# Coreference Resolution for Russian: Taking Stock and Moving Forward

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# Introduction

- Coreference intuitive explanation:

  Identifying all real world entities mentioned throughout the text.

# Example

Шариков злобно покосился на профессора, а он отправил ему косой взгляд. Через десять минут Шариков уехал в цирк. Филлип Филлипович остался один в своем кабинете. Он начал мерять комнату.

Sharikov gave the professor an angry look, and he returned him a sideways glance. Ten minutes later Sharikov left for the circus. Philip Philipovich  was alone in his cabinet. He started pacing the room.

# Example

**Шариков** злобно покосился на **Филлипа Филлиповича**, а **он** отправил **ему** косой взгляд. Через десять минут **Шариков** уехал в **цирк**. **Профессор** остался один в **своем кабинете**. **Он** начал мерять **комнату**.

**Sharikov** gave **Philip Philipovich** an angry look, and **he** returned **him** a sideways glance. Ten minutes later **Sharikov** left for the **circus**. **The professor** was alone in **the cabinet**. **He** started pacing **the room**.

# Terminology

- Mention — several words from text that denote an entity
- Antecedent — a mention with already established referent
- Anaphor — a mention referring to an earlier occurring antecedent

# Example

**Шариков** злобно покосился на **Филлипа Филлиповича**, а **он** отправил **ему** косой взгляд. Через десять минут **Шариков** уехал в **цирк**. **Профессор** остался один в **кабинете**. **Он** начал мерять **комнату**.

- Шариков ← ему
    - Sharikov ← him
- Филлипа Филлиповича ← Профессор
    - Philip Philipovich ← The professor

# Brief history

- A well researched area for English:
  - Methods vary from manually compiled rule-based structures to machine learning algorithms
- Machine learning methods evolved from the most basic to complex
- A great variety of clustering techniques including partitions on whole text

# Coreference for Russian

- A shared task on coreference resolution for Russian in 2014 as a part of Dialog Evaluation

- Following papers:

  - Toldova & Ionov 2017: “Coreference resolution for Russian: the impact of semantic features”

  - Sysoev & Andrianov & Khadzhiiskaia 2017: “Coreference resolution in russian: State-of-the-art approaches application and evolvement”

# Data and metrics

- RuCor — a corpus of texts from various genres compiled in 2014

- Corpus statistics
  - 179 texts
  - 3 354 chains
  - 15 764 mentions

- Metrics: versions of Precision/Recall/F1
  - MUC
  - B3
  - $\text{CEAF}_{\text{entity}}$
  - $\text{CEAF}_{\text{mention}}$

# Baseline

- Two step process from our previous work*
    - Mention pair classification
    - Clustering
- Adaptations made:
    - Different scheme for syntactic preprocessing
    - Classifier tuning

* A. Sysoev, I. Andrianov, and A. Khadzhiiskaia, "Coreference resolution in Russian: State-of-the-art approaches application and evolvement."

# Baseline: classification

- Random Forest Classifier
- Trained on antecedent-anaphor pairs from RuCor
- Negative examples for training: every anaphor with every mention between itself and its antecedent
- Testing scenario pair generation: a pre-set window of preceding mentions
- Saving all pairs with classifier confidence

# Baseline: clustering

- Easy-First Mention Pair algorithm*

**Sharikov$_1$** gave **Philip Philipovich** an angry look, and **he** returned **him** a sideways glance. Ten minutes later **Sharikov$_2$** left for the circus. **The professor** was alone in the cabinet. **He** started pacing the room.

- Sharikov$_1$ — Sharikov$_2$
- Sharikov$_1$ — him
- Sharikov$_1$ — Philip Philipovich
- Philip Philipovich — he
- him — Sharikov$_2$
- he — him
- Philip Philipovich — The professor

$\longrightarrow$

- {Sharikov$_1$, him, Sharikov$_2$}
- {Philip Philipovich, The professpor, he}

* O. Uryupina and A. Moschitti, "A state-of-the-art mention-pair model for coreference resolution."

