

Automatic Construction and Evaluation of a Large Semantically Enriched Wikipedia

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SAPIENZA
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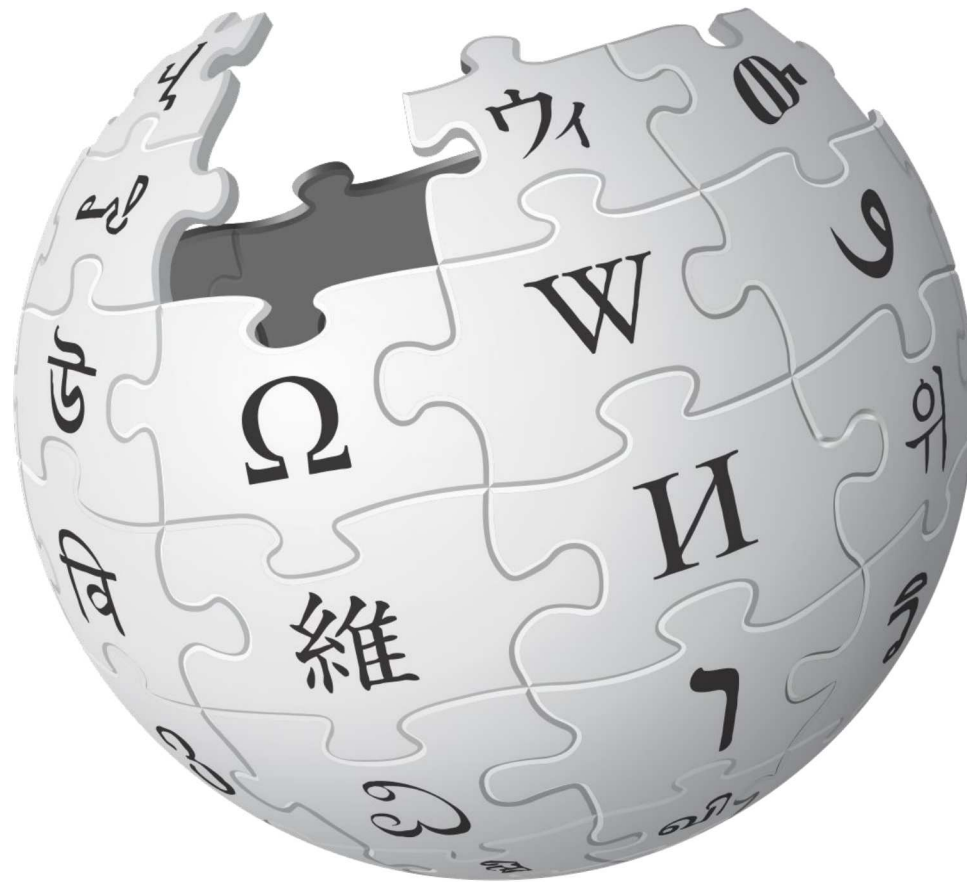


IJCAI-16

13/07/2016



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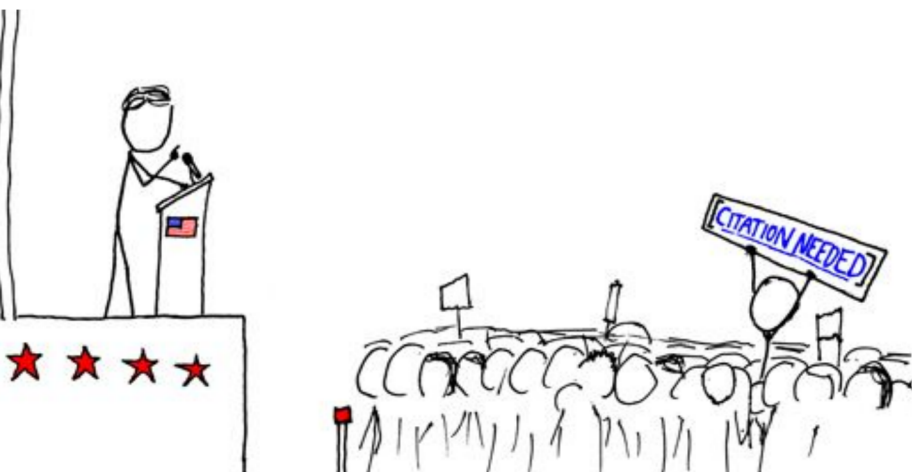
Problem: Wikipedia is designed for humans!

