Unsupervised Natural Language Text Segmentation and Categorization?

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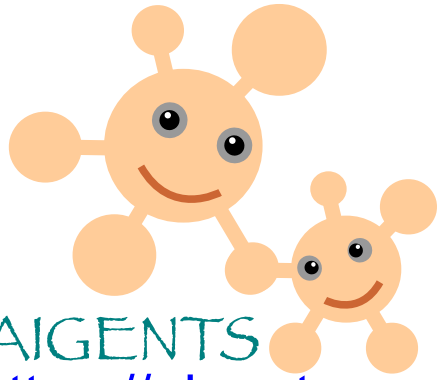
*THE REAL SCIENCE

https://www.nsu.ru/

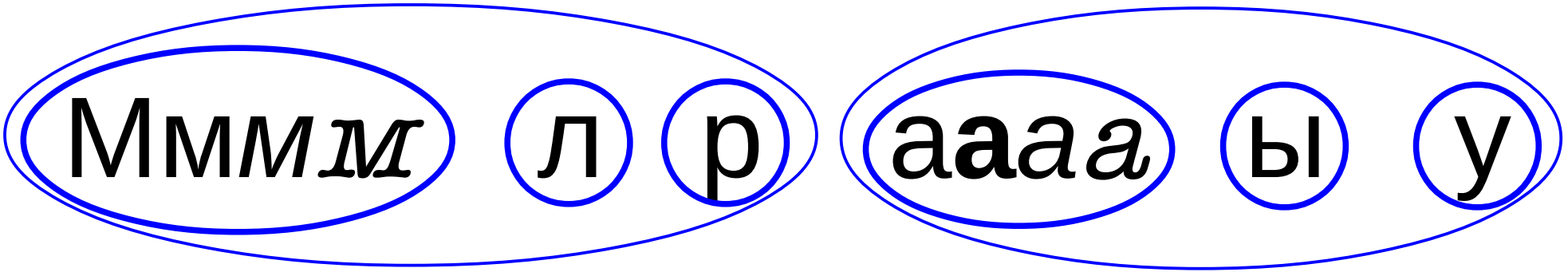


https://aigents.com

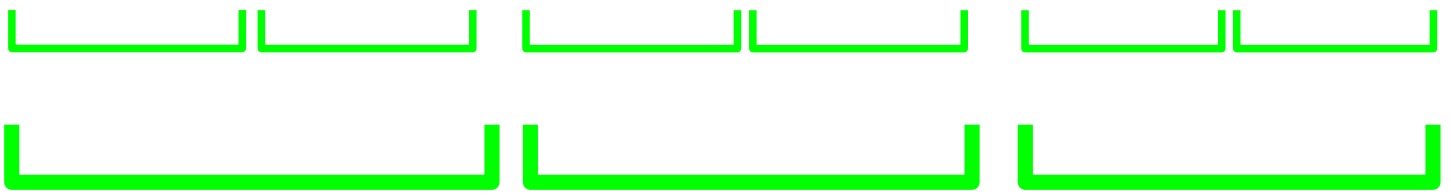
AGI IN RUSSIAN

https://agirussia.org

Clustering and Segmentation



Мама мыла раму



Clustering and Segmentation

_ м а л о ы н ш у

ма ло мы ла на шу

мало_мама_мыла_нашу_машу_мылом

Clustering and Segmentation

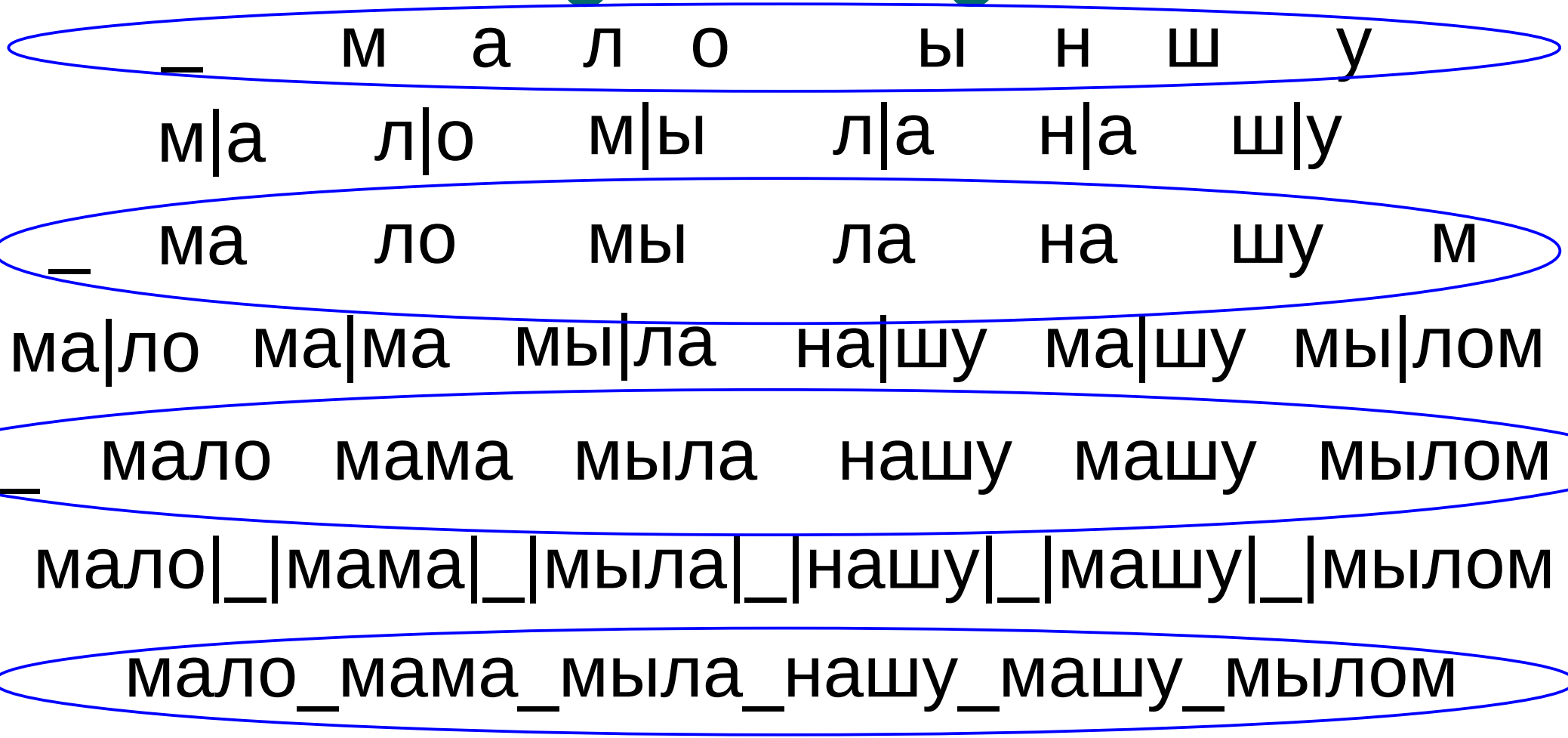
_ м а л о ы н ш у

ма|ло ма|ма мы|ла на|шу ма|шу мы|лом

мало|_|мама|_|мыла|_|нашу|_|машу|_|мылом

мало_мама_мыла_нашу_машу_мылом

Clustering and Segmentation



Clustering and Segmentation

мама_мыла_машу маша_мыла_маму

маша_ела_кашу мама_ела_кашу

маша_ела_суши мама_ела_суши

маша_ела_мало_каши

мама_ела_мало_суши

Motivation

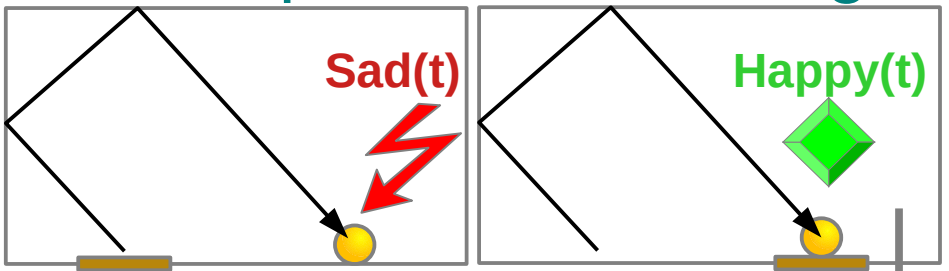
Identifying successful/unsuccessful sequential experiences for experiential learning for global (self)reinforcement

Discovering NLP patterns such as words and punctuation for further unsupervised language learning

https://arxiv.org/abs/2205.11443
https://github.com/aigents/pygents

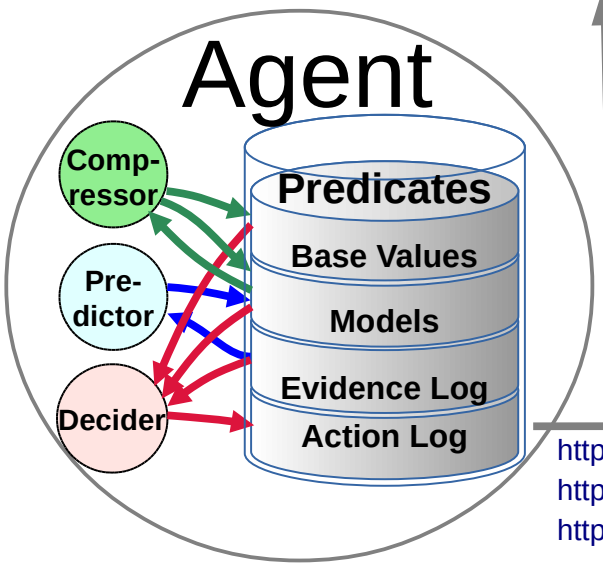
Unsupervised Learning of Temporal Abstractions with Slot-based Transformers
Anand Gopalakrishnan, Kazuki Irie, Jürgen Schmidhuber, Sjoerd van Steenkiste
https://arxiv.org/abs/2203.13573

Identifying successful/unsuccessful sequential experiences for experiential learning with global (self)reinforcement

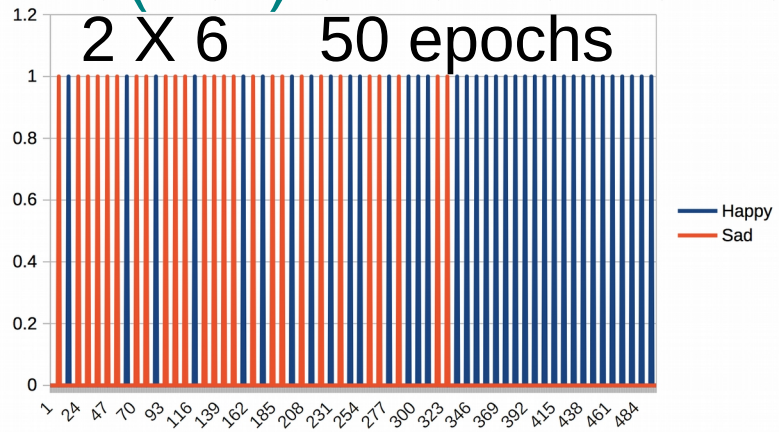


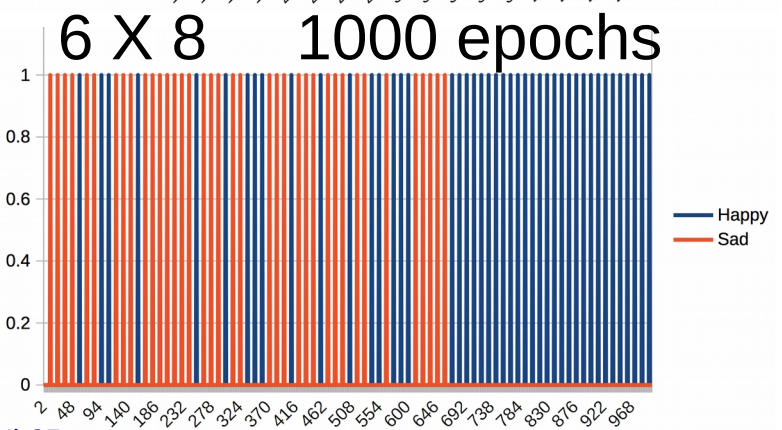
Left(t) Stay(t) Right(t)

