Align, Disambiguate, and Walk

A Unified Approach for Measuring Semantic Similarity

SAPIENZA
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David Jurgens
Roberto Navigli

Semantic Similarity;
how similar are a
pair of lexical items?

Semantic Similarity

Sentence Level	Word Level	Sense Level

Semantic Similarity

Sentence Level	Word Level	Sense Level
		

Semantic Similarity

Sentence level

The worker was terminated

The boss fired him

- Applications
  - Paraphrase recognition (Tsatsaronis et al., 2010)
  - MT evaluation (Kauchak and Barzilay, 2006)
  - Question Answering (Surdeanu et al., 2011)
  - Textual Entailment (Dagan et al., 2006)

Semantic Similarity

Sentence Level

Word Level

Sense Level

Semantic Similarity

Word level

heater

fireplace

- **Applications**
  - **Lexical simplification**

    (Biran et al., 2011)

    Locuacious → *Talkative*

  - Lexical substitution

    (McCarthy and Navigli, 2009)

Semantic Similarity

Sentence Level

Word Level

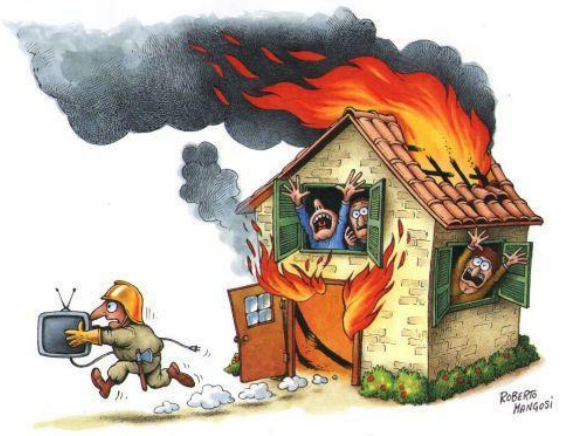
Sense Level

Semantic Similarity

Sense level

fire sense #1

fire sense #8

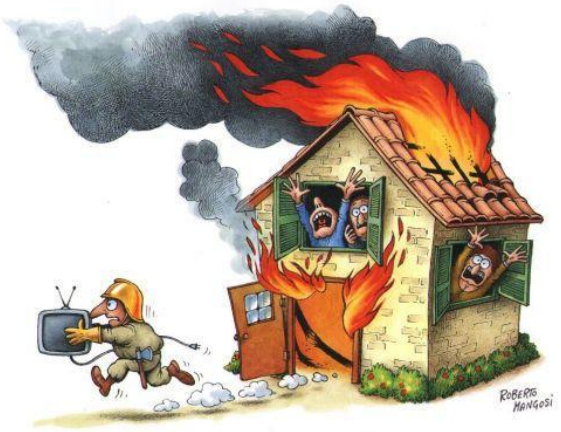


Semantic Similarity

Sense level

fire sense #1

fire sense #8



- **Applications**
  - Coarsening sense inventories (Snow et al., 2007)
  - Semantic priming (Neely et al., 1989)

Exisiting Similarity Measures

Exisiting Similarity Measures

Allison and Dix (1986)

Gusfield (1997)

Wise (1996)

Keselj et al. (2003)

Sentence | Word | Sense

Exisiting Similarity Measures

Allison and Dix (1986)

Gusfield (1997)

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Sentence Word Sense

Exisiting Similarity Measures

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Sussna (1993, 1997)

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Leacock and Chodorow (1998)

Sentence | Word | Sense

Exisiting Similarity Measures

But

Allison and Dix (1986)
Gusfield (1997)
Wise (1996)
Keselj et al. (2003)

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Sussna (1993, 1997)
Wu and Palmer (1994)
Leacock and Chodorow (1998)

Sense Word Sentence

Exisiting Similarity Measures

But

None directly covers all levels at the same time

Allison and Dix (1986)

Gusfield (1997)

Wise (19

Keselj et al

(2003)

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Sense

Word

Sentence

Exisiting Similarity Measures

But

None directly covers all levels at the same time

Different output scales

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Ran

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Leacock and Chodorow (1998)

Sense

Word

Sentence

Exisiting Similarity Measures

But

None directly covers all levels at the same time

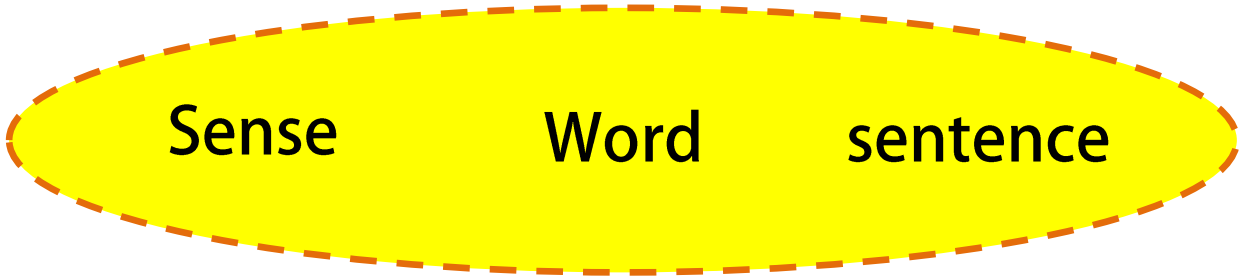
Different output scales

Different internal representations which are not comparable to each other

Contribution

Sense Word sentence

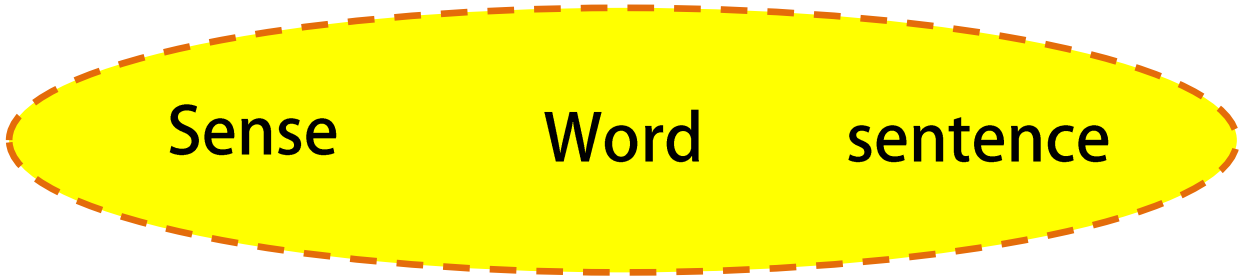
Contribution



A unified representation

for any lexical item

Contribution

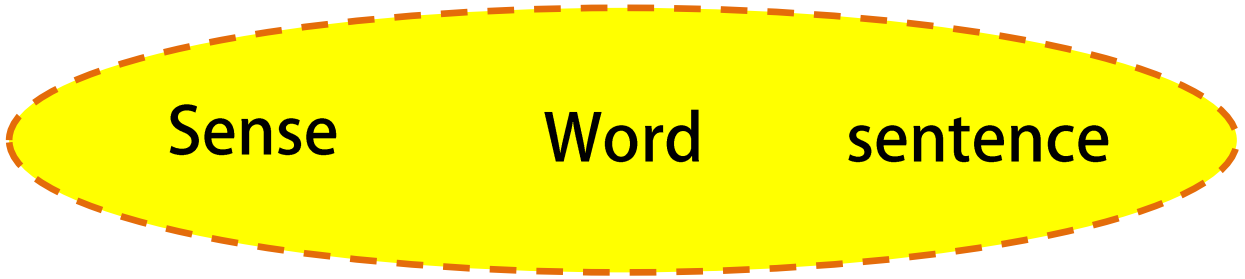


A unified representation

for any lexical item

State-of-the-art performance in each level

Contribution



A unified representation
for any lexical item

State-of-the-art performance in each level

Using only WordNet

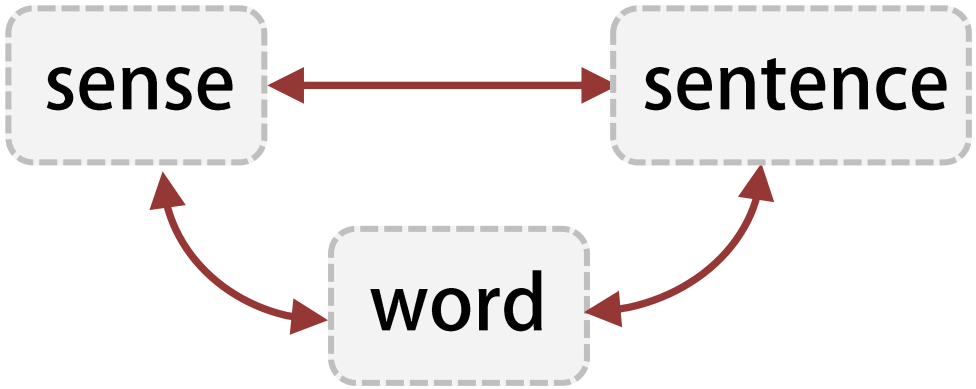
Advantage 1
Unified representation

sense

sentence

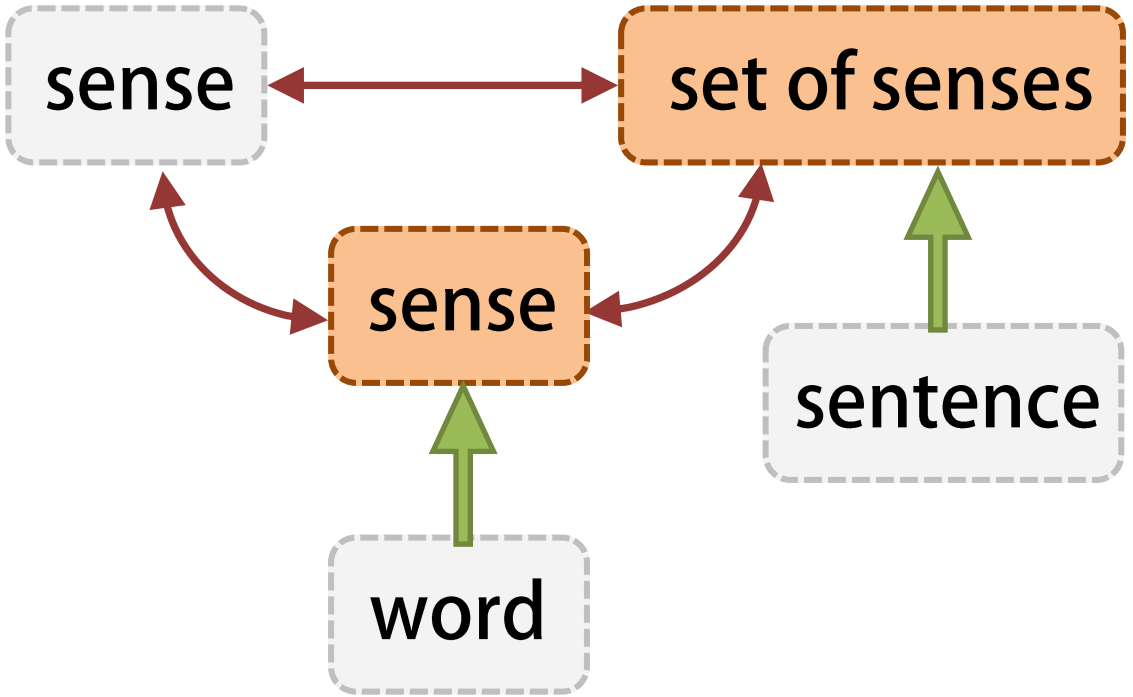
word

Advantage 2
Cross-level semantic similarity



A large and imposing house *vs.* Mansion *vs.* Residence#3

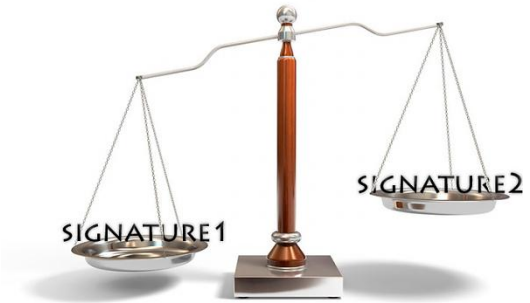
Advantage 3
Sense-level operation



Outline

Introduction

Methodology



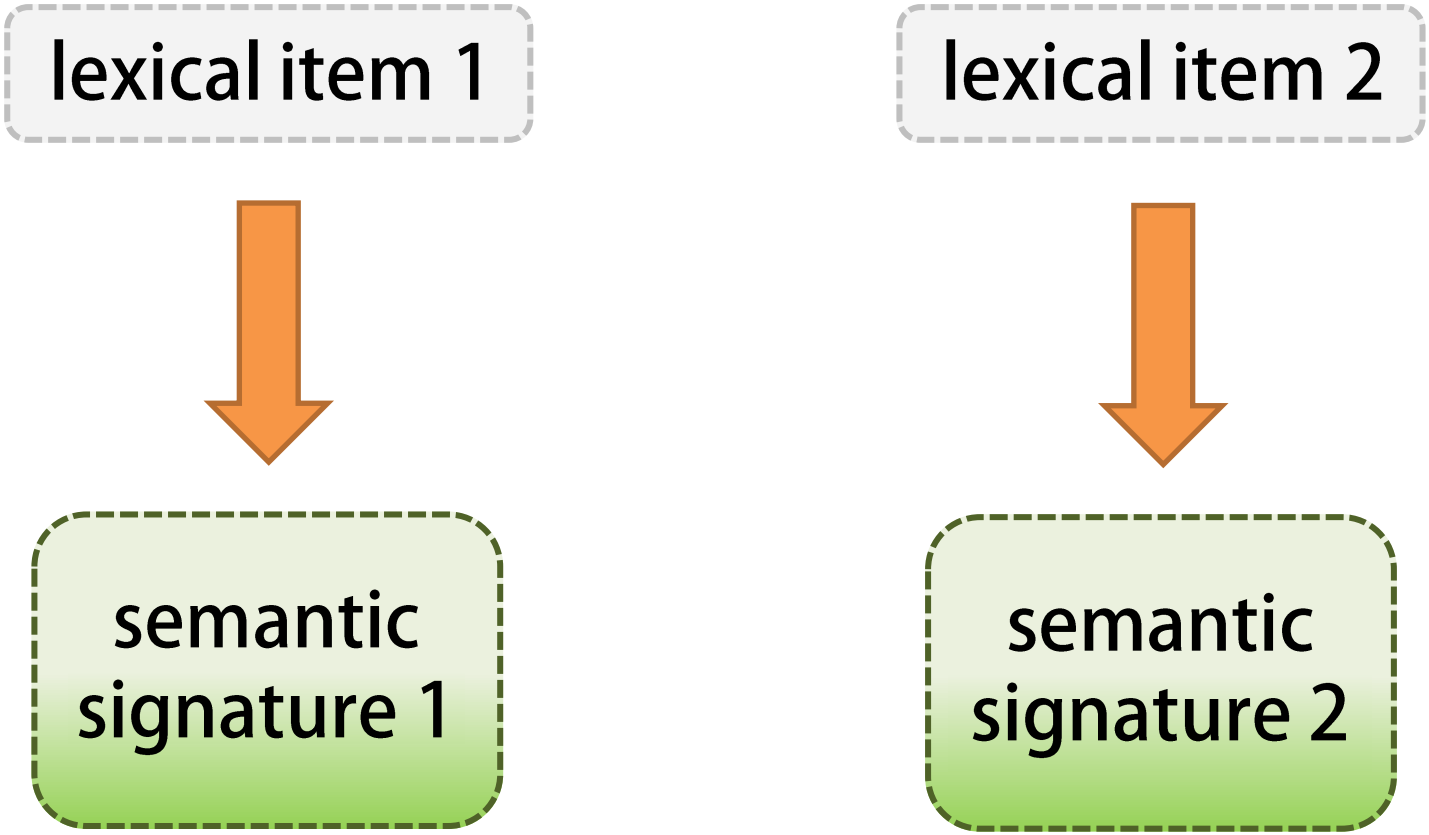
Experiments

How Does it work?

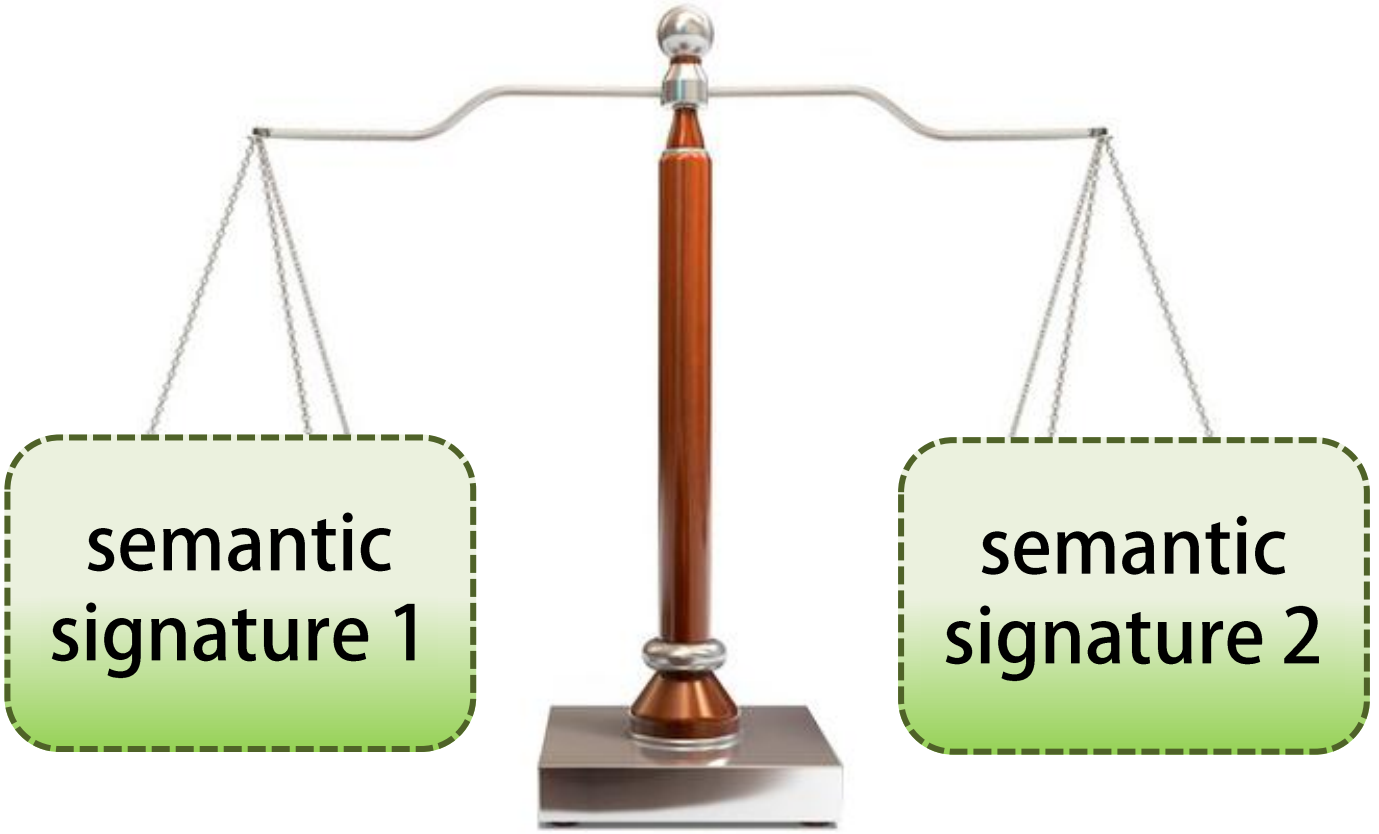
lexical item 1

lexical item 2

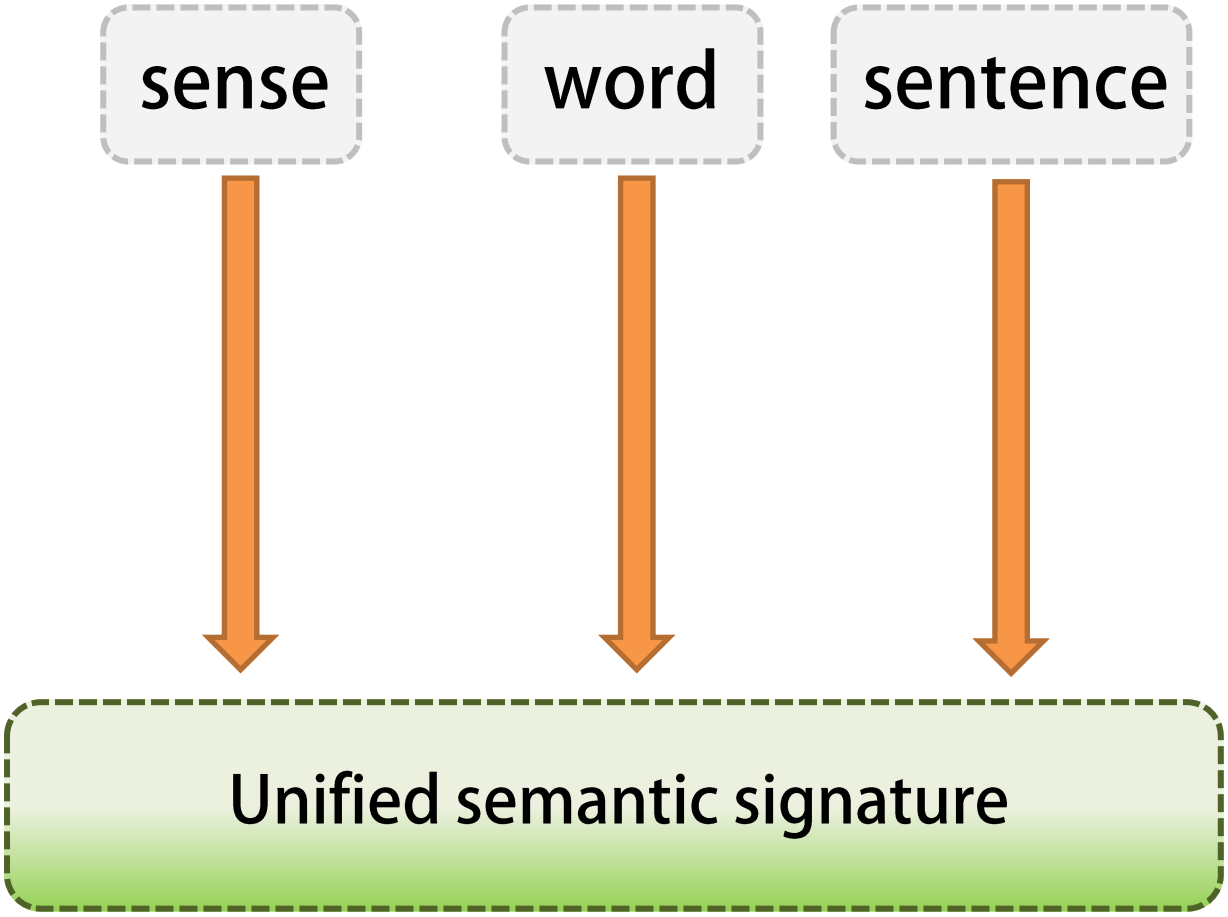
How Does it work?



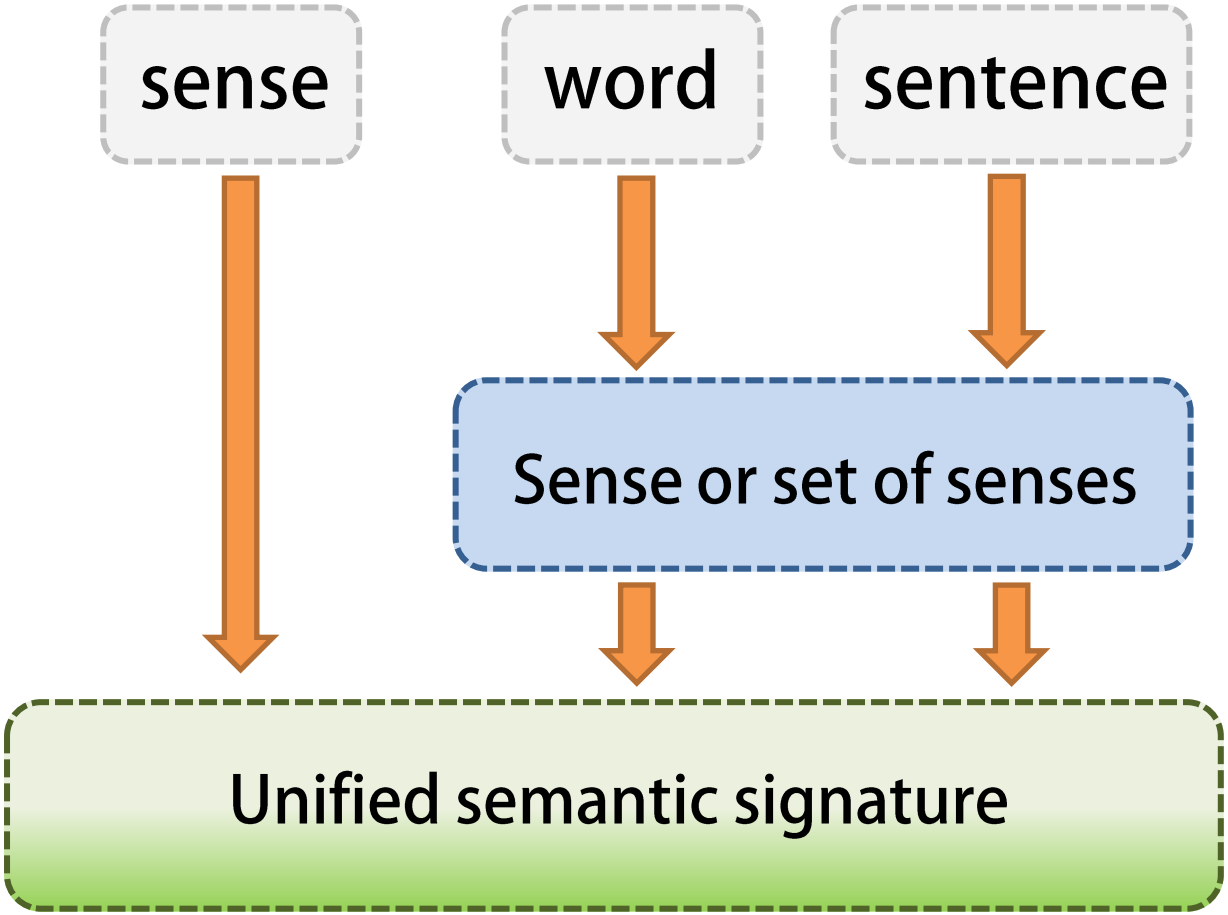
How Does it work?