# Feature Engineering

- Different types of anaphors:
  - Same lexemes: *Sharikov — Sharikov*
  - Synonyms: *cabinet — room*
  - Contextual synonyms: *Philip Philipovich — professor*
  - Pronouns: *Sharikov — him*, *Philip Philipovich — he*
- Pronouns form a special class

# Feature Engineering

- Pronouns do not hold any lexical meaning of their own
- Pronouns serve as a referencing mechanism
- Pronouns have shorter referencing scope: about 3 sentences
- Pronoun resolution relies heavily on grammar and distance

# Feature Engineering: surface form matching

- Acronym matching: *домком — домовый комитет*

- Comparison of lemmas representing each mention: *him — He —> he*

- Different lexicographic similarity measure (strings overlapping, minimum edit distance measure, etc.): *professor Philip Preobrazhensky — Philip Philipovich Preobrazhensky*

# Feature Engineering: surface form matching

- Our suggestion: to filter out these features for mention pairs with one or both pronominal mentions
- Error analysis examples:
  - **Sharikov** gave **Philip Philipovich** an angry look, and **he** returned **him** a sideways glance. **The professor** was alone in **the cabinet**. **He** started pacing **the room**.
- RFC fails to divide data into groups:
  - Pronouns make up a third of all mentions (5078 out of ~15000)
  - Misleading features for pronominal group

# Feature Engineering: context analysis

- Error analysis examples:
  - Ten minutes later **Sharikov** left for the **circus**. **Philip Philipovich** was alone in **the cabinet**. **He** started pacing **the room**.
- Adding more features for pronoun resolution
- General idea: is there a better candidate?
  - Analysis of all mentions between currently analysed antecedent and pronoun

# Feature Engineering: context analysis

- Boolean matchers for grammatical role, morphological properties, named entities combinations

- Counters for different combinations of same attributes

- Distribution of mentions per sentence in context.

# Feature Engineering: context analysis

- Ten minutes later **Sharikov** left for the **circus**. **Philip Philipovich** was alone in **the cabinet**. **He** started pacing **the room**.

- **Philip Philipovich** — Subject + animated + masculine + single + NE:Person

- **the cabinet** — Indirect Object + inanimated + masculine + single

# Feature Engineering: Semantics

- Incorporating semantic information:
  - Semantic similarity between mention head words*

    The professor  was alone in ***the cabinet***. He started pacing ***the room***.