Only a fraction of linkable mentions is in fact **hyperlinked**:

- **580M** noun tokens, only **116M** covered (~19%) *

Partly due to the Wikipedia style guidelines:

- Link each concept **at most once** within a page
- Link only when **relevant** and **helpful** in the context



Lorenzo de' Medici

From Wikipedia, the free encyclopedia

For other uses, see [Lorenzo de' Medici \(disambiguation\)](#).

Lorenzo de' Medici (Italian pronunciation: [loˈrentso de ˈmɛːditʃi], 1 January 1449 – 9 April 1492) was an Italian statesman and *de facto* ruler of the [Florentine Republic](#), who was one of the most powerful and enthusiastic patrons of the [Renaissance](#).^{[1][2][3]} Also known as **Lorenzo the Magnificent** (*Lorenzo il Magnifico* [loˈrentso il maɲˈniːfiko]) by contemporary Florentines, he was a [magnate](#), diplomat, politician and patron of scholars, artists and poets. He is well known for his contribution to the art world by sponsoring artists such as [Botticelli](#) and [Michelangelo](#). His life coincided with the mature phase of Italian Renaissance and his death coincided with the end of the Golden Age of Florence.^[4] The fragile peace that he helped maintain among the various [Italian states](#) collapsed with his death. He is buried in the [Medici Chapel](#) in [Florence](#).

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Youth

Lorenzo's grandfather, [Cosimo de' Medici](#), was the first member of the [Medici family](#) to combine running the [Medici Bank](#) with leading the Republic of Florence. Cosimo was one of the wealthiest men in Europe and spent a very large portion of his fortune in government and philanthropy. He was a patron of the arts and funded public works.^[5] Lorenzo's father, [Piero di Cosimo de' Medici](#), was equally at the centre of Florentine life, chiefly as an art patron and collector, while Lorenzo's uncle, [Giovanni di Cosimo de' Medici](#), took care of the family's business interests. Lorenzo's mother, [Lucrezia Tornabuoni](#), was a writer of [sonnets](#) and a friend to poets and philosophers of the Medici Academy. She became her son's advisor after the deaths of his father and uncle.^[5]

Lorenzo, considered the brightest of the five children of Piero and Lucrezia, was tutored by a diplomat and bishop, [Gentile de' Becchi](#), and the humanist philosopher [Marsilio Ficino](#),^[6] and he was trained in Greek by [John Argyropoulos](#).^[7] With his brother [Giuliano](#), he participated in [jousting](#), [hawking](#), hunting, and horse breeding for the [Palio](#), a horse race in [Siena](#). At 19 he won first prize in a tournament of the sons of the leading families of Florence against the best men at arms of Italy; [Niccolò Machiavelli](#) would write that he did so "not by way of favour, but by his own valour and skill in arms".^[8] His own horse was named Morello di Vento.^[9]

Lorenzo de' Medici



Portrait by Verrocchio

Lord of Florence

Reign2 December 1469 – 9 April 1492

Predecessor[Piero the Gouty](#)

Successor[Piero the Unfortunate](#)

Spouse(s)[Clarice Orsini](#)

Issue

- [Lucrezia de' Medici](#)
- [Piero de' Medici](#)
- [Maddalena de' Medici](#)
- [Contessina Beatrice de' Medici](#)
- [Giovanni de' Medici](#), [Pope Leo X](#)
- [Luisa de' Medici](#)
- [Contessina de' Medici](#)
- [Giuliano de' Medici](#), [Duke of Nemours](#)

Full name

Lorenzo di Piero de' Medici

Lorenzo de' Medici

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potentially linkable mentions!