Semantic Signature



Semantic Signature



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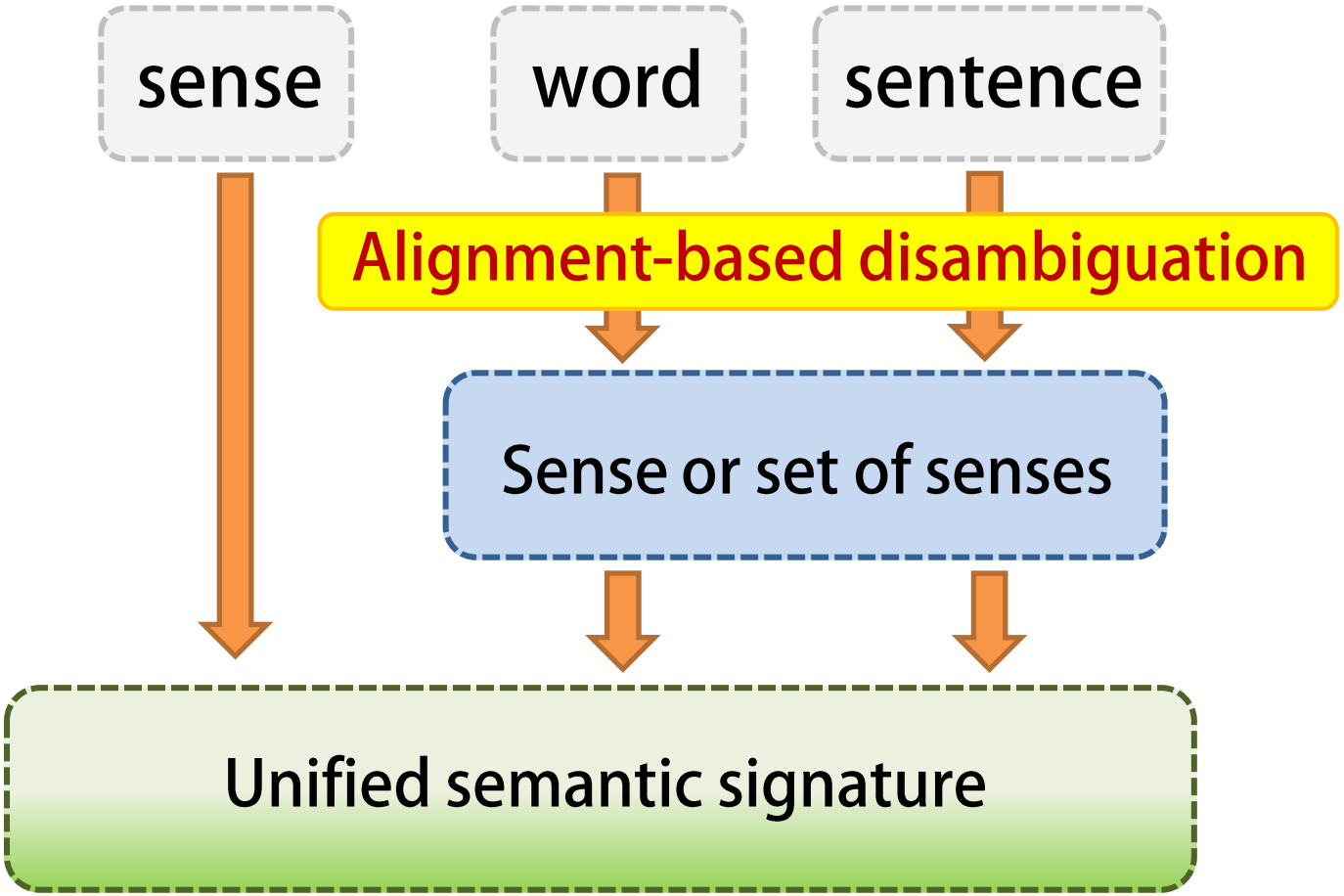

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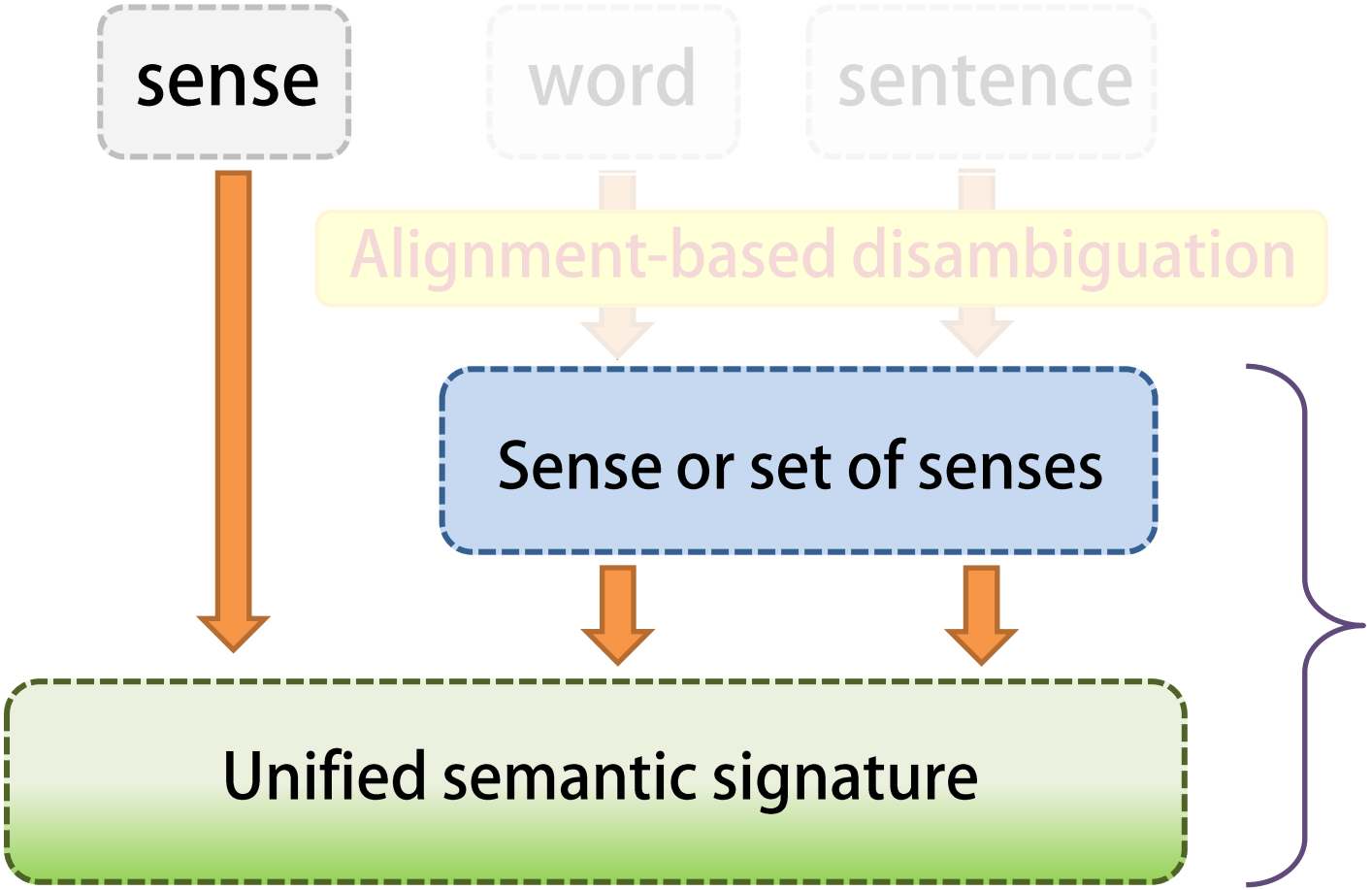

Semantic Signature

A woman is frying food

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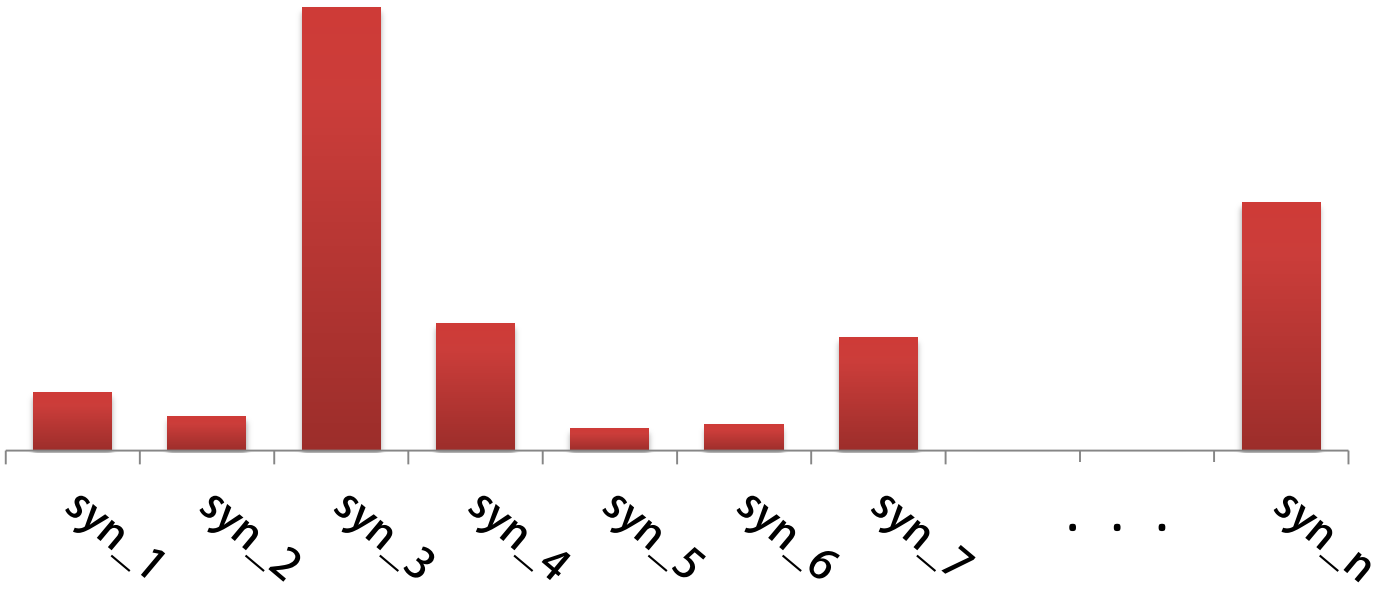
Distributional representation

over all synsets in WordNet



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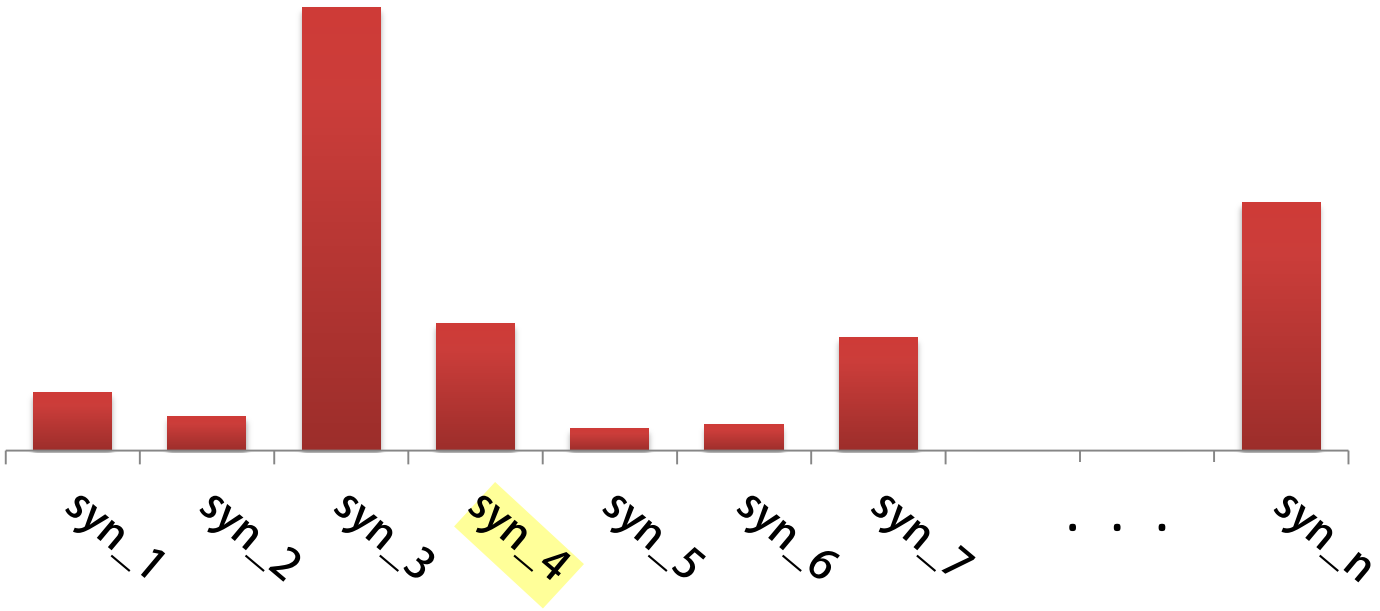

Semantic Signature

Distributional representation

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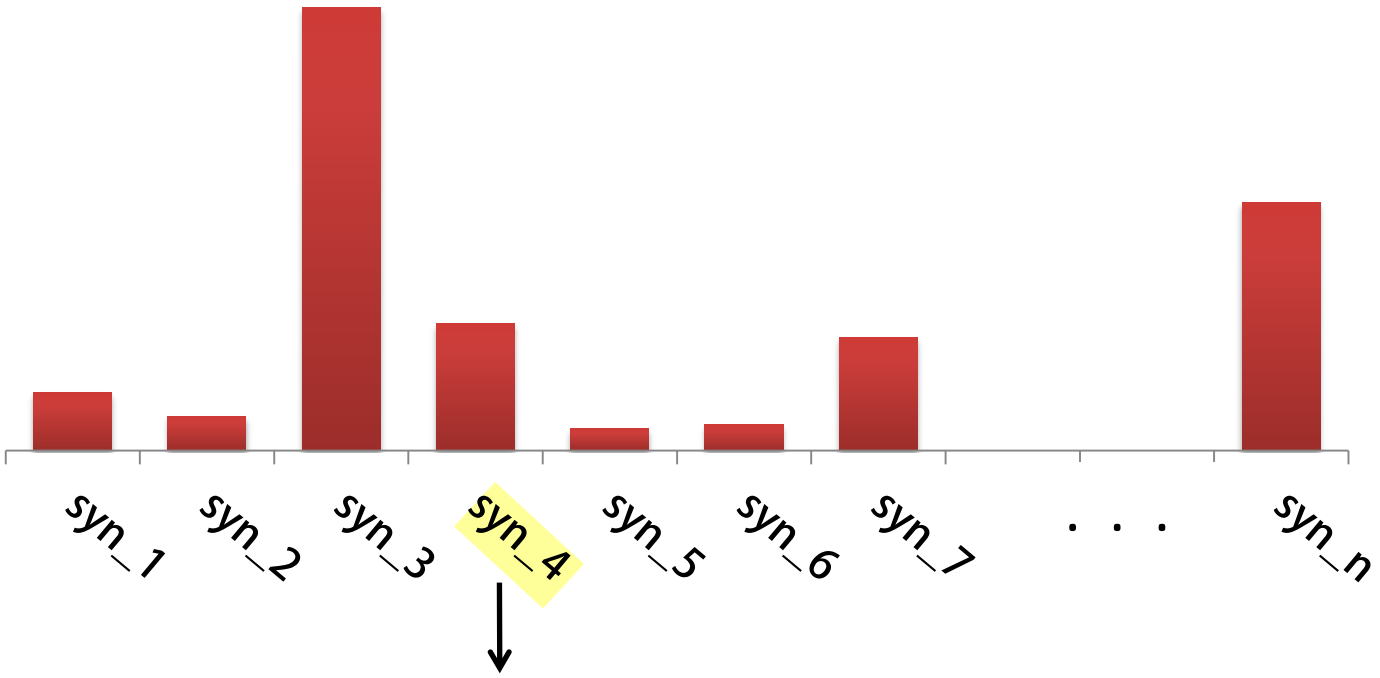

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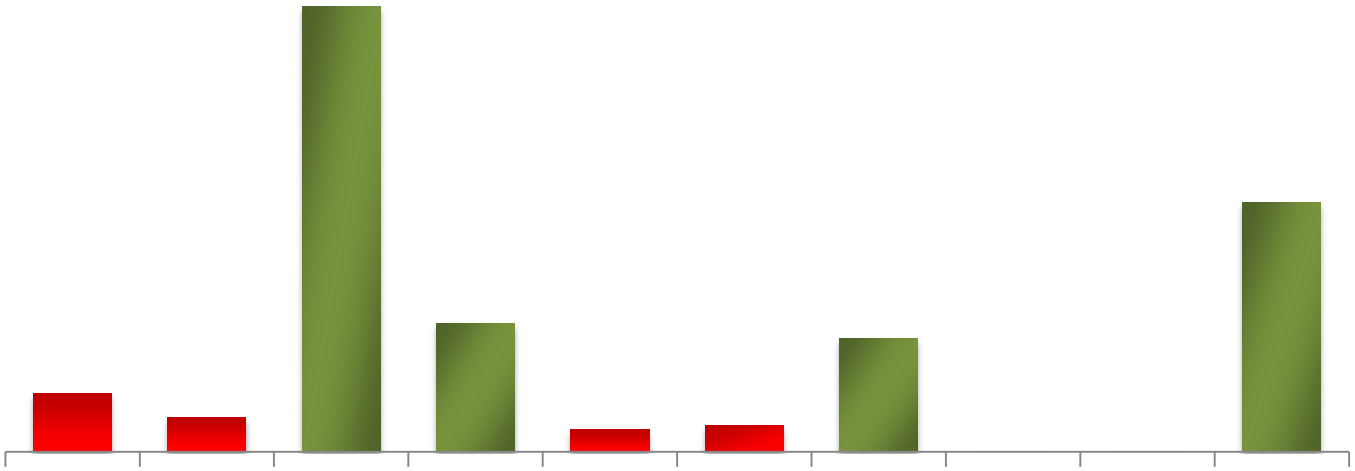

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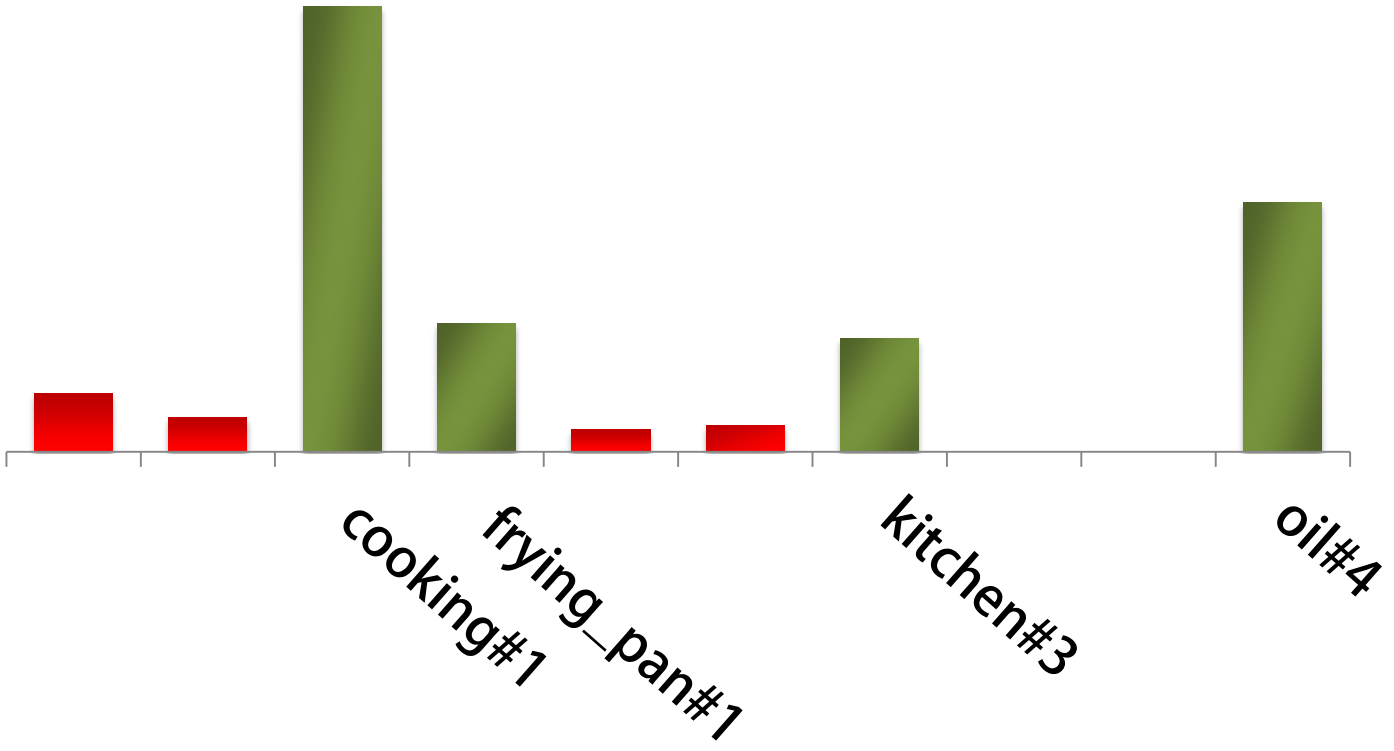

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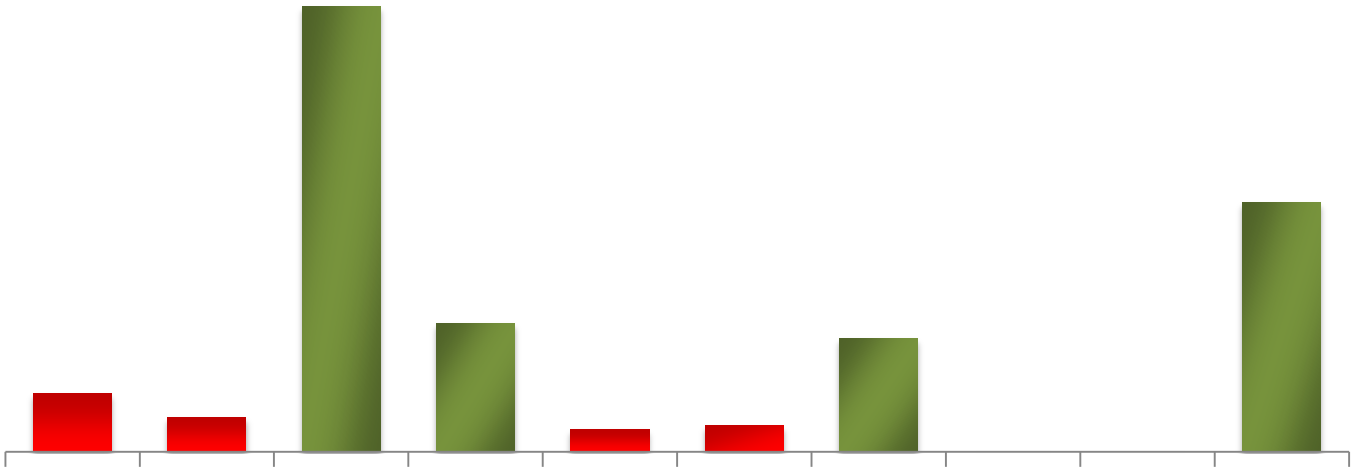

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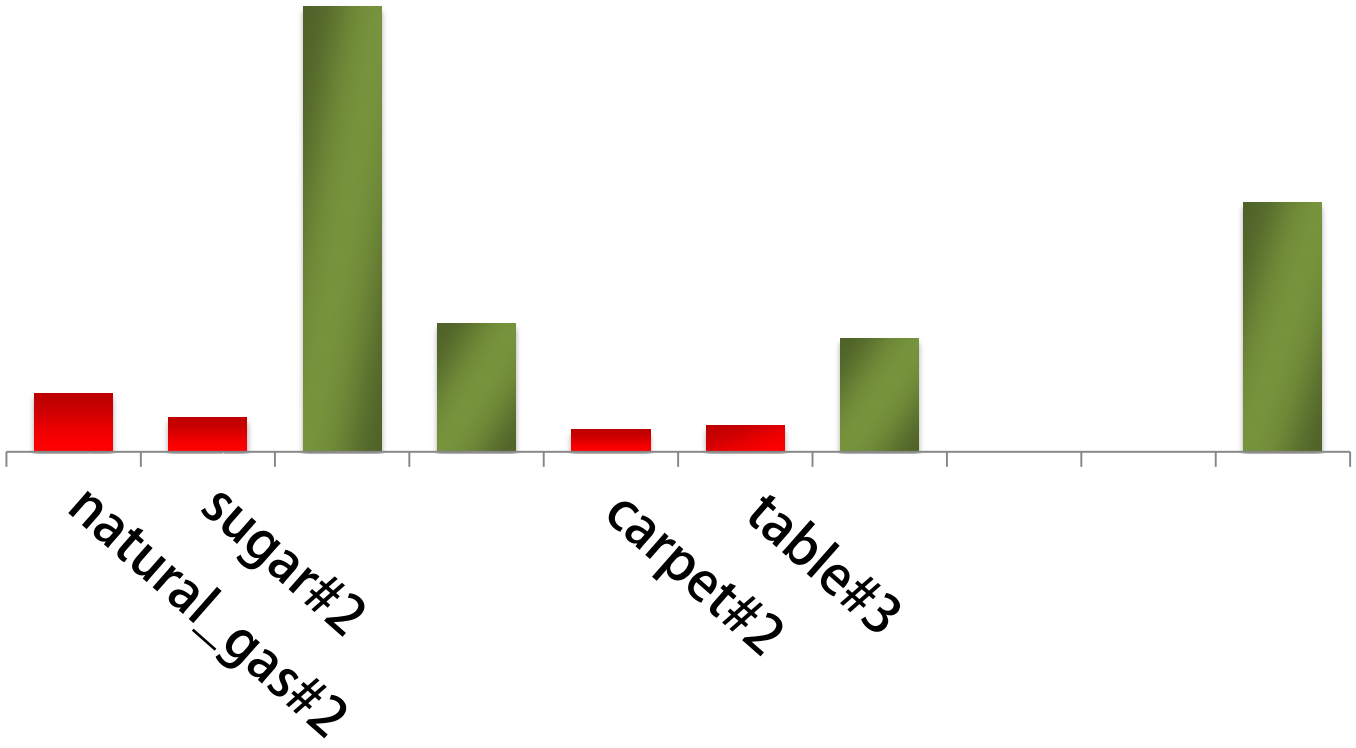