Xball(t)
Yball(t)
Xracket(t)
Sad(t)
Happy(t)



Move(t)



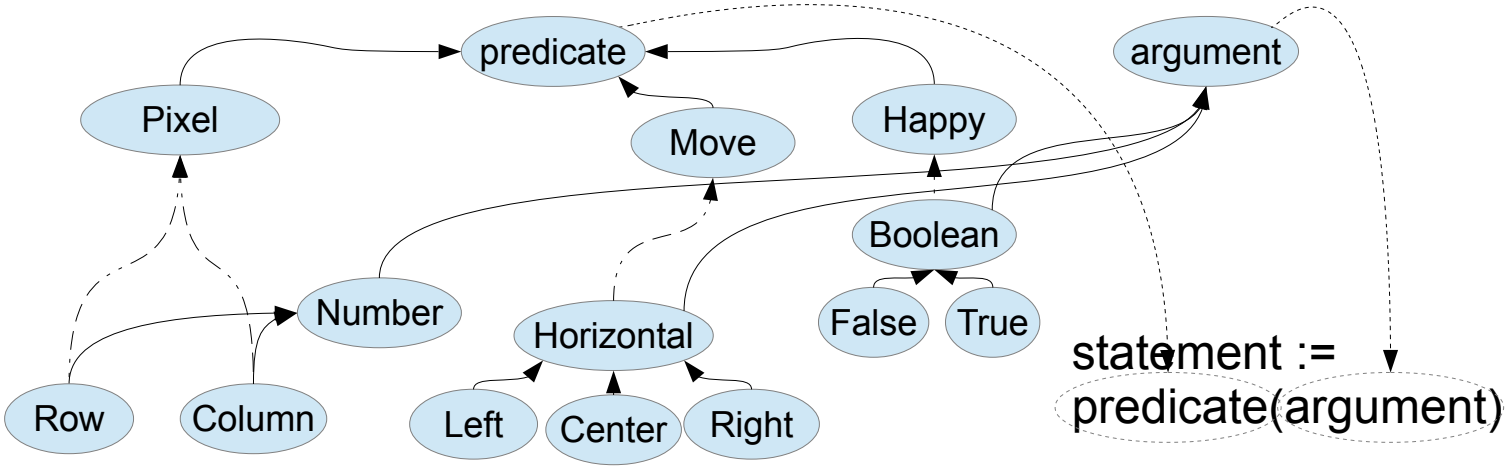


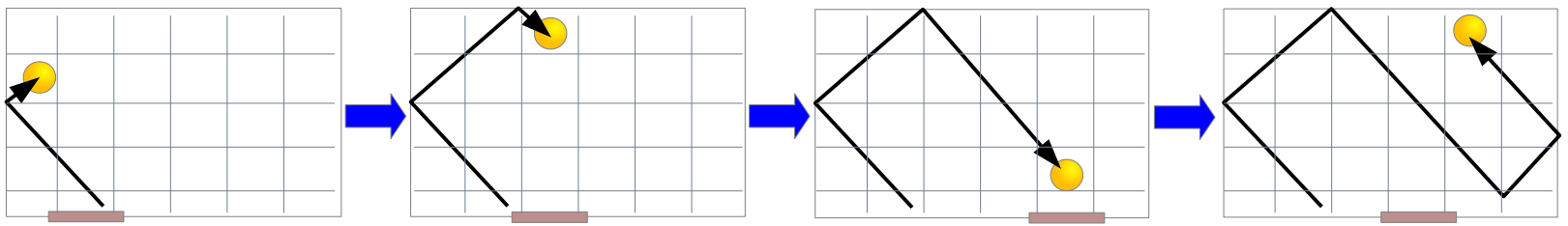
https://www.youtube.com/watch?v=2LPLhJKh95g

https://www.springerprofessional.de/neuro-symbolic-architecture-for-experiential-learning-in-discret/20008336

https://github.com/aigents/aigents-java/tree/master/src/main/java/net/webstructor/agi

Ontology and Grammar (“Discrete”)





Pixel(1,0)
Pixel(4,1)
Happy(False)
=>
Move(Left)

Pixel(0,2)
Pixel(4,2)
Happy(False)
=>
Move(Right)

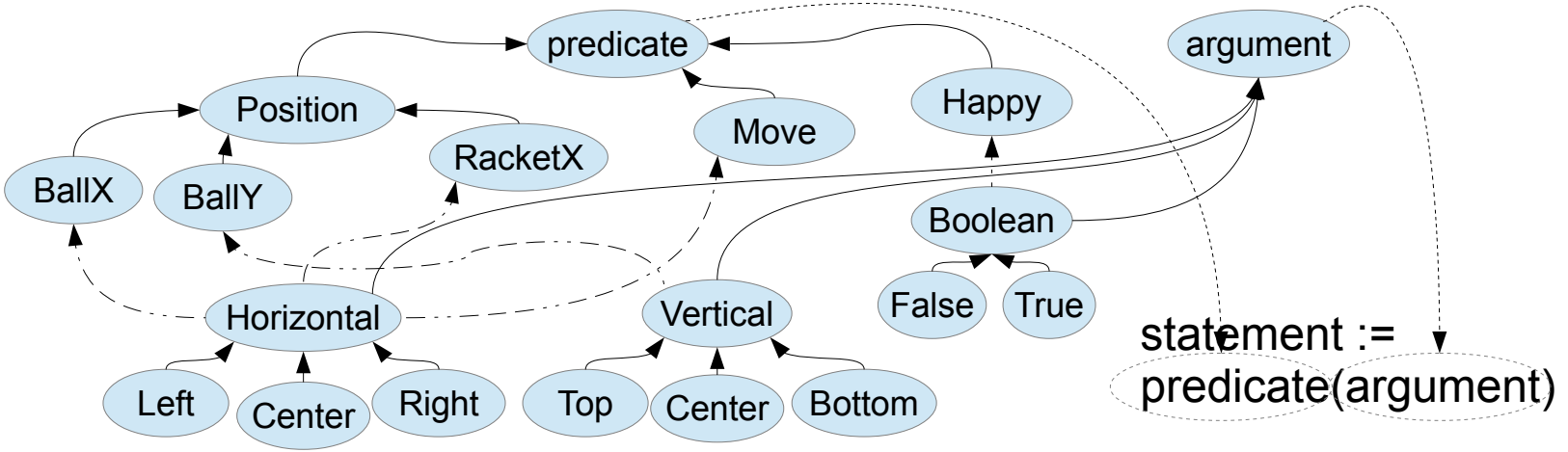
Pixel(3,4)
Pixel(4,4)
Happy(False)
=>
Move(Left)

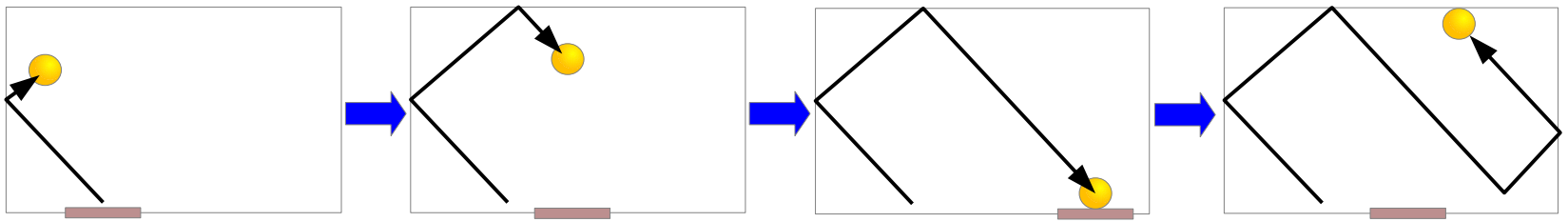
Pixel(0,4)
Pixel(4,3)
Happy(True)
=>
Move(Left)

Global Feedback

https://www.youtube.com/watch?v=2LPLhJKh95g

Ontology and Grammar (“Symbolic”)





BallY(Top)
BallX(Left)
RacketX(Left)
Happy(False)
=> **Move(Left)**

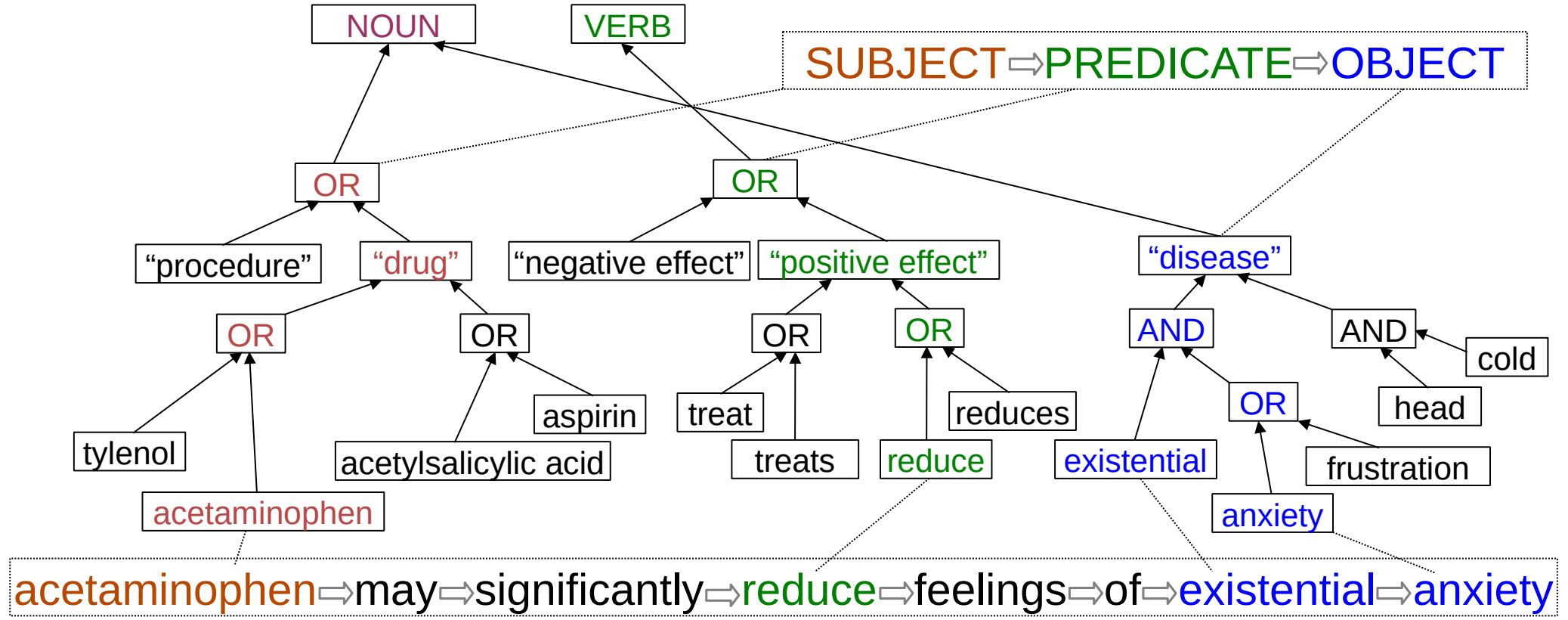
BallY(Top)
BallX(Center)
RacketX(Center)
Happy(False)
=> **Move(Right)**

BallY(Bottom)
BallX(Right)
RacketX(Right)
Happy(False)
=> **Move(Right)**

BallY(Bottom)
BallX(Right)
RacketX(Right)
Happy(True)
=> **Move(Left)**

Global Feedback

Discovering NLP patterns such as words or phrase structures for unsupervised language learning (Aigents® “Deep Patterns”)



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

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

Unsupervised Segmentation

No stop/start/break tokens, lexicons and rules are known!!!