Portrait by Verrocchio

Lorenzo de' Medici

Lord of Florence
Reign 2 December 1469 – 9 April 1492
Predecessor Piero the Gouty
Successor Piero the Unfortunate
Spouse(s) Clarice Orsini
<div><div>Issue</div><div><div><div>Lucrezia de' Medici</div><div>Piero de' Medici</div><div>Maddalena de' Medici</div><div>Contessina Beatrice de' Medici</div><div>Giovanni de' Medici, Pope Leo X</div><div>Luisa de' Medici</div><div>Contessina de' Medici</div><div>Giuliano de' Medici, Duke of Nemours</div></div></div></div>
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A Semantically Enriched Wikipedia (SEW)



Our goal:

- **Augment** Wikipedia with as much **semantic information** as possible

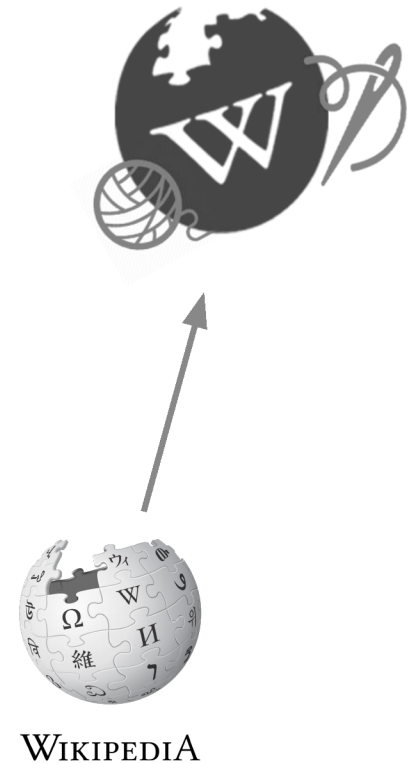
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Our goal:

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How?

- The existing Wikipedia **hyperlink structure**:
 - Page-to-page direct connections (**Wikilinks**)
 - Connections between pages and **Wikipedia categories**



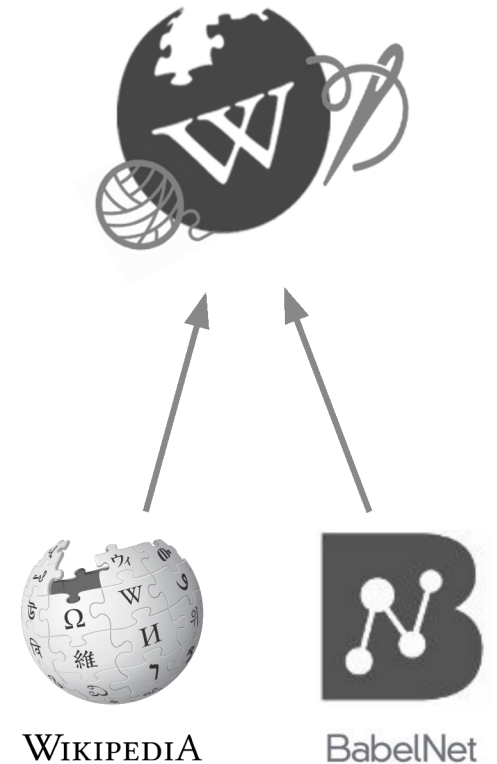
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How?

- The existing Wikipedia **hyperlink structure**:
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 - Connections between pages and **Wikipedia categories**
- The multilingual sense inventory of **BabelNet**:
 - **merger** of many different resources (including WordNet and Wikipedia itself)
 - **14M** entries and **380M** semantic connections



A Semantically Enriched Wikipedia (SEW)



The algorithm:

For each Wikipedia page **p** in **W**



Preprocessing



Hyperlink Propagation



Refinement

A Semantically Enriched Wikipedia (SEW)



The algorithm:

For each Wikipedia page p in W



Preprocessing



Hyperlink Propagation



Refinement

- Tokenization
- Part-of-speech tagging
- Lemmatization
- Filtering of uninformative pages

A Semantically Enriched Wikipedia (SEW)



The algorithm:

For each Wikipedia page p in W



Preprocessing



Hyperlink Propagation

Cascade of **propagation heuristics**, which

- collect a list S^p of hyperlinks to be propagated across p
- scan the text of p to match any potential lexicalization
(**one-sense-per-page** assumption)



Refinement

A Semantically Enriched Wikipedia (SEW)



The algorithm:

For each Wikipedia page p in W



Preprocessing



Hyperlink Propagation



Refinement

Conservative policy to remove
duplicates and **overlapping**
mentions

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Hyperlink Propagation - A bird's eye view

A Semantically Enriched Wikipedia (SEW)

Hyperlink Propagation - A bird's eye view

Intra-page heuristics:

Propagate links that occur as mentions within **p**



- Surface Mention Propagation
- Lemmatized Mention Propagation
- Person Mention Propagation

A Semantically Enriched Wikipedia (SEW)