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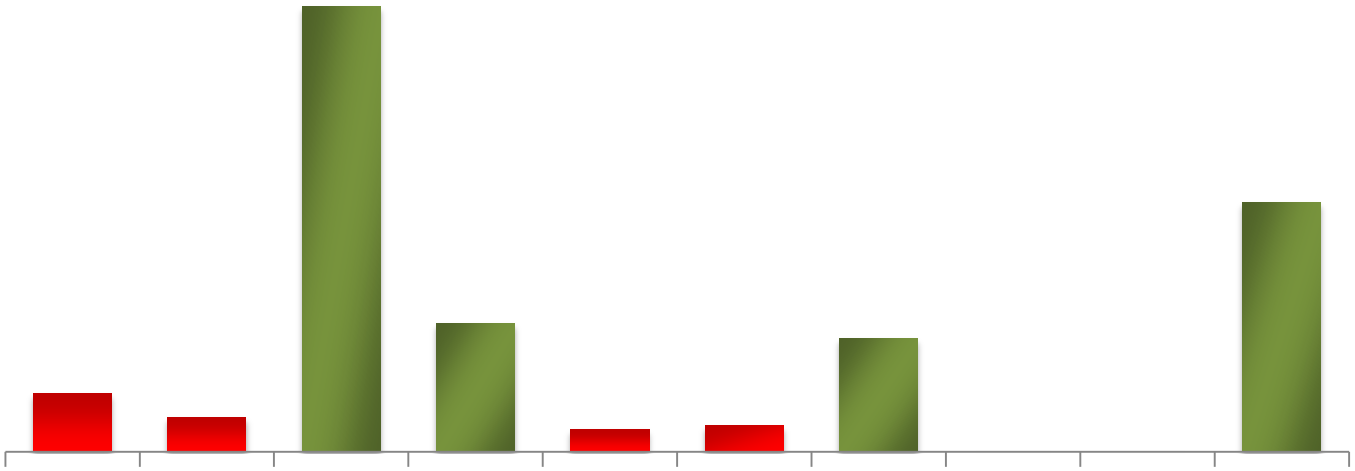

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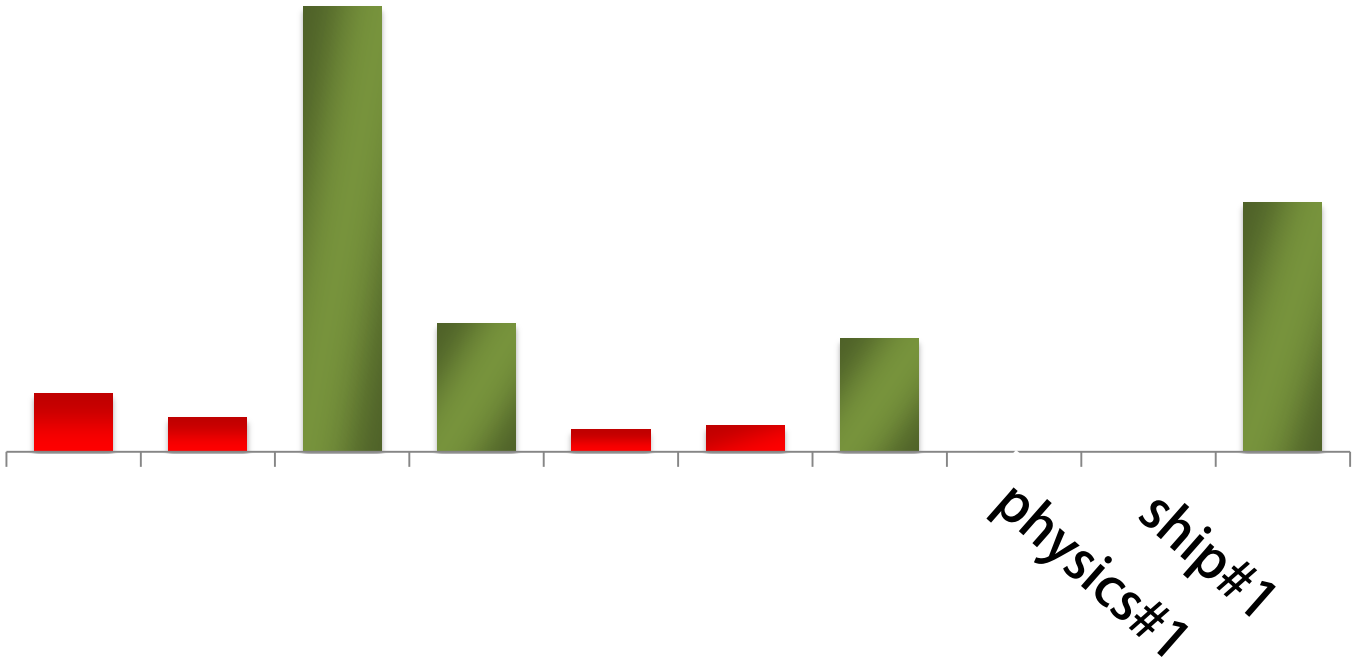
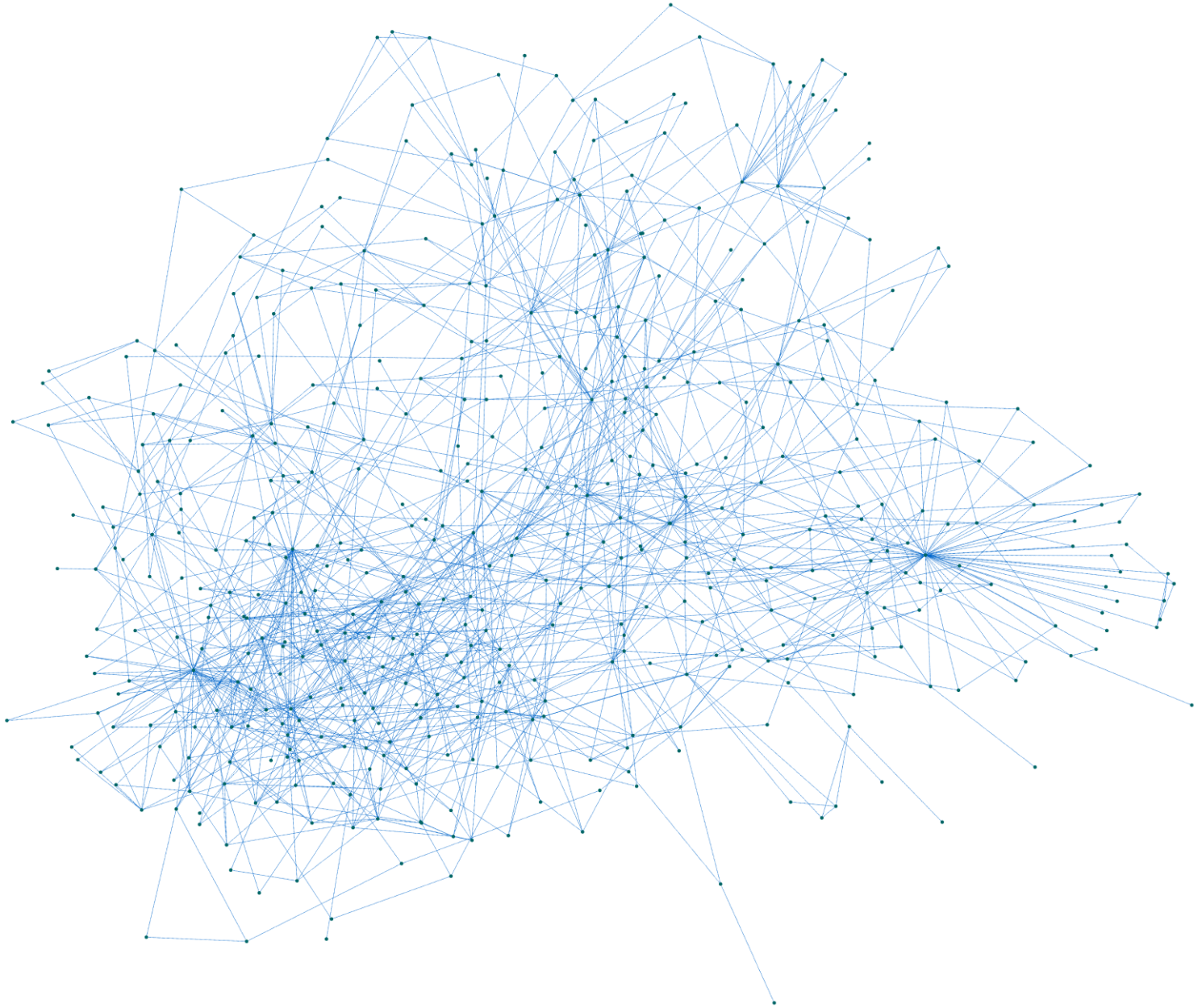


Personalized PageRank



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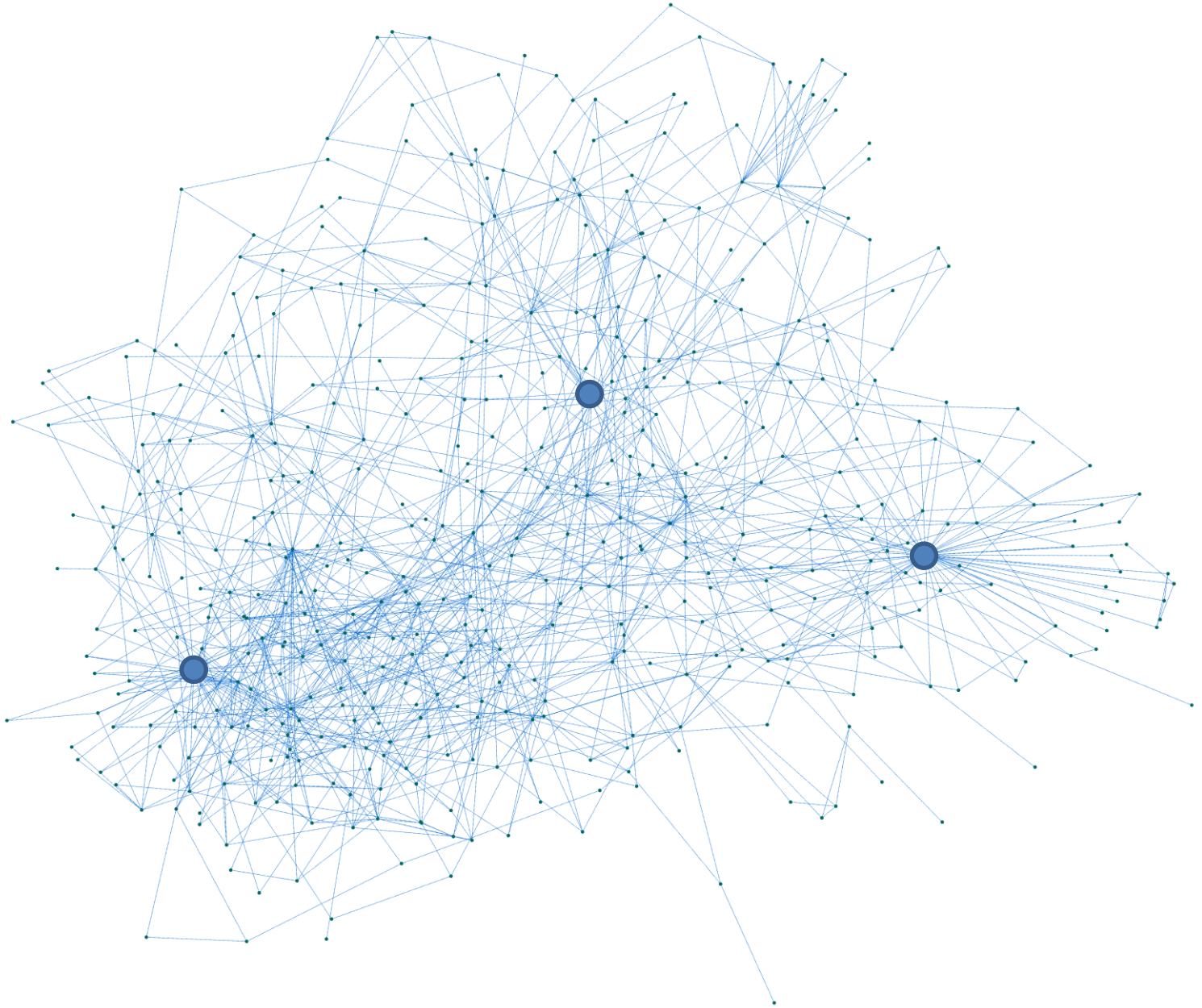

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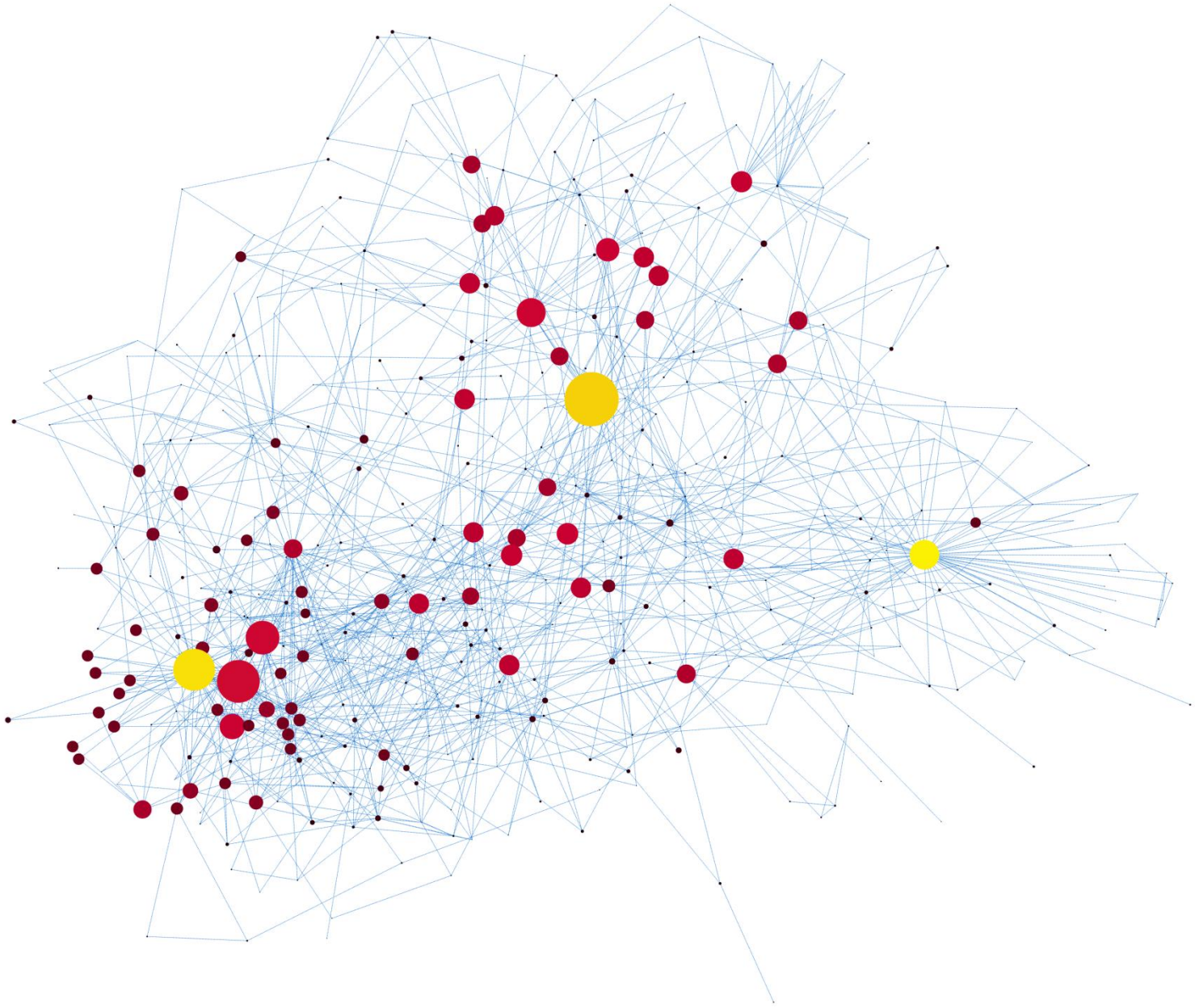

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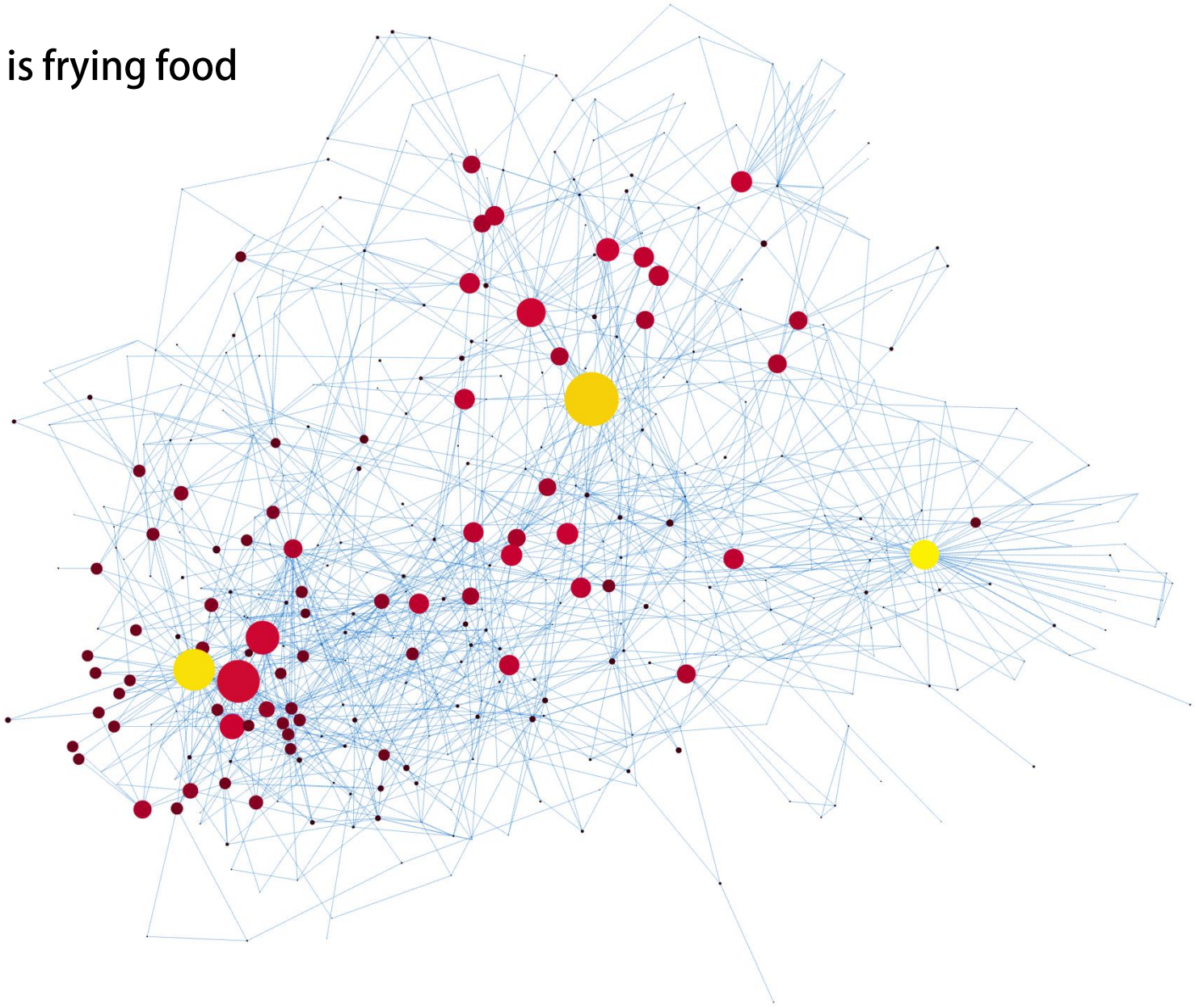
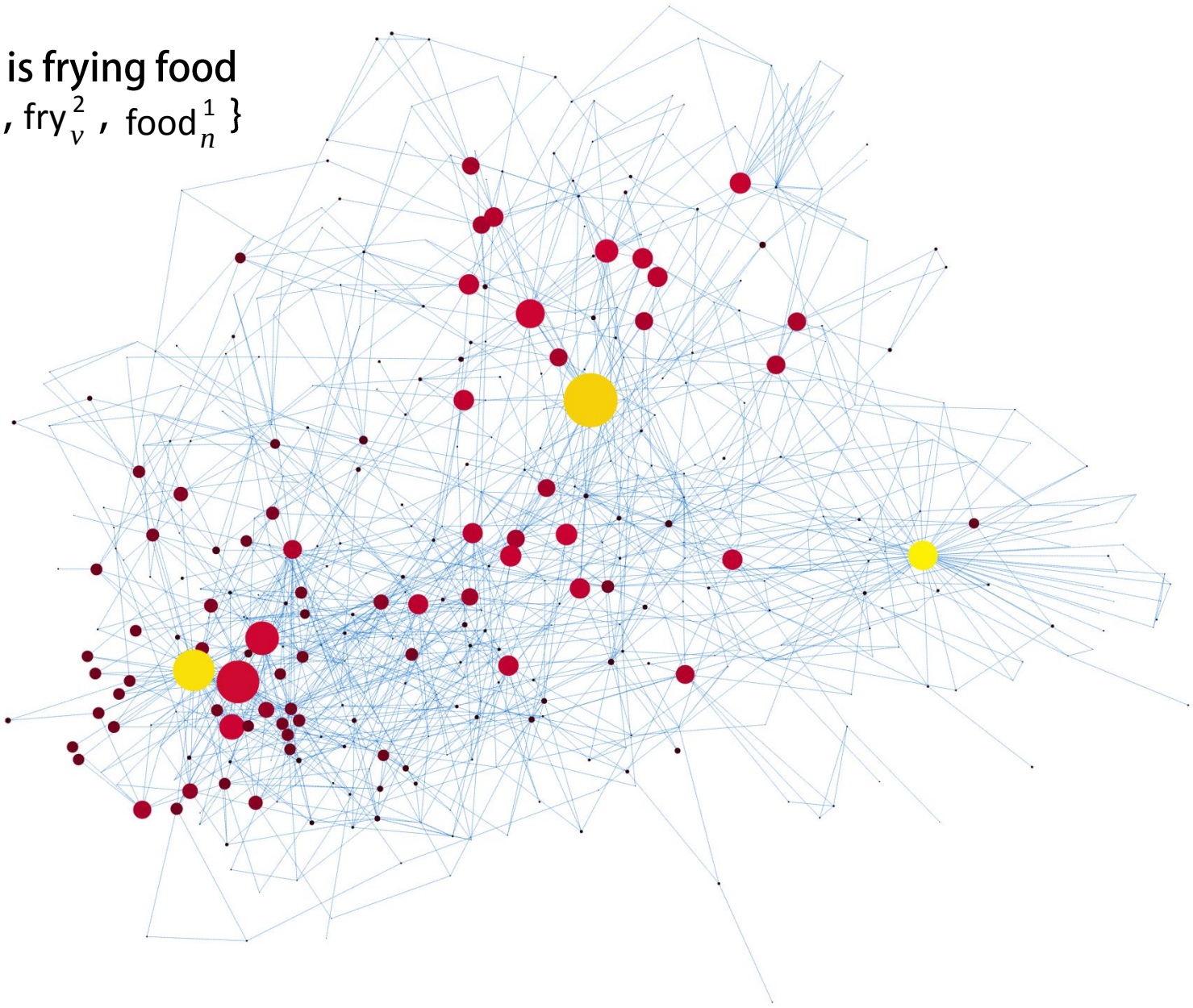


Personalized PageRank

a woman is frying food

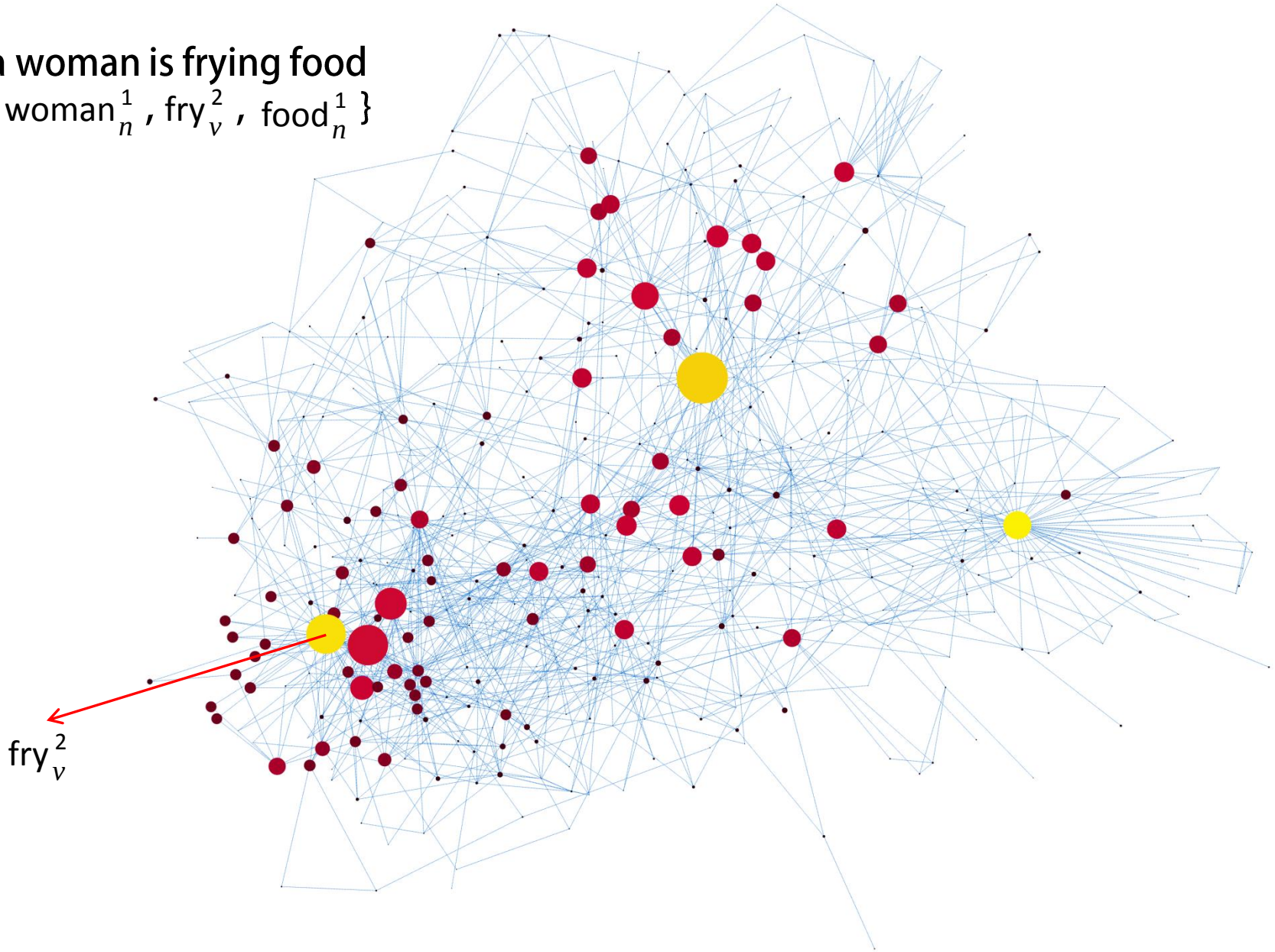
$\{\text{woman}_n^1, \text{fry}_v^2, \text{food}_n^1\}$



