Towards a Fine-Grained Entity Linking Approach

Henry Rosales-Méndez

Supervisors: Aidan Hogan and Barbara Poblete

Dissertation Defense

June 11th, 2021

Outline

- Introduction
- Problem
- Hypothesis
- Consensus about Entity Linking
- Multilingualism
- Fine-Grained Entity Linking
- Fine-Grained Entity Linking Systems
- Conclusions

Example

Joseph Walter “Joe” Jackson, was a steelworker at U.S. Steel. In an interview with Martin Bashir for the 2003 documentary Living with Michael Jackson, Jackson recalled that Joe often sat in a chair with a belt in his hand as he and his siblings rehearsed.

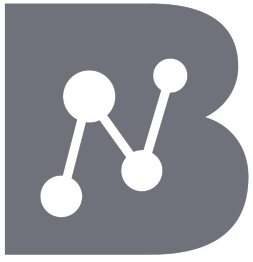
Example - Entity Recognition

Joseph Walter "Joe" Jackson, was a steelworker at U.S. Steel. In an interview with Martin Bashir for the 2003 documentary Living with Michael Jackson, Jackson recalled that Joe often sat in a chair with a belt in his hand as he and his siblings rehearsed.

Example - Entity Disambiguation

Joseph Walter "Joe" Jackson, was a steelworker at U.S. Steel. In an interview with Martin Bashir for the 2003 documentary Living with Michael Jackson, Jackson recalled that Joe often sat in a chair with a belt in his hand as he and his siblings rehearsed.

Knowledge Bases



BabelNet

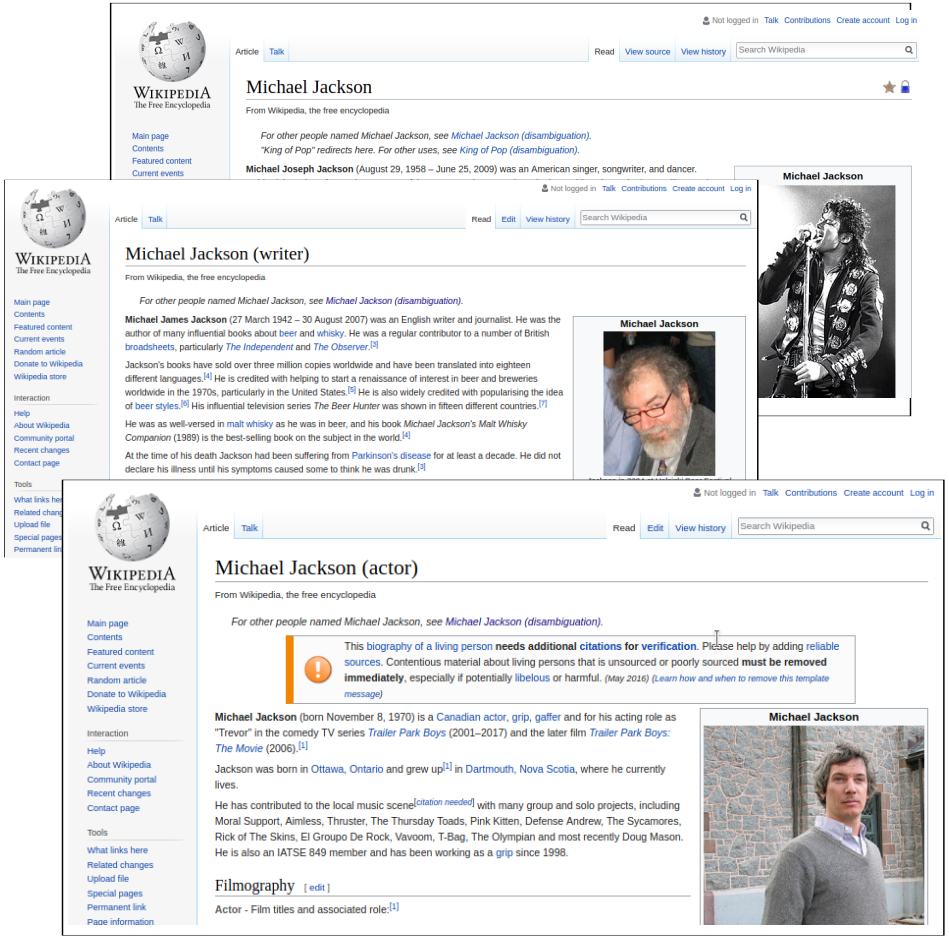
Name Variations in Entity Linking

Michael Joseph Jackson

Michael J. Jackson

King of Pop

Name Variations in Entity Linking



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Problem

- Initial steps: Multilingualism

Problem - Multilingual EL Datasets

Dataset	$\|D\|$	$\|S\|$	$\|E\|$	**Mn**	**Languages**
AIDA/CoNLL-Complete	1393	22,137	34,929	✓	EN
KORE50	50	50	144	✓	EN
IITB	103	1,781	18,308	✓	EN
ACE2004	57	-	306	✗	EN
AQUAINT	50	533	727	✗	EN
MSNBC	20	668	747	✗	EN
DBpedia Spotlight	10	58	331	✓	EN
N3-RSS 500	1	500	1000	✓	EN
Reuters 128	128	-	881	✓	EN
Wes2015	331	-	28,586	✓	EN
News-100	100	-	1656	✓	DE
Thibaudet	1	3,807	2,980	✗	FR
Bergson	1	4,280	380	✗	FR
SemEval 2015 Task 13	4	137	769	✓	EN,ES,IT
DBpedia Abstracts	39,132	-	505,033	✗	DE,EN,ES,FR,IT,JA,NL
MEANTIME	120	597	2,790	✓	EN,ES,IT,NL

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- We decided to create a multilingual EL benchmark dataset.

Problem

- We decided to create a multilingual EL benchmark dataset.
- What should Entity Linking link?

Problem - Any other entity?

Joseph Walter "Joe" Jackson, was a steelworker at U.S. Steel. In an interview with Martin Bashir for the 2003 documentary Living with Michael Jackson, Jackson recalled that Joe often sat in a chair with a belt in his hand as he and his siblings rehearsed.

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Research Questions

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1. What should Entity Linking link?
   - How can we define the goal of the EL task?
   - Is consensus possible on the definition of an "entity"?
   - How can we define benchmark EL datasets and what metrics can we use to reflect the lack of consensus?

Research Questions

2. How well do EL systems perform in multilingual settings?

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   - How well do available EL systems for languages other than English?
   - How does the performance of systems compare for multilingual EL?
   - How would a method based on machine translation to English compare with directly configuring the system for a particular language?