Hyperlink Propagation - A bird's eye view

Intra-page heuristics:

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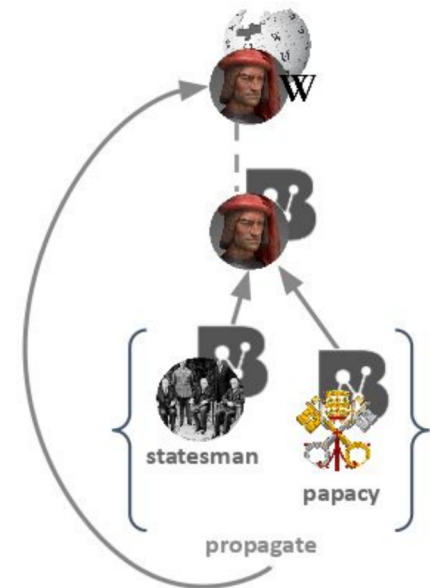


- **Surface Mention Propagation**
- **Lemmatized Mention Propagation**
- **Person Mention Propagation**

Inter-page heuristics:

Exploit the connection of **p** with other pages or categories

- **Wikipedia Inlink Propagation**
- **BabelNet Inlink Propagation**
- **Category Propagation**
- **Monosemous Content Word**



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Lord of Florence

Reign

2 December 1469 – 9 April 1492

Predecessor

Piero the Gouty

Successor

Piero the Unfortunate

Spouse(s)

Clarice Orsini

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Lucrezia de' Medici

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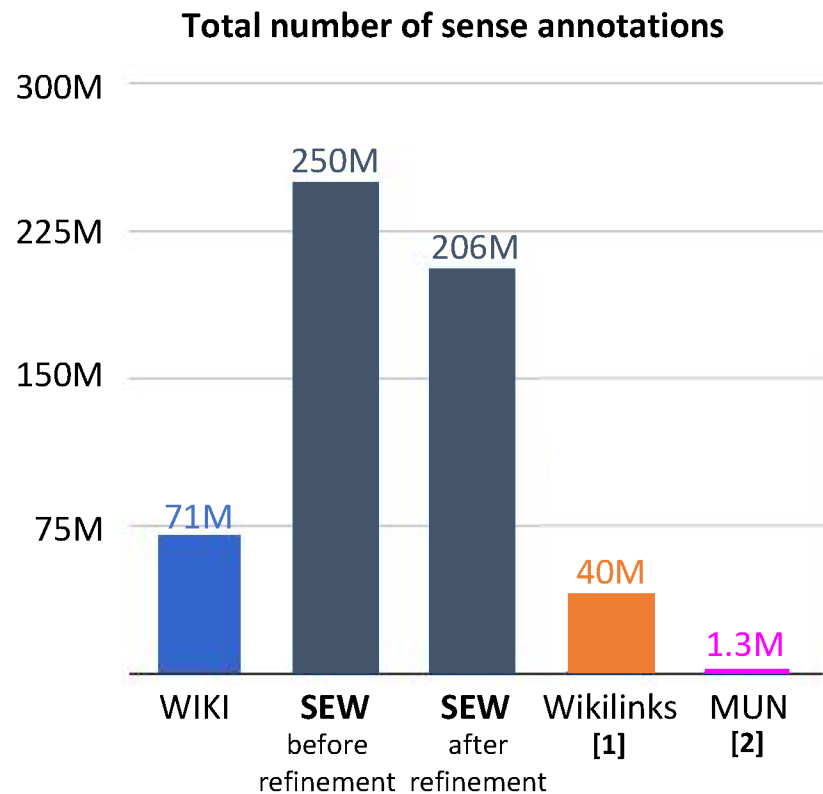


Statistics - Another bird's eye view

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Statistics - Another bird's eye view