Personalized PageRank

a woman is frying food

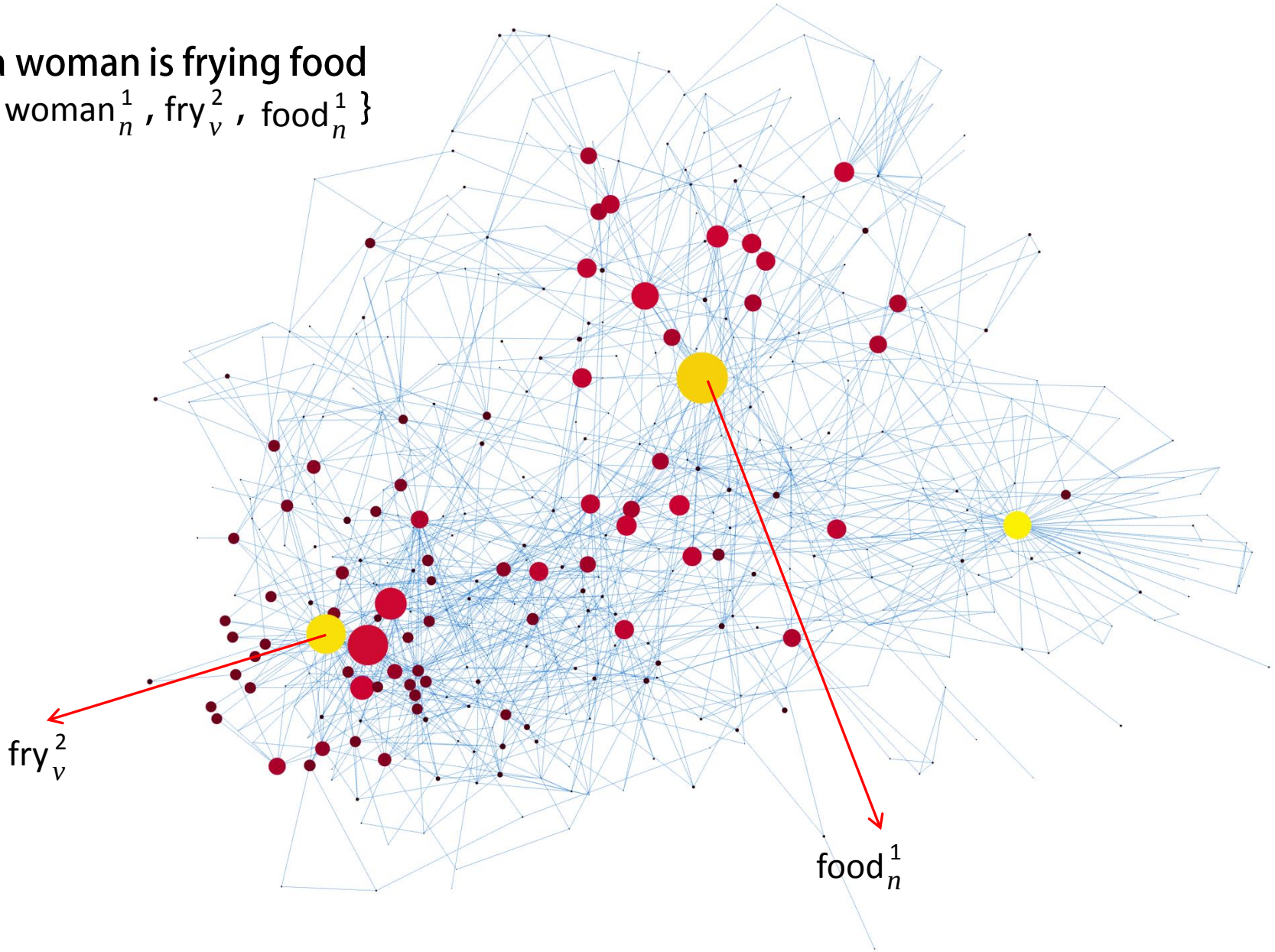
$\{\text{woman}_n^1, \text{fry}_v^2, \text{food}_n^1\}$



Personalized PageRank

a woman is frying food

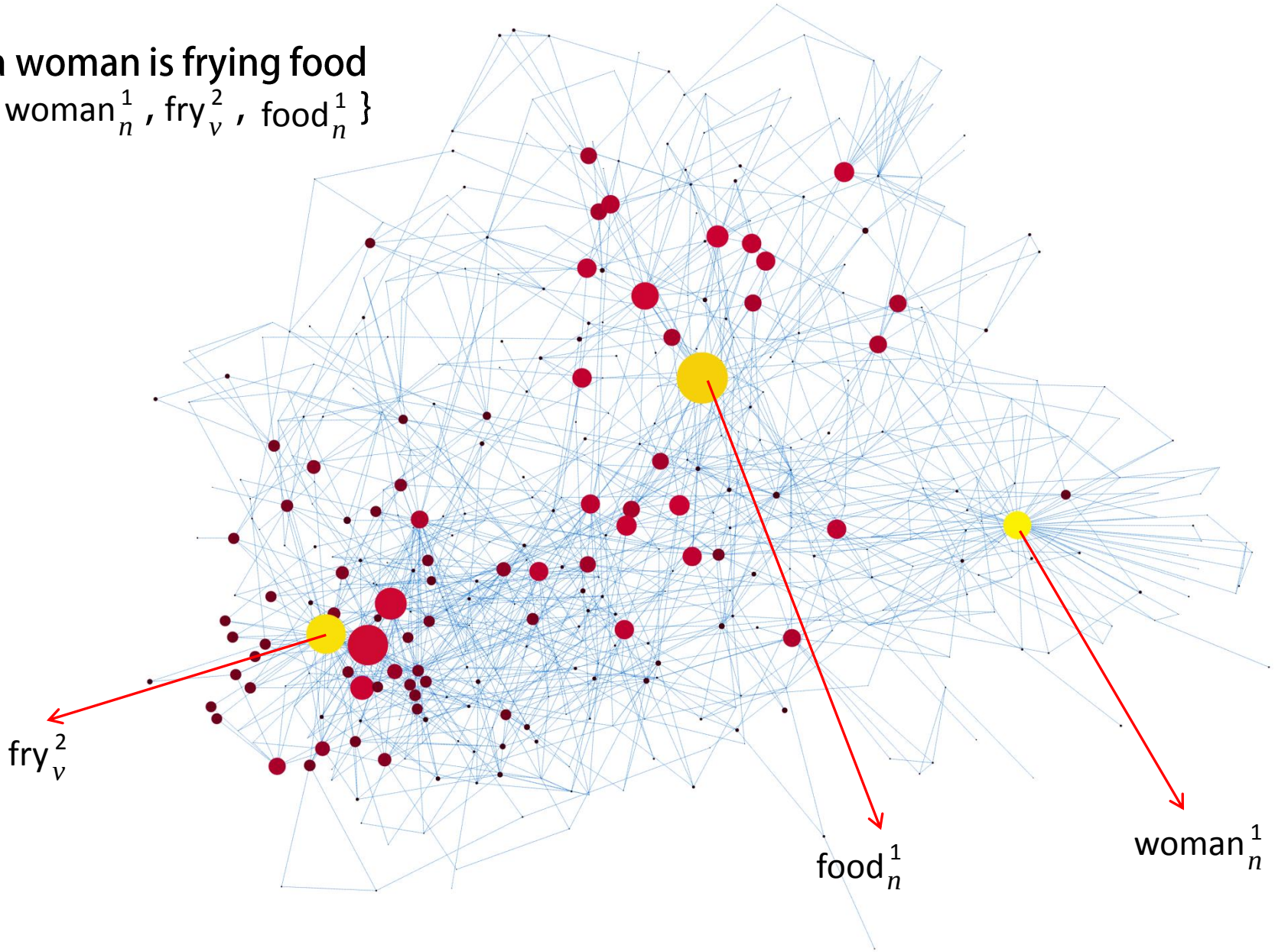
$\{\text{woman}_n^1, \text{fry}_v^2, \text{food}_n^1\}$



Personalized PageRank

a woman is frying food

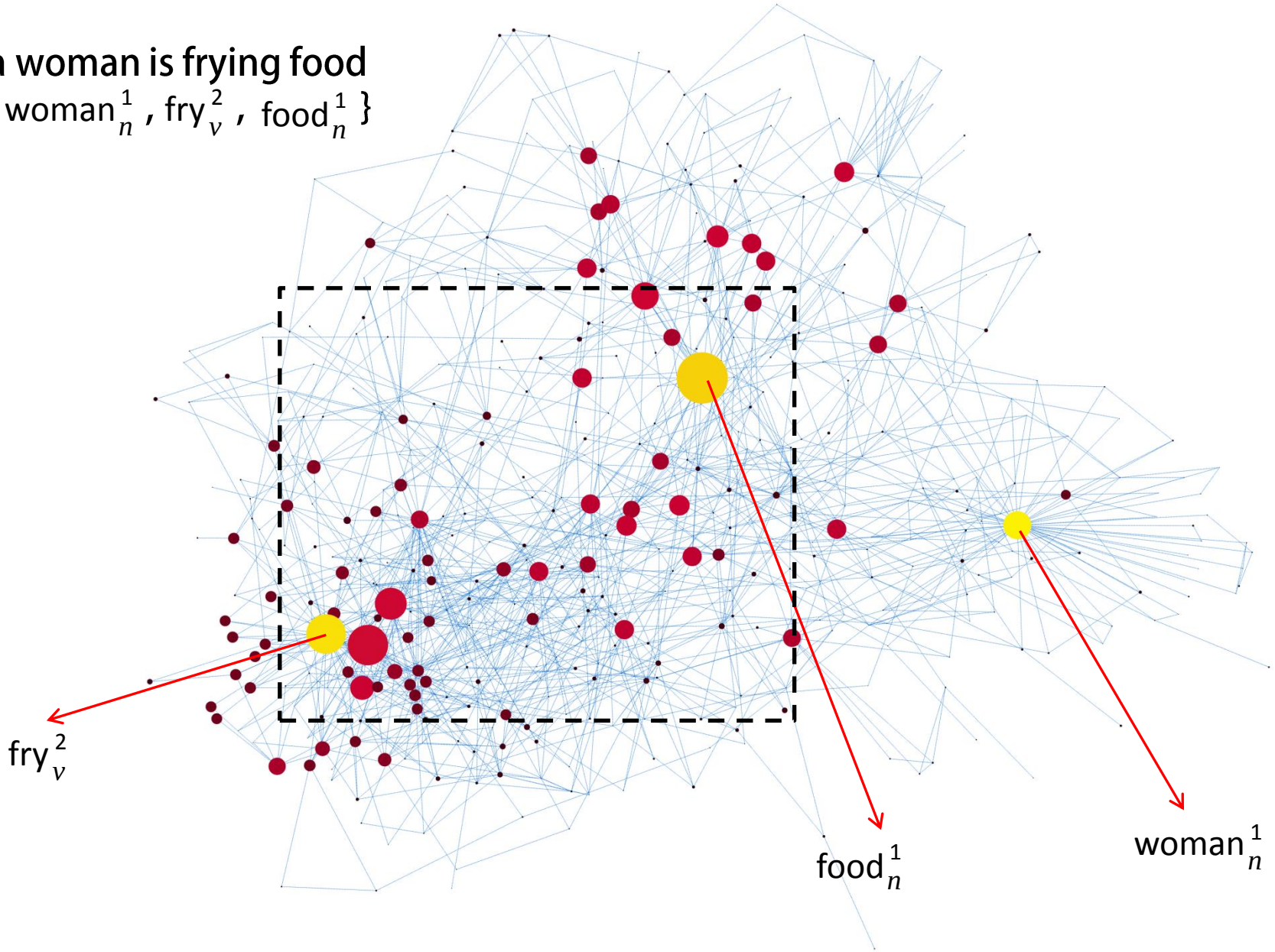
$\{\text{woman}_n^1, \text{fry}_v^2, \text{food}_n^1\}$

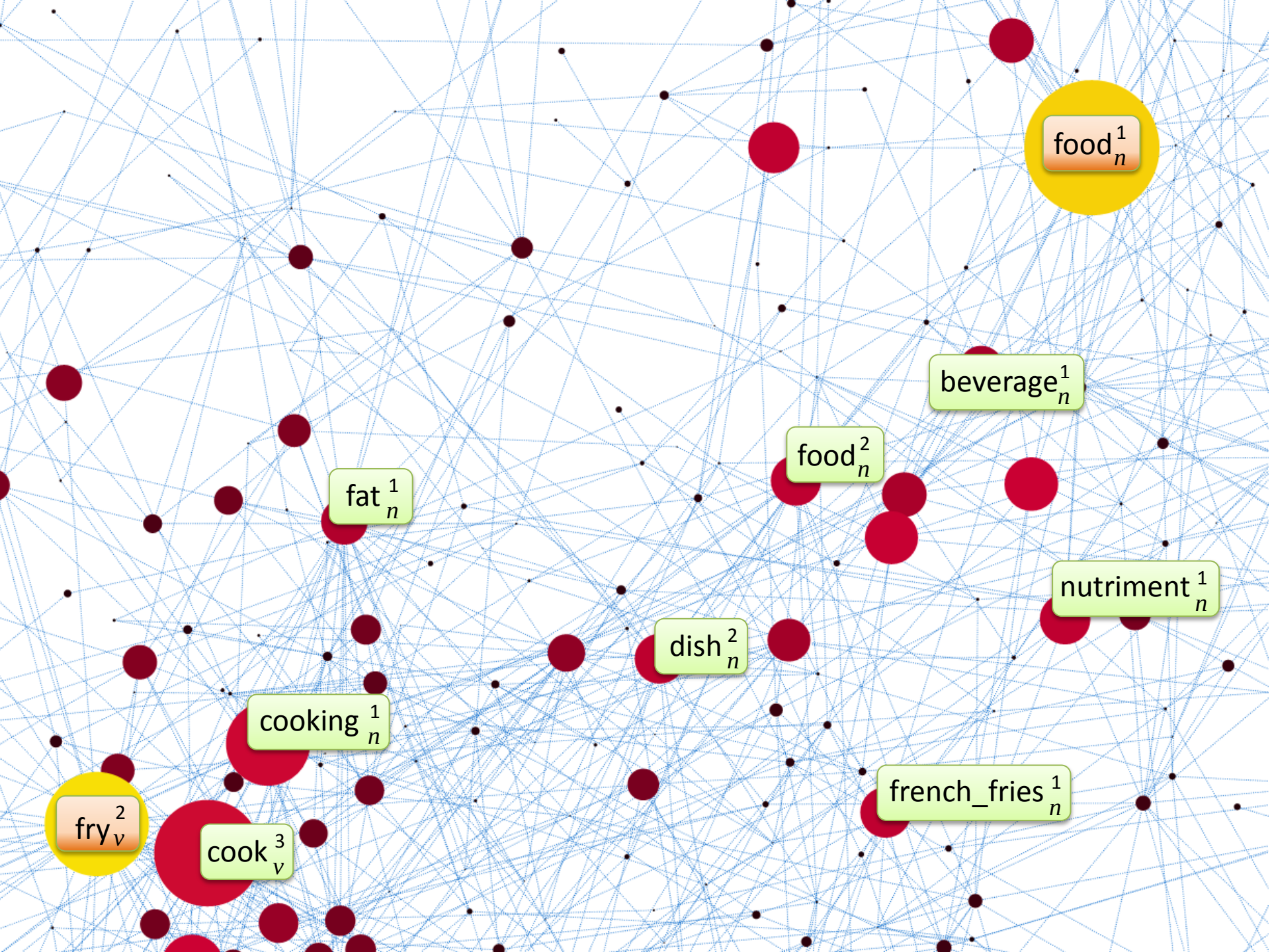


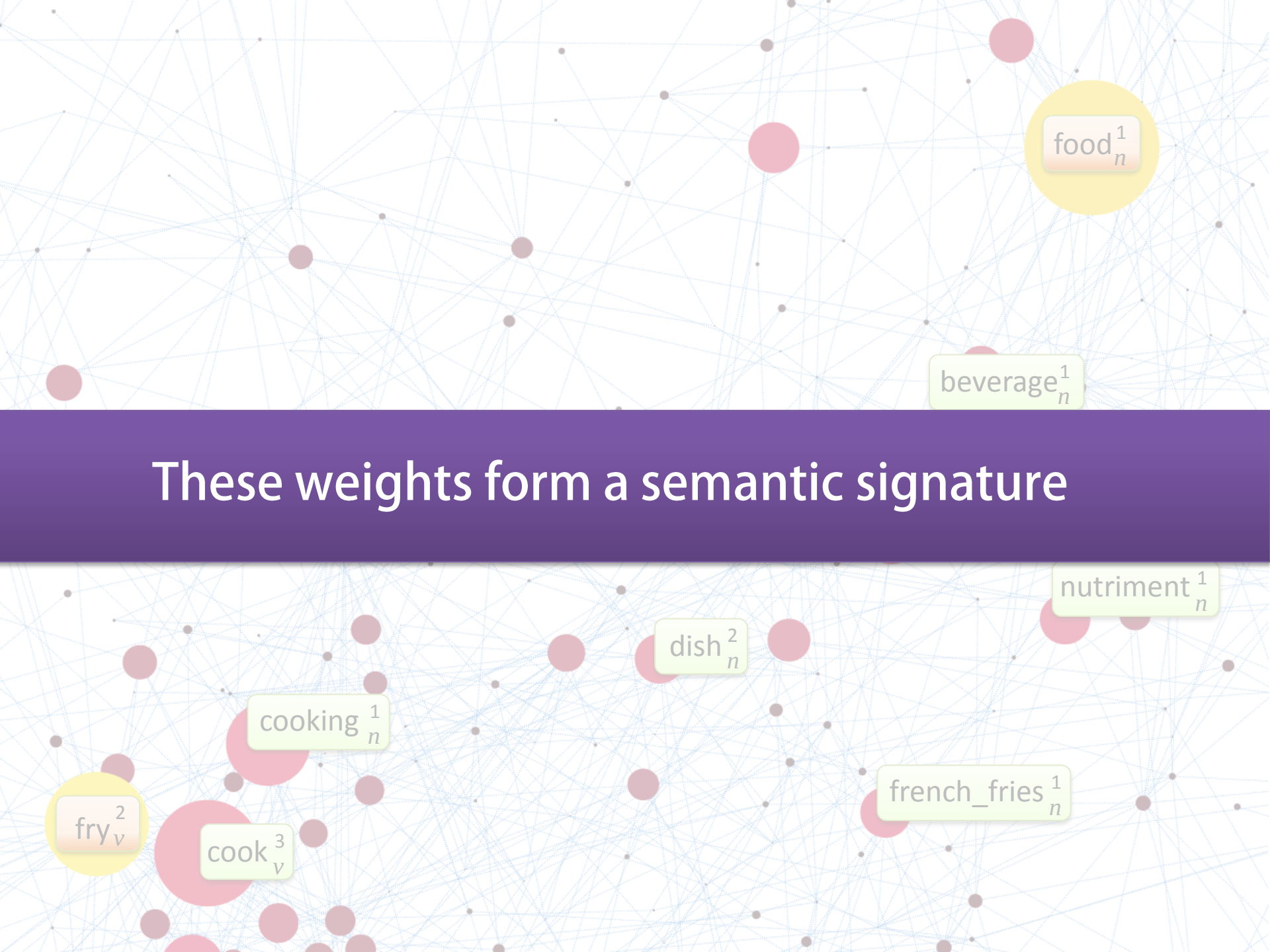
Personalized PageRank

a woman is frying food

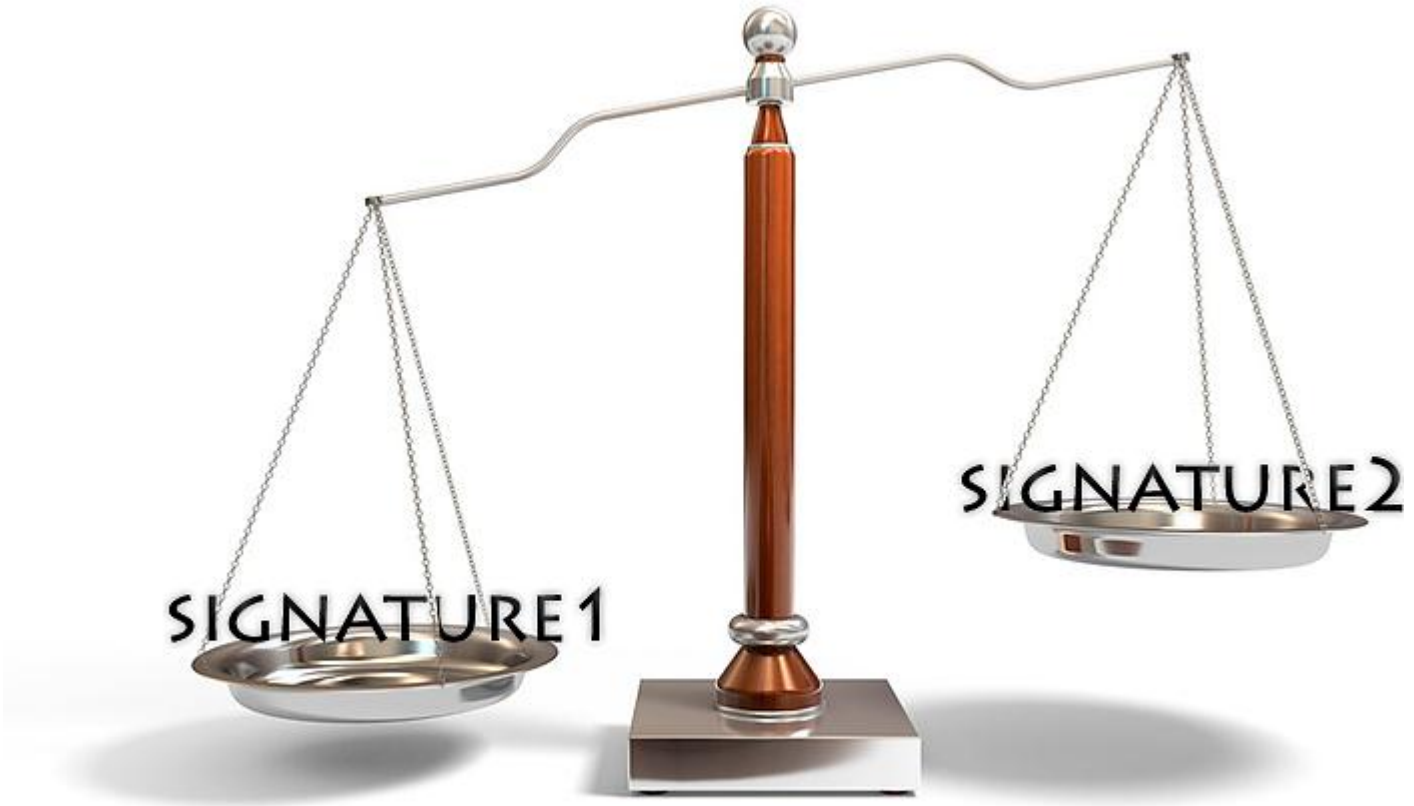
$\{\text{woman}_n^1, \text{fry}_v^2, \text{food}_n^1\}$




food 1 n
beverage 1 n
food 2 n
fat 1 n
nutriment 1 n
dish 2 n
cooking 1 n
fry 2 v
cook 3 v
french_fries 1 n


food 1 n
beverage 1 n
These weights form a semantic signature
nutriment 1 n
dish 2 n
cooking 1 n
fry 2 v
cook 3 v
french_fries 1 n