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General hypothesis

One size does not fit all: different scenarios and different applications may have different requirements for an EL system, including, but not limited to, the types of entities targeted, the languages supported, etc.

1. Different EL systems consider different "entity" definitions, and thus target different sets of KB entities.
2. Current EL quality measures are not suitable for the evaluation of approaches that consider different "entity" definitions.
3. The majority of multilingual EL approaches behave in different ways for different languages.
4. Machine translation could be used in multilingual EL scenarios and reach/improve state-of-the-art multilingual EL approaches.

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Consensus about Entity Linking

Class-based definition

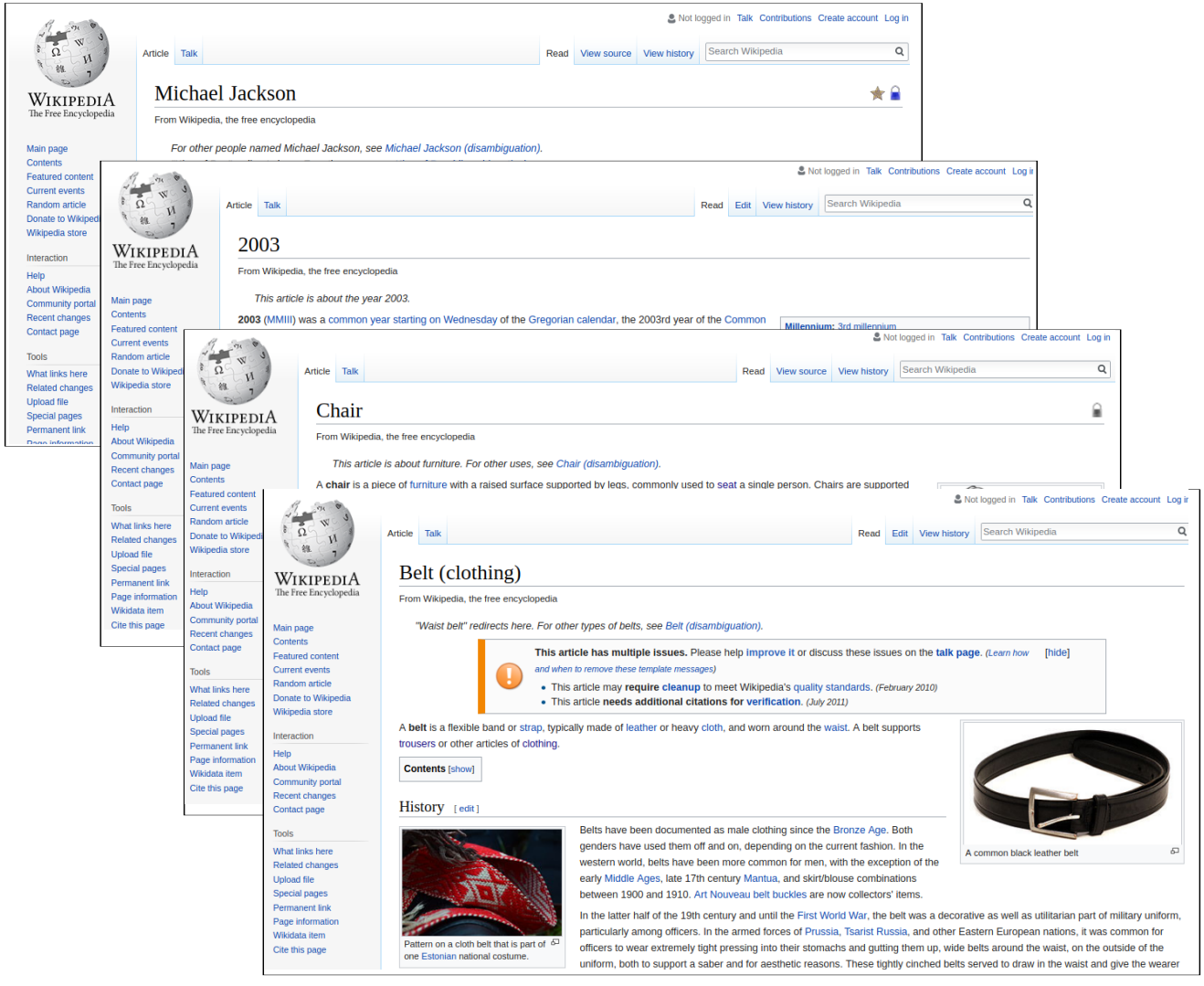
person | *location* | *organization* | *temporal expressions* | *quantities*

Class-based definition

?

person › *location* › *organization* › *temporal expressions* › *quantities* ›

Knowledge Base definition



Questionnaire

Gong-Qing Wu, Ying He, and Xuegang Hu. 2018. Entity linking: An issue to extract corresponding entity with knowledge base. IEEE Access, 6:6220–6231.

Questionnaire

In an interview with Martin Bashir for the 2003 documentary Living with Michael Jackson, the King of Pop recalled that Joe often sat with a white belt at hand as he and his four siblings rehearsed.

Russian daily Kommersant reports that Moscow will supply the Greeks with gas at rock bottom prices as Tsipras prepares to meet the Russian President.

Questionnaire

[[Russian]] daily Kommersant reports that ...

- [ ] Annotate "Russian" with https://en.wikipedia.org/wiki/Russia <tick all that apply>
- [ ] Annotate "Russian" with https://en.wikipedia.org/wiki/Russian_language <tick all that apply>
- [ ] Annotate "Russian" with https://en.wikipedia.org/wiki/Russians <tick all that apply>
- [ ] Do not annotate "Russian"

Russian [[daily]] Kommersant reports that ...

- ( ) Annotate "daily" with https://en.wikipedia.org/wiki/Newspaper
- ( ) Do not annotate "daily"

Questionnaire

- We sent the questionnaire to 321 researchers, of which 232 requests were delivered successfully.
- We received a total of 36 responses.

Questionnaire

In an [interview]$^{\cdot 19}$ with [Martin Bashir]^{1} for the [2003]$^{\cdot 28}$ [documentary]$^{\cdot 28}$ [Living with {Michael Jackson}$^{\cdot 75}$]$^{\cdot 97}$, the [{King}$^{\cdot 08}$ of {Pop}$^{\cdot 33}$]$^{\cdot 94}$ [recalled]$^{\cdot 06}$ that [Joe]^{1} often [sat]$^{\cdot 08}$ with a [white]$^{\cdot 11}$ [belt]$^{\cdot 14}$ at [hand]$^{\cdot 14}$ as [{he}$^{\cdot 56}$ and {his}$^{\cdot 39}$ {four}$^{\cdot 08}$ {siblings}$^{\cdot 14}$]$^{\cdot 50}$ [rehearsed]$^{\cdot 08}$.