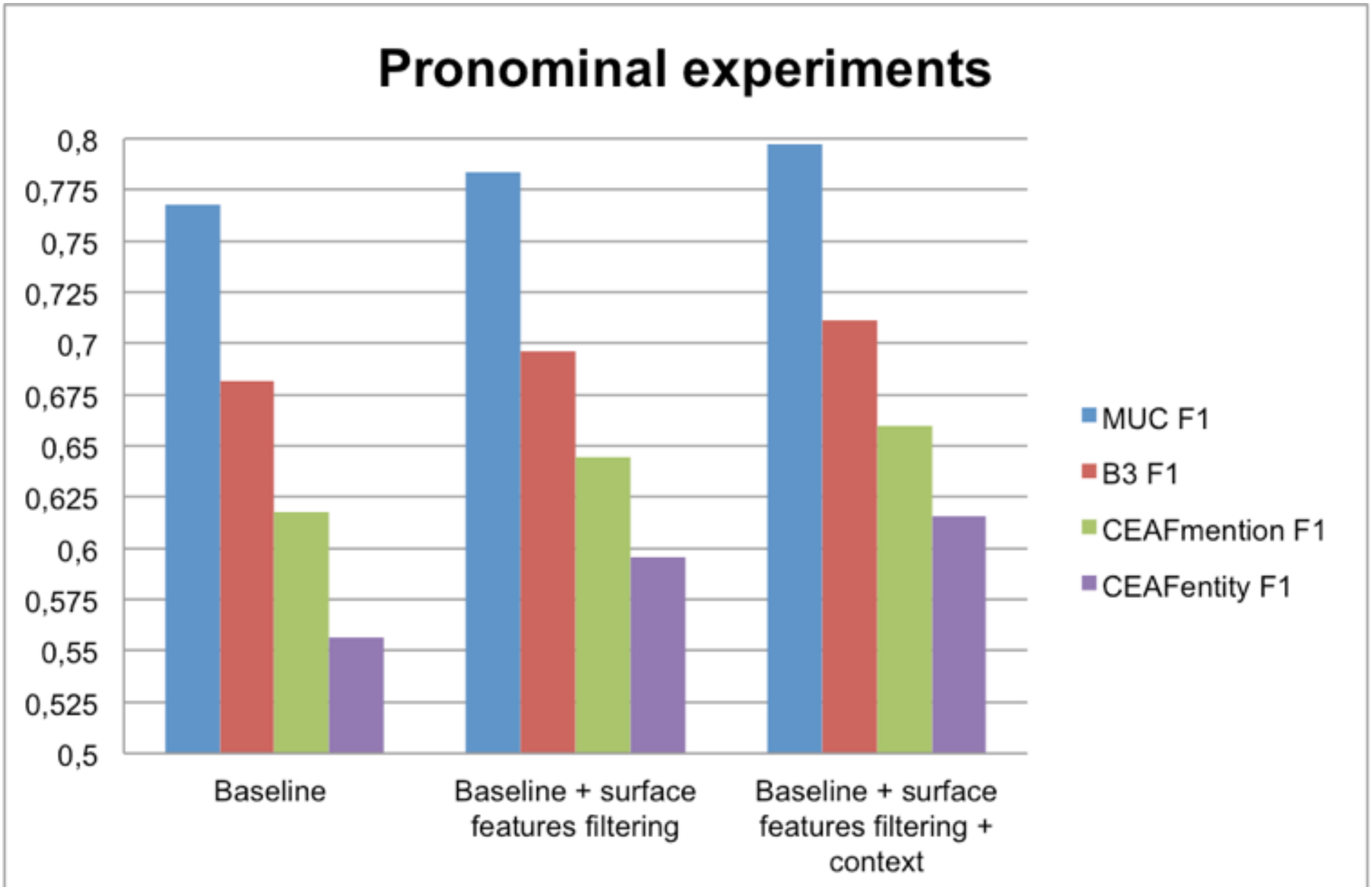
- Experiments with filtering for pronominal mention pairs

* S. Toldova and M. Ionov, “Coreference resolution for Russian: the impact of semantic features”