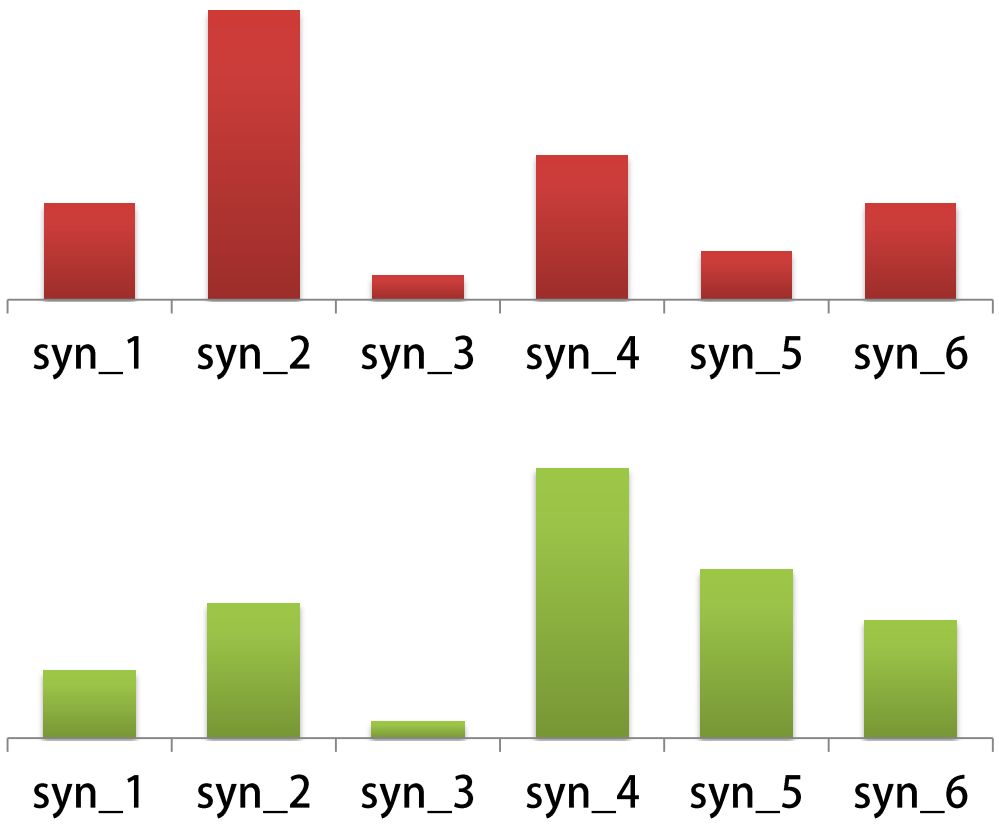
Comparing Semantic Signatures



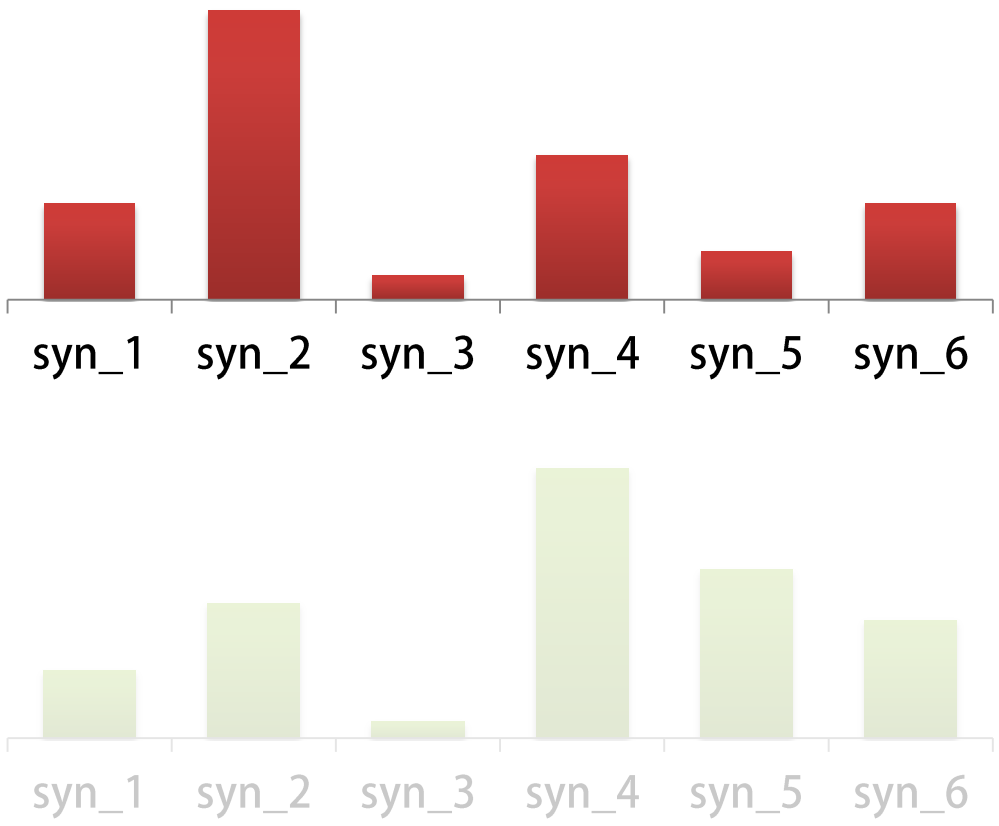
Comparing Semantic Signatures

- Parametric
  - Cosine
- Non-parametric
  - Weighted Overlap
  - Top-k Jaccard

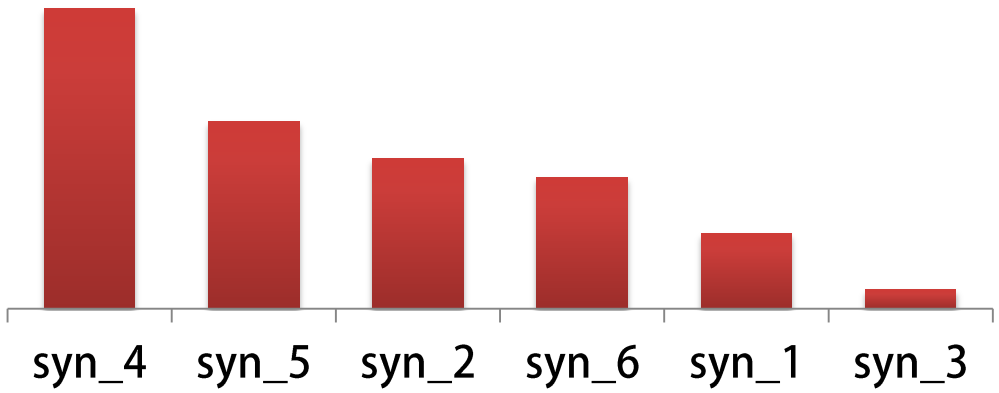
Comparing Semantic Signatures
Weighted Overlap



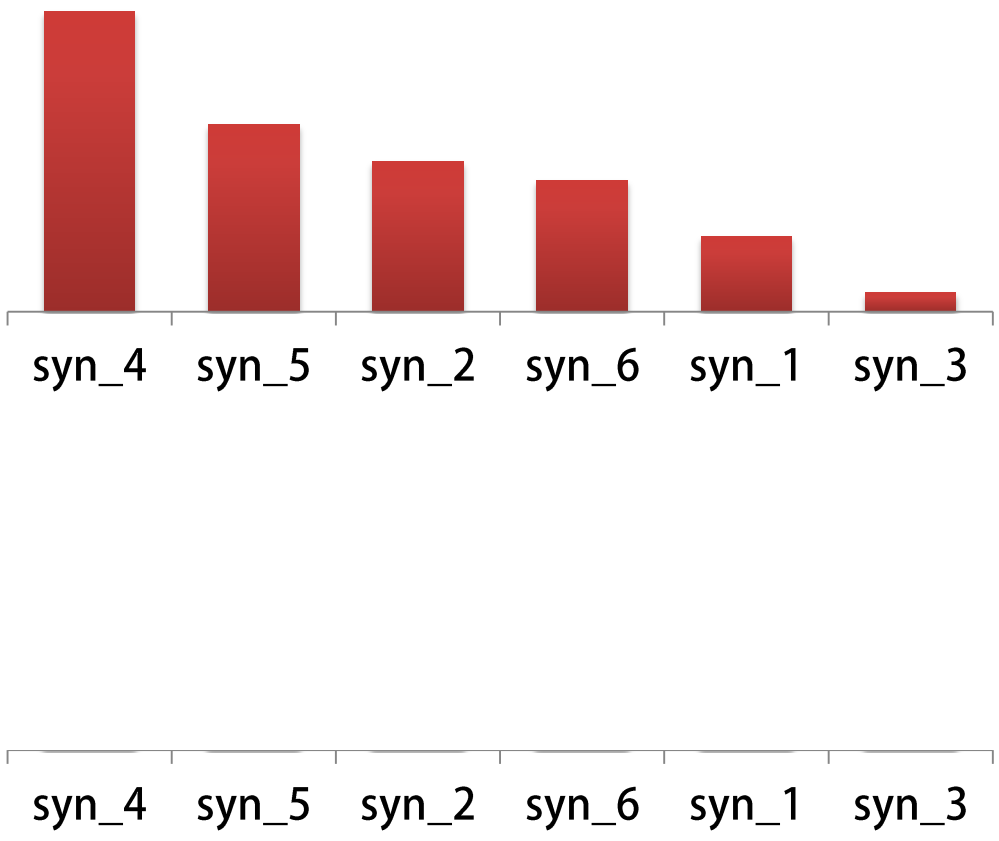
Comparing Semantic Signatures
Weighted Overlap



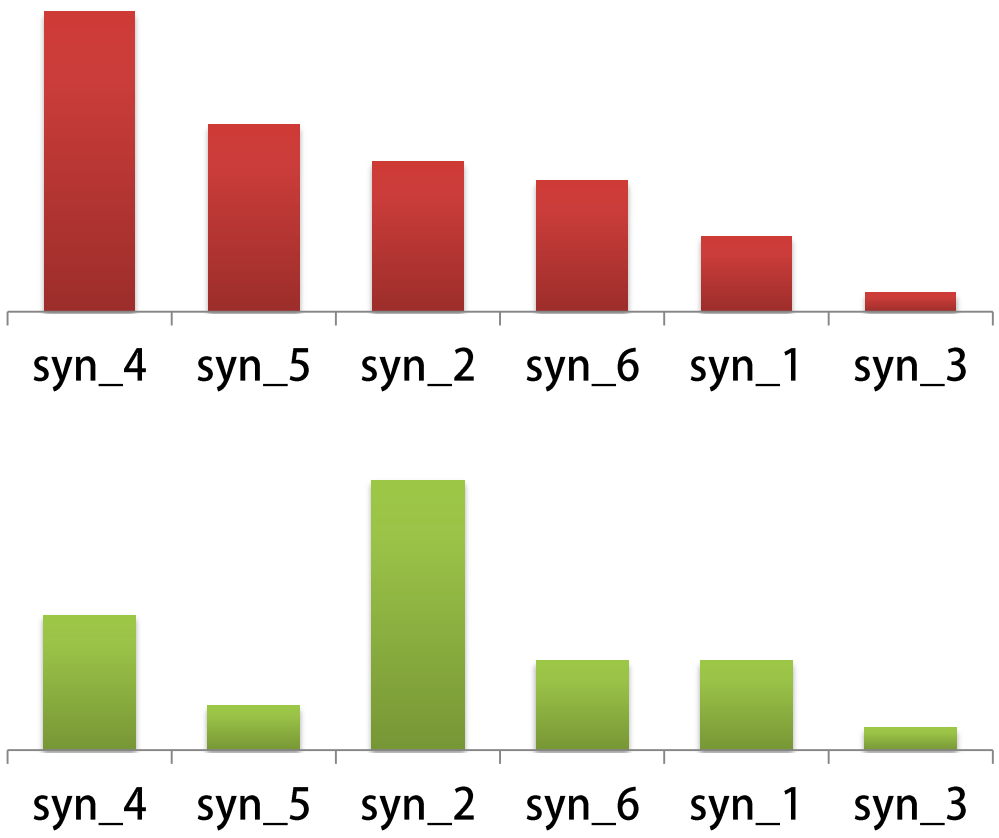
Comparing Semantic Signatures
Weighted Overlap