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Our Position

- It depends on the application.

Application in Semantic Search

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Finding all documents about US singers

> Michael Joseph Jackson was an American singer, songwriter, and dancer. He was invited to the White House ...

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Application in Relation Extraction

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Extract new facts from text

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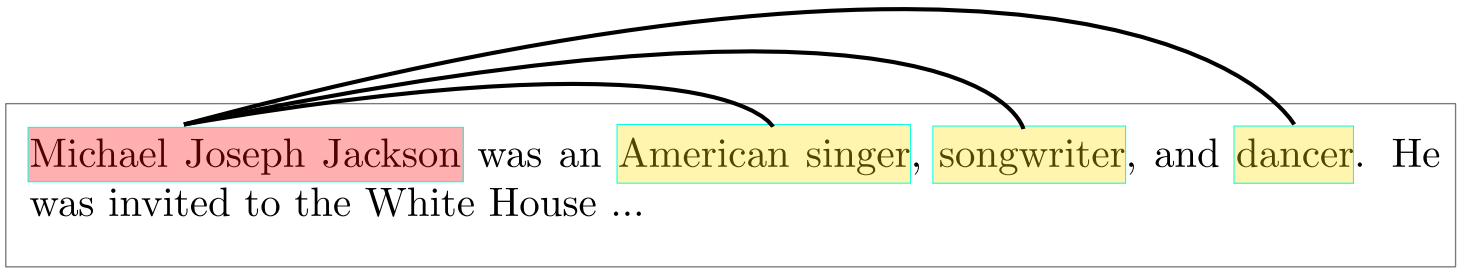

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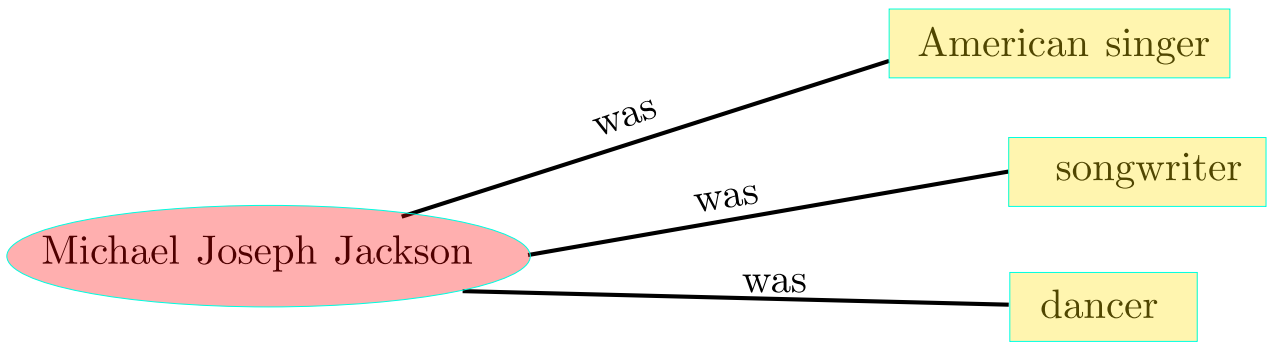

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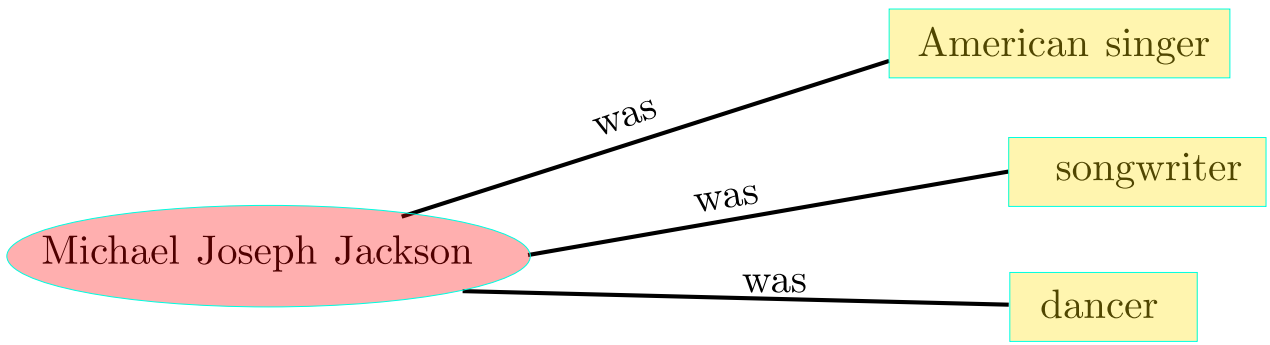

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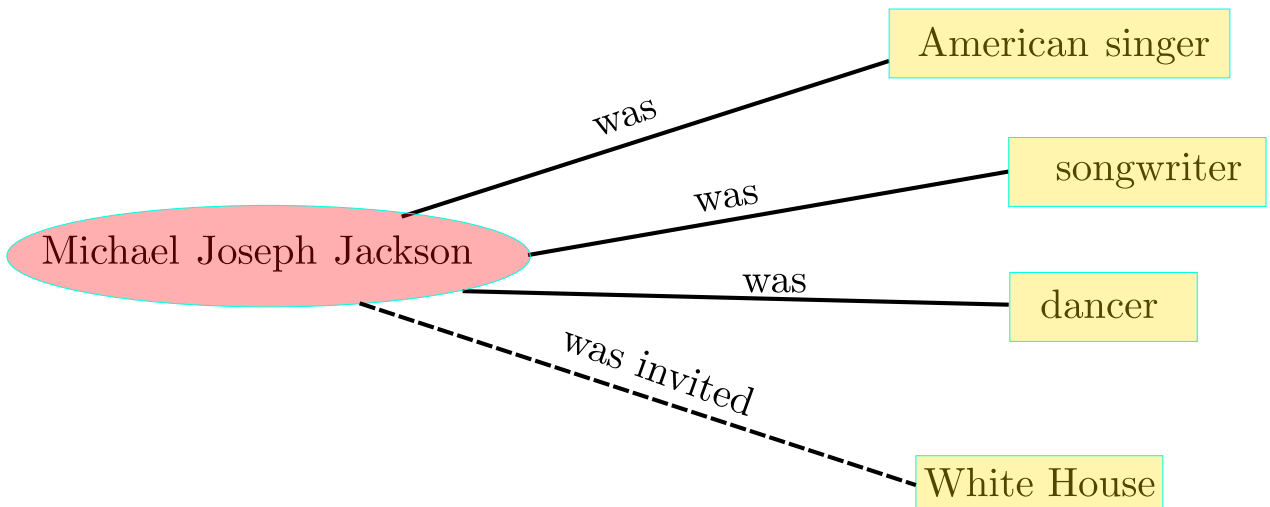

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Multilingualism

VoxEL

1. Create a benchmark dataset for multilingual Entity Linking

VoxEL

1. Create a benchmark dataset for multilingual Entity Linking
2. Create two versions of the dataset: strict and relaxed.

Creation of VoxEL dataset

- It based on curated text from five languages.
- Same sentences for each corresponding document.
- Same annotations for each corresponding sentence.

