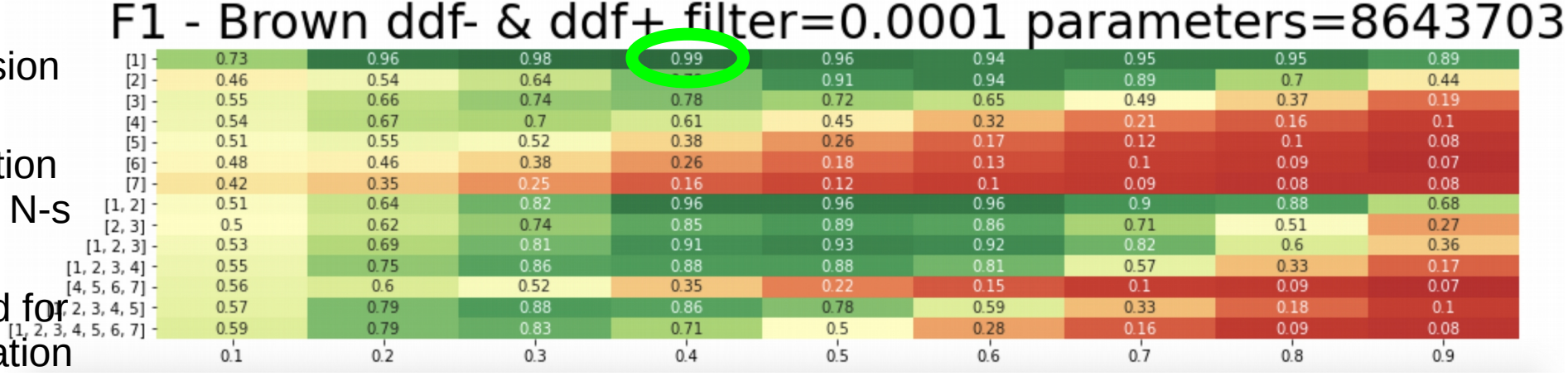
Hyper-Parameters:

Metric: Transition Freedom

Threshold for model compression

Combination of Ngram N-s

Threshold for segmentation



Results – Freedom-based Tokenization against Lexicon-based one (referring to Rule-based)

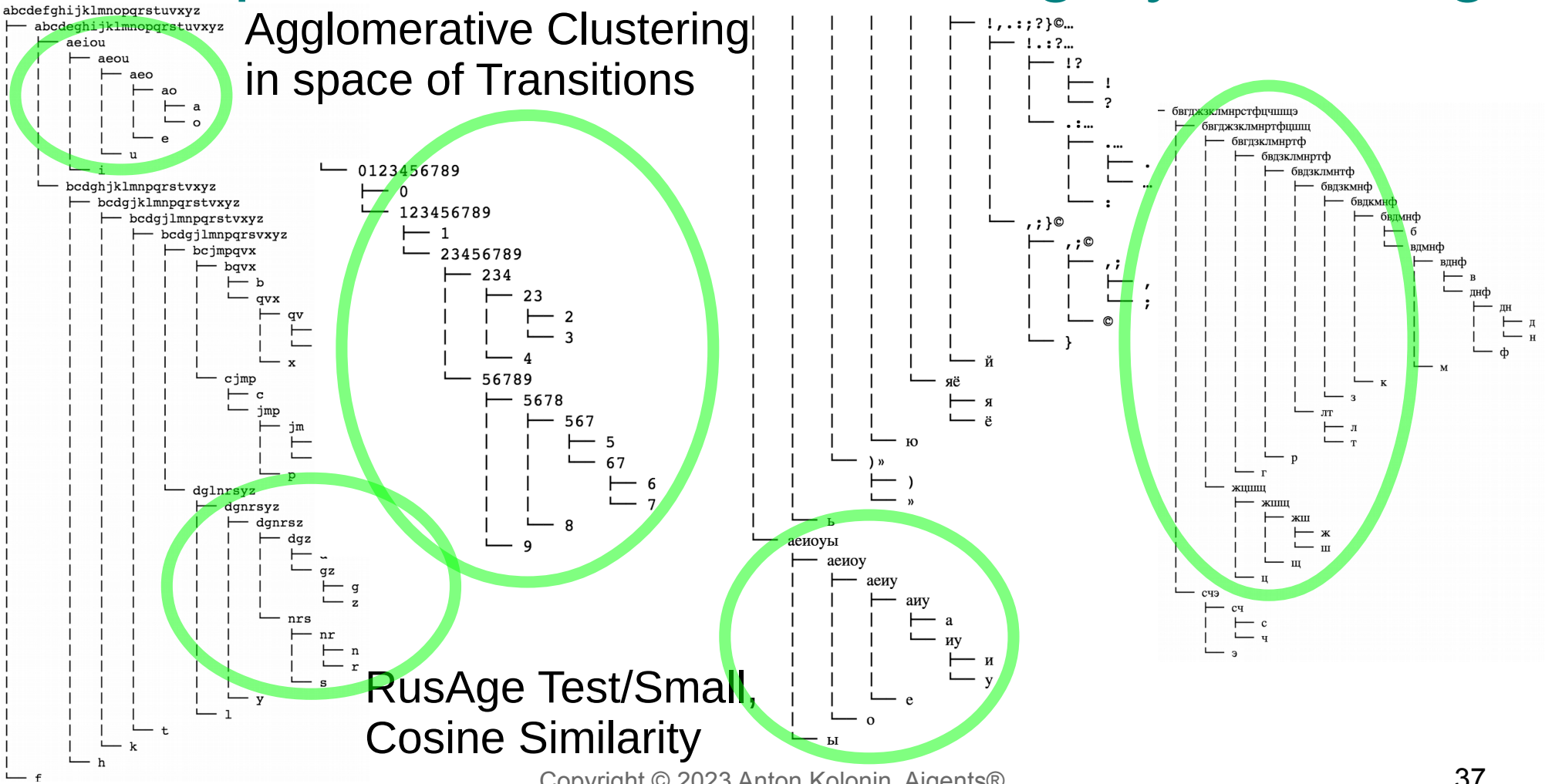
Language	Tokenizer	Tokenization F_1	Lexicon Discovery Precision
English	Freedom-based	**0.99**	**0.99** (vs. 1.0)
English	Lexicon-based*	0.99	-
Russian	Freedom-based	**1.0**	**1.0** (vs. 1.0)
Russian	Lexicon-based*	0.94	-
Chinese	Freedom-based	**0.71**	**0.92** (vs. 0.94)
Chinese	Lexicon-based*	0.83	-