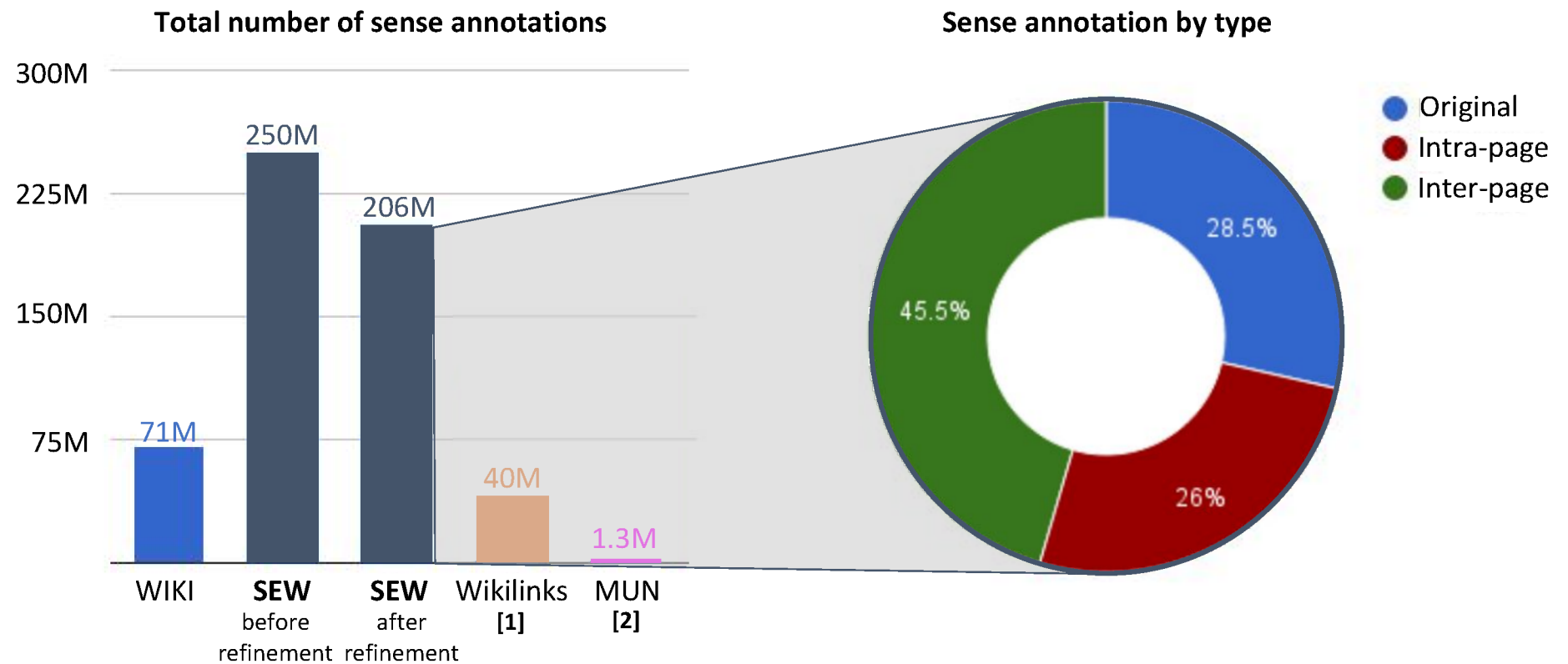
[1] S. Singh, A. Subramanya, F. Pereira, and A. McCallum. *Wikilinks: A large-scale cross-document coreference corpus labeled via links to Wikipedia*. Technical Report UM-CS-2012-015.

[2] K. Taghipour and H. Ng. *One million sense-tagged instances for word sense disambiguation and induction*. CoNLL, 2015.

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Statistics - Another bird's eye view



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Experiments

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Experiments

- **Intrinsic Evaluation - Annotation Quality**

We compared our sense annotations against those discovered by **3W** (Noraset et al. 2014), a Wikipedia-specific system designed to add automatically high-precision hyperlinks



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Experiments

- **Intrinsic Evaluation - Annotation Quality**

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- **Extrinsic Evaluation - Entity Linking and Semantic Similarity**

We used **SEW** both as **training set** for Entity Linking, and as **semantic network** to develop Wikipedia-based vector representations for Semantic Similarity