Issues to Address

Absence of explicit start/stop tags in continuous streams of spaces in experiential (reinforcement/self-reinforcement) learning with delayed/sparse feedback

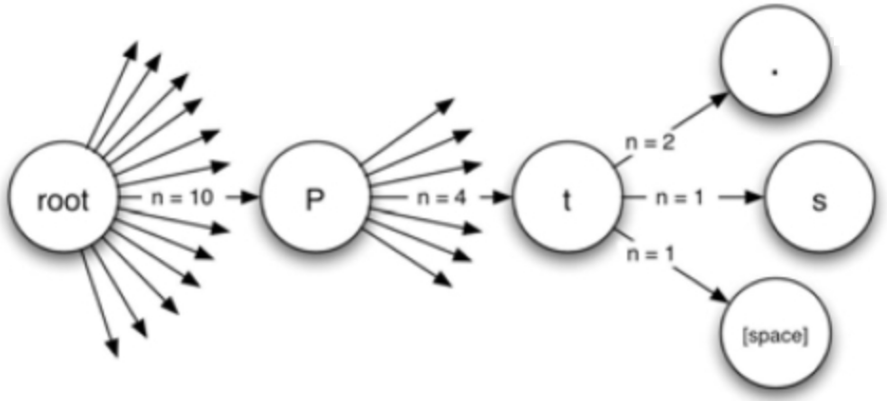
https://www.youtube.com/watch?v=2LPLhJKh95g
https://www.springerprofessional.de/neuro-symbolic-architecture-for-experiential-learning-in-discret/20008336
https://github.com/aigents/aigents-java/tree/master/src/main/java/net/webstructor/agi

Complex, cumbersome, unreliable and expensive language-specific tokenization process for unsupervised language learning in NLP

Low quality of unsupervised parsing and tokenization learning based on mutual information and conditional probabilities

https://www.springerprofessional.de/unsupervised-language-learning-in-opencog/15995030
https://www.springerprofessional.de/en/programmatic-link-grammar-induction-for-unsupervised-language-le/17020348
https://github.com/singnet/language-learning/
https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=6983&context=etd

Tokenization or Text Segmentation as Language Modeling



Trie data structure. The probability of observing an ‘s’ given the preceding string “Pt” is ¼, or 25%. The freedom following “pt” is 3.

Contrastive Evaluation: Test Specific Phenomena

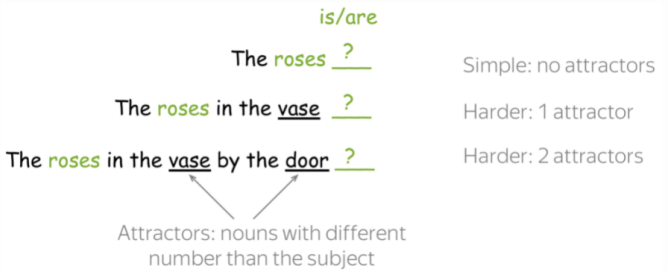
To test if your LM knows something very specific, you can use contrastive examples. These are the examples where you have several versions of the same text which differ only in the aspect you care about: one correct and at least one incorrect. A model has to assign higher scores (probabilities) to the correct version.

The roses in the vase by the door _?_ Competing answers: is, are

P(The roses in the vase by the door are)
P(The roses in the vase by the door is)
→ Is the correct answer ranked higher? P(...are) > P(...is)?

A very popular phenomenon to look at is subject-verb agreement, initially proposed in the Assessing the Ability of LSTMs to Learn Syntax-Sensitive Dependencies paper. In this task, contrastive examples consist of two sentences: one where the verb agrees in number with the subject, and another with the same verb, but incorrect inflection.

Examples can be of different complexity depending on the number of **attractors**: other nouns in a sentence that have different grammatical number and can "distract" a model from the subject.



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

https://lena-voita.github.io/nlp_course/language_modeling.html

Claims

Transition Freedom (TF) appears to be superior (over **Mutual Information** and **Conditional Probability**) for unsupervised text segmentation (tokenization).

English and Russian require one specific way (variance) of handling the TF while Chinese requires a bit different specific way (derivative-based “peak values”) for the same purpose.

Tokenization quality for Russian and English may be as high as F1=0.96-1.0, depending on training and testing corpora while for Chinese the minimum is F1=0.71-0.92, depending on the assessment assumptions.

Larger training corpora does not necessarily effect in better tokenization quality, while compacting the models eliminating statistically weak evidence typically improve the quality.

TF-based tokenization appear quality same or better than lexicon-based one for Russian and English while for Chinese appears the opposite (as it could be anticipated).

Doing Russian and English tokenization with removed spaces makes the situation similar to Chinese with reasonable quality on lexicon-based tokenization but much worse results on TF-based one.

https://arxiv.org/abs/2205.11443

https://github.com/aigents/pygents

Corpora and Methodology

Train corpora

Chinese
CLUE News 2016 Validation – 270M
CLUE News 2016 Train – 8,500M

English
Brown – 6M
Gutenberg Children – 29M
Gutenberg Adult – 140M
Social Media – 68M
All above – combined

Russian
RusAge Test – 141M
RusAge Previews – 825M

Test corpus

Parallel Chinese/English/Russian – 100 multi-sentence statements on finance

Metrics/Indicators:

Ngram (Character)
- Probability or Conditional Transition Probability (p-/p+)
  - Deviation (dvp-/dvp+) from mean
  - Derivative (dp-/dp+) and “Peak”
- Transition Freedom (f-/f+)
  - Deviation (dvf-/dvf+) from mean
  - Derivative (df-/df+) and “Peak”

Hyper-parameters:

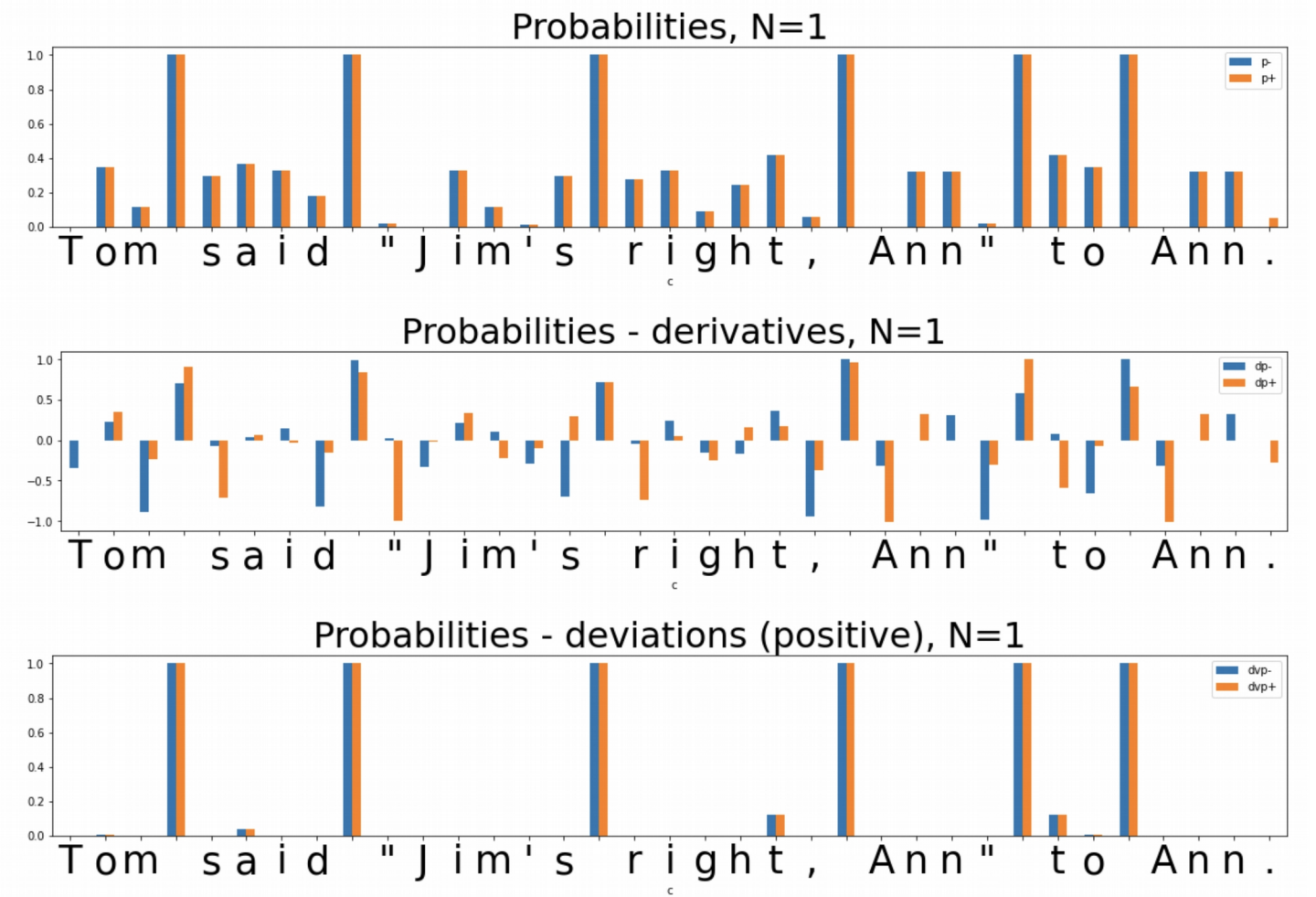
Combination of Ngram ranks N ([1],[2],[3],[1,2],[1,2,3],…)
Threshold for model compression
Threshold for segmentation

Evaluations:

Tokenization F1, on set of tokens found comparing to delimiter-based (English/Russian) or Jieba (Chineze)
Precision on set of tokens found comparing to reference lexicons

Unsupervised Text Segmentation (Tokenization)

Metrics/Indicators:
Ngram (Character)
Probability



Unsupervised Text Segmentation (Tokenization)

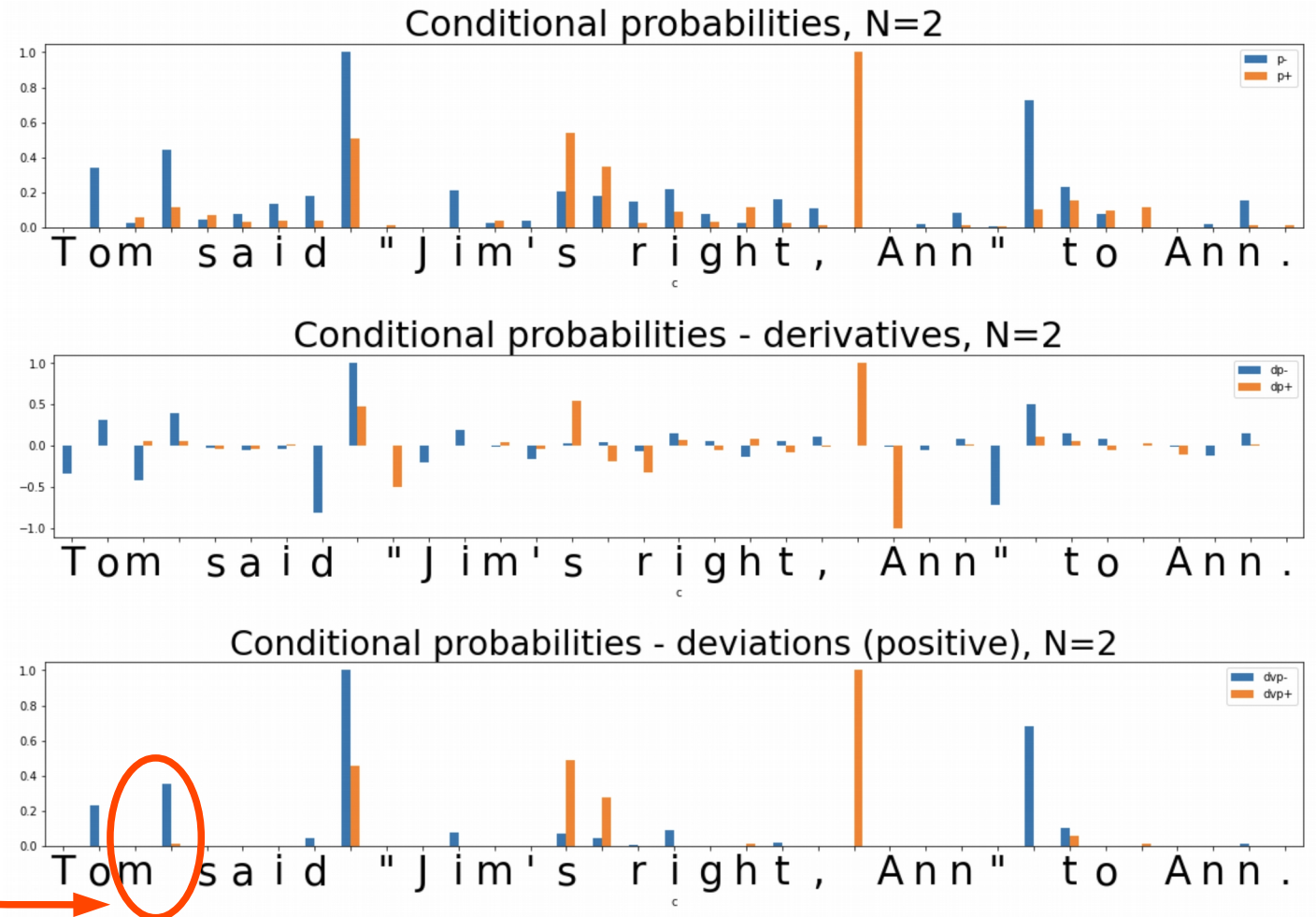
Metrics/Indicators:

Ngram (Character) Conditional Probability

(of Transition)

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

P(“m ”)/P(“m”)

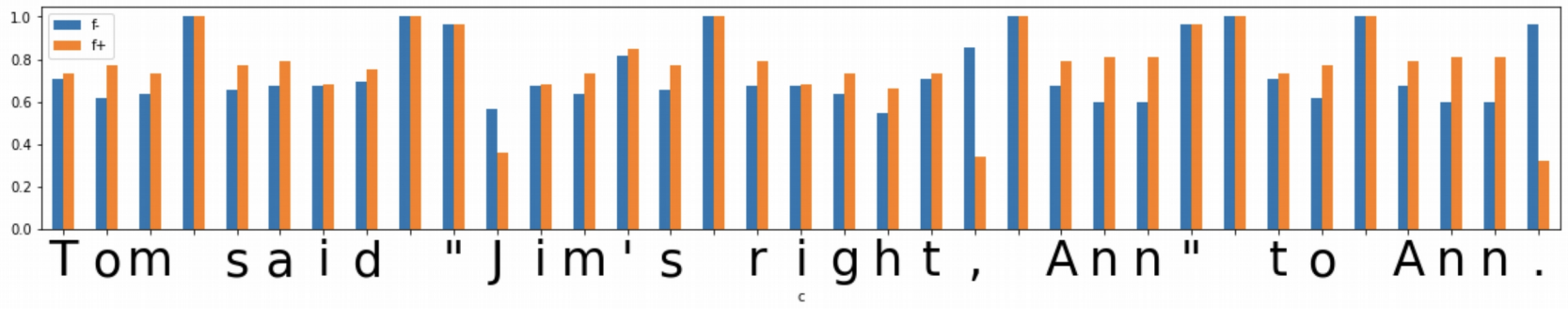


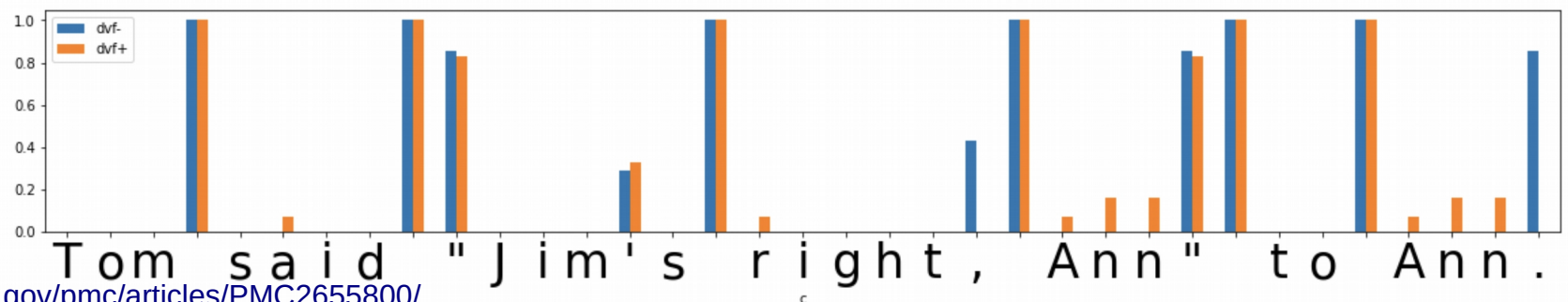
Unsupervised Text Segmentation (Tokenization)

Metrics/ Indicators:
Transition Freedom (Freedom of Transition)

Transition Freedom Deviation

```
Threshold 0.25
Tom said "Jim's right, Ann" to Ann.
['Tom', ' ', 'said', ' ', '"', "Jim's", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
['Tom', ' ', 'said', ' ', '"', 'Jim', "'", 's', ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
0.89
Threshold 0.35
Tom said "Jim's right, Ann" to Ann.
['Tom', ' ', 'said', ' ', '"', "Jim's", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
['Tom', ' ', 'said', ' ', '"', "Jim's", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
1.0
```





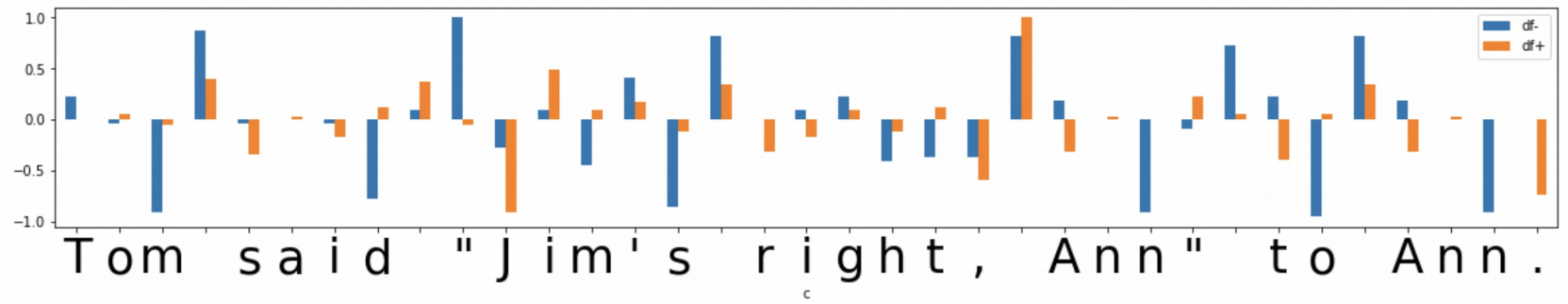
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2655800/

Unsupervised Text Segmentation (Tokenization)

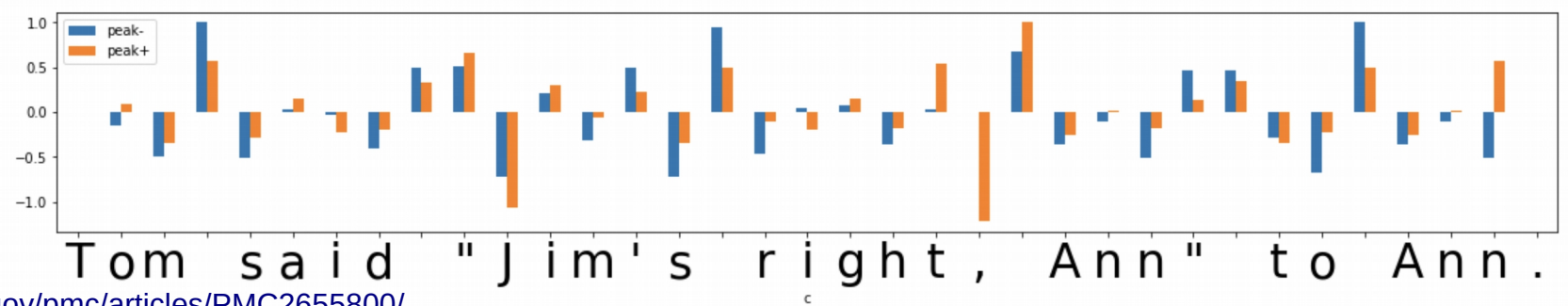
Metrics/ Indicators:

```
Threshold 0.25
Tom said "Jim's right, Ann" to Ann.
['Tom', ' ', 'said', ' ', '"', "Jim's", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
['Tom', ' ', 'said', ' ', '"', 'Ji', 'm', "'s", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
0.89
Threshold 0.35
Tom said "Jim's right, Ann" to Ann.
['Tom', ' ', 'said', ' ', '"', "Jim's", ' ', 'right', ',', ' ', 'Ann', '"', ' ', 'to', ' ', 'Ann', '.']
['Tom', ' ', 'said', ' ', '"', 'Jim', "'s", ' ', 'right', ',', ' ', 'Ann', '"', ' to', ' ', 'Ann', '.']
0.82
```

Transition Freedom (Freedom of Transition) Derivative



Transition Freedom “Peak”)



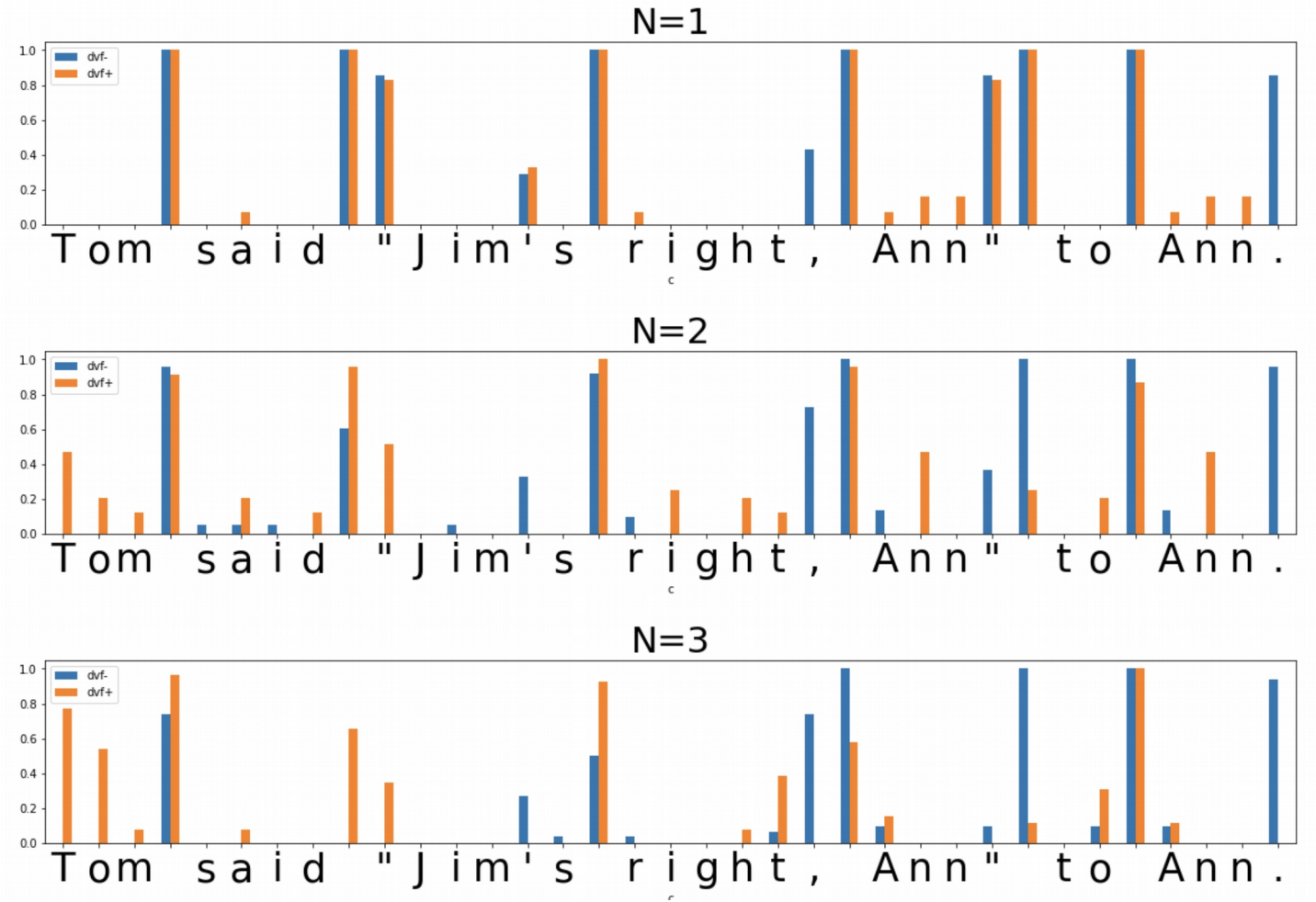
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2655800/