Comparing Semantic Signatures
Weighted Overlap

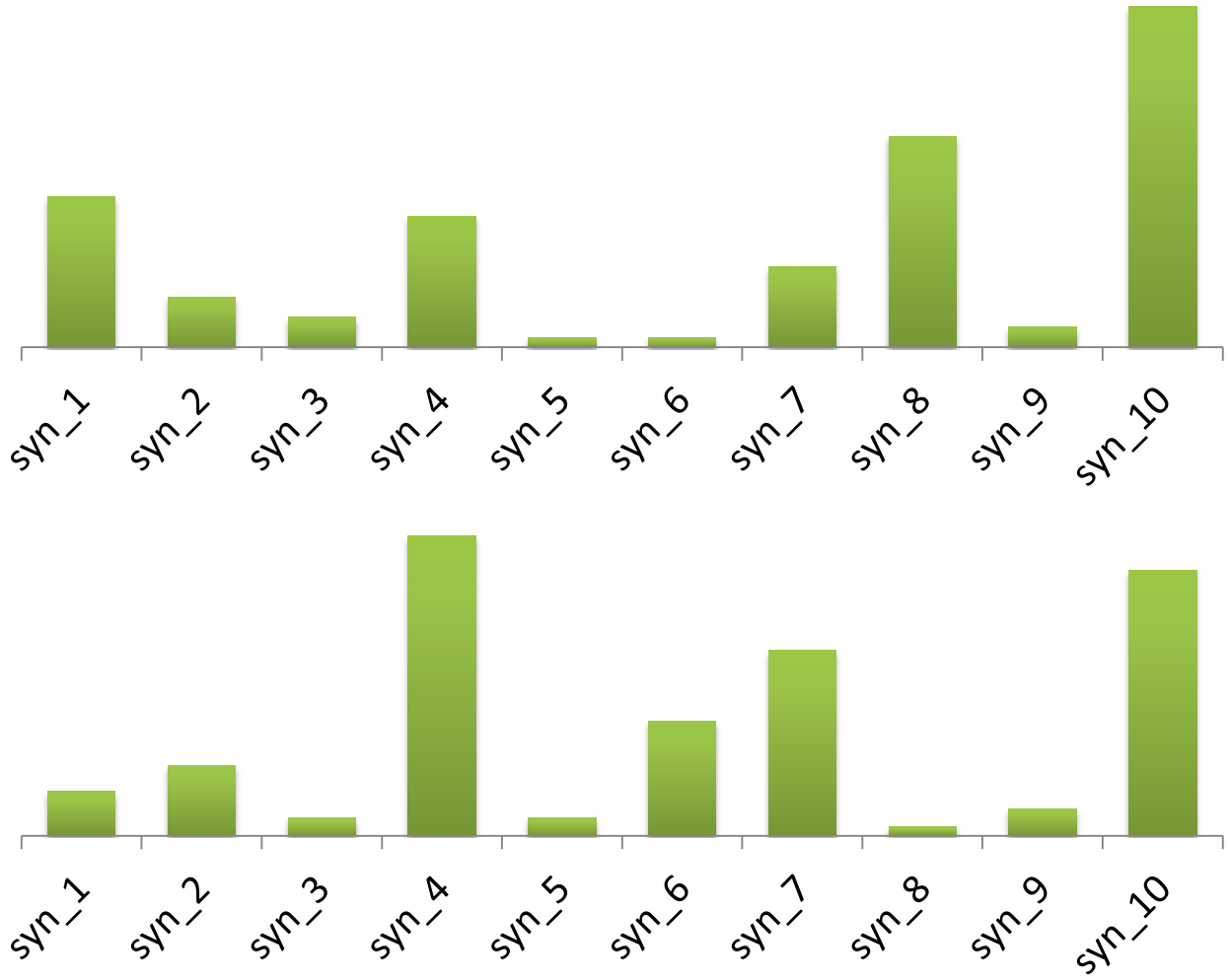


Comparing Semantic Signatures
Weighted Overlap



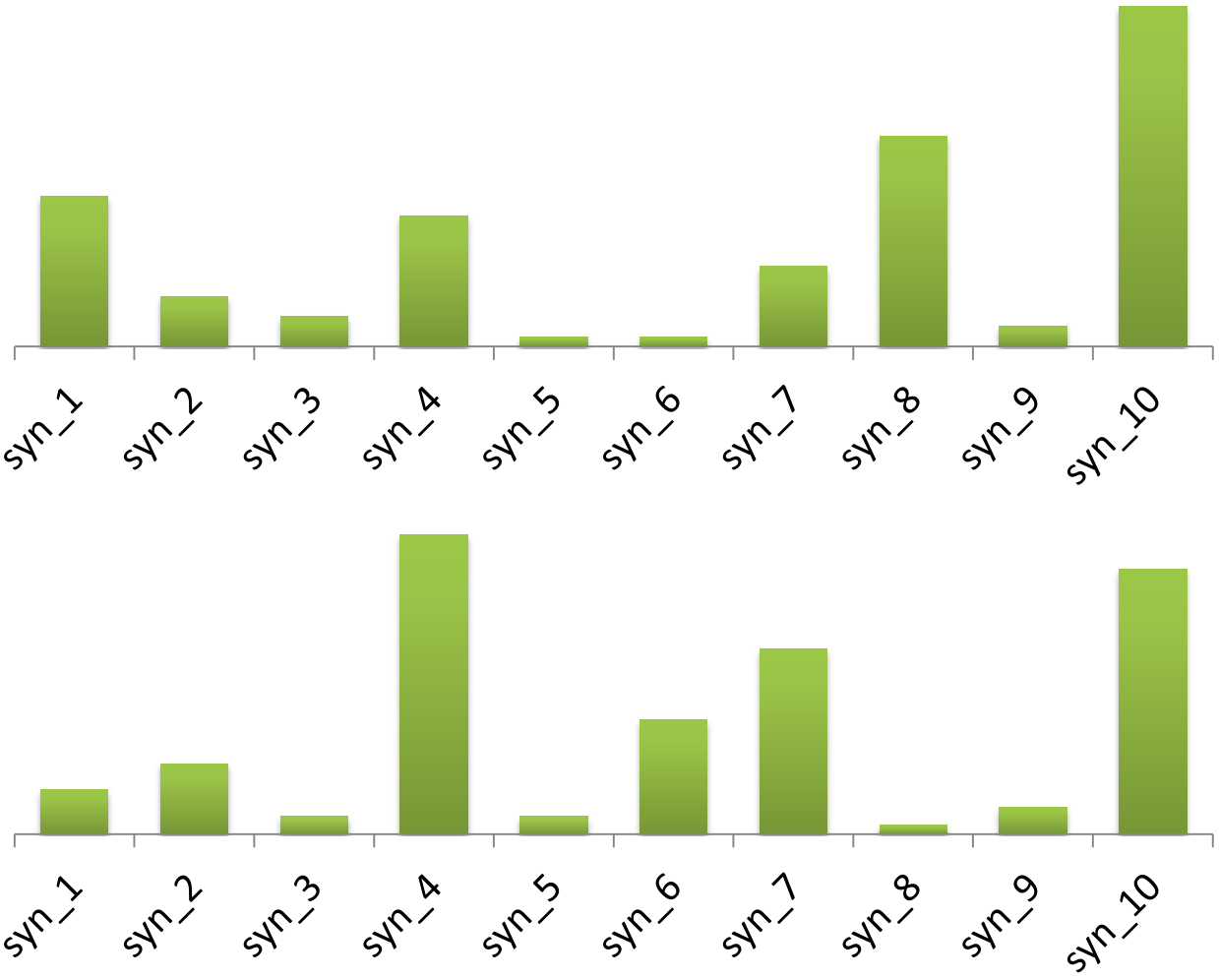
Comparing Semantic Signatures

Top-k Jaccard



Comparing Semantic Signatures

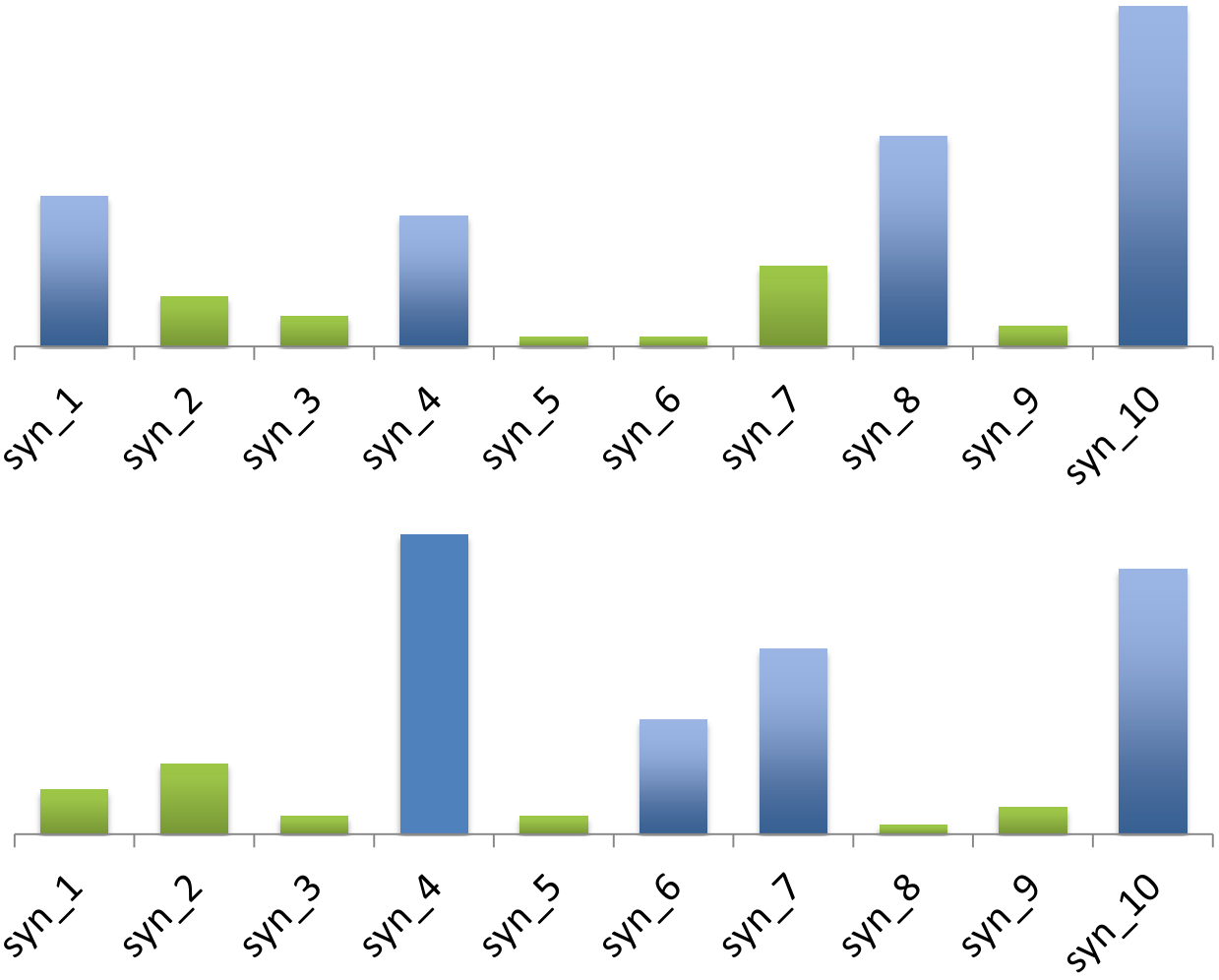
Top-k Jaccard



$k = 4$

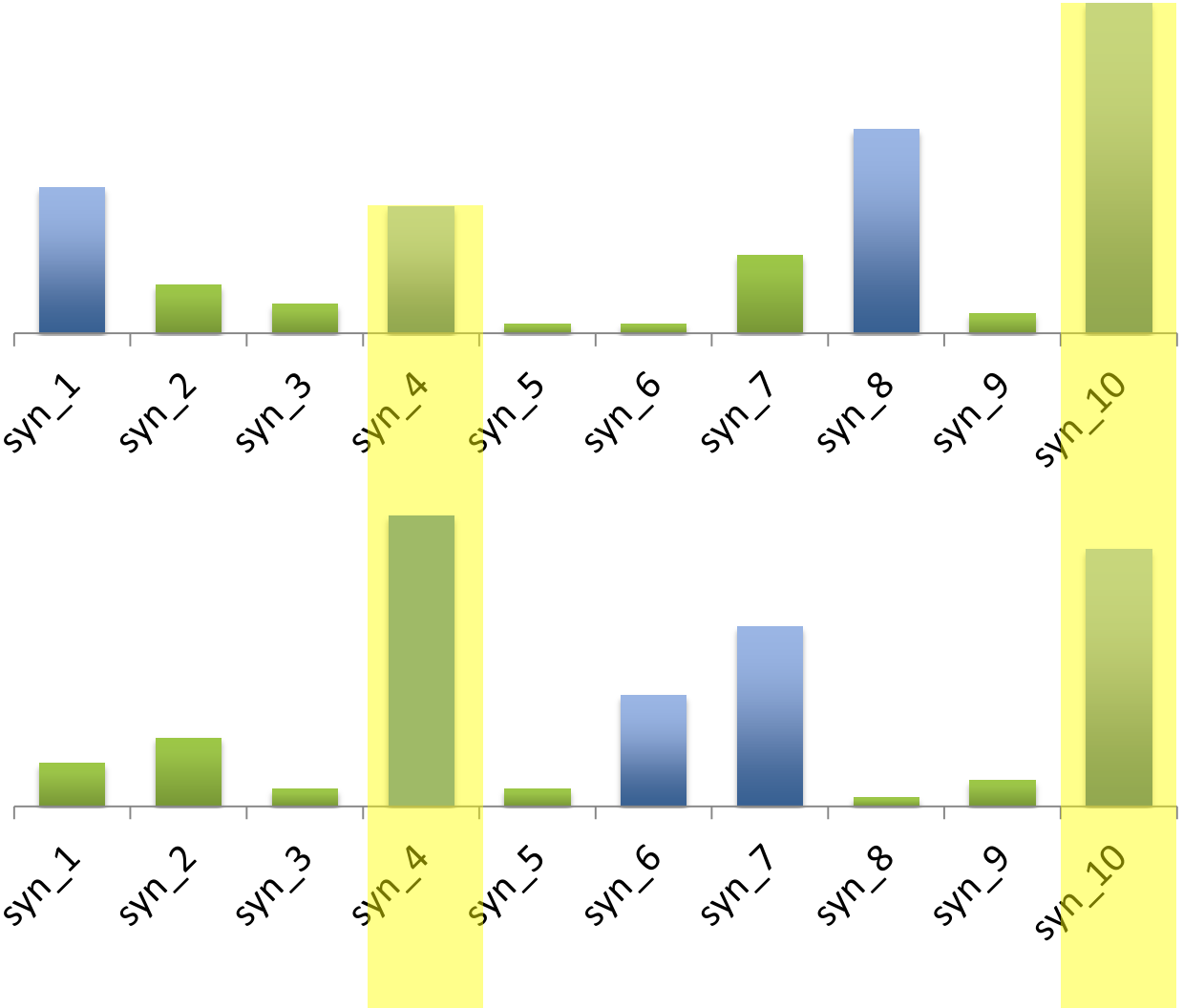
Comparing Semantic Signatures

Top-k Jaccard



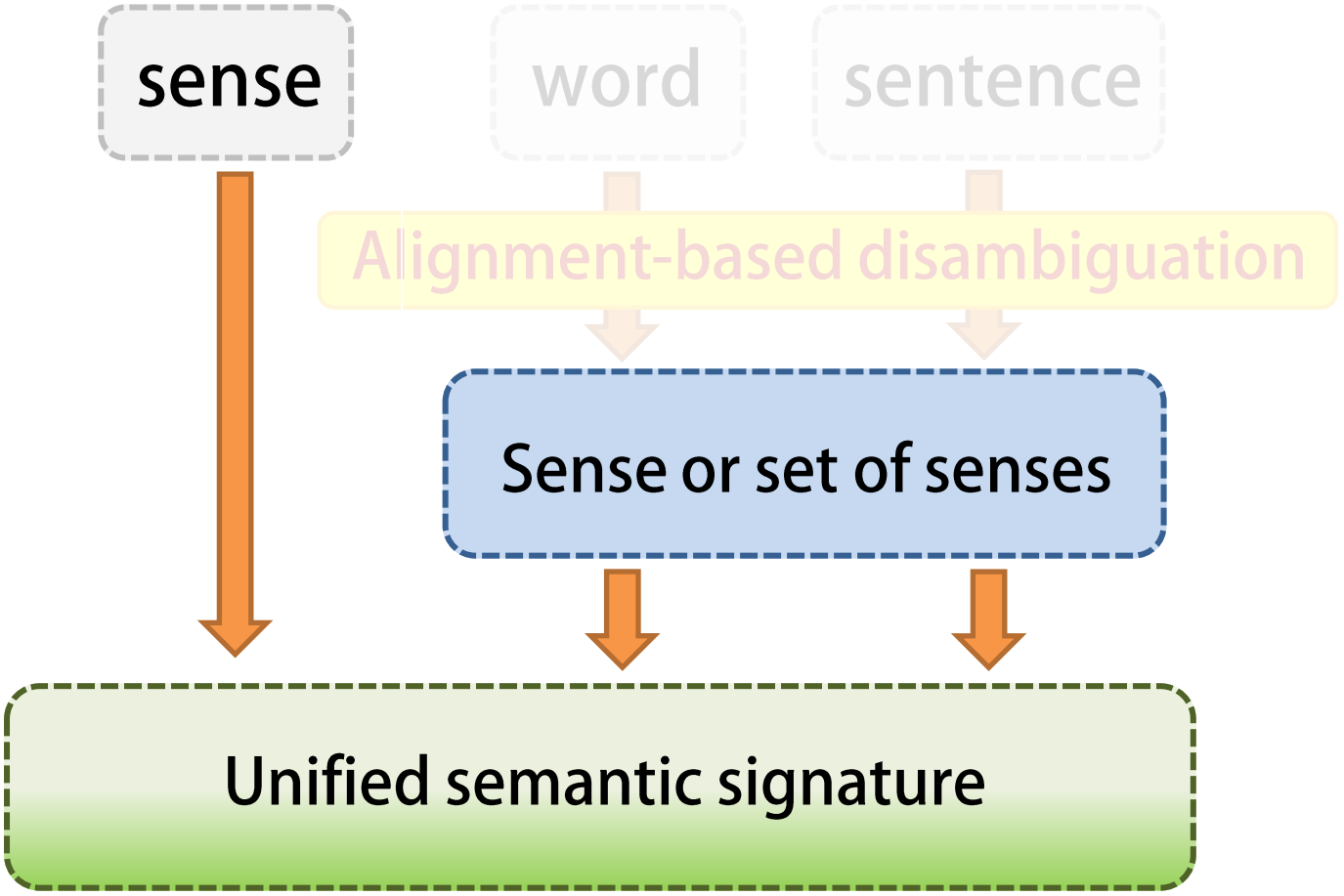
$k = 4$

Comparing Semantic Signatures
Top-k Jaccard

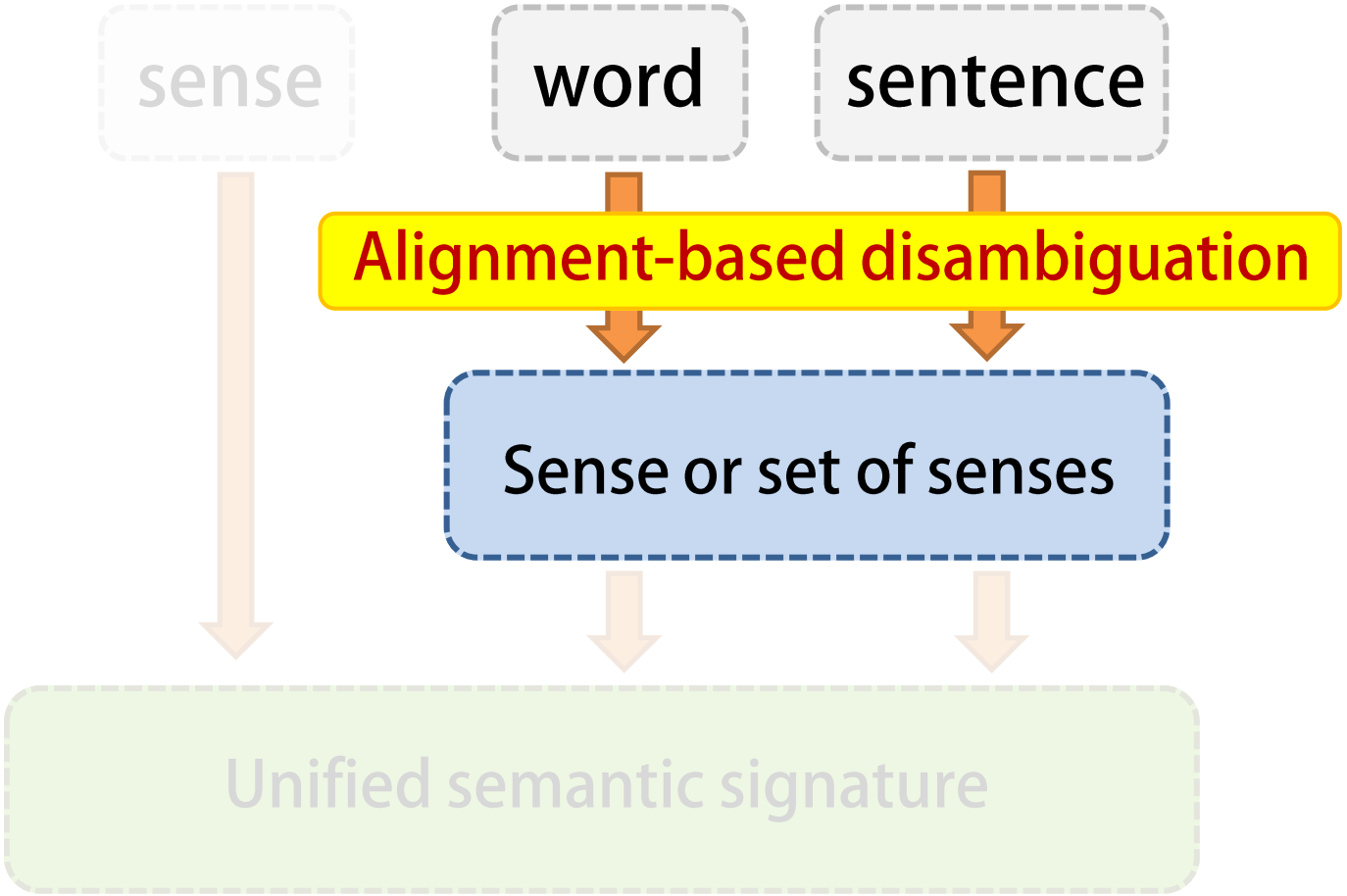


$k = 4$

Alignment-based disambiguation



Alignment-based disambiguation



Why is disambiguation needed?

Why is disambiguation needed?

The worker was fired

He was terminated

Why is disambiguation needed?

The worker was fired

He was terminated

Why is disambiguation needed?

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He was terminated

Why is disambiguation needed?

The worker was fired

He was terminated

Alignment-based disambiguation

A manager fired the worker.

An employee was terminated from work by his boss.

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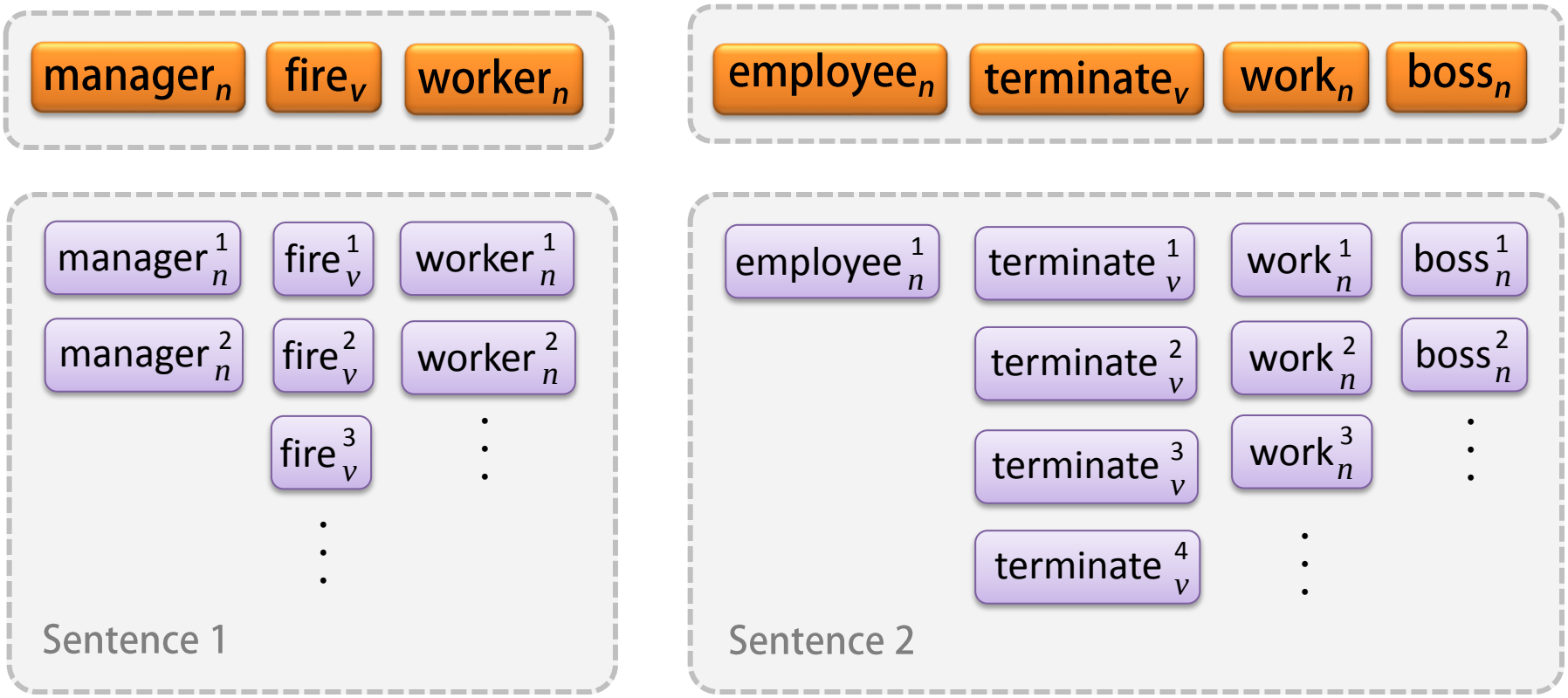

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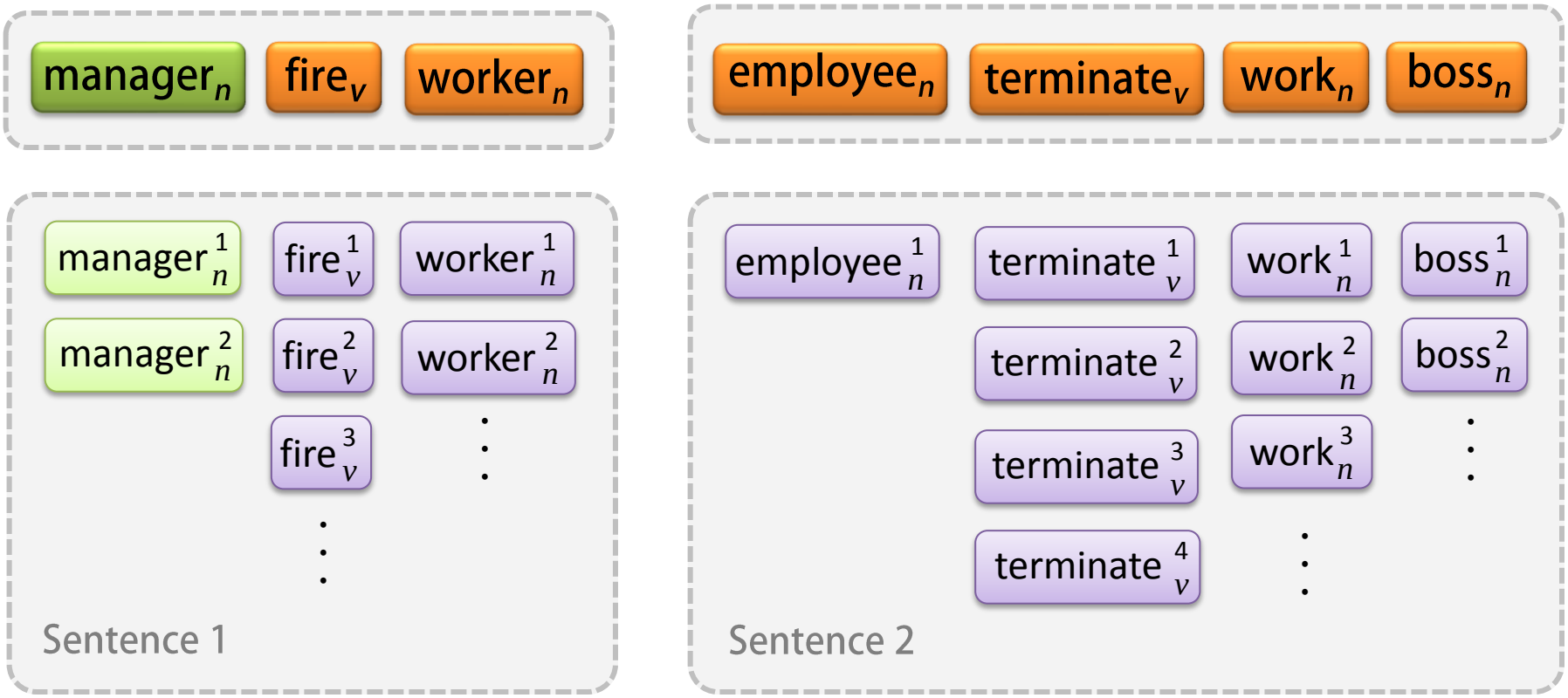
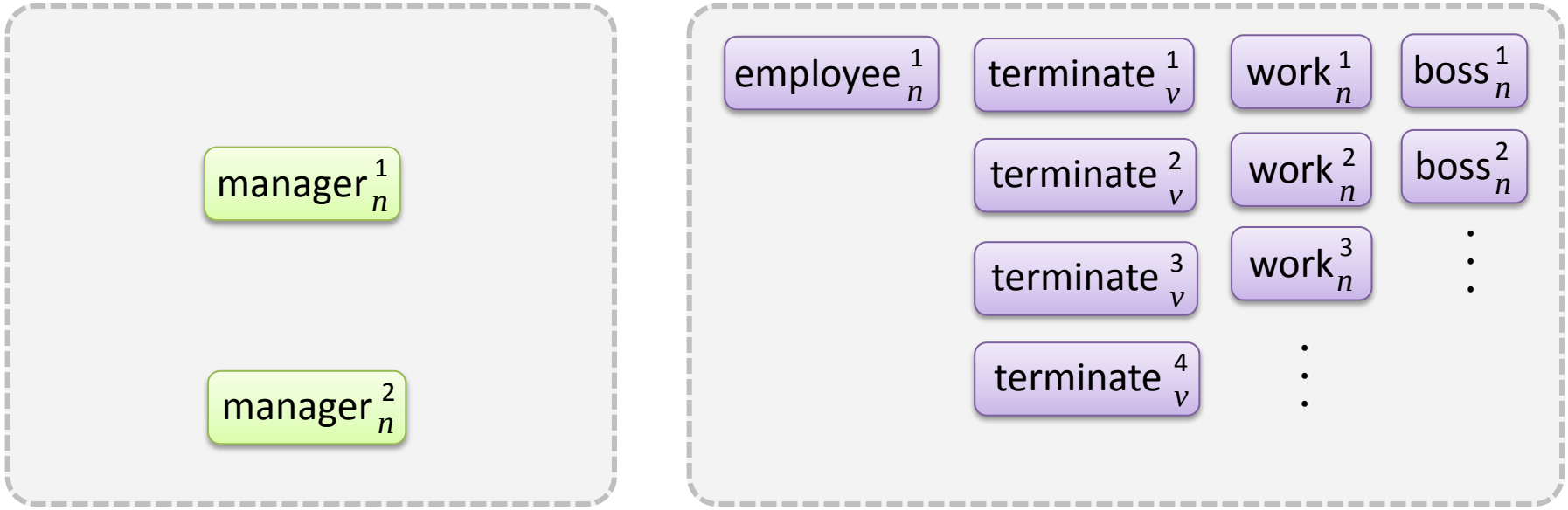


Alignment-based disambiguation



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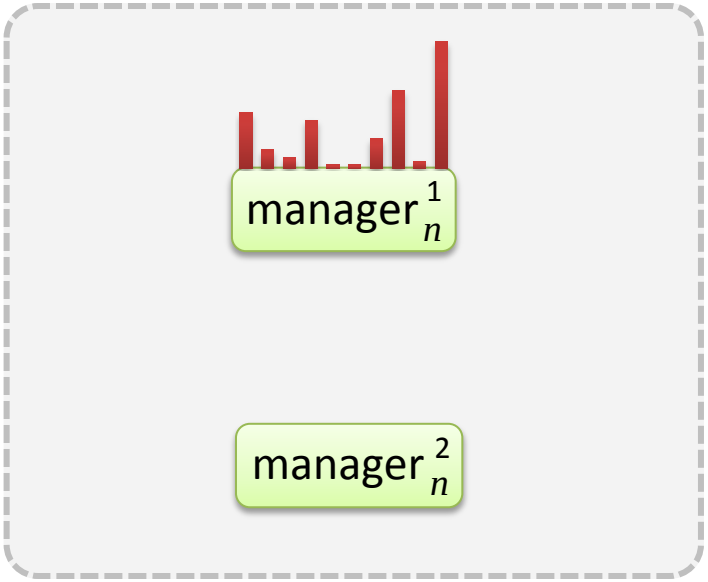

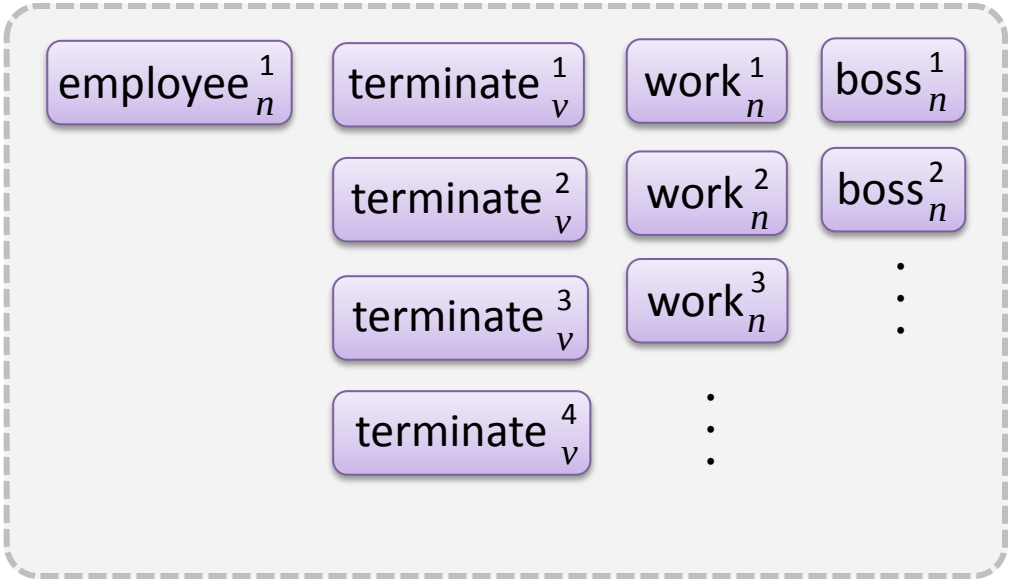

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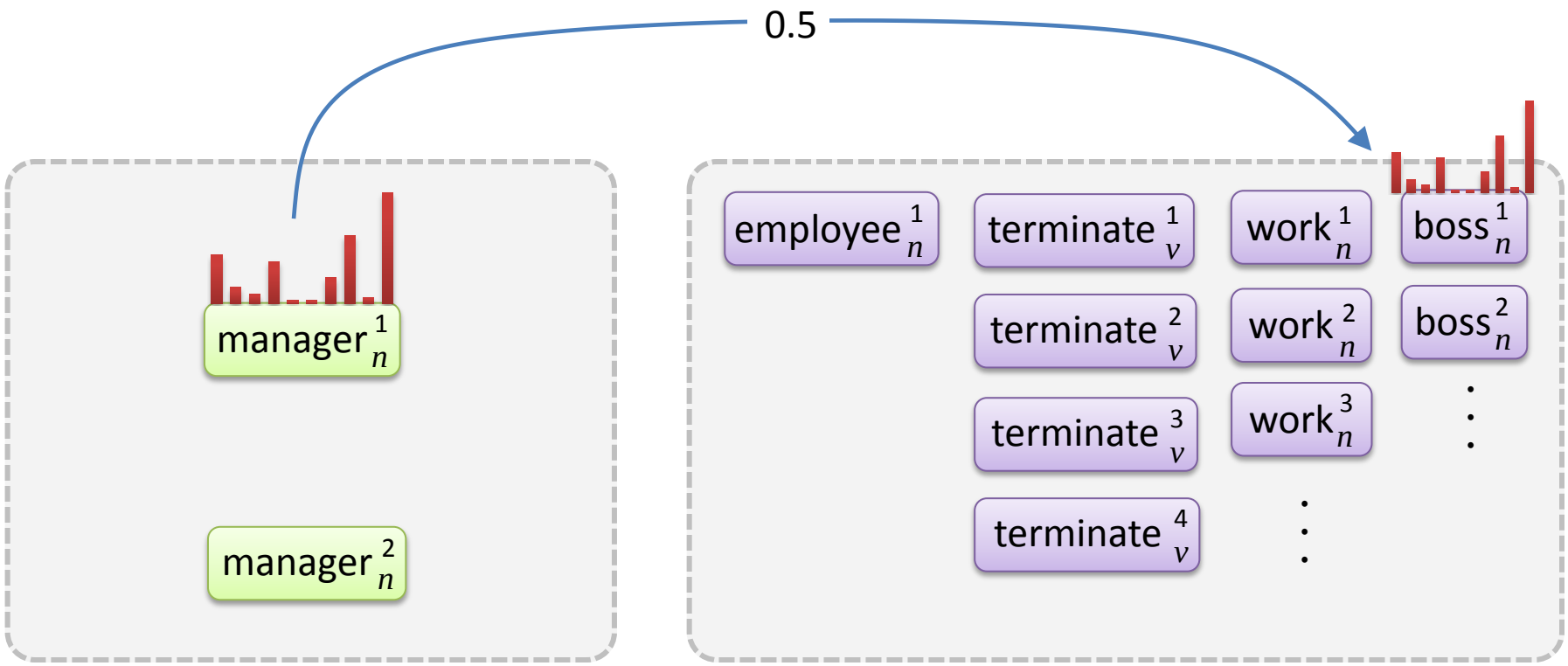
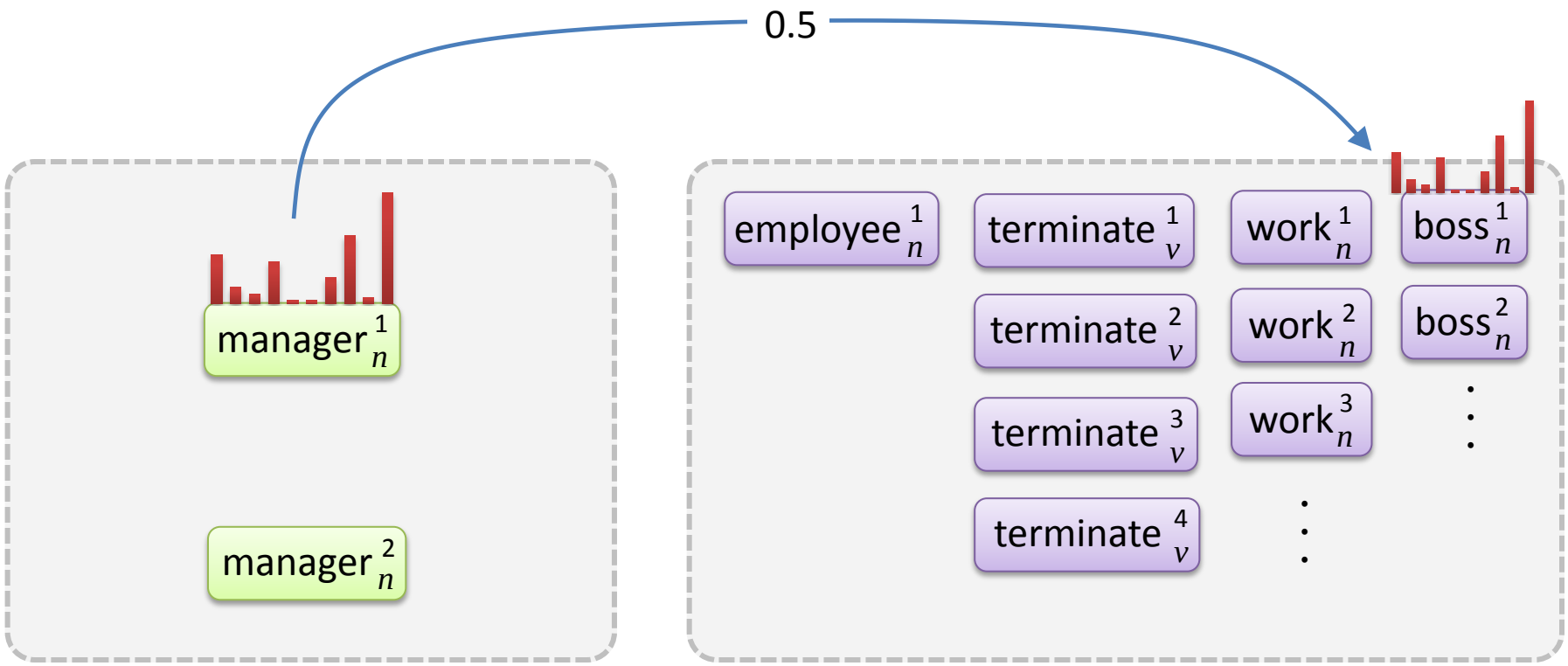


Alignment-based disambiguation



Tversky (1977)
Markman and Gentner (1993)

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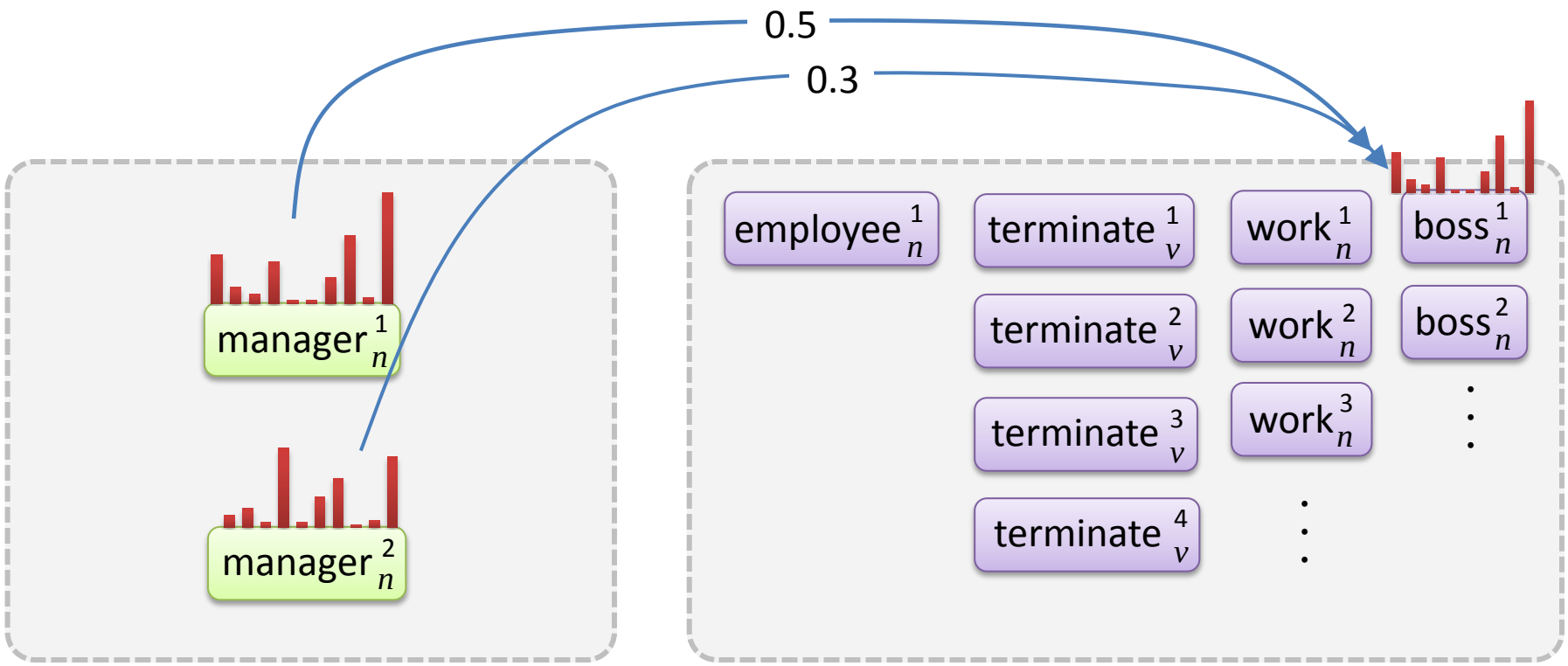