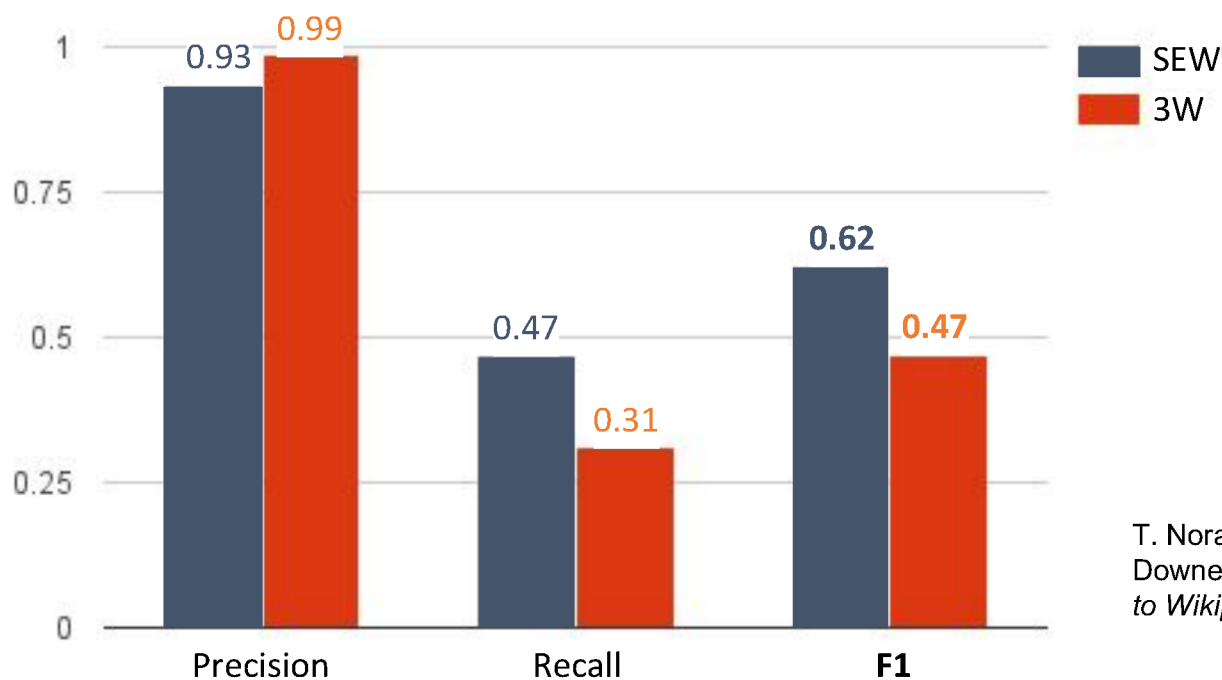


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Intrinsic Evaluation

Hand-labeled evaluation set of **2000** Wikipedia pages (Noraset et al. 2014):



T. Noraset, C. Bhagavatula, and D. Downey. *Adding high-precision links to Wikipedia*. EMNLP, 2014.

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Extrinsic Evaluation #1 - Entity Linking

- **Benchmark system:**

IMS (Zhong and Ng 2010), a state-of-the-art supervised system for Word Sense Disambiguation in English based on SVMs

- **IMS + SEW** IMS trained on SEW
- **IMS + HL** IMS trained only on the original hyperlinks (baseline #1)
- **MFS** Most Frequent Sense provided by BabelNet (baseline #2)

- **Datasets:**

- **SemEval 2013, task 12**
- **SemEval 2015, task 13**
- **MSNBC**
- **AIDA-CoNLL**

A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #1 - Entity Linking

	SemEval-2013	SemEval-2015	MSNBC	AIDA-CoNLL
IMS+SEW	0.810	0.882	0.789	0.726
IMS+HL	0.775	0.758	0.695	0.712
MFS	0.802	0.857	0.620	0.535
UMCC-DLSI	0.548	-	-	-
Babelfy	0.874	-	-	0.821
DFKI	-	0.889	-	-
SUDOKU	-	0.870	-	-
Wikifier	-	-	0.812	0.724
M&W	-	-	0.685	0.823

A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #2 - Semantic Similarity

A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #2 - Semantic Similarity

We used **SEW** to build Wikipedia-based vector representations for **BabelNet** senses:

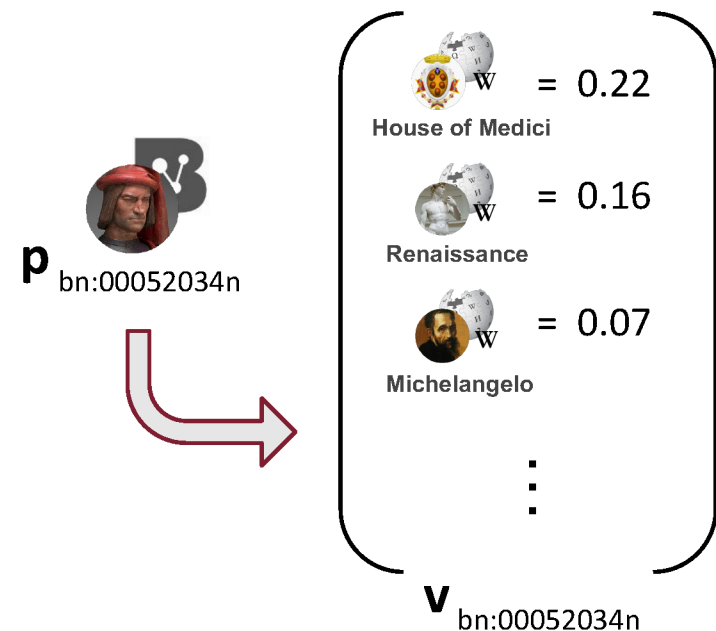
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- **WB-SEW**: associates a vector \mathbf{v} with each sense in BabelNet, defined in the space of Wikipedia pages;



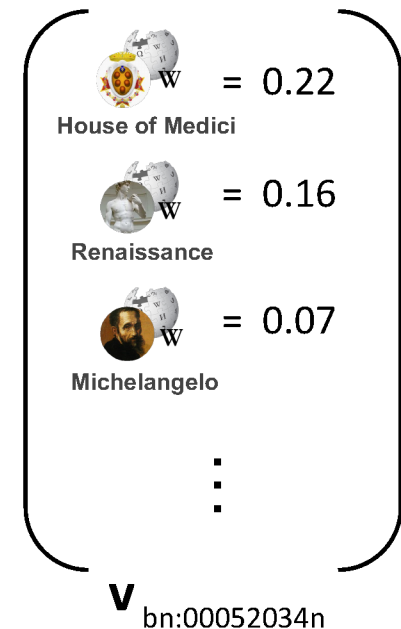
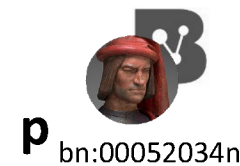
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- **WB-SEW**: associates a vector \mathbf{v} with each sense in BabelNet, defined in the space of Wikipedia pages;
- Each component of \mathbf{v} is an estimated frequency based on either **raw count (RC)** or **lexical specificity (LS)**



A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #2 - Semantic Similarity

Pearson (r) and Spearman (ρ) correlation in the word similarity task:

		WB-SEW		WB-HL	
		RC	LS	RC	LS
WS-Sim	r	0.65	0.64	0.58	0.58
	ρ	0.69	0.70	0.59	0.61
SimLex-666	r	0.38	0.38	0.32	0.32
	ρ	0.40	0.41	0.31	0.32

Baseline:
only original
hyperlinks (**HL**)

A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #2 - Semantic Similarity

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SimLex-666	r	0.38	0.38	0.32	0.32
	ρ	0.40	0.41	0.31	0.32

Baseline: only original hyperlinks (HL)

ADW (Pilehvar et al. 2013) on WS-Sim: $r = 0.63$ $\rho = 0.69$

ESA (Gabrilovich and Markovitch, 2007) on WS-Sim: $r = 0.40$ $\rho = 0.47$

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Extrinsic Evaluation #2 - Semantic Similarity (cont.)

A Semantically Enriched Wikipedia (SEW)



Extrinsic Evaluation #2 - Semantic Similarity (cont.)

Pearson (r) and Spearman (ρ) for multilingual word similarity on RG-65:

		WB-SEW		WB-HL		Word2Vec		Polyglot
		RC	LS	RC	LS	original	retro	
EN	r	0.673	0.674	0.619	0.614	-	-	0.51
	ρ	0.608	0.620	0.592	0.592	0.73	0.77	0.55
FR	r	0.808	0.811	0.773	0.778	-	-	0.38
	ρ	0.755	0.759	0.693	0.681	0.47	0.61	0.35
DE	r	0.639	0.639	0.584	0.580	-	-	0.18
	ρ	0.689	0.695	0.637	0.615	0.53	0.60	0.15
ES	r	0.811	0.804	0.757	0.740	-	-	0.51
	ρ	0.815	0.812	0.764	0.759	-	-	0.56