Unsupervised Text Segmentation (Tokenization)

Metrics/ Indicators:

Transition
Freedom
Deviation

(varying “N” of N-gram)



Unsupervised Text Segmentation (Tokenization)

English

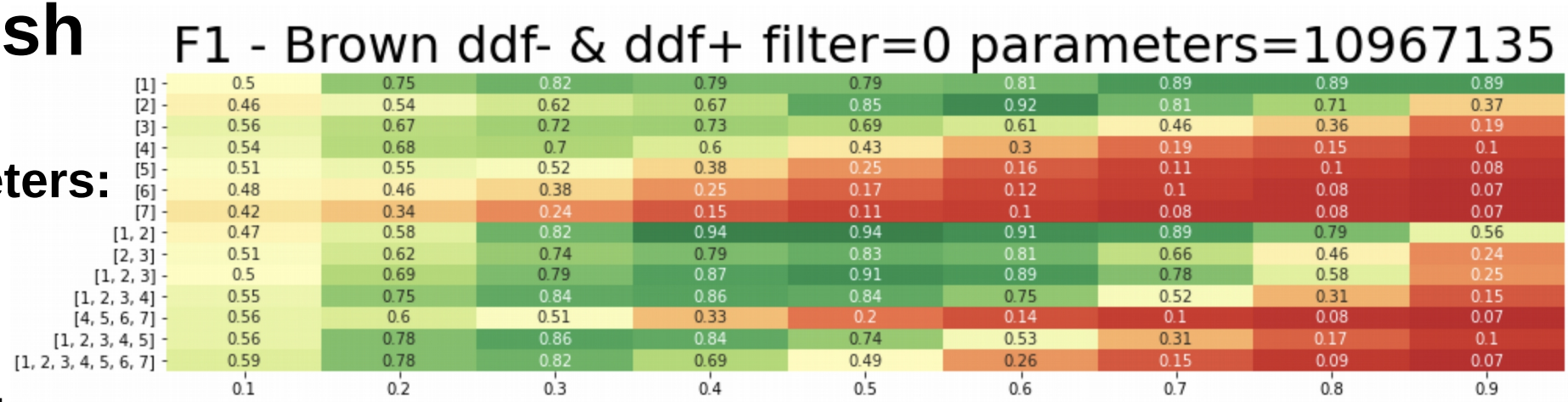
Hyper-Parameters:

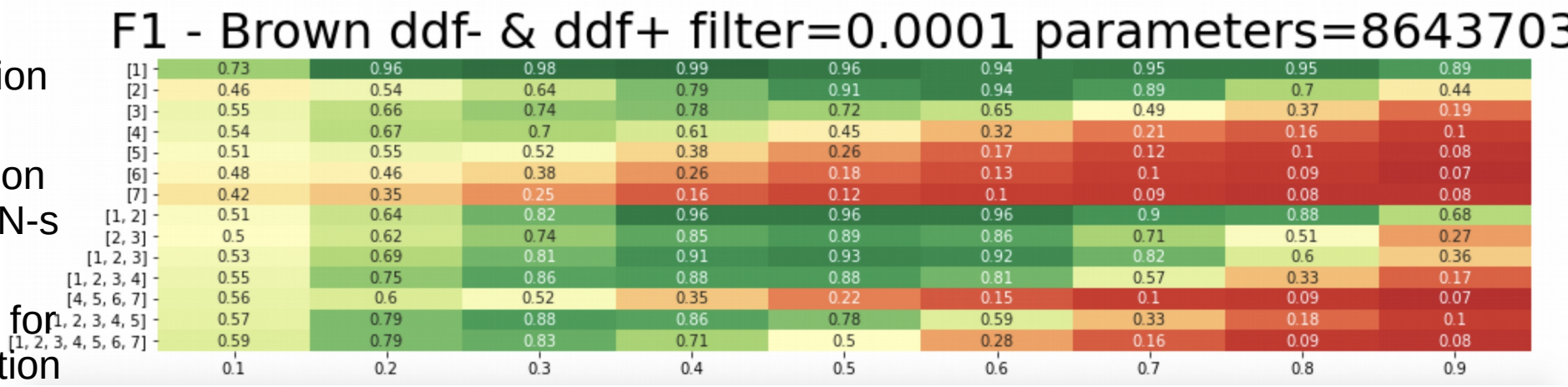
Metric: Transition Freedom

Threshold for model compression

Combination of Ngram N-s

Threshold for segmentation





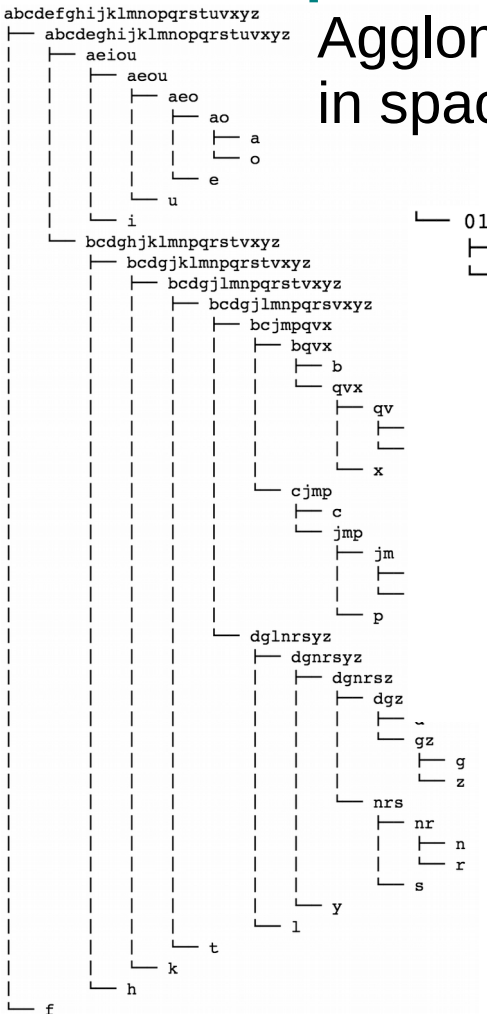
Results – Freedom-based Tokenization against Lexicon

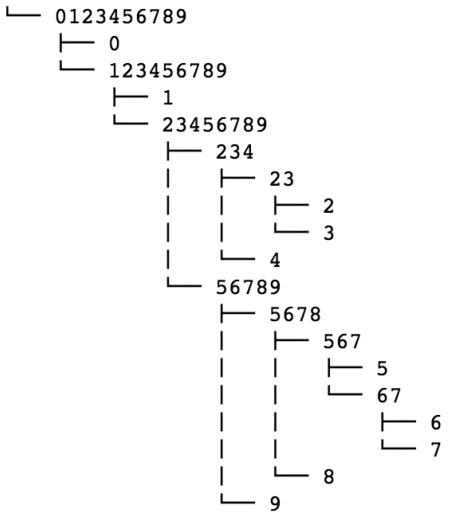
Language	Tokenizer	Tokenization F1	Lexicon Discovery Precision
English	Freedom-based	**0.99**	**0.99** (vs 1.0)
English	Lexicon-based	0.99	-
English no spaces	Freedom-based	0.42	-
English no spaces	Lexicon-based	0.79	-
Russian	Freedom-based	**1.0**	**1.0** (vs 1.0)
Russian	Lexicon-based	0.94	-
Russian no spaces	Freedom-based	0.26	-
Russian no spaces	Lexicon-based	0.72	-
Chinese	Freedom-based	**0.71**	**0.92** (vs 0.94)
Chinese	Lexicon-based	0.83	-

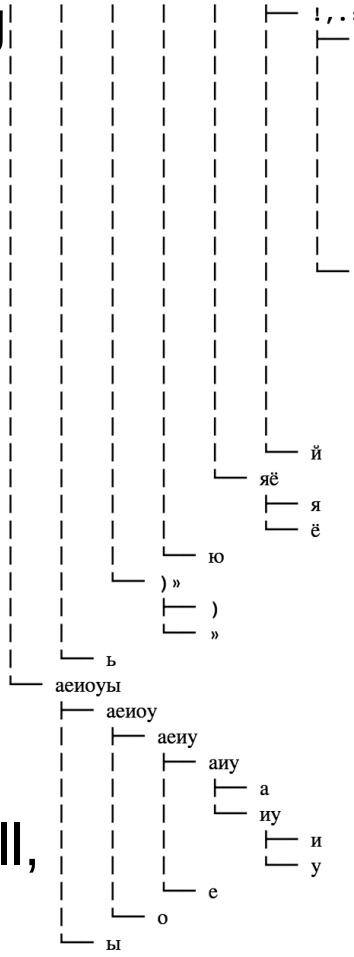
Lexicon-based Tokenization - greedy/beam search on word length (optimal) or frequency

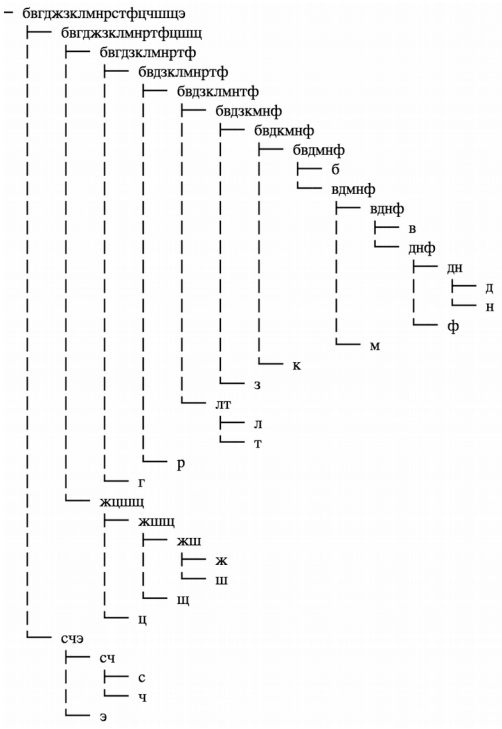
Unsupervised Character Category Learning

Agglomerative Clustering
in space of Transitions









RusAge Test/Small,
Cosine Similarity

Conclusion and Further Work

Unsupervised Tokenization based on Transition Freedom (TF) recall and precision appears good enough as initial approximation for further applications of self-reinforcement learning as part of interpretable unsupervised learning of natural language.

Optimal thresholds and specific TF-based metrics are specific to language. The process and policy of their discovery and adjustment should be further explored.

Clustering or parts of speech on space of transition graphs may provide some insights on morphology and punctuation structure of low-resource and domain-specific languages.

Hybridization of TF-based tokenization approach with lexicon-based one might be efficient for low-resource and domain-specific languages.

Further unsupervised grammar learning experiments can be run on the basis of suggested unsupervised tokenization approach.

Applications for other Experiential Learning environments, including the ones with delayed/sparse feedback.

Using Reinforcement Learning techniques with self-reinforcement on historical data under Unsupervised Learning setup.