**Lexicon-based Tokenization - greedy/beam search on word length (optimal) or frequency*

Preprint: https://arxiv.org/abs/2205.11443 **EMNLP-2022**

Unsupervised Character Category Learning

Agglomerative Clustering
in space of Transitions



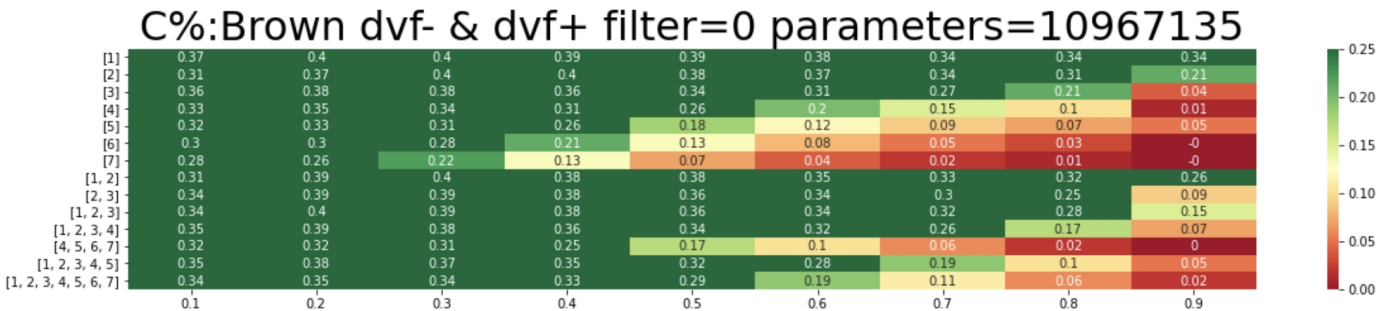
RusAge Test/Small,
Cosine Similarity

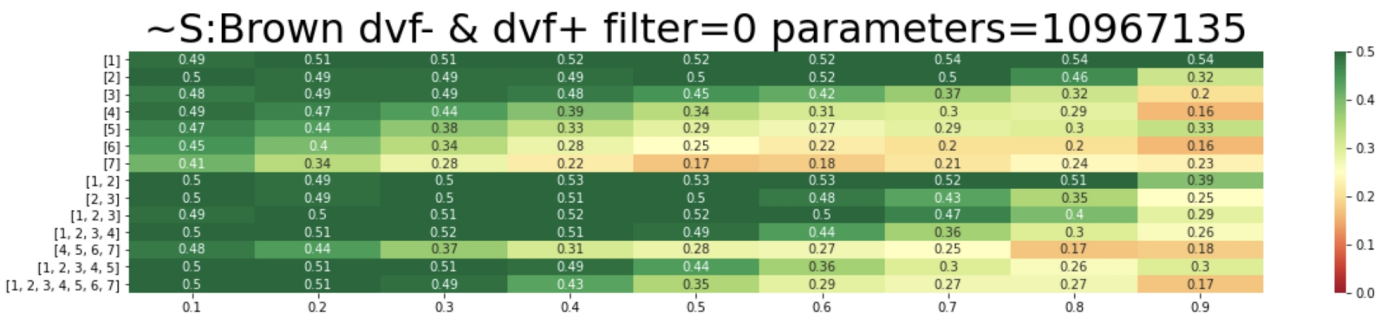
Hyper-parameters: F1 vs. language-agnostic metrics

English,

Brown corpus

Maximizing F1, compression factor (C%) and normalized anti-entropy (~S) in the space of hyper-parameters

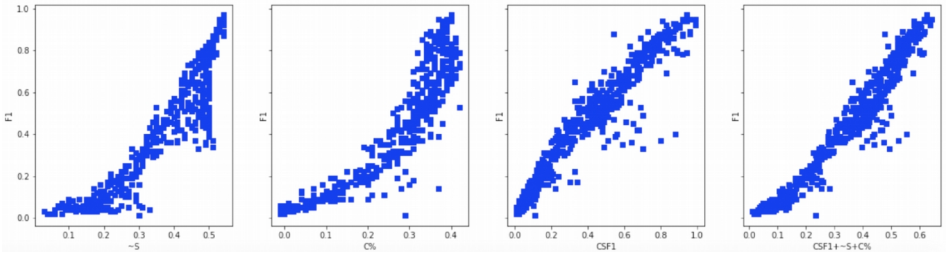




https://arxiv.org/abs/2303.02427

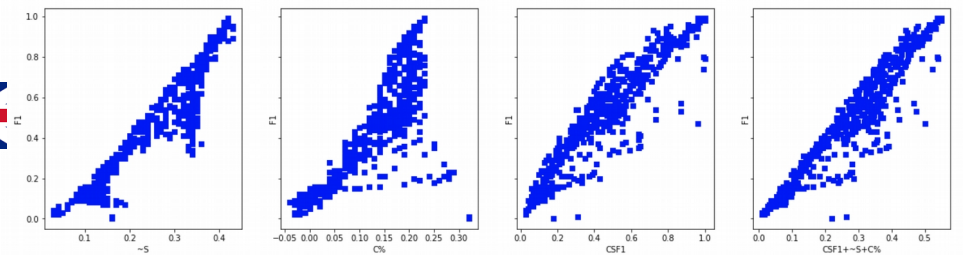
Different corpora, different sizes

English, Train: Brown, Test: Brown 1000

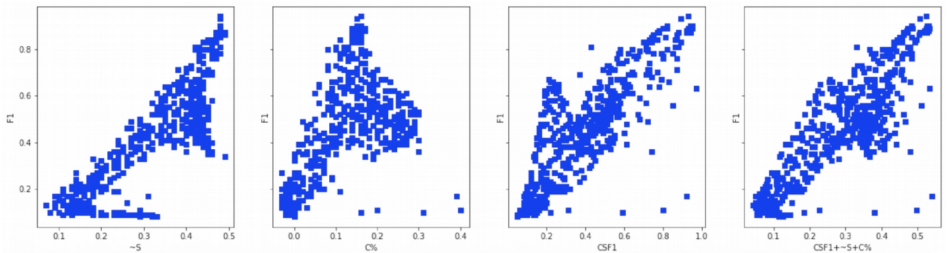


https://github.com/aigents/pygents/blob/main/notebooks/nlp/english/en_tokenizer_auto.ipynb