Curated source: VoxEurop

VOXeurop — DAS BESTE AUS EUROPAS PRESSE

cs de en es fr it nl pl pt ro

Proteste in Rumänien | Rettungsplan Griechenland | Griechenland-Krise | Griechenland-Rettung | Polen | Quellen | Autoren | Länder

UNTERSTÜTZEN SIE VOXEUROP

EUROPÄISCHE LINKE IN DER KRISE:

Die europäische Sozialdemokratie kämpft ums politische Überleben

10. Januar 2018 – DER SPIEGEL (HAM

In ganz Europa kämpfen sozial Bedeutungsverlust. Eine der äl Bestandsaufnahme.

Marcel Pauly

"In einem konstitutionellen St

VOXeurop — THE TALK OF THE CONTINENT

cs de en es fr it nl pl pt ro

Europe and populism | Hungary and fundamental rights | General elections in Sweden | 2018 State of | Sources | Authors | Countries

SUPPORT US

THE CRISIS OF THE EUROPEAN LEFT:

Are social democrats still alive?

10 January 2018 – DER SPIEGEL (HAMBURG)

All across Europe, social democratic pa the oldest political ideologies is in cris

Marcel Pauly

"In a constitutional state, the true ruler Lassalle, the champion of workers and democracy. But in the meantime, the v

VOXeurop — LO MEJOR DE LA PRENSA EUROPEA

cs de en es fr it nl pl pt ro

Hungría | Anti-corrupción | Brexit | Croacia | Inmigración UE | Fuentes | Autores | Países

AYUDE A SOSTENER VOXEUROP

LA CRISIS DE LA IZQUIERDA EUROPEA:

¿Están todavía vivos los socialdemócratas?

11 enero 2018 – DER SPIEGEL (HAMBURGO)

En toda Europa, los partidos socialdemócratas luchan para relevantes. Una de la más antiguas ideologías en crisis. Par actual.

Marcel Pauly

"En un Estado constitucional, el verdadero gobernante es e

VOXeurop — LE NOTZIE CHE FANNO DISCUTERE GLI EUROPEI

cs de en es fr it nl pl pt ro

Manifestazioni contro la corruzione in Romania | L'Ungheria sanzionata | Discorso sullo stato dell'Ue 2018 | Fonti | Autori | Paesi

CRISI DELLA SINISTRA EUROPEA:

I socialdemocratici lottano per la sopravvivenza

Enrico Bertuccioli

10 gennaio 2018 – DER SPIEGEL (AMBURGO)

In tutta Europa i partiti socialdemocratici devono vedersela con la perdita di consensi. Una delle più antiche idee politiche è in crisi. Il punto della situazione.

Marcel Pauly

"In uno stato costituzionale il vero sovrano è l'elettore", diceva un tempo

SOSTIENI VOXEUROP

VOXeurop

VoxEurop è realizzato da una squadra di giornalisti e di traduttori volontari, ma ci sono costi di funzionamento che non possono essere evitati. **Aiutaci a mantenere il sito online e ad andare avanti facendo un dono al progetto.** Grazie!

NEWSLETTER

Abbonati alla nostra **settimanale** in **italiano**.

Email:

Puoi disabbonarti in qualsiasi momento. La tua email non verrà comunicata ad altri

Iscriviti

EVENTI

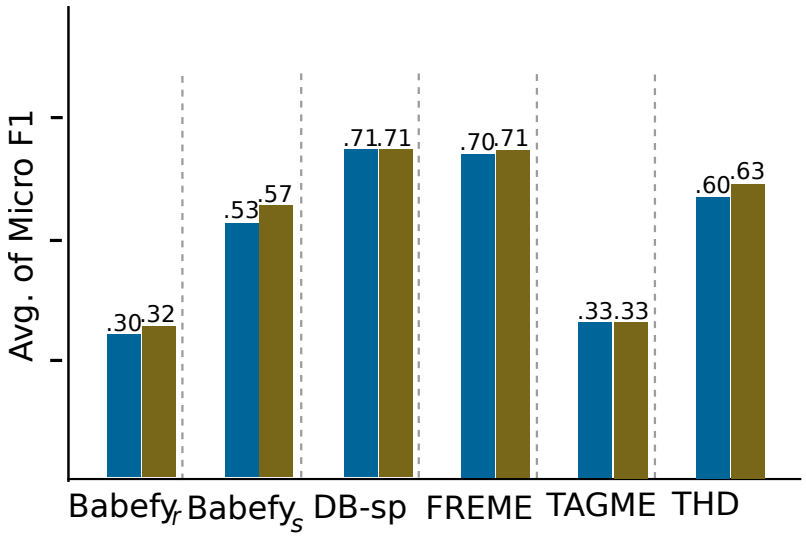
Creation of VoxEL dataset

- It based on curated text from five languages.
- Same sentences for each corresponding document.
- Same annotations for each corresponding sentence.