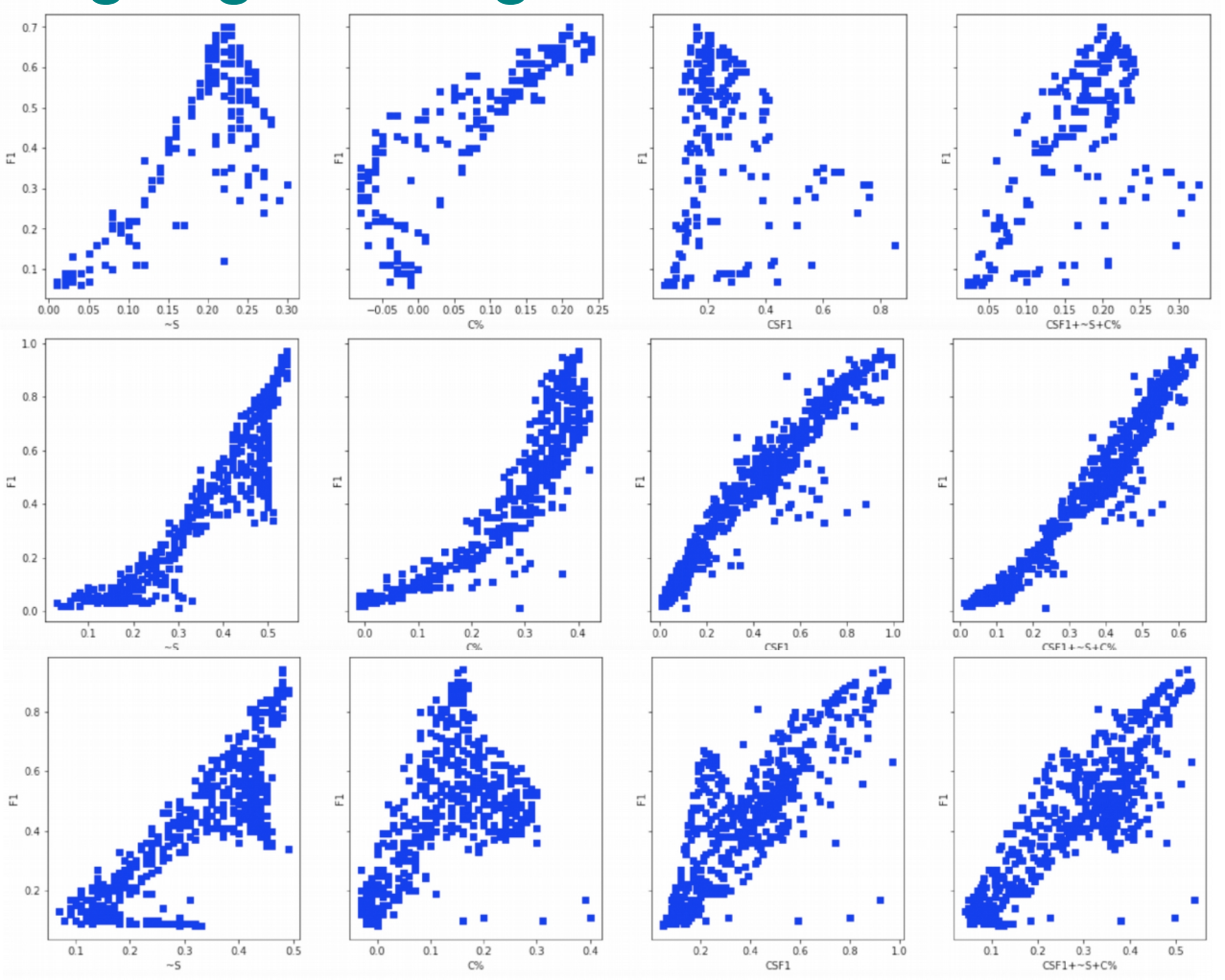
https://arxiv.org/abs/2205.11443
https://github.com/aigents/pygents

Which language is English, Chinese, Russian?

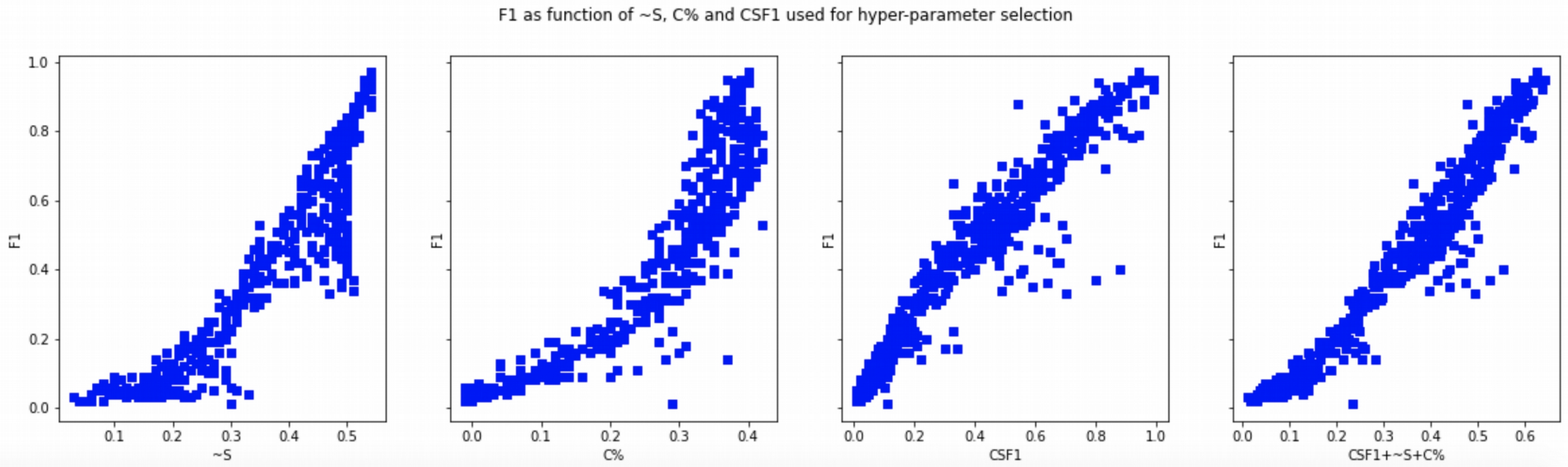
Language 1

Language 2

Language 3

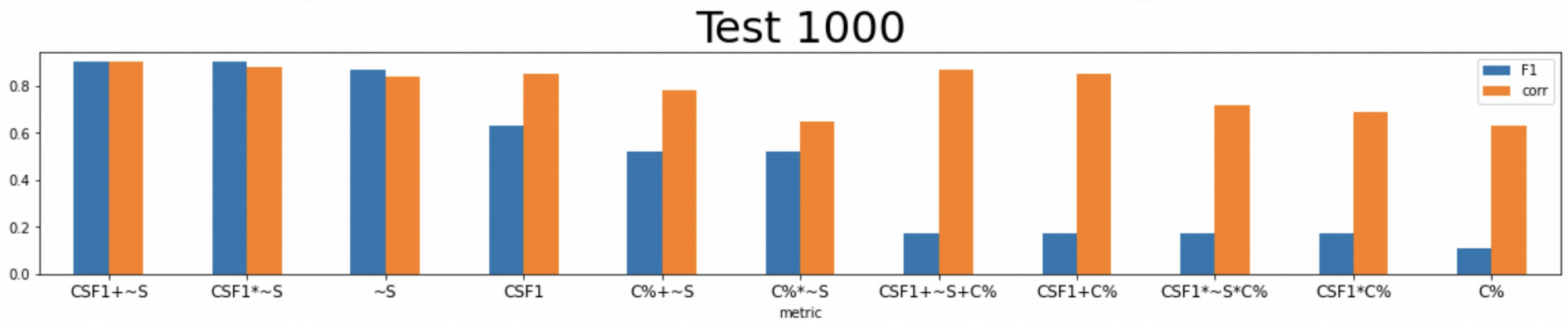


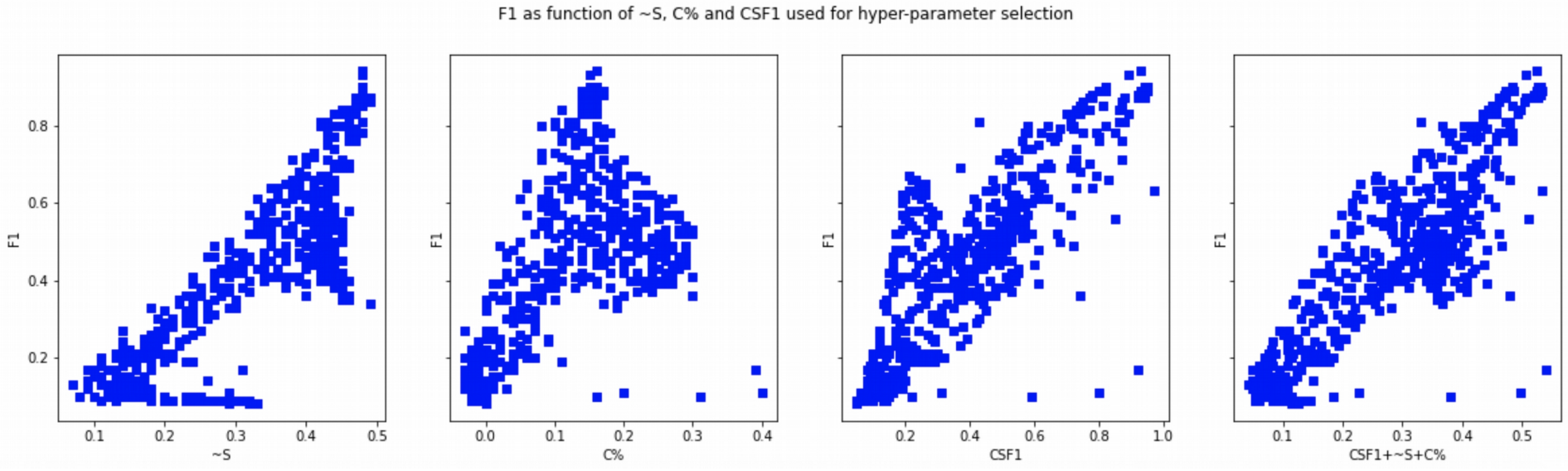
Self-tuning Hyperparameters – English (TF variance)



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

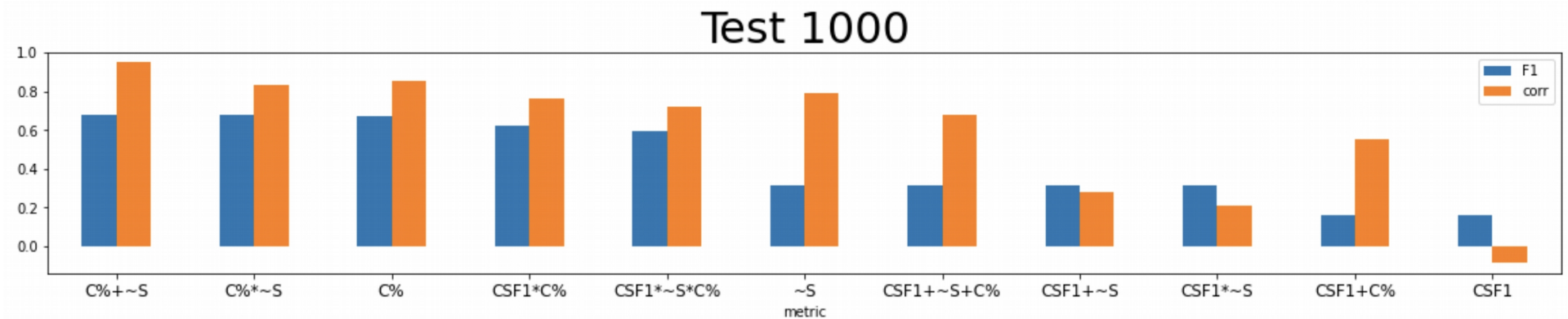
Self-tuning Hyperparameters – Russian (TF variance)