English, Train: Brown, Test: MagicData 100

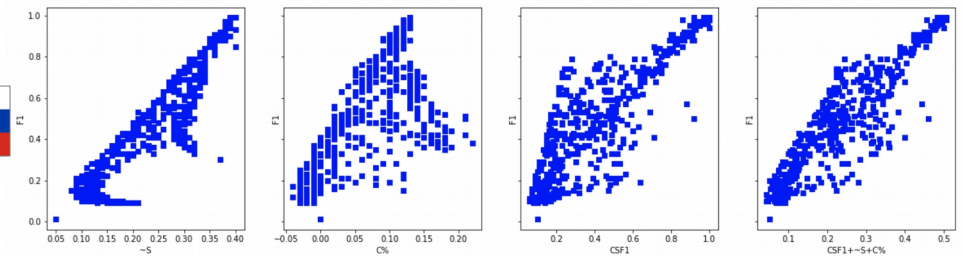


Russian, Train: RusAge, Test: RusAge 1000

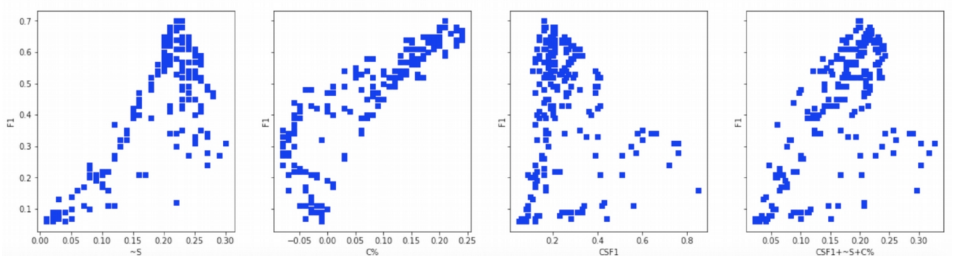


https://github.com/aigents/pygents/blob/main/notebooks/nlp/russian/ru_tokenizer_auto.ipynb

Russian, Train: Brown, Test: MagicData 100

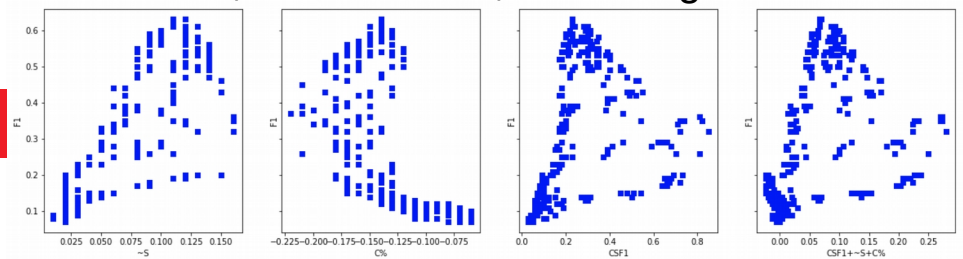


Chinese, Train: CLUE News, Test: CLUE News 1000



https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_auto.ipynb

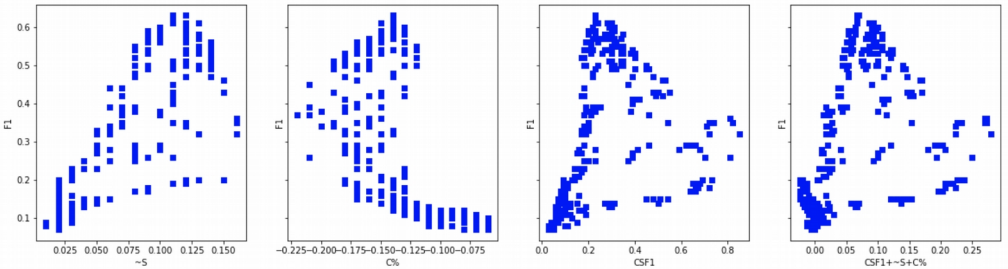
Chinese, Train: Brown, Test: MagicData 100



https://github.com/aigents/pygents/blob/main/notebooks/nlp/tokenization/brown/tokenization_brown_en_ru_zh.ipynb

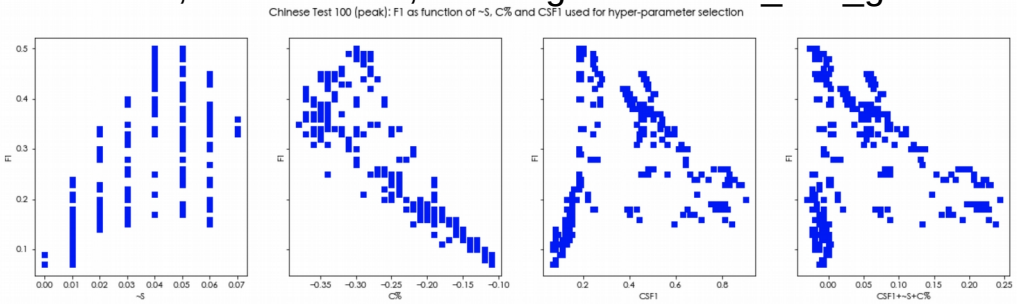
Chinese corpora, different sizes

Chinese, Train: Brown, Test: MagicData 100

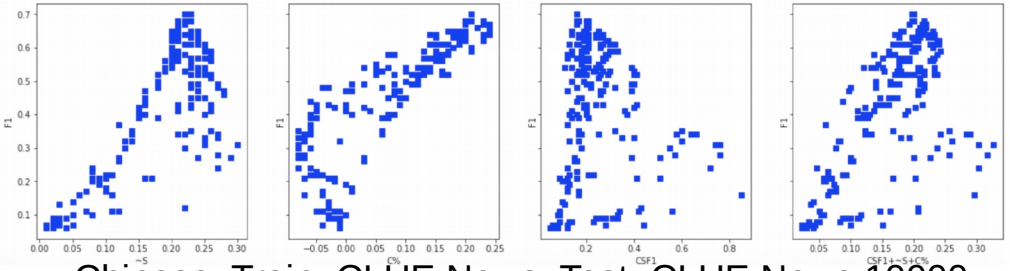


https://github.com/aigents/pygents/blob/main/notebooks/nlp/tokenization/brown/tokenization_brown_en_ru_zh.ipynb