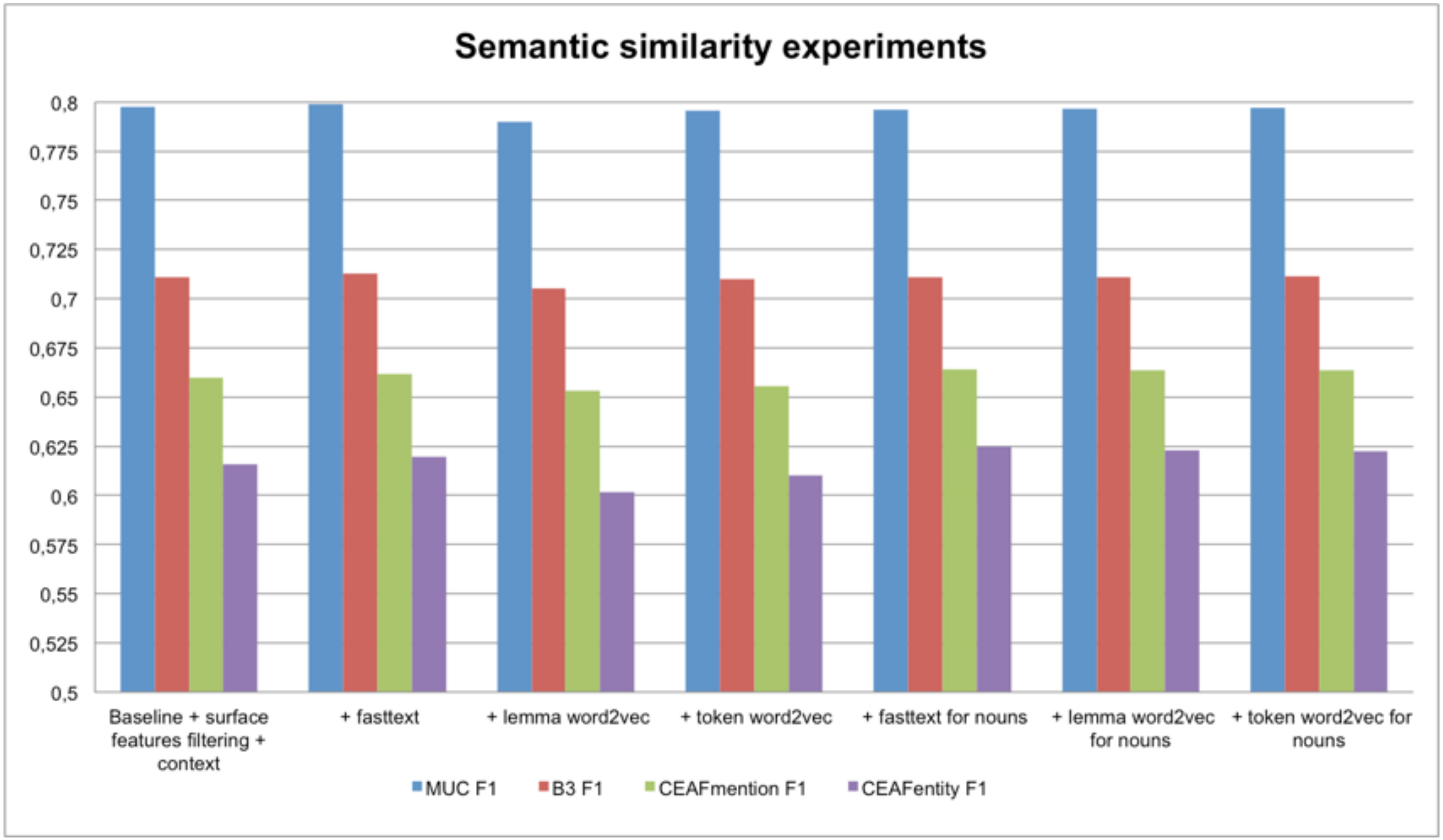
# Feature Engineering: Semantics

- Two models tested: word2vec VS fasttext
- Both trained on
  - Russian Wikipedia
  - FactRuEval-2016 corpus
  - LibRuSec sample
  - Blog posts collection
- Dimensionality for both: 100 features vector
- Word2vec trained for lemmas and tokens
- Fasttext trained for tokens

# Results


Pronominal experiments
0,8
0,775
0,75
0,725
0,7
0,675
0,65
0,625
0,6
0,575
0,55
0,525
0,5
Baseline
Baseline + surface features filtering
Baseline + surface features filtering + context
MUC F1
B3 F1
CEAFmention F1
CEAFentity F1

# Results


Semantic similarity experiments
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0,55
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Baseline + surface features filtering + context
+ fasttext
+ lemma word2vec
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MUC F1
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# Clustering

- One option: previously described EFMP
- More straightforward approach:
  - Take only true pairs
  - Trim them by confidence threshold
  - Unroll into clusters

# Clustering: all positive

- Sharikov$_1$ — Sharikov$_2$
- Sharikov$_1$ — him
- Philip Philipovich — he

Confidence threshold

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- him — Sharikov$_2$
- Sharikov$_1$ — Philip Philipovich

- {Sharikov$_1$, him, Sharikov$_2$}, {Philip Philipovich, he}

# Clustering: by anaphor

- Combining all antecedents for an anaphor
- Two options:
    - Choose the most confident antecedent
    - Choose the closest antecedent classified as true

# Clustering: by anaphor

**Sharikov$_1$** gave **Philip Philipovich** an angry look, and **he** returned ***him*** a sideways glance. Ten minutes later **Sharikov$_2$** left for the circus. **The professor** was alone in **the cabinet**. ***He*** started pacing the room.