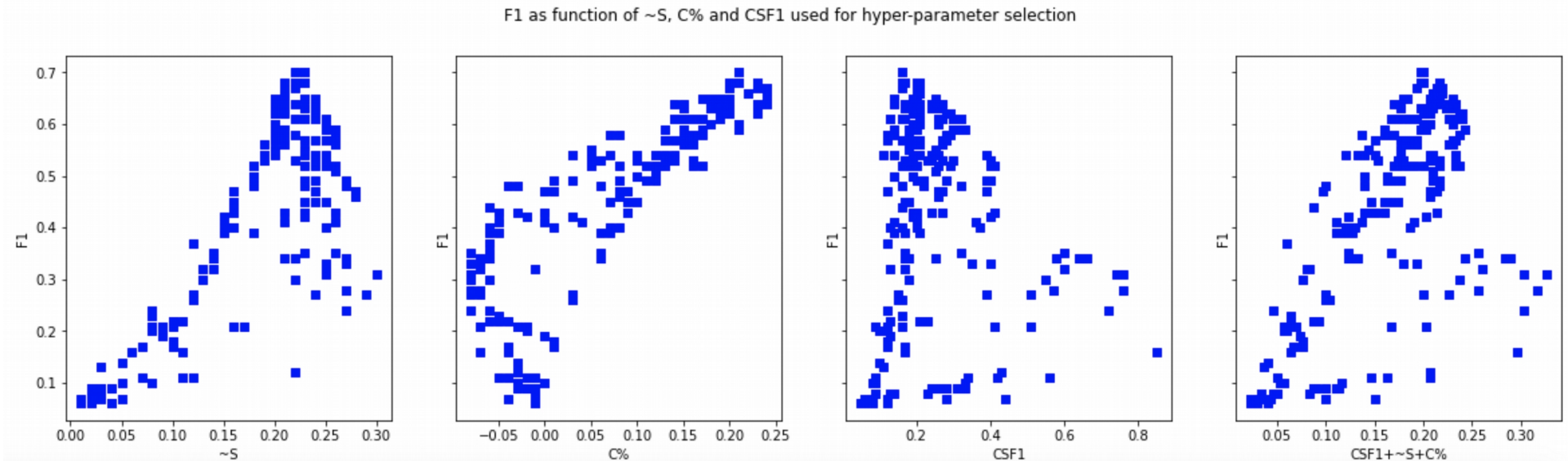




https://github.com/aigents/pygents/blob/main/notebooks/nlp/russian/ru_tokenizer_auto.ipynb

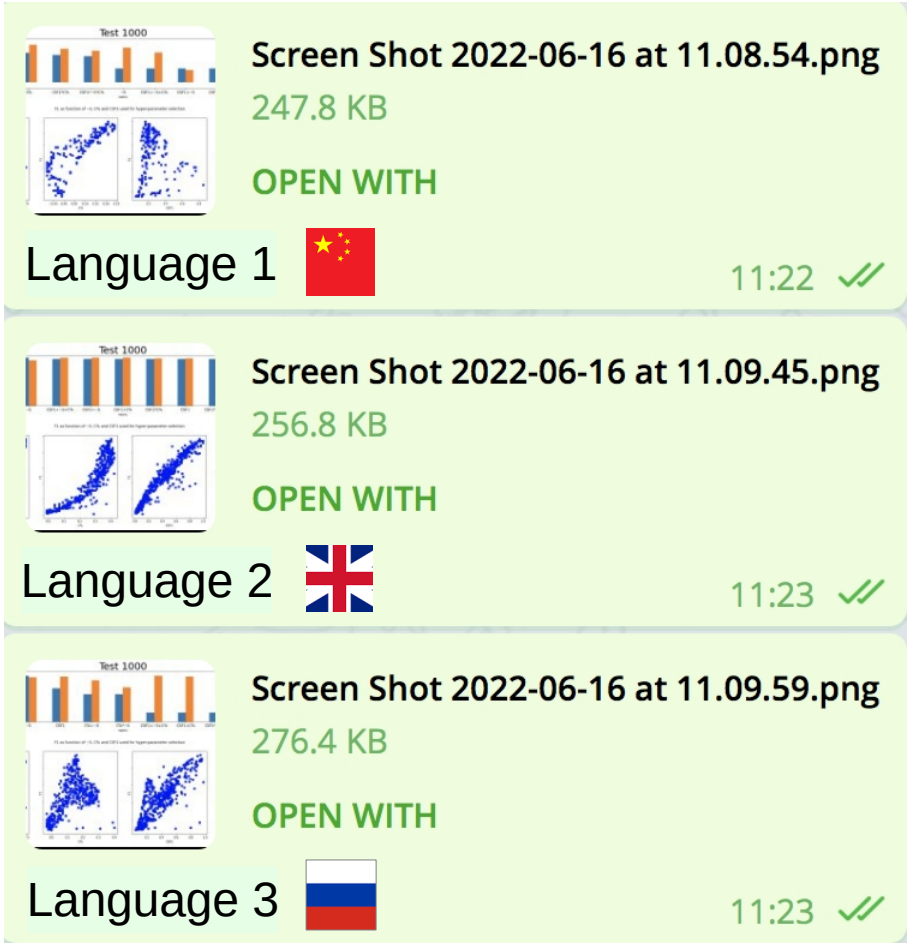
Self-tuning Hyperparameters – Chinese (TF “peak”)

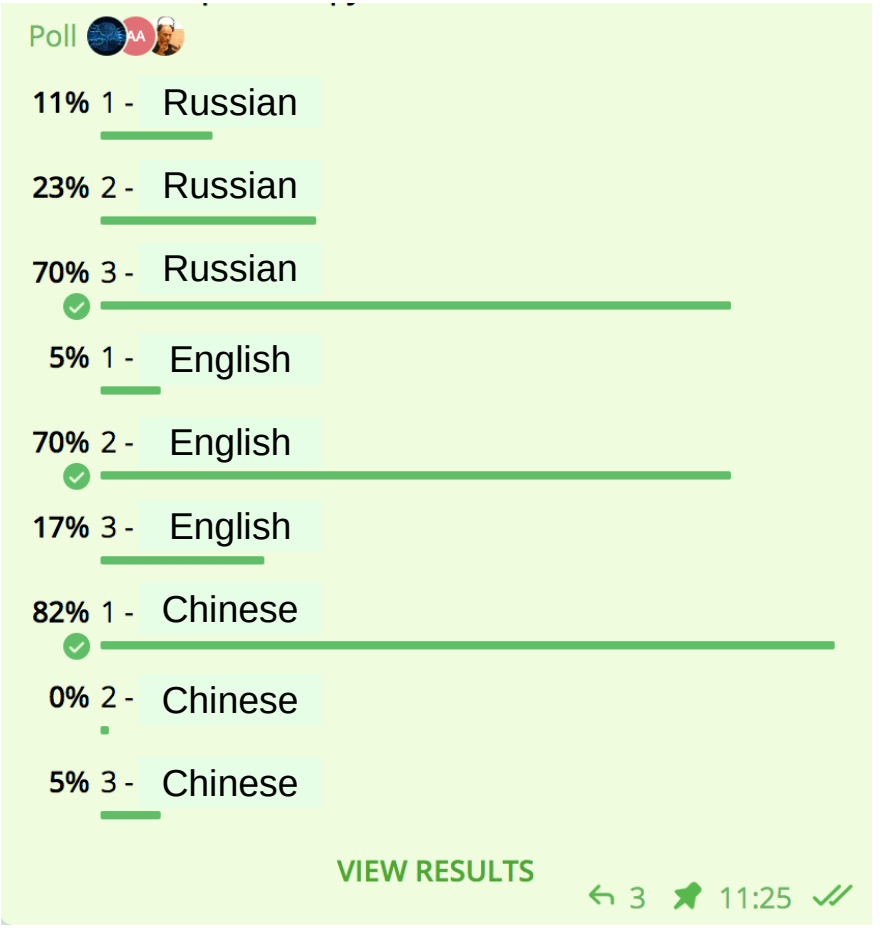




https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_auto.ipynb

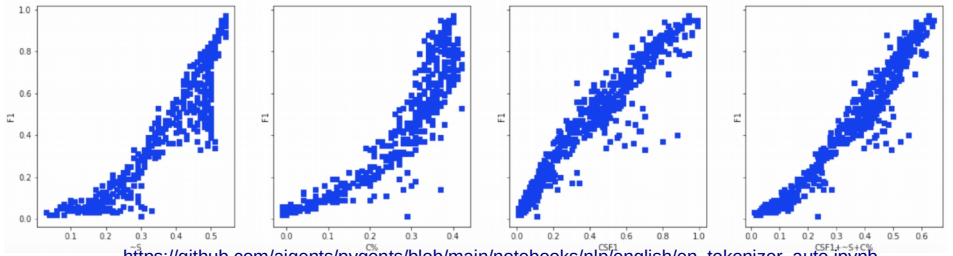
Something about Human Intuition!





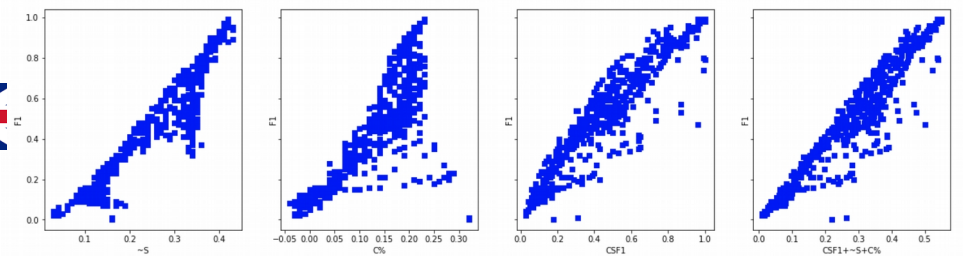
Different corpora, different sizes

English, Train: Brown, Test: Brown 1000

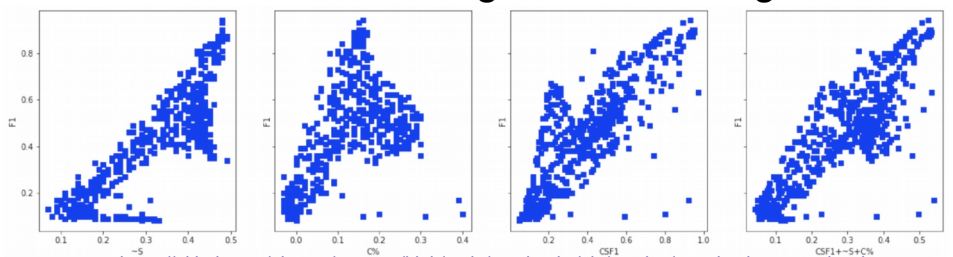


https://github.com/aigents/pygents/blob/main/notebooks/nlp/english/en_tokenizer_auto.ipynb

English, Train: Brown, Test: MagicData 100

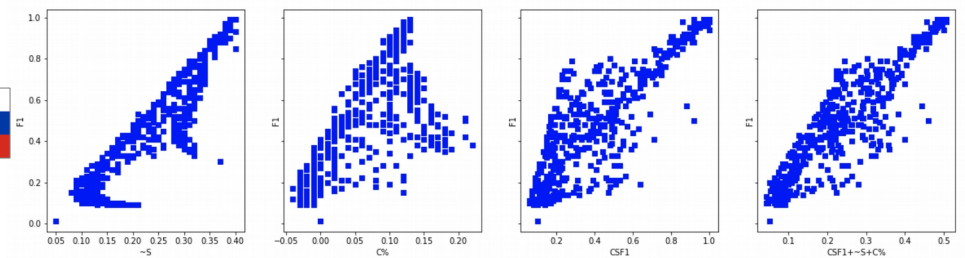


Russian, Train: RusAge, Test: RusAge 1000

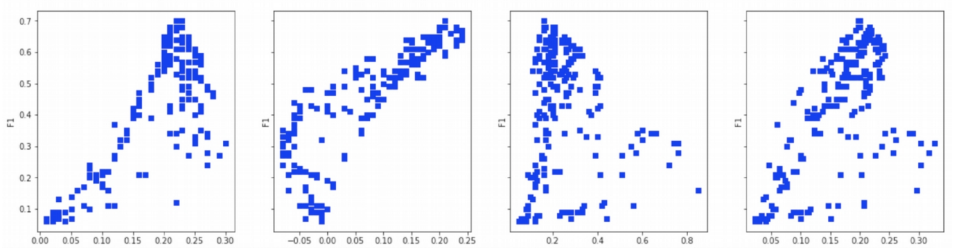


https://github.com/aigents/pygents/blob/main/notebooks/nlp/russian/ru_tokenizer_auto.ipynb