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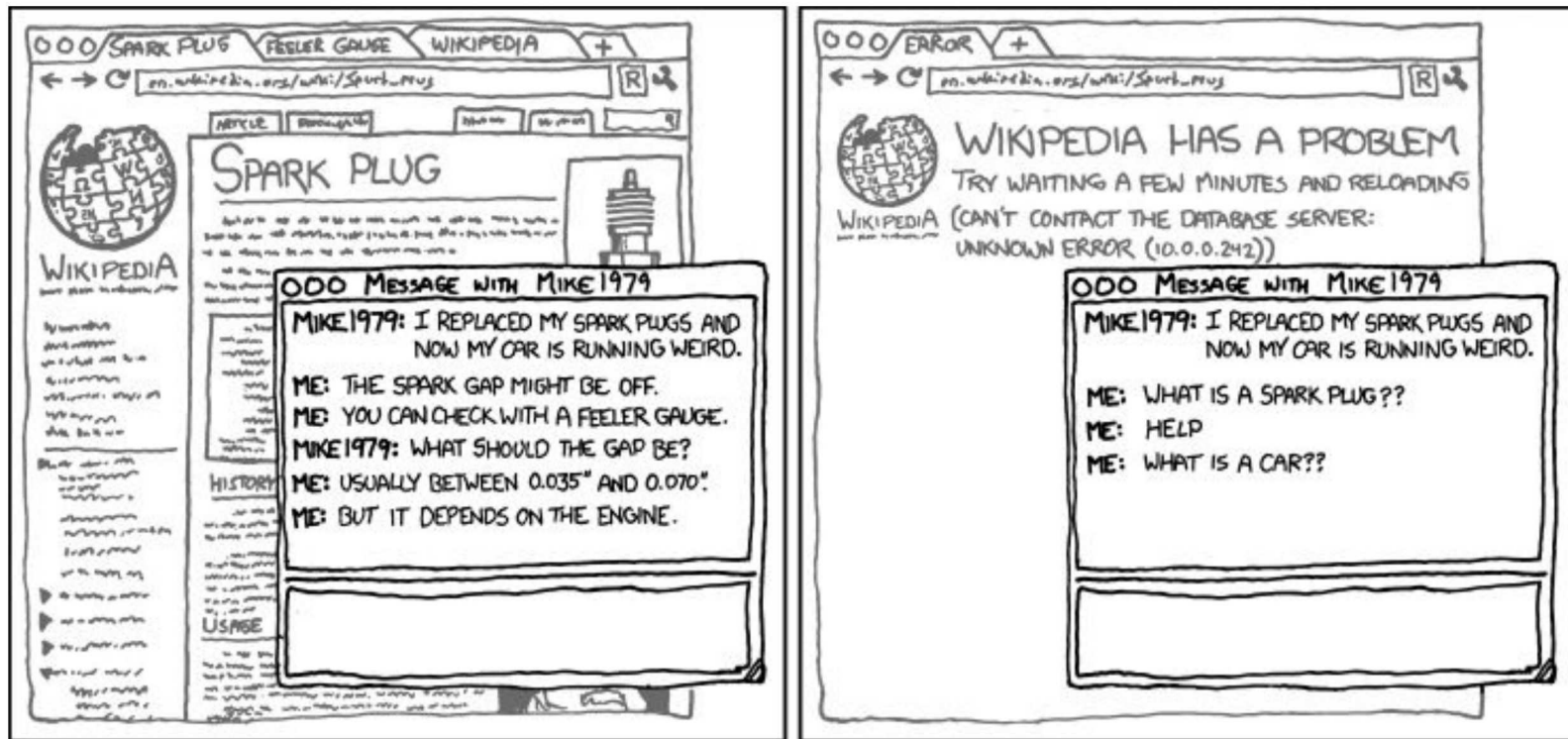


Conclusion

- **SEW**: A Semantically Enriched Wikipedia with more than **200M** annotations of over **4M** different word senses and named entities from the very same, wide-coverage sense inventory of BabelNet
- The cascade of **propagation heuristics** used for SEW is surprisingly simple, fully automatic and self contained (no need for training, validation or tuning any off-the-shelf system)
- Our **extensive evaluation**, beside proving the quality of SEW's annotations, sets important performance baselines for multiple tasks and datasets

Thank you!

(and see you at the poster session this evening)



WHEN WIKIPEDIA HAS A SERVER OUTAGE, MY APPARENT IQ DROPS BY ABOUT 30 POINTS.



<http://lcl.uniroma1.it/sew>