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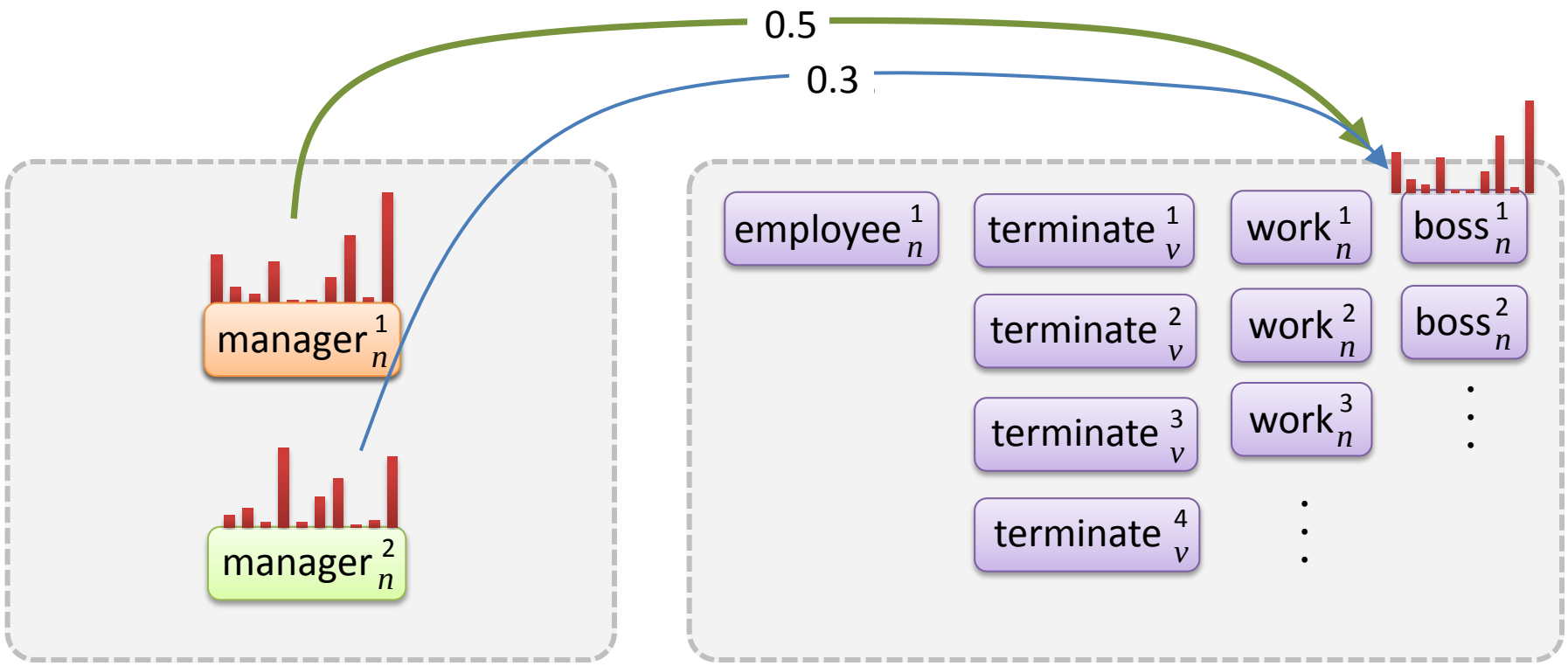

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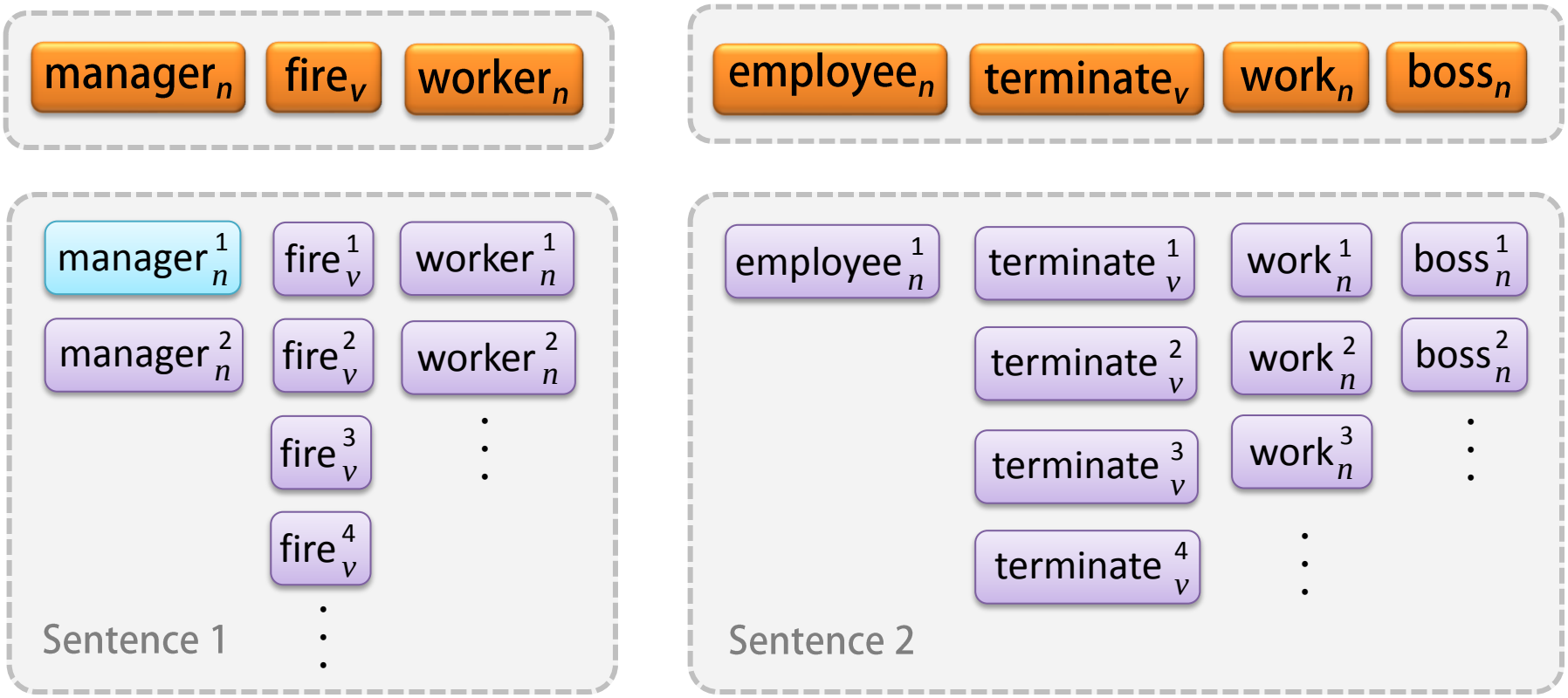
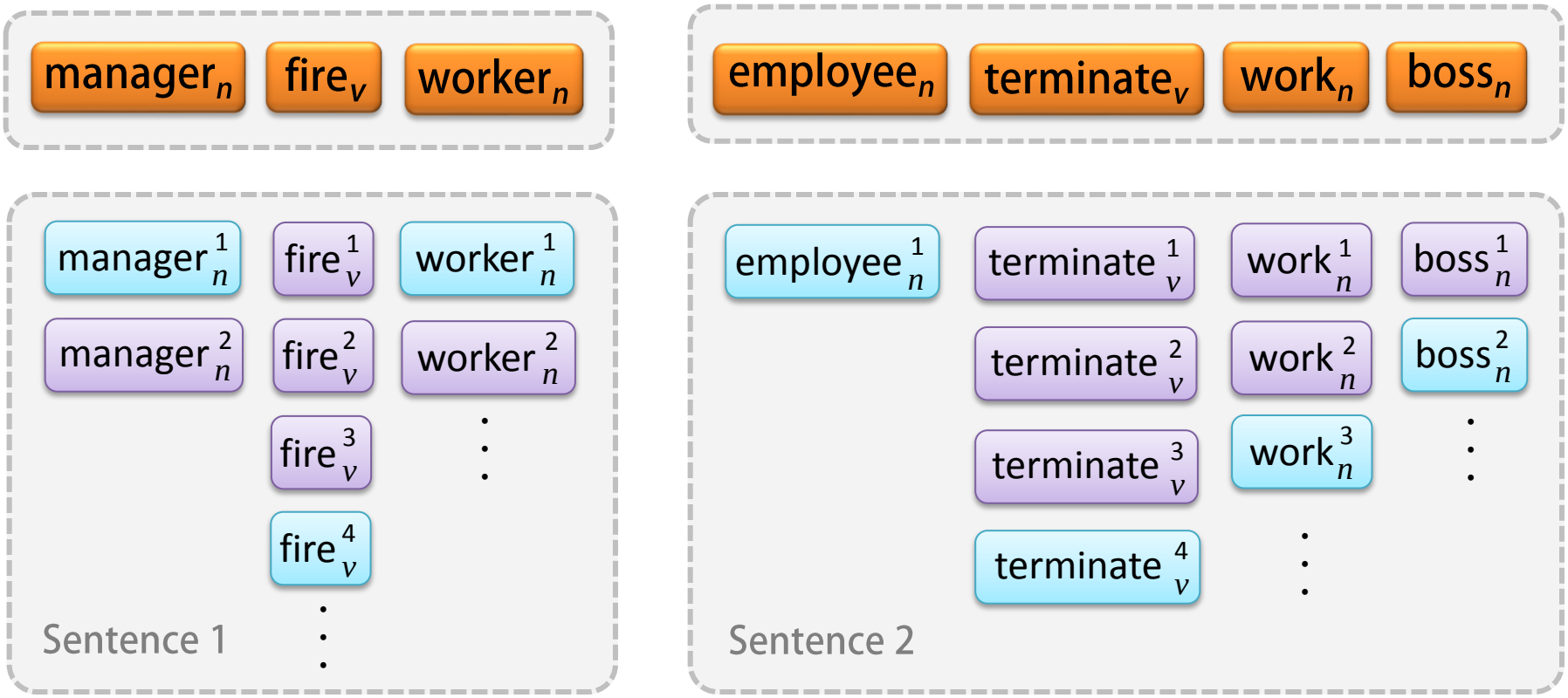


Alignment-based disambiguation

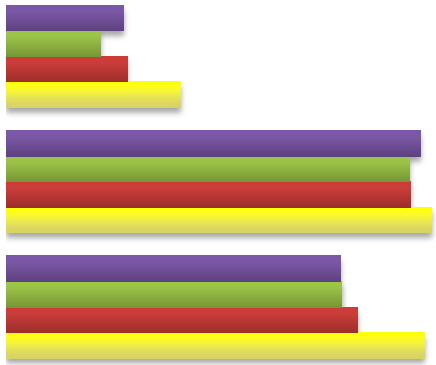


Outline

Introduction

Methodology

Experiments



Experiments

- **Sentence level**
  - Semantic Textual Similarity (SemEval-2012)

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- **Sense level**
  - Coarsening WordNet sense inventory

Experiment 1
Similarity at Sentence level

- **Semantic Textual Similarity (STS-12)**
  - 5 datasets
  - Three evaluation measures
    - ALL, ALLnrm, and Mean

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    - ALL, ALLnrm, and Mean
- **Top-ranking systems**
  - UKP2 (Bär et al., 2012)
  - TLSim and TLSyn (Šarić et al., 2012)

Experiment 1
Similarity at Sentence level

Features

- Main features
  - Cosine
  - Weighted Overlap
  - Top-k Jaccard

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Similarity at Sentence level

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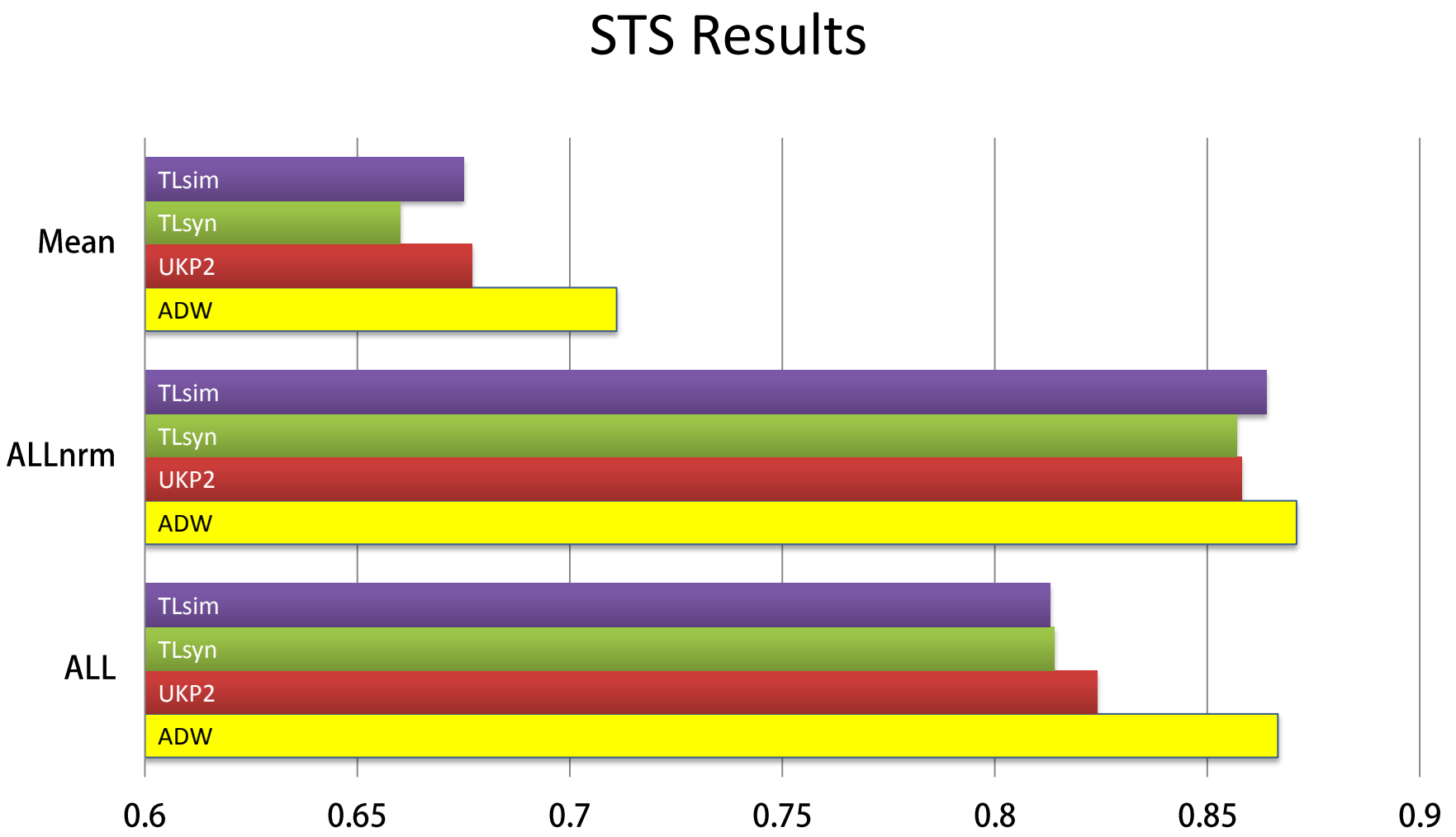
- Main features
  - Cosine
  - Weighted Overlap
  - Top-k Jaccard

- String-based features
  - Longest common substring
  - Longest common subsequence
  - Greedy string tiling
  - Character/word n-grams

Experiment 1
Similarity at Sentence level



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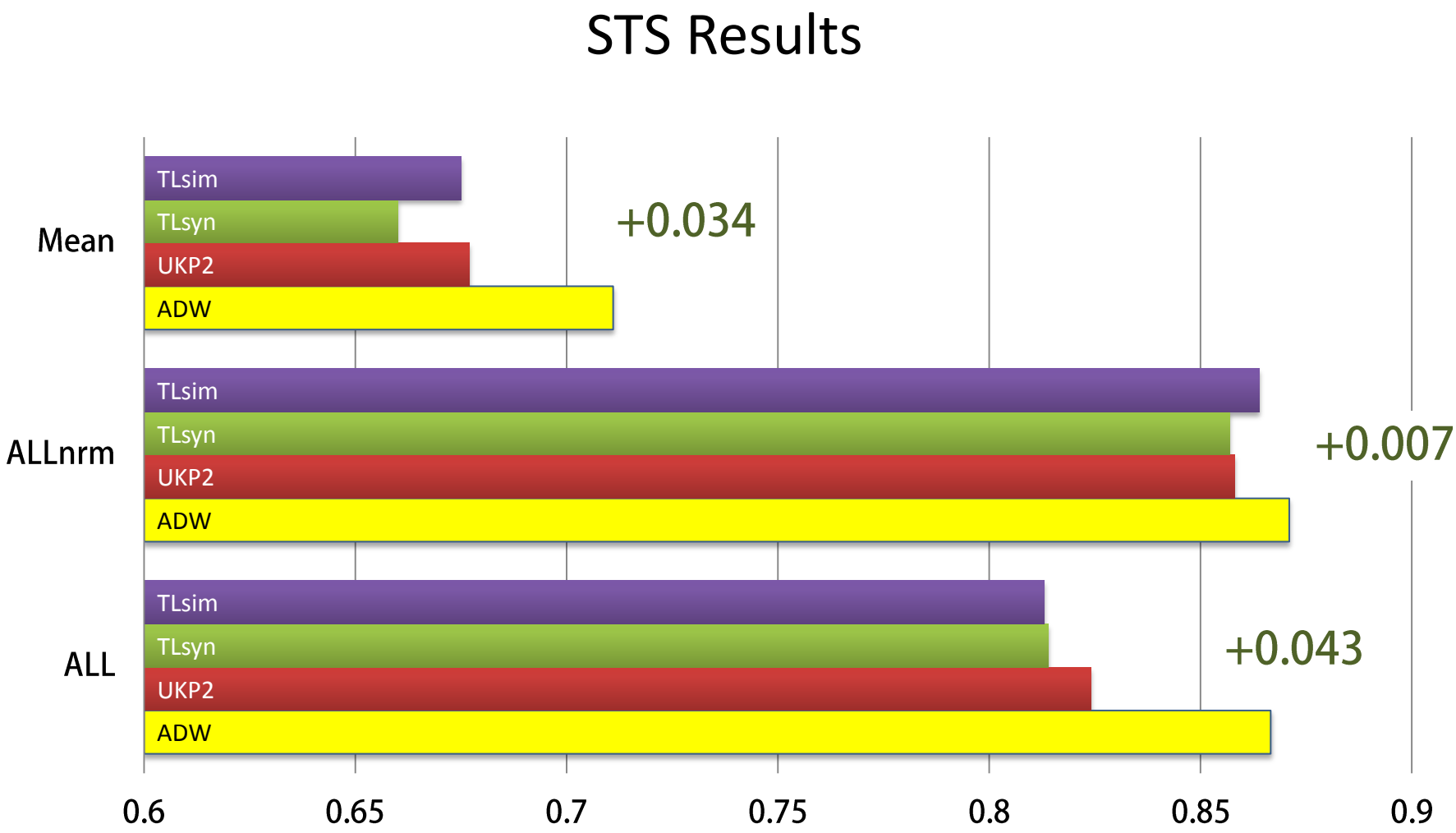

Experiments

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Experiment 2
Similarity at Word Level

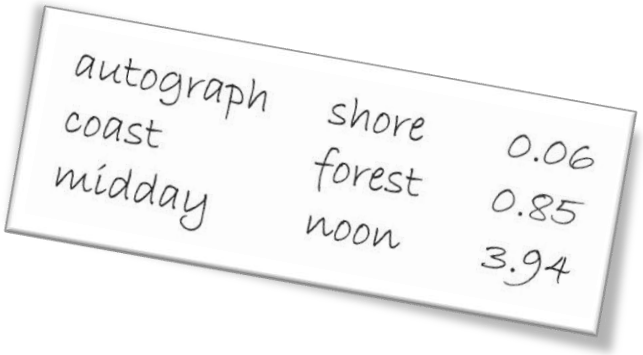
Experiment 2
Similarity at Word Level

Synonymy recognition

Experiment 2
Similarity at Word Level

Synonymy recognition

Correlating word similarity judgments

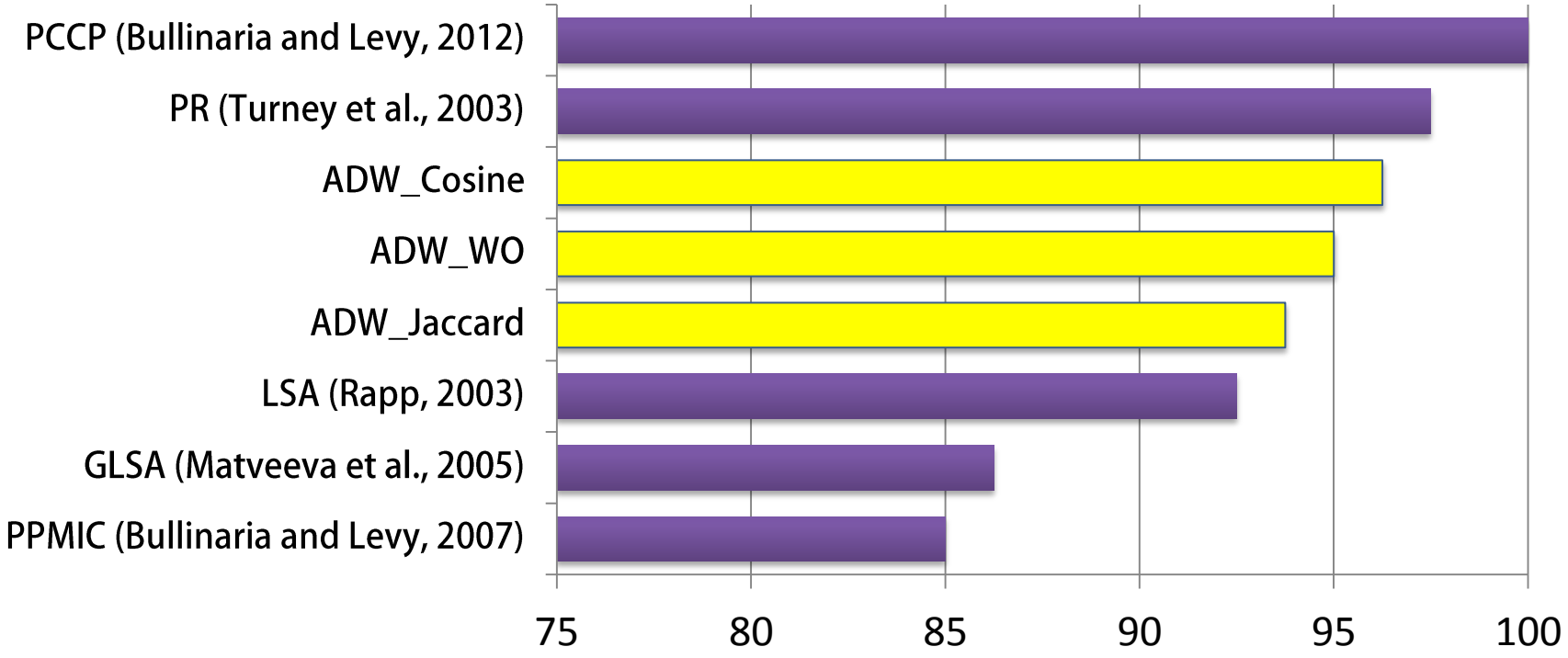


Similarity at Word Level
Synonym Recognition

- TOEFL dataset (Landauer and Dumais, 1997)
  - 80 multiple choice questions
  - Human test takers: 64.5% only

Similarity at Word Level
Synonym Recognition

Accuracy on TOEFL dataset

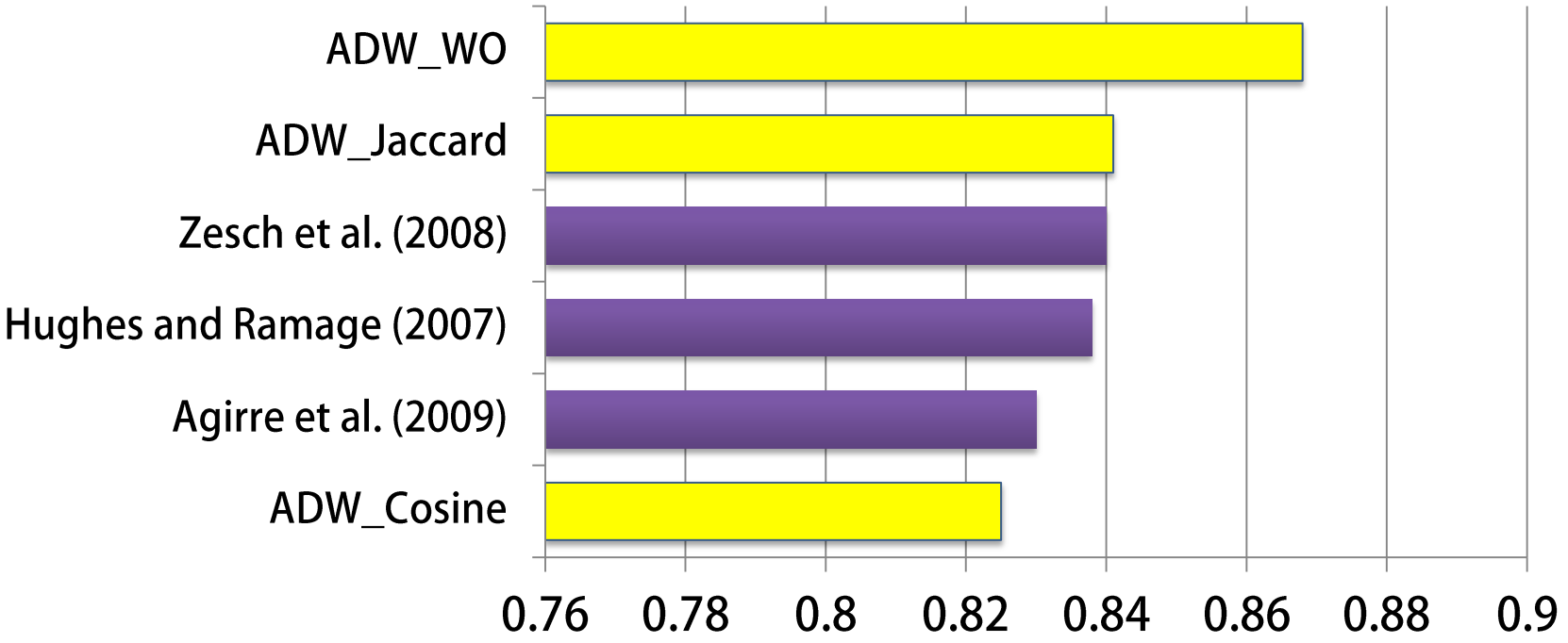


Similarity at Word Level
Judgment Correlation

- Dataset: RG-65 (Rubenstein and Goodenough, 1965)
  - 65 word pairs
    - judged by 51 human subjects
  - Scale of 0 → 4