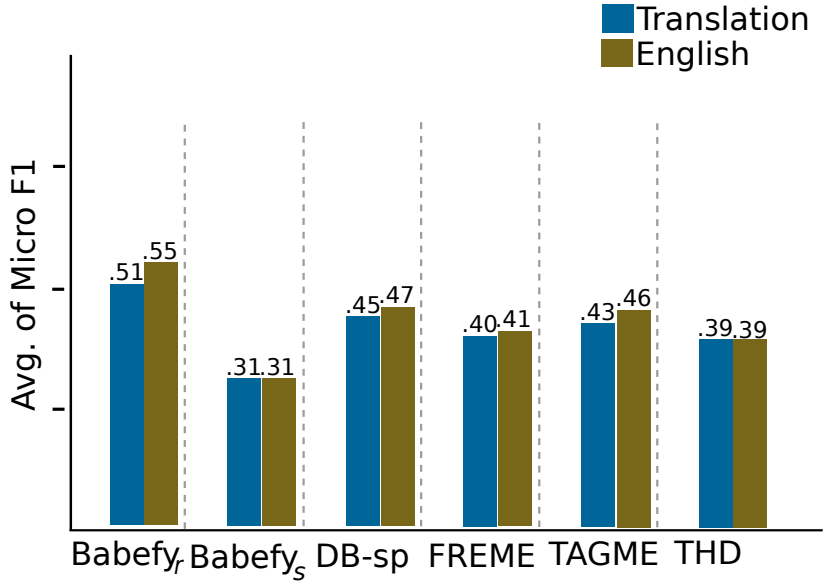
Experiments

1. Evaluate the performance of state-of-the-art approaches using machine translation.

Experiments



Results of the Strict version of VoxEL



Results of the Relaxed version of VoxEL

- VoxEL does not consider intermediate definitions of entities

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Fine-Grained Entity Linking

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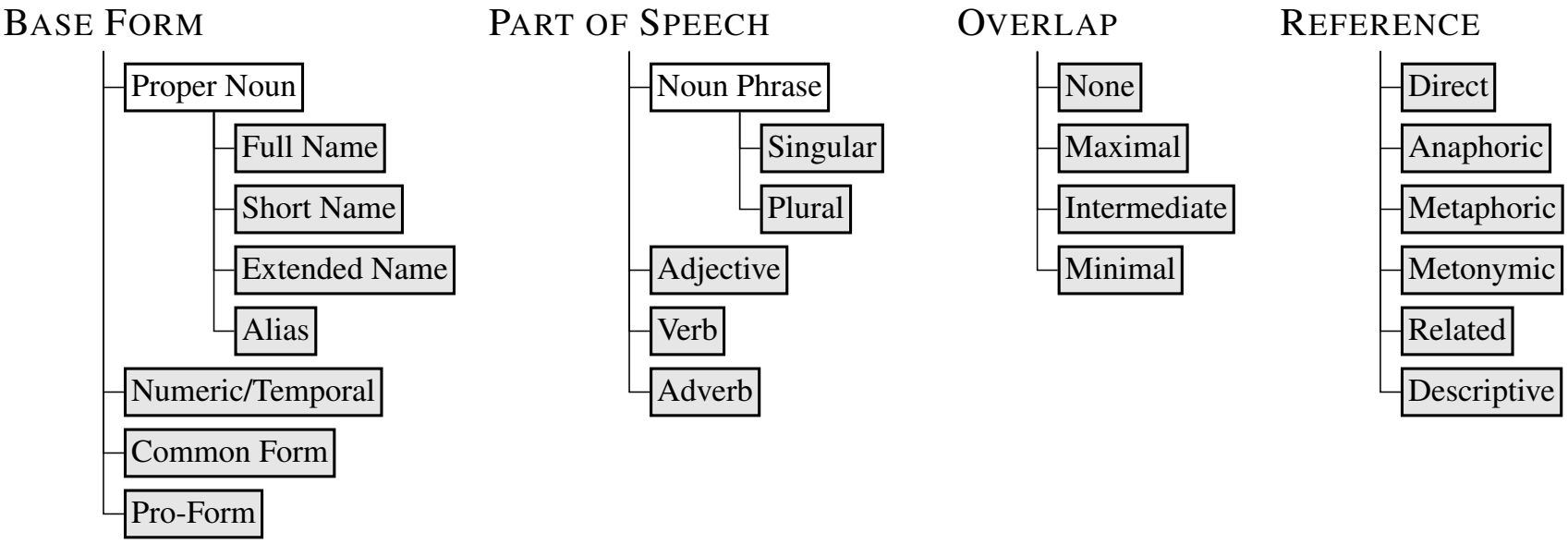
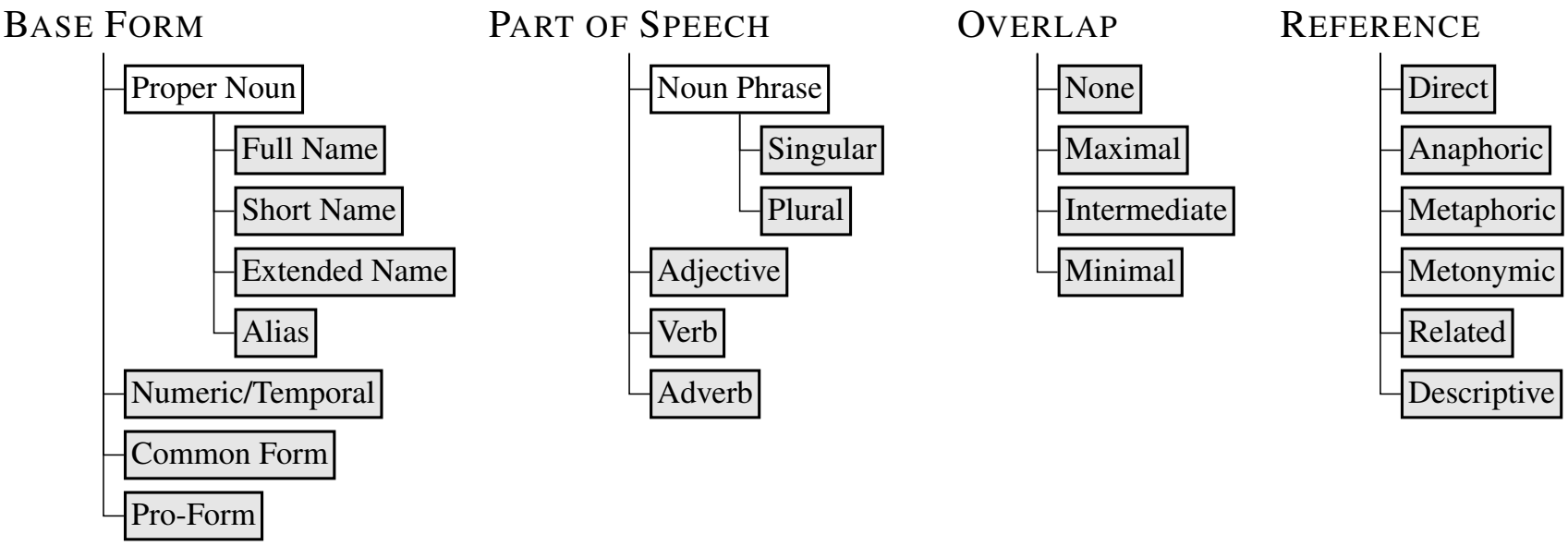

BASE FORM
Proper Noun
Full Name
Short Name
Extended Name
Alias
Numeric/Temporal
Common Form
Pro-Form
PART OF SPEECH
Noun Phrase
Singular
Plural
Adjective
Verb
Adverb
OVERLAP
None
Maximal
Intermediate
Minimal
REFERENCE
Direct
Anaphoric
Metaphoric
Metonymic
Related
Descriptive

Categories



Joseph Walter, was a steelworker at U.S Steel.