Russian, Train: Brown, Test: MagicData 100

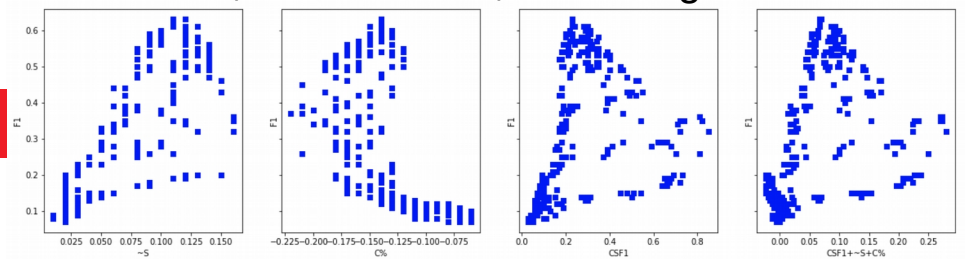


Chinese, Train: CLUE News, Test: CLUE News 1000



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

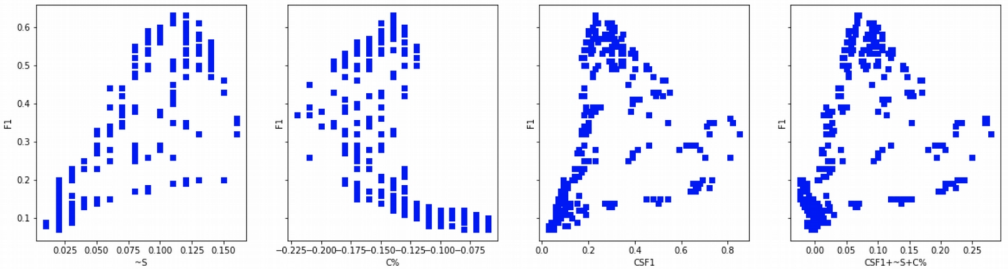
Chinese, Train: Brown, Test: MagicData 100



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

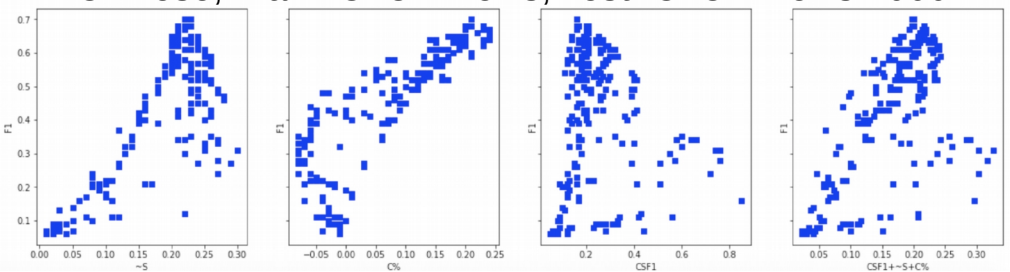
Chinese corpora, different sizes

Chinese, Train: Brown, Test: MagicData 100



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

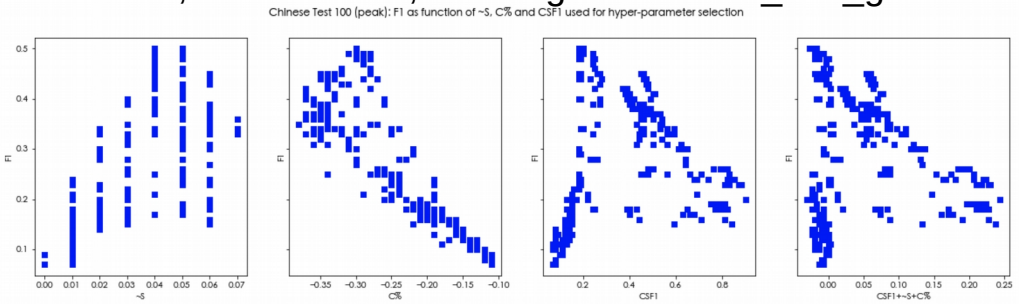
Chinese, Train: CLUE News, Test: CLUE News 1000



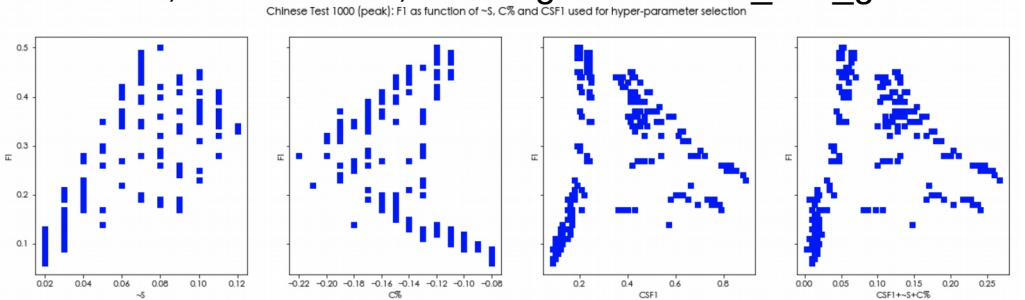
Chinese, Train: CLUE News, Test: CLUE News 10000

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

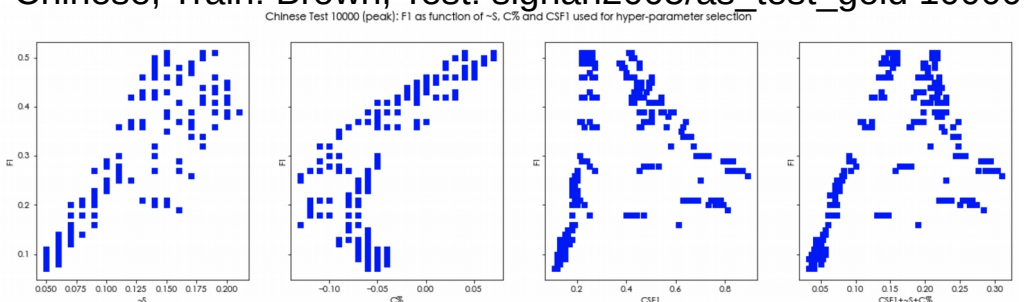
Chinese, Train: Brown, Test: sighan2005/as_test_gold 100



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



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



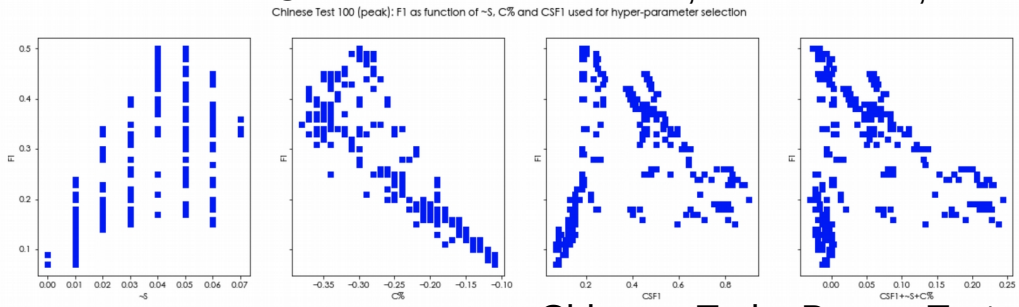
https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_multi-criteria-cws.ipynb

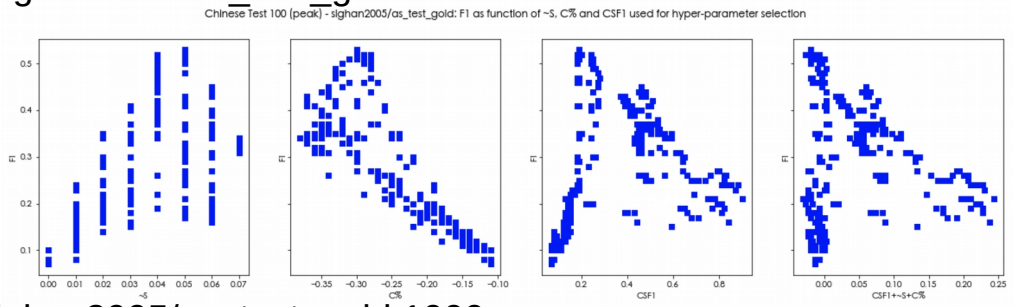
Chinese corpora, different “ground truth” tokenizers

Ground truth: sighan2005

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

Ground truth: Jieba





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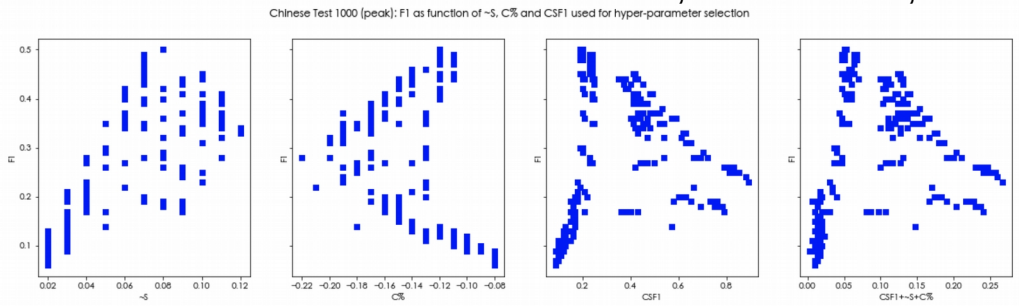

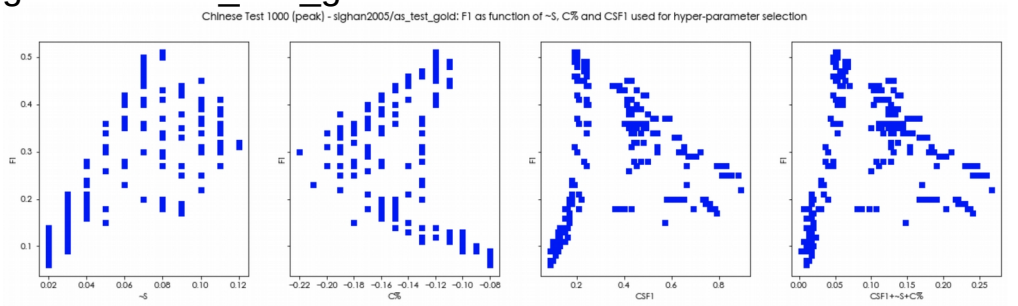

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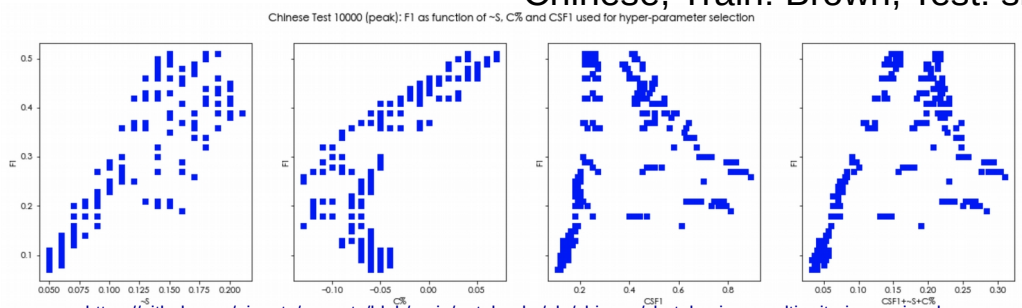

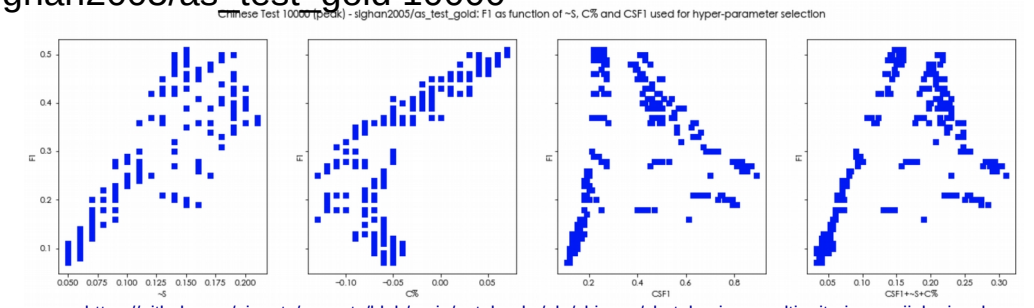

https://github.com/aigents/pygents/blob/main/notebooks/nlp/chinese/zh_tokenizer_multi-criteria-cws.ipynb

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

Thank You and Welcome!

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