- [Sharikov$_1$ , Philip Philipovich, he] — him
- [Sharikov$_2$, The professor, the cabinet] — He

# Clustering: by anaphor

- Choose the most confident antecedent
  - [**Sharikov$_1$** , Philip Philipovich, he] — him
  - [Sharikov$_2$, **The professor**, the cabinet] — He

# Clustering: by anaphor

- Choose the most confident antecedent
  - [**Sharikov$_1$**, Philip Philipovich, he] — him
  - [Sharikov$_2$, **The professor**, the cabinet] — He
- Choose the closest antecedent classified as true
  - [Sharikov$_1$, Philip Philipovich, he] — him
  - [Sharikov$_2$, The professor, the cabinet] — He

# Clustering: by anaphor

- Choose the most confident antecedent
  - [**Sharikov$_1$** , Philip Philipovich, he] — him
  - [Sharikov$_2$, **The professor**, the cabinet] — He
- Choose the closest antecedent classified as true
  - [Sharikov$_1$ , **Philip Philipovich**, he] — him
  - [Sharikov$_2$, **The professor**, the cabinet] — He

# Clusters: Markov clustering

- Basic idea: to represent classified pairs as a weighted graph.
- Apply Markov clustering algorithm*
- Formula for confidence to weight converting:

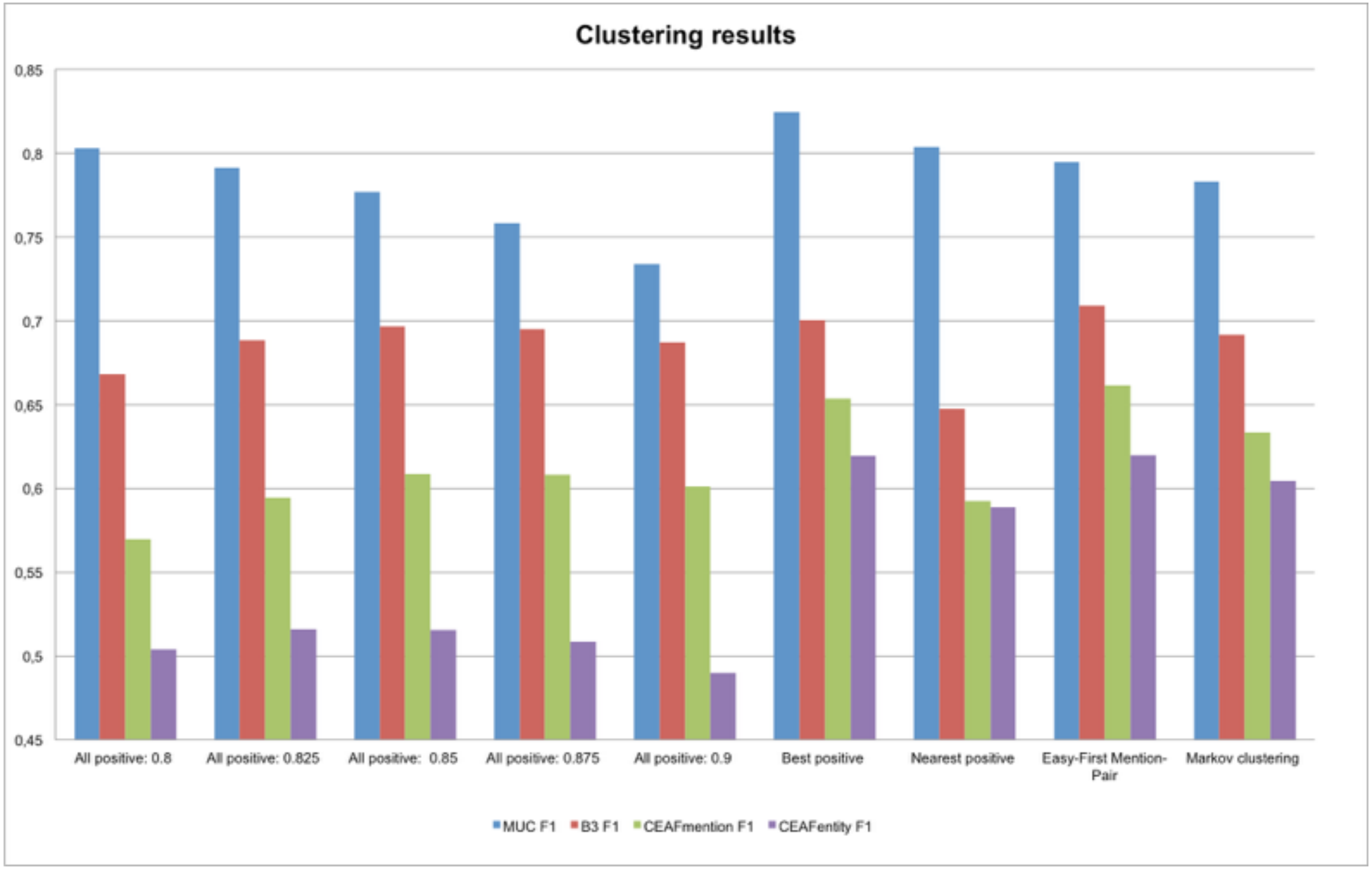
$$w(pair) = \begin{cases} 2 * confidence - 1, & \text{pair is coreferent} \\ 0 & \text{otherwise} \end{cases}$$