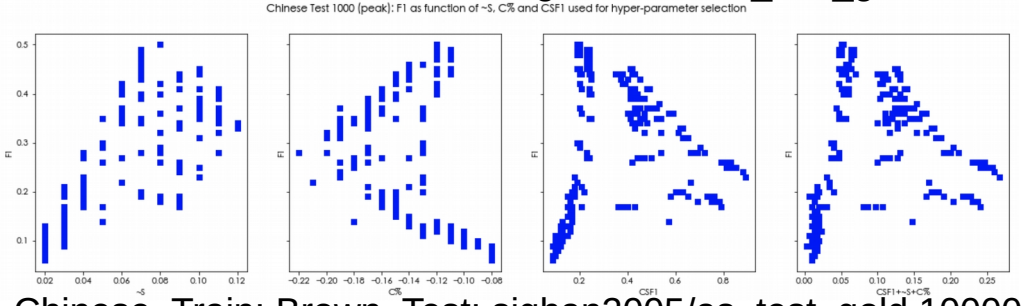
Chinese, Train: Brown, Test: sighan2005/as_test_gold 100



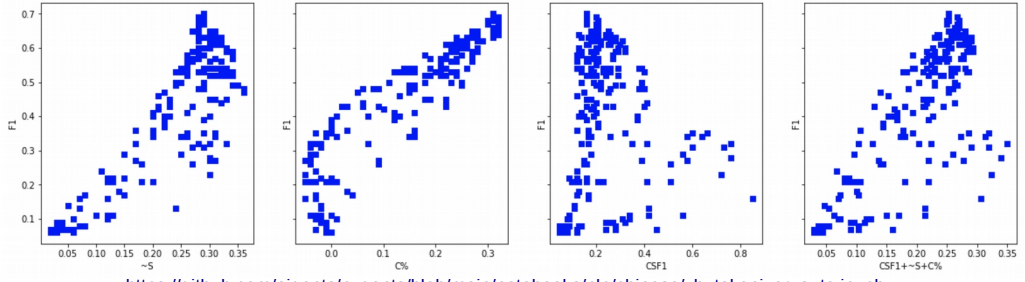
Chinese, Train: CLUE News, Test: CLUE News 1000



Chinese, Train: Brown, Test: sighan2005/as_test_gold 1000

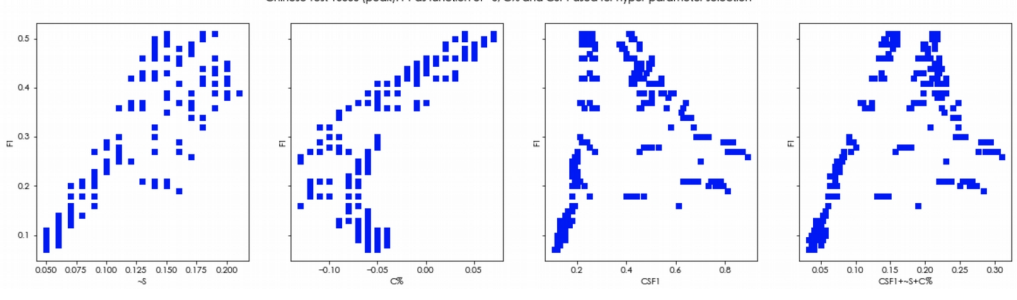


Chinese, Train: CLUE News, Test: CLUE News 10000



https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_auto.ipynb

Chinese, Train: Brown, Test: sighan2005/as_test_gold 10000



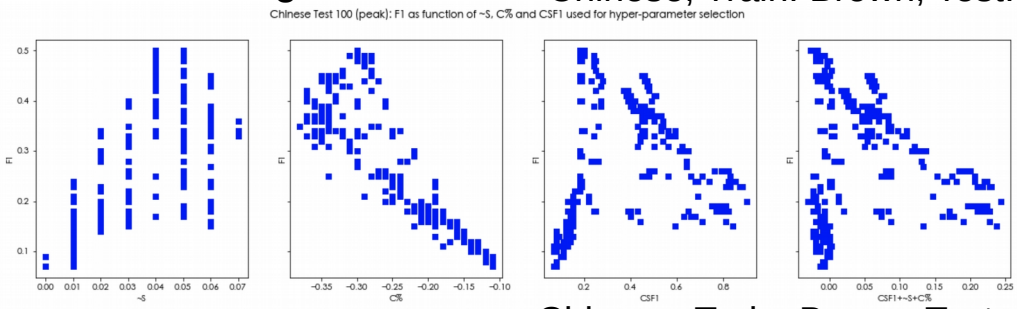
https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_multi-criteria-cws.ipynb

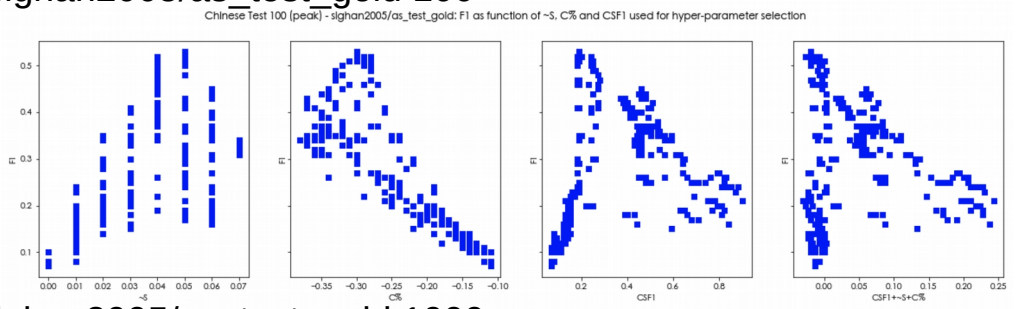
Chinese corpora, different “ground truth” tokenizers