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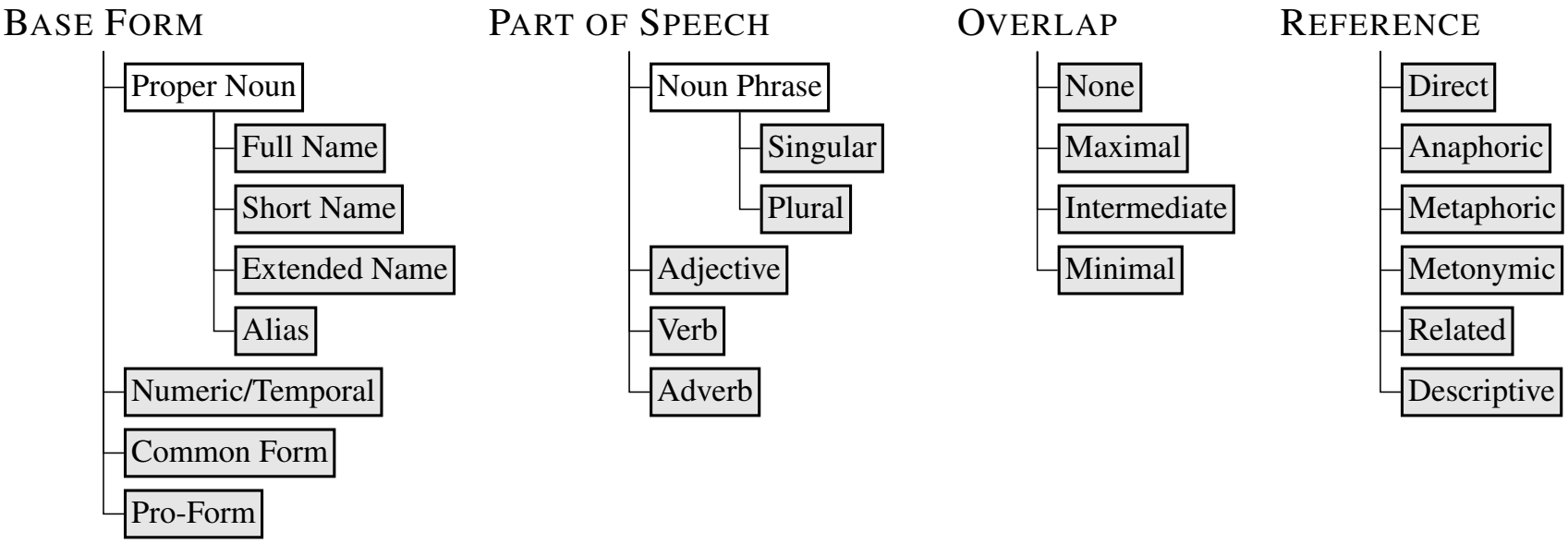

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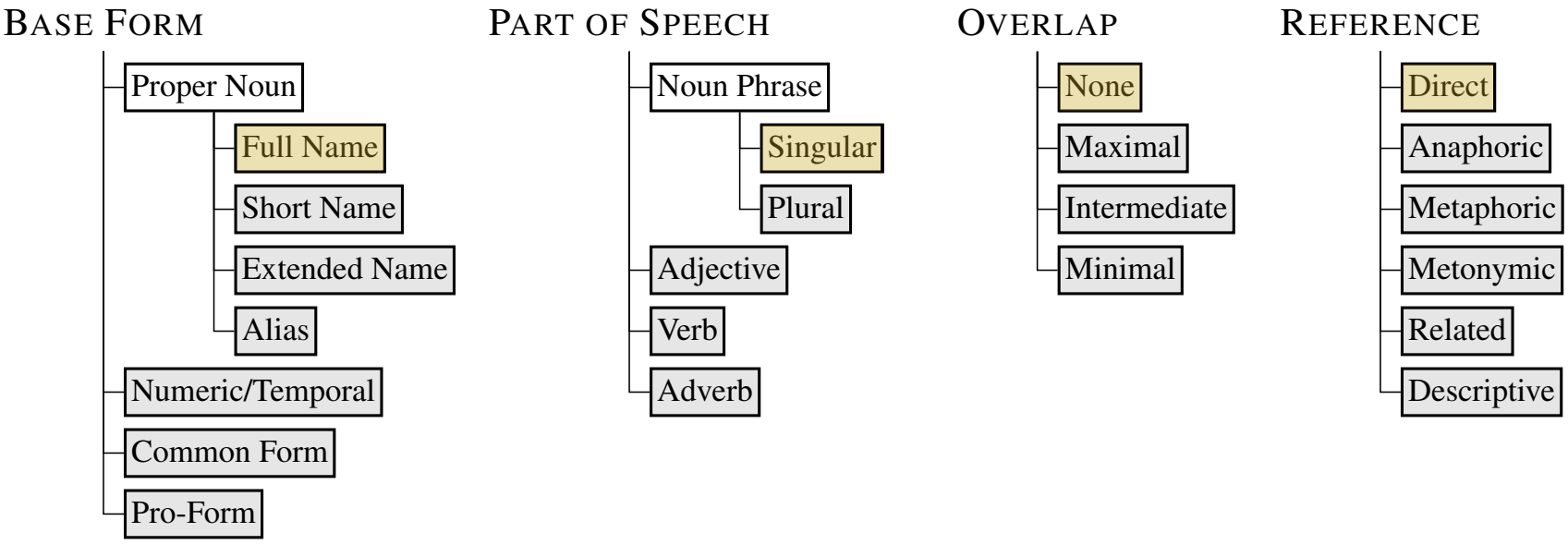
https://en.wikipedia.org/wiki/Joseph_Walter_(manager)