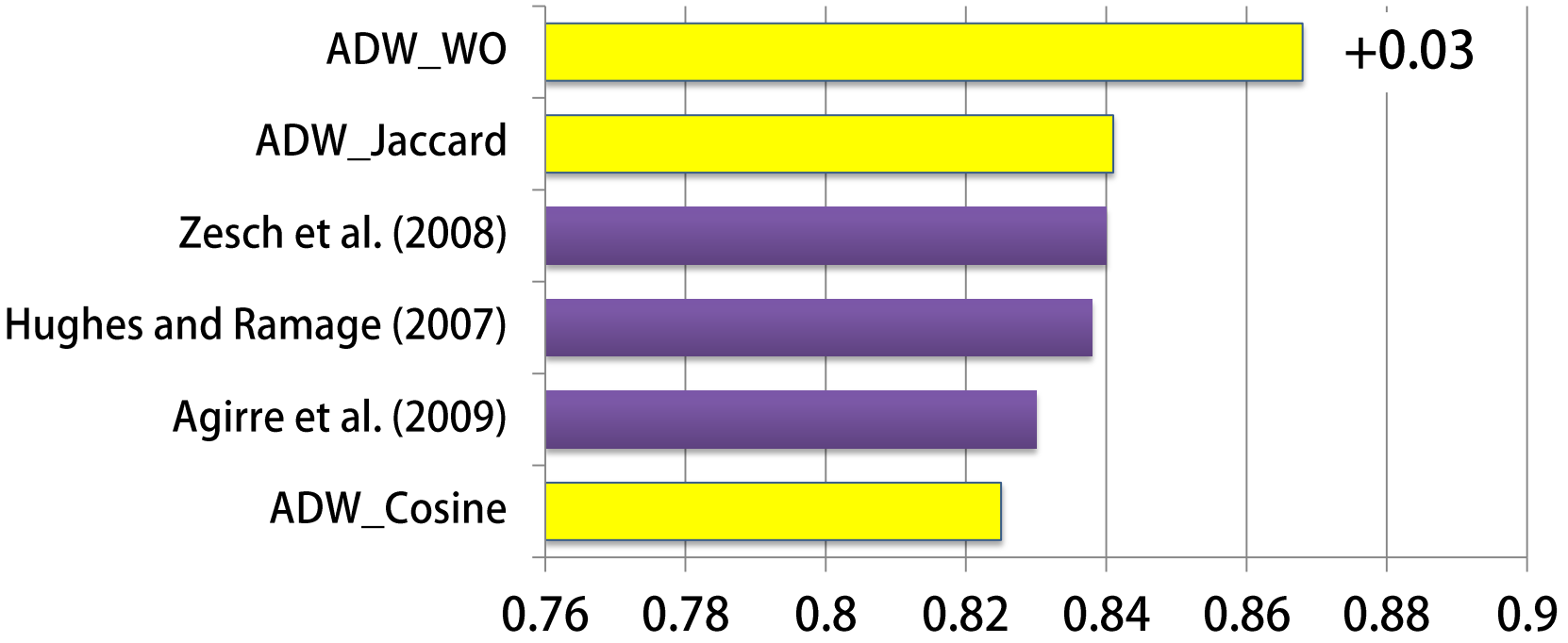
Similarity at Word Level
Judgment Correlation

Spearman correlation, RG-65 dataset



Similarity at Word Level
Judgment Correlation

Spearman correlation, RG-65 dataset



Experiments

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Experiment 3
Similarity at Sense Level

- Coarse-graining WordNet

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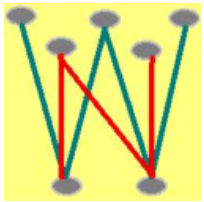
Navigli (2006)



Experiment 3
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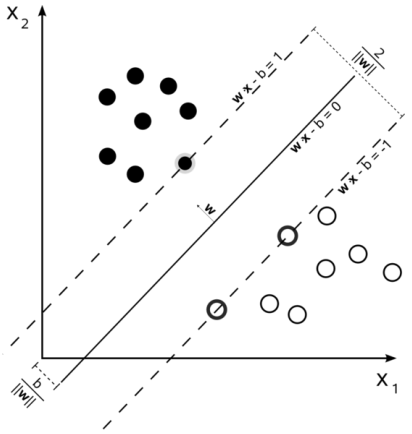
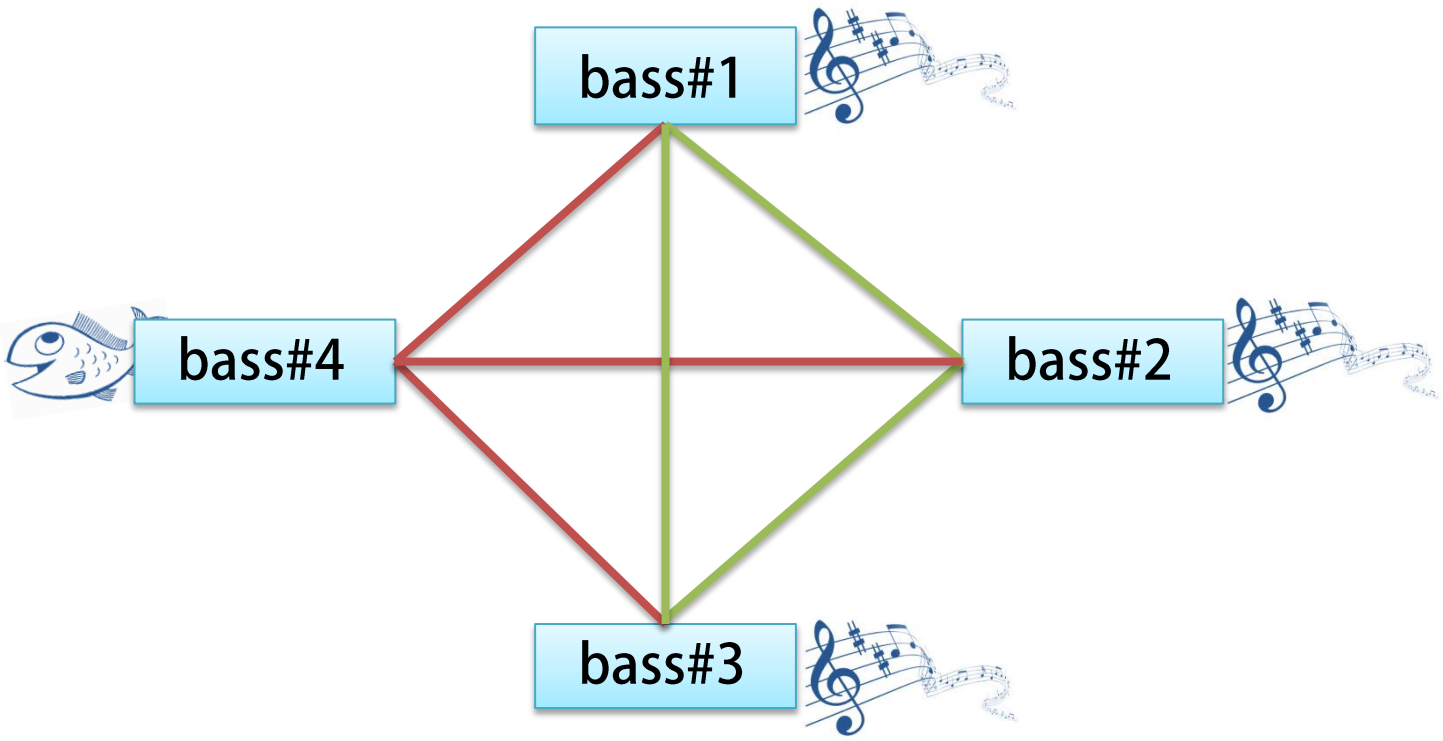
Navigli (2006)

Snow et al. (2007)



Experiment 3
Similarity at Sense Level

- Binary classification: Merged or not-merged



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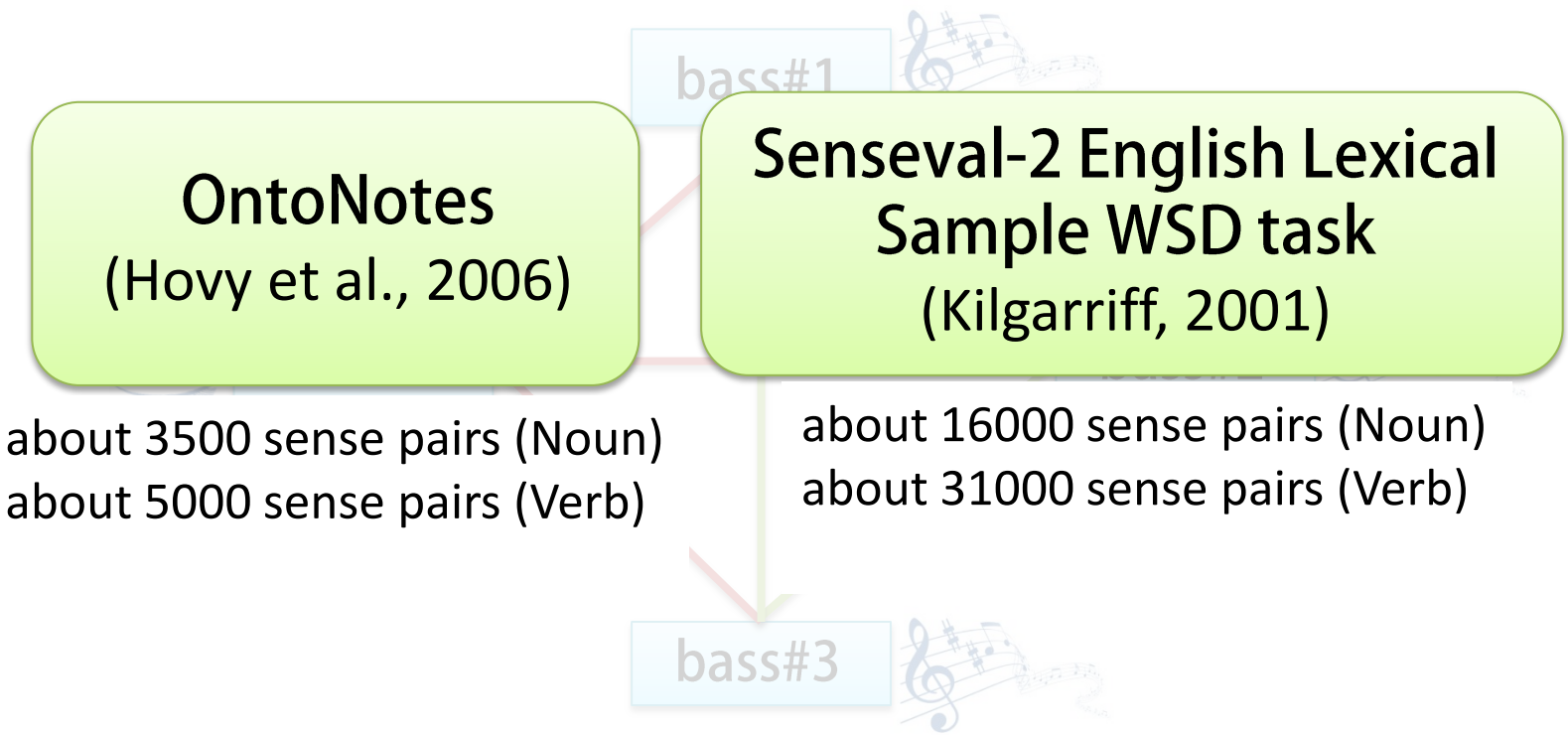


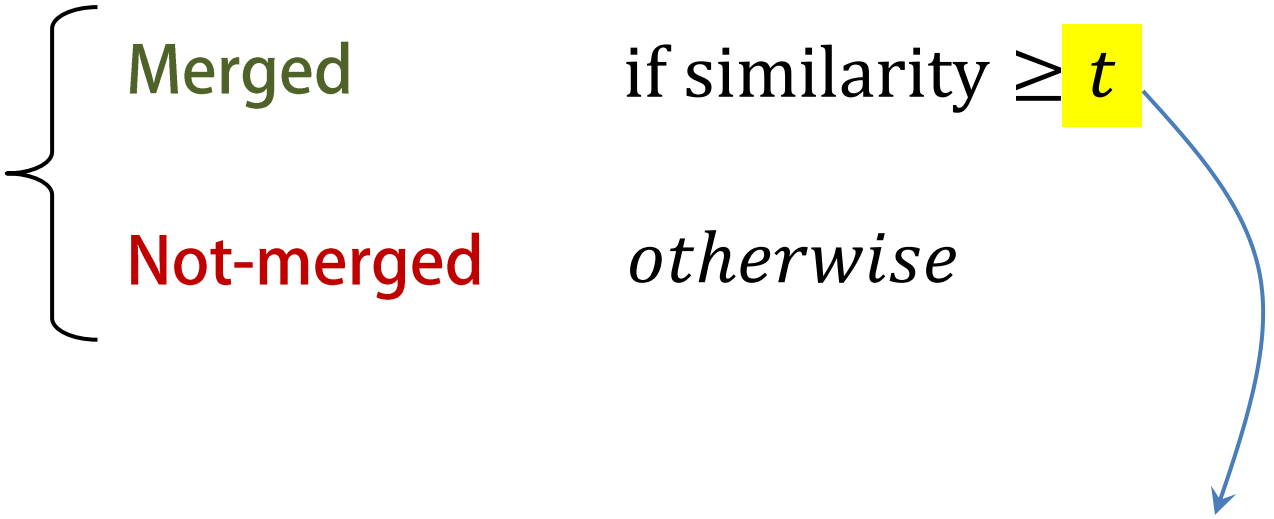
Experiment 3
Similarity at Sense Level

- Binary classification: Merge or not-merged

$$\begin{cases} \text{Merged} & \text{if similarity} \geq t \\ \text{Not-merged} & otherwise \end{cases}$$

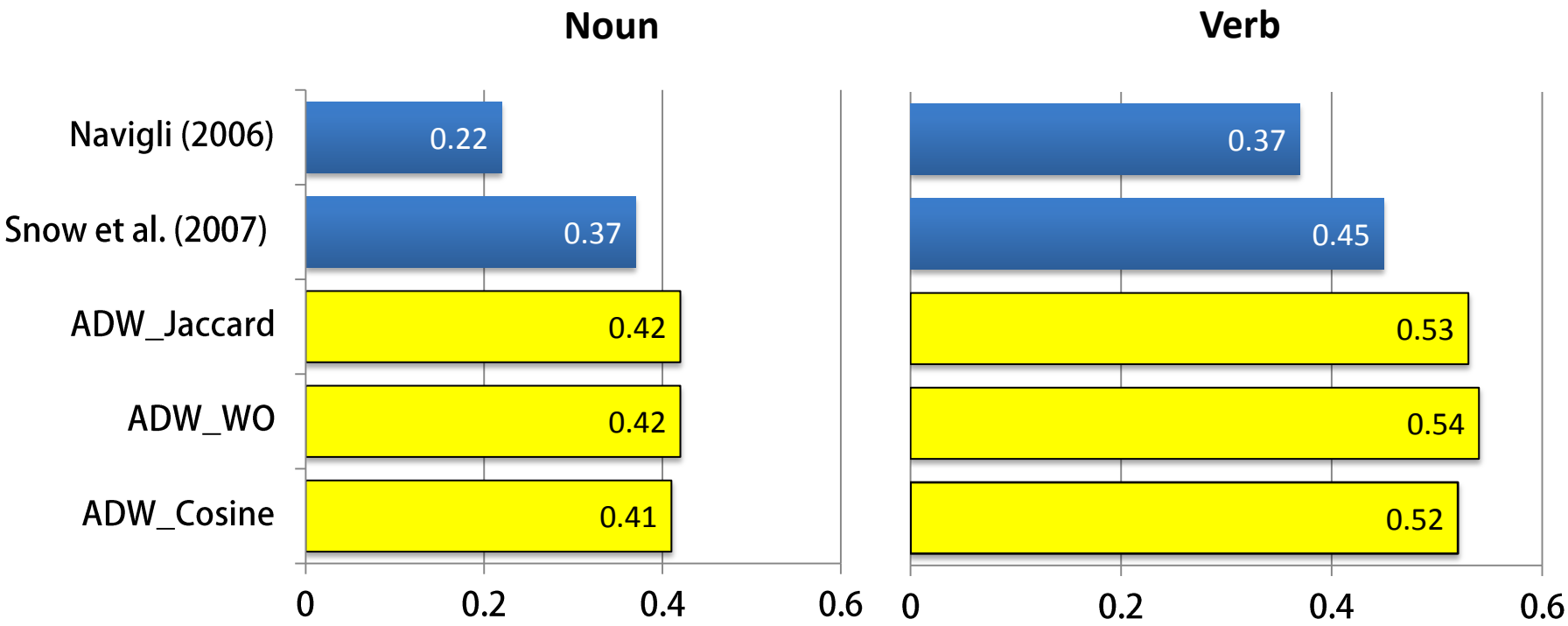
Experiment 3
Similarity at Sense Level

- Binary classification: Merge or not-merged



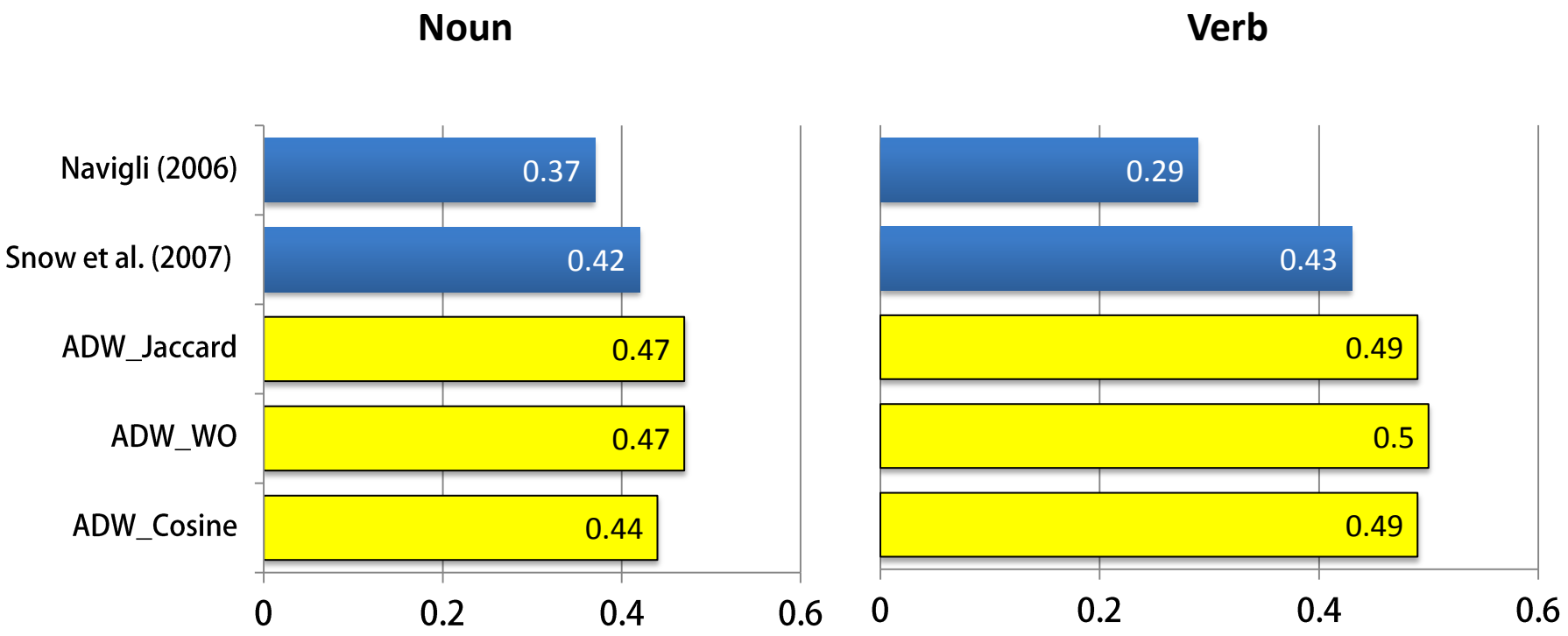
Experiment 3
Similarity at Sense Level

F-score on OntoNotes dataset



Experiment 3
Similarity at Sense Level

F-score on Senseval-2 dataset



Conclusions

- A unified approach for computing semantic similarity for any pair of lexical items

- Experiments with SOA performance
  - Sense level (sense coarsening)
  - Word level (synonymy recognition and judgment)
  - Sentence level (Semantic Textual Similarity)

Future Direction

- Larger sense inventories (e.g., BabelNet)

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- Cross-level semantic similarity

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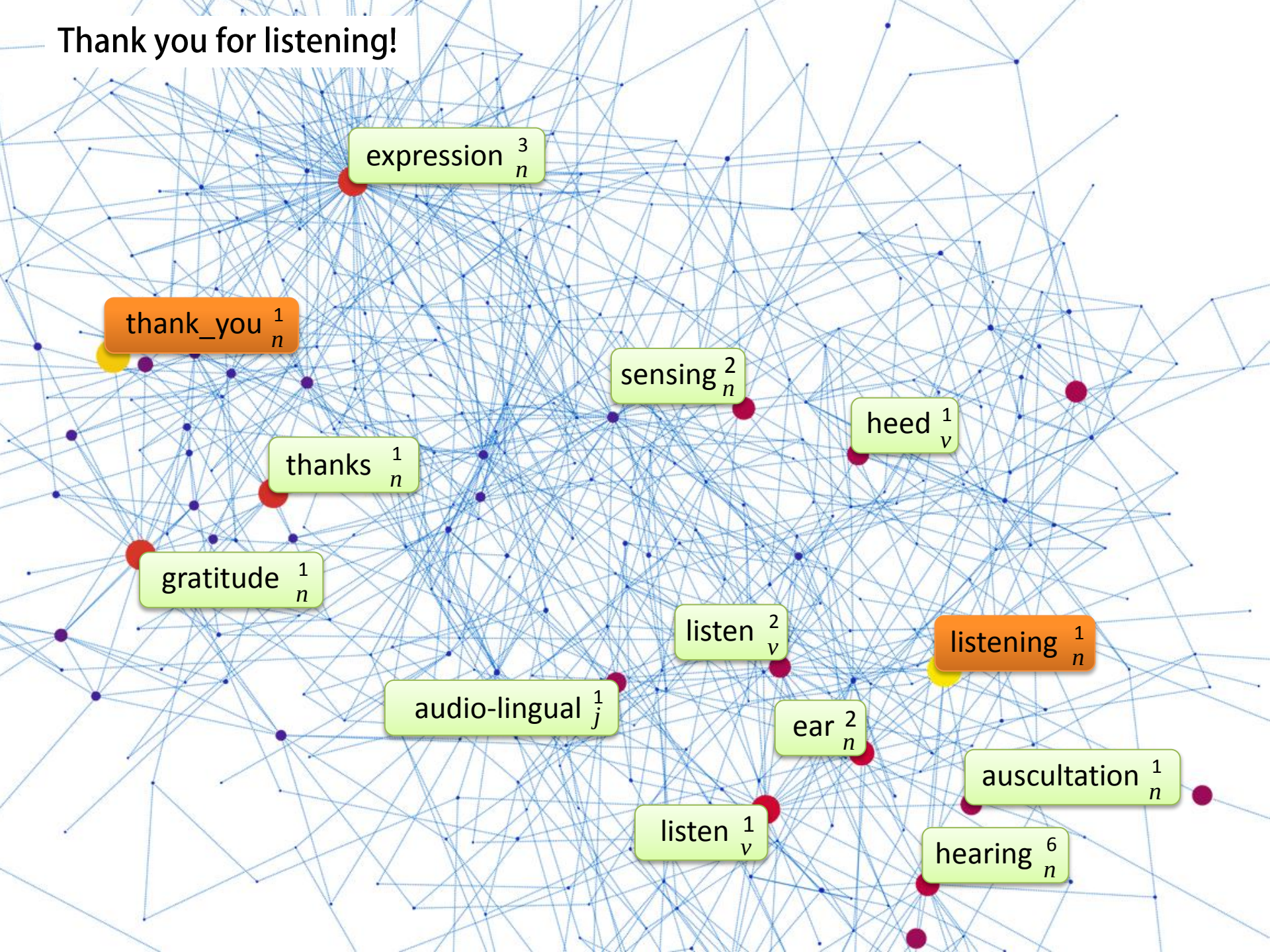
- Cross-level semantic similarity

  Create datasets for cross-level similarity
  - Future Semeval task?

Thank you for listening!



fanciful	familiar	apparent	imaginative	logical
verbal	oral	overt	fitting	verbose
resolved	settled	forgotten	publicized	examined
percentage	volume	sample	proportion	profit
figure	list	solve	divide	express
highlight	alter	imitate	accentuate	restore

STS-13

System	HDL	OnWN	FNWN	SMT	mean	Rank
Dkpro	**0.735**	**0.735**	0.341	0.323	0.565	6
TakeLab	0.486	0.633	0.269	0.279	0.434	58
ADW (STS-13)	0.621	0.511	**0.446**	**0.384**	0.502	34
ADW (All) GP	0.717	0.697	0.411	0.272	0.538	20
ADW (All) LR	0.667	0.735	0.409	0.374	0.565	6