Ground truth: sighan2005

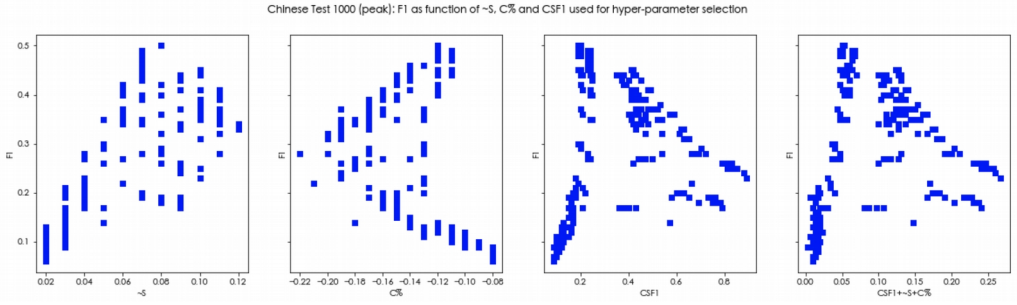
Chinese, Train: Brown, Test: sighan2005/as_test_gold 100

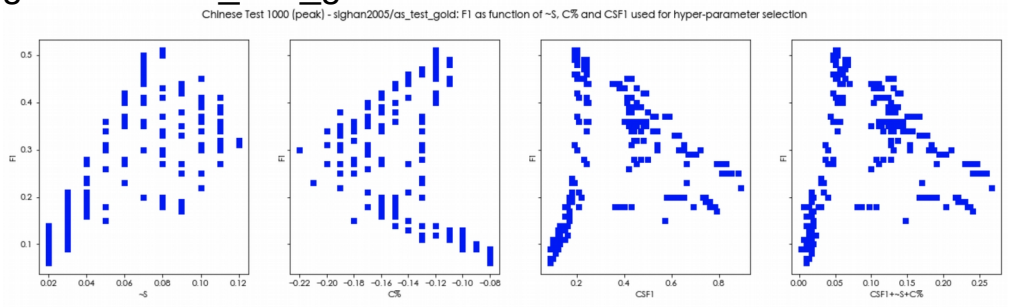
Ground truth: Jieba



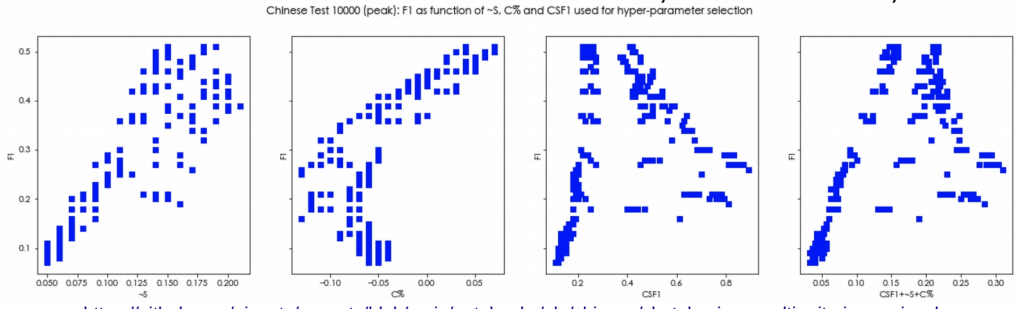


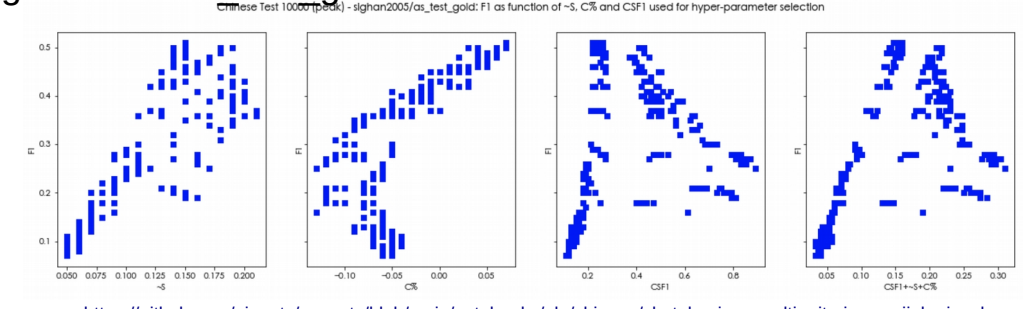
Chinese, Train: Brown, Test: sighan2005/as_test_gold 1000