Categories



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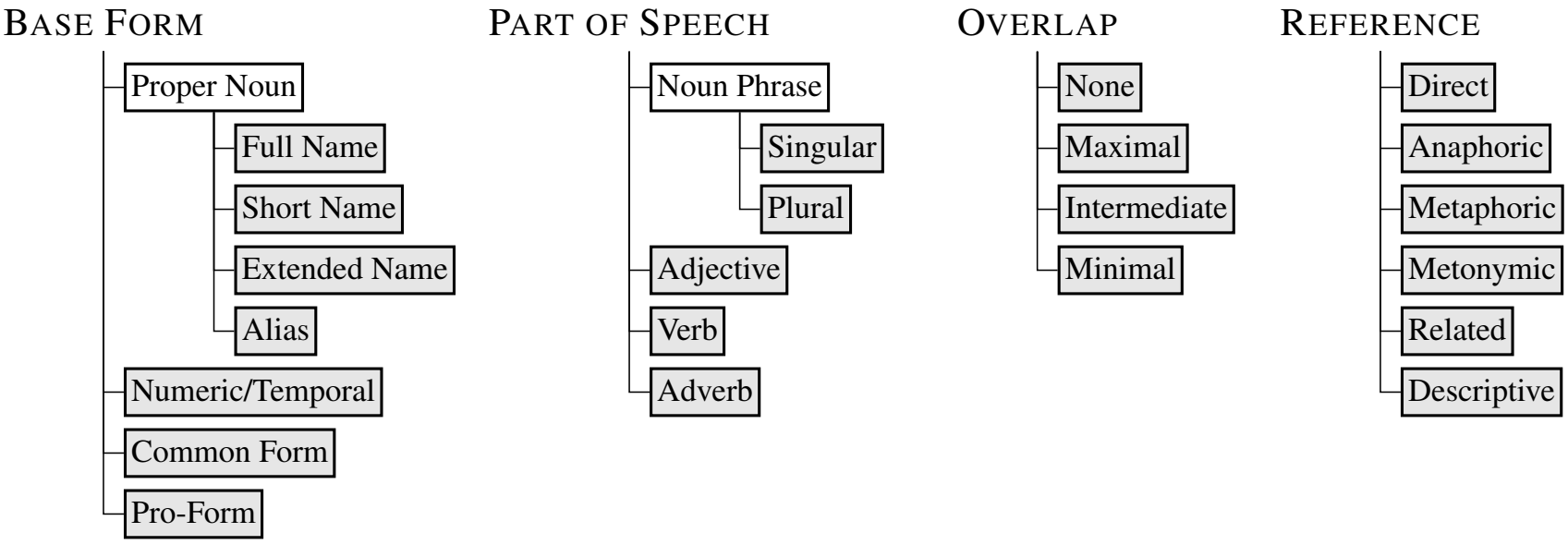

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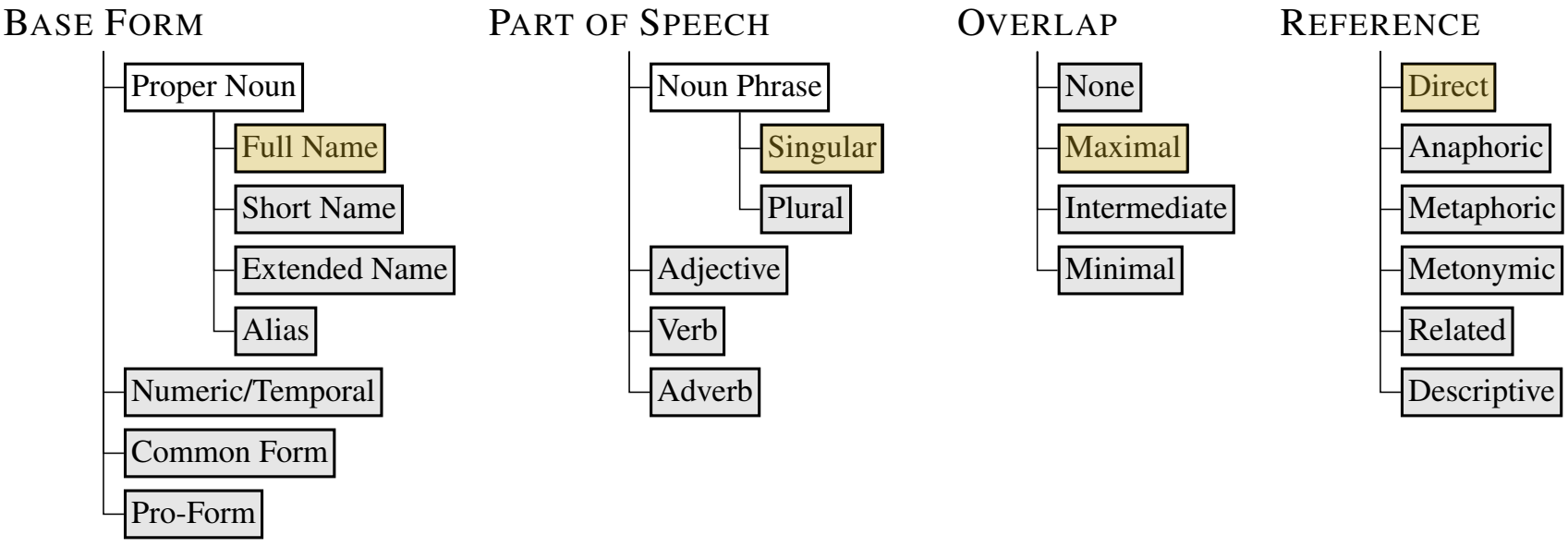