* A. Enright, S. V. Dongen, and C. Ouzounis, “An efficient algorithm for large-scale detection of protein families.”

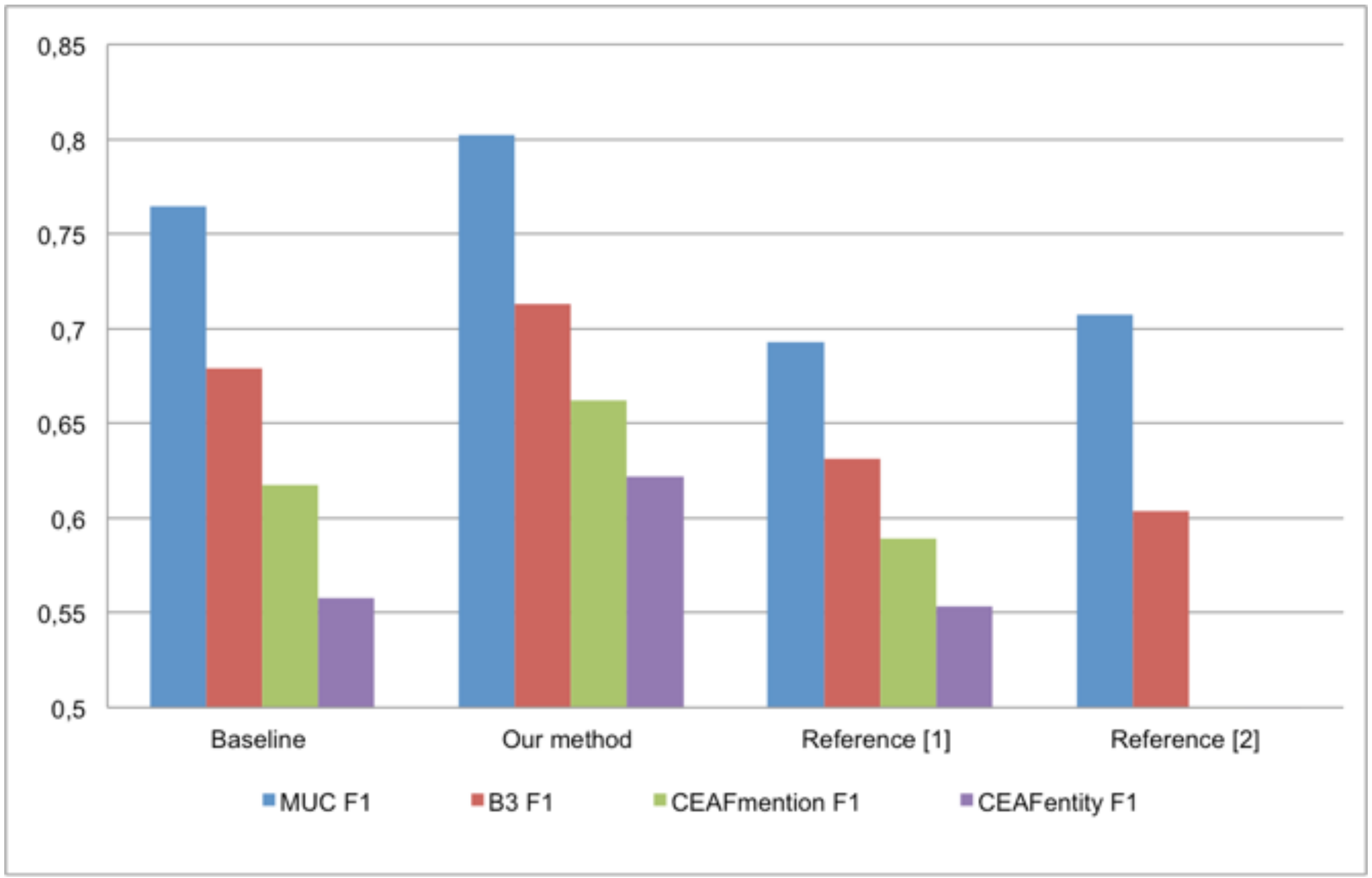
# Clusters: Markov clustering

- MCL is a mathematical representation of efficient random walks
- Alternation of two operations:
    - **Expansion** — emulates random walks from each starting point
    - **Inflation** — to establish the boundaries promote already more probable steps from each starting point and demote less probable.
- Final step: unrolling graph into clusters

# Clusters: results



# Comparison




- [1] Sysoev & Andrianov & Khadzhiiskaia: “Coreference resolution in Russian: State-of-the-art approaches application and evolvement”
- [2] Toldova & Ionov: “Coreference resolution for Russian: the impact of semantic features”

# Future work

- Direct speech boundaries:

**Борменталь** многозначительно кивнул головой.

- **Я** тяжко раненный при операции, - хмуро подвывал **Шариков**, - **меня** вишь как **он** отделал, - и **он** указал голову.

- **Вы анархист-индивидуалист**? - спросил Швондер, высоко поднимая брови.

**Bormental** nodded significantly.

"**I** was severely wounded in the course of the operation," whined **Sharikov**. "Look what **he** did to **me**," and he pointed to his head.

"Are **you** an **anarchist-individualist**?" asked Shvonder, raising his brows.

# Future work

- Coherent text structure:

В погоне за вожделенным миллионом **Бендер** не задумывается над тем, что, став обладателем миллиона, **он** разделит участь Корейко. Бендер с невероятным упорством стремится к обладанию миллионом,

**в то время как** перед читателем уже полностью прошла судьба **Корейко**, человека с сорока рублями жалованья и с десятью миллионами в потрепанном чемодане, который **он** сдает в камеры хранения то одного, то другого вокзала.

In pursuit of the coveted million **Bender** does not think that, having become the owner of a million, **he** will share the fate of Koreiko. Bender with incredible tenacity aspires to own a million,

**while** the reader has already witnessed the fate of **Koreiko**, a man with forty rubles of salary and with ten millions in a worn suitcase,which **he** hands over to the storage rooms of station after station.