Chinese, Train: Brown, Test: sighan2005/as_test_gold 10000

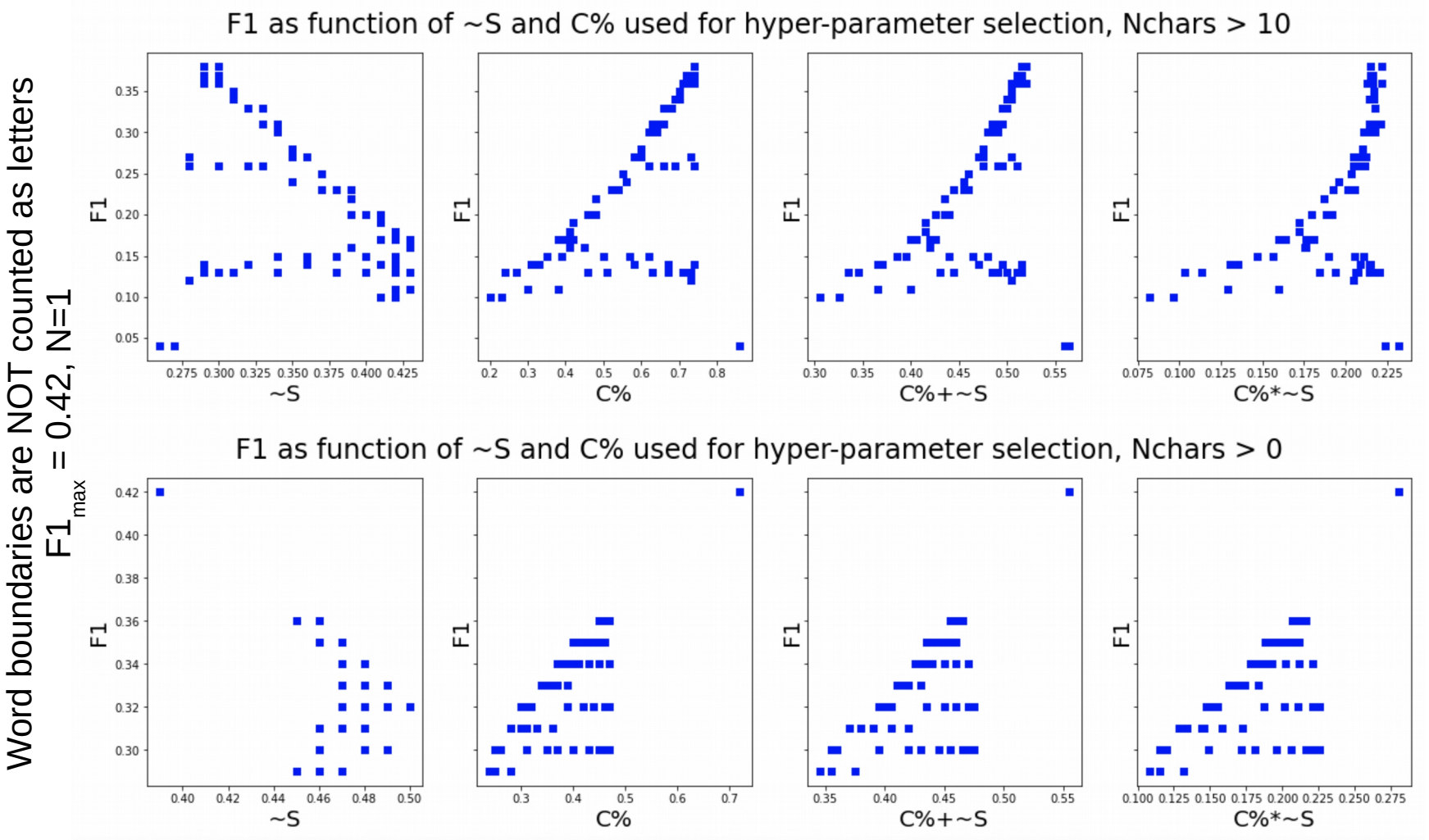




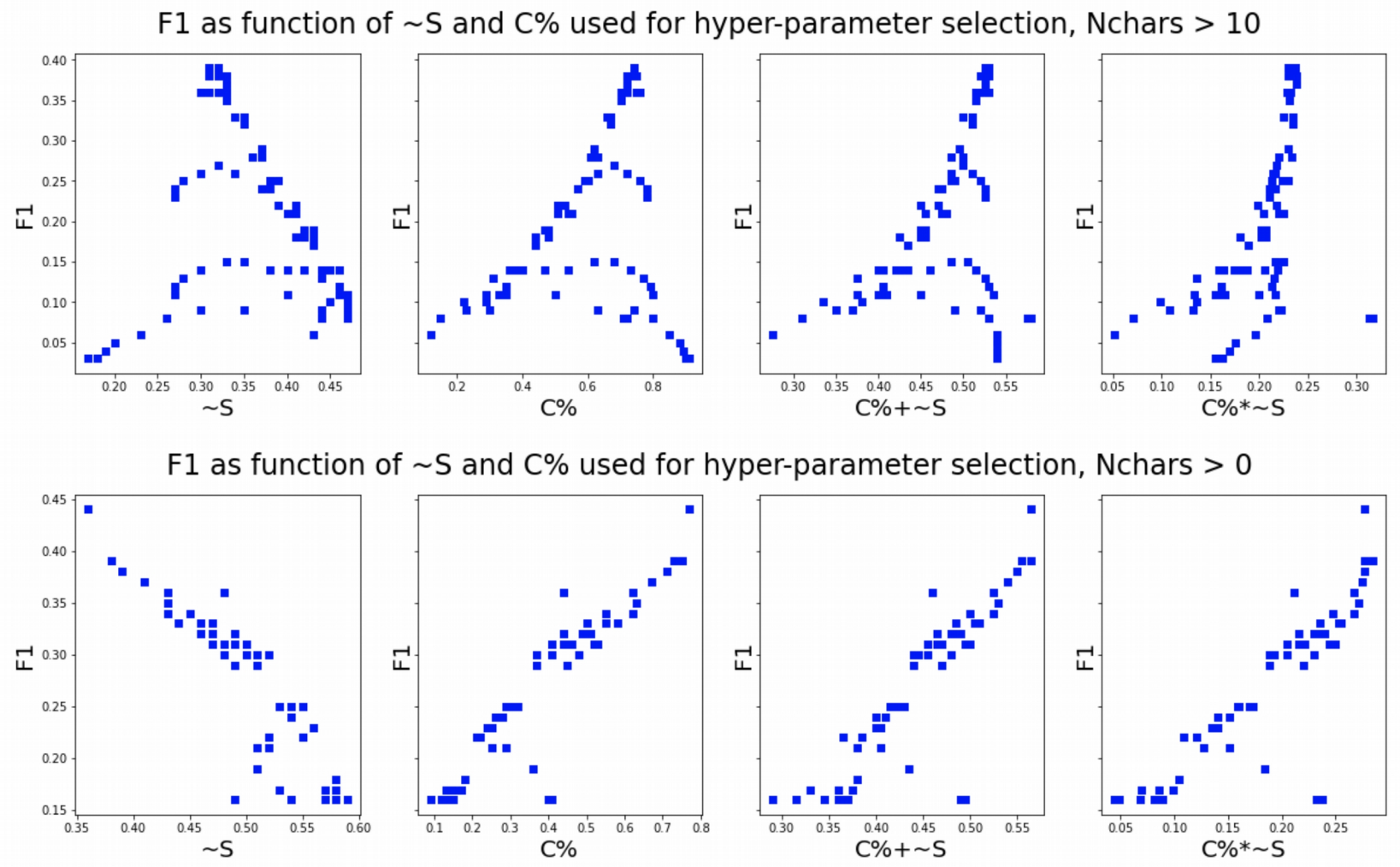
https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_multi-criteria-cws.ipynb

https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_multi-criteria-cws-jieba.ipynb

Unsupervised learning for subword segmentation



Unsupervised learning for subword segmentation



Word boundaries are NOT counted as letters,
$F1_{max}$ = 0.44, N = 2

Unsupervised learning for subword segmentation

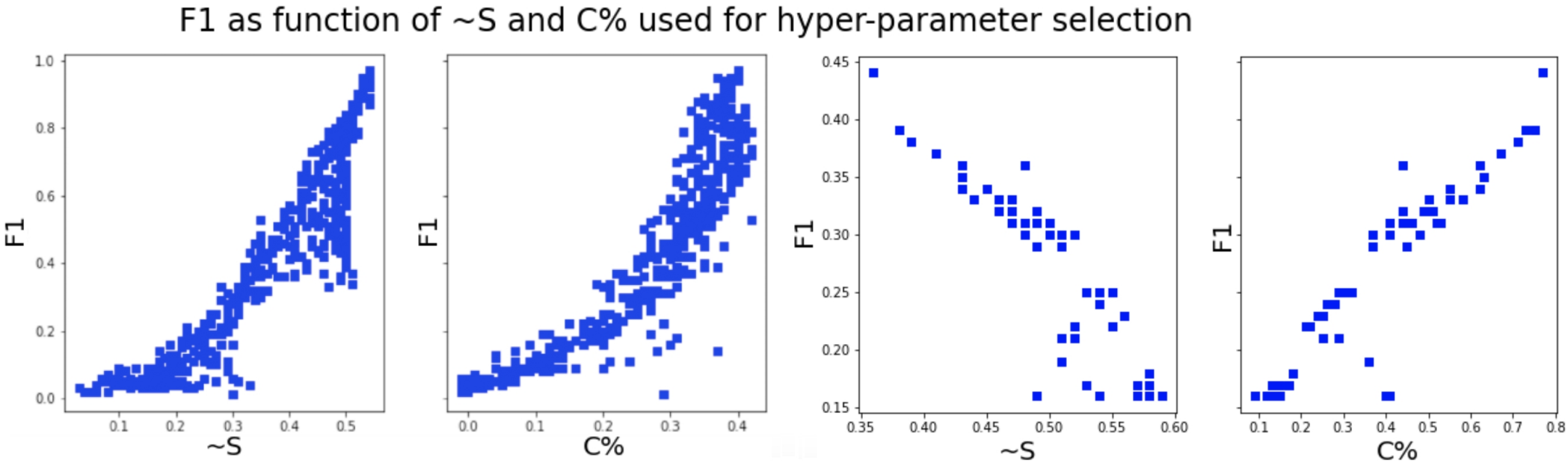
Reference	Morphology-based	BPE	DPE	Transtion-freedom-based
['euro', 'zone']	['eu', 'rozone']	['eurozone']	['euro', 'zone']	['euro', 'z', 'one']
['entrepreneur', 'ship']	['ent', 're', 'pre', 'neur', 'ship']	['entrepreneurship']	['entrepreneur', 'ship']	['entre', 'preneur', 'sh', 'ip']
['pre', 'sent', 'ly']	['pre', 's', 'ent', 'ly']	['pres', 'ently']	['present', 'ly']	['pre', 's', 'ently']
['bloc']	['bloc']	['blo', 'c']	['bl', 'oc']	['b', 'lo', 'c']
['tree', 's']	['tr', 'ee', 's']	['tre', 'es']	['tr', 'ees']	['tre', 'es']
['multi', 'lateral', 'ism']	['multi', 'lat', 'er', 'al', 'ism']	['multilater', 'alism']	['multilateral', 'ism']	['multi', 'later', 'al', 'ism']
['motive', 's']	['mot', 'ive', 's']	['mo', 'tives']	['motiv', 'es']	['mo', 'tiv', 'es']
['progress', 'ive', 'ly']	['pro', 'gr', 'ess', 'ive', 'ly']	['pro', 'gressively']	['progressive', 'ly']	['pro', 'gressiv', 'ely']
['de', 'cent', 'ral', 'isation']	['dec', 'ent', 'r', 'al', 'isation']	['decent', 'ralisation']	['decent', 'ral', 'isation']	['de', 'centralis', 'ation']
['margin', 'al', 'is', 'ed']	['marginali', 's', 'ed']	['margin', 'alised']	['marginal', 'ised']	['mar', 'ginal', 'is', 'ed']
['re', 'cast']	['re', 'cast']	['rec', 'ast']	['re', 'cast']	['re', 'c', 'ast']
['out', 'line', 's']	['out', 'l', 'ine', 's']	['out', 'lines']	['outline', 's']	['out', 'l', 'ines']
['pre', 'vent', 'at', 'ive']	['pre', 'v', 'ent', 'ative']	['preven', 'tative']	['prevent', 'ative']	['pre', 'vent', 'ative']
['en', 'danger', 'ed']	['end', 'an', 'g', 'er', 'ed']	['endang', 'ered']	['endanger', 'ed']	['en', 'dang', 'ered']
['vulner', 'abil', 'ity']	['vulnerabil', 'ity']	['vul', 'n', 'era', 'bility']	['vul', 'ner', 'ability']	['vul', 'ner', 'ability']
F1	**0.46**	**0.05**	**0.55**	**0.25**

Ref:
https://arxiv.org/pdf/2005.06606.pdf

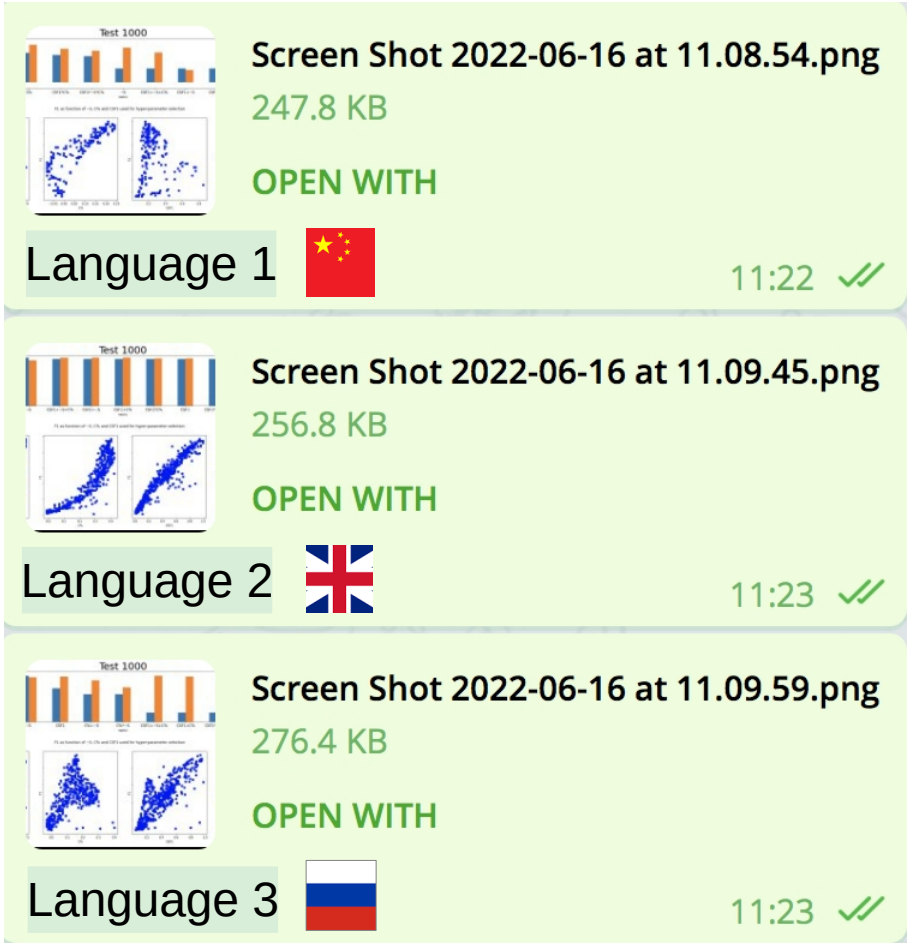
https://github.com/aigents/pygents/blob/main/data/corpora/English/morphology/prefixes.txt
https://github.com/aigents/pygents/blob/main/data/corpora/English/morphology/suffixes.txt

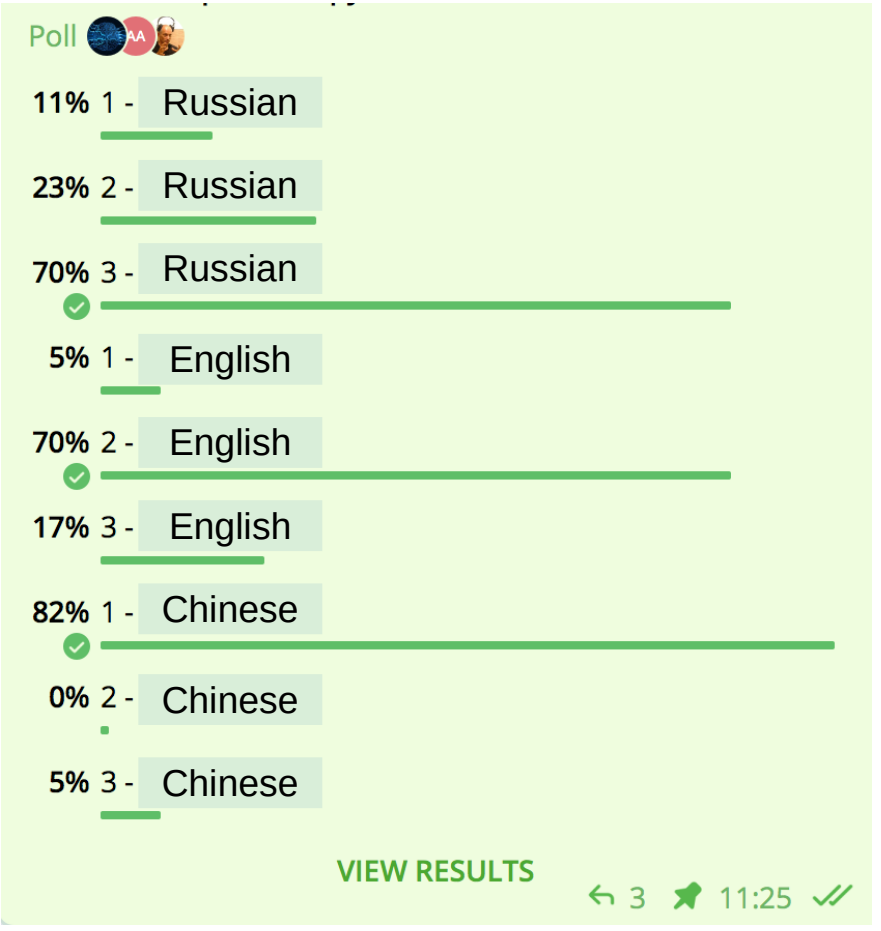
Tokenization vs. sub-word segmentation

F1 connection to anti-entropy and compression factor



The riddle - answer: you have got it!





Welcome to the Interpretable Natural Language Processing Community and Series of Workshops

Telegram English
https://t.me/internlp

Telegram Russian
https://t.me/agibots

Workshop 2023 (Stockholm, Sweden & Virtual)
https://aigents.github.io/inlp/2023/

Workshop 2022
https://aigents.github.io/inlp/2022/

Thank You and Welcome!

Anton Kolonin

akolonin@aigents.com

Facebook: akolonin

Telegram: akolonin

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