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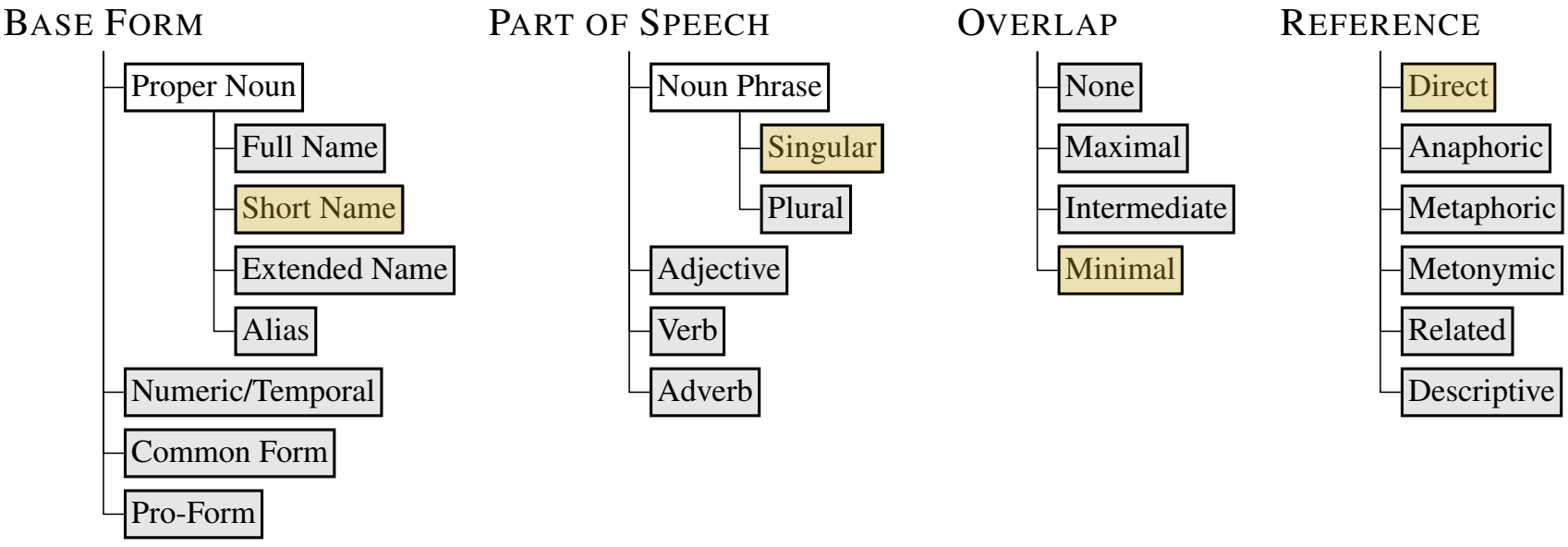
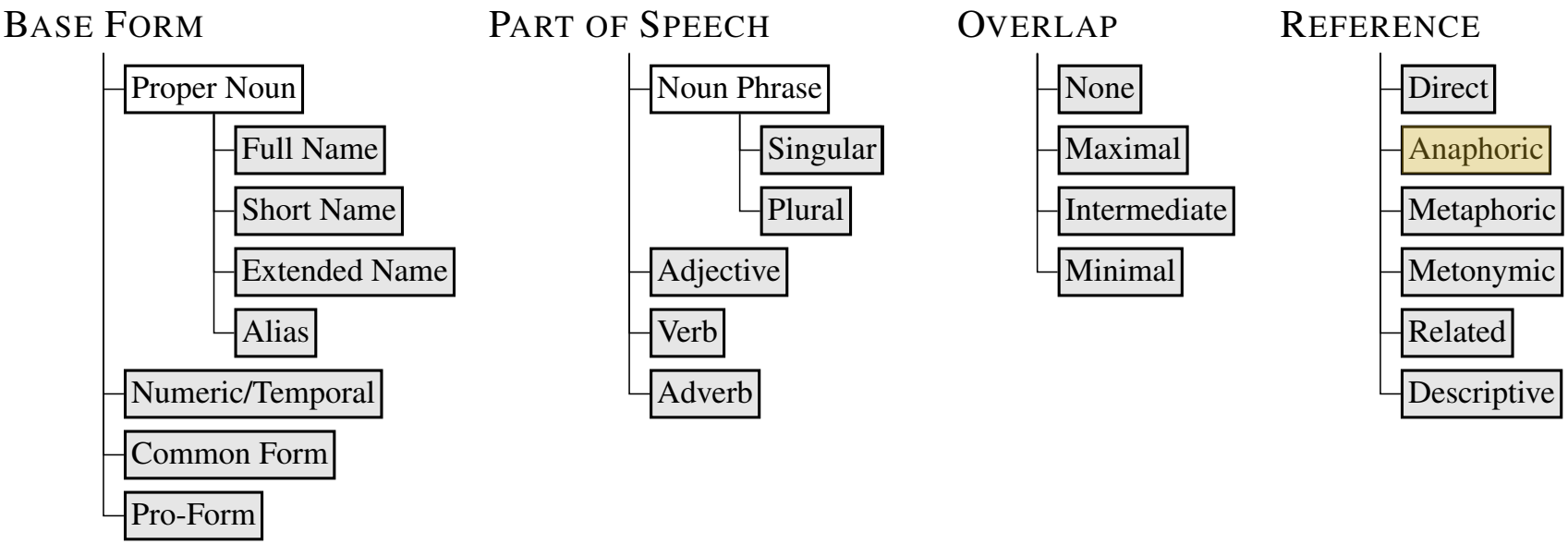


Joseph Walter, was a steelworker at U.S Steel.

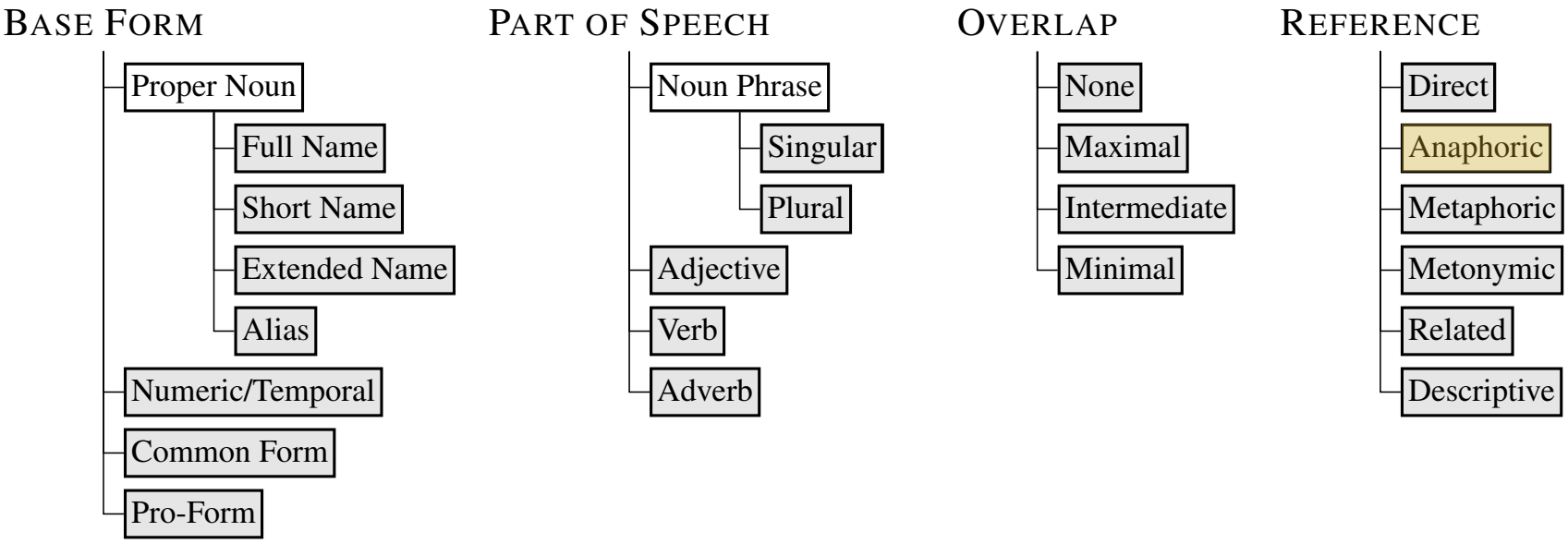
https://en.wikipedia.org/wiki/United_States

Categories



Michael Jackson was an American singer, songwriter, and dancer. He is regarded worldwide as one of the most significant cultural figures of the 20th century.

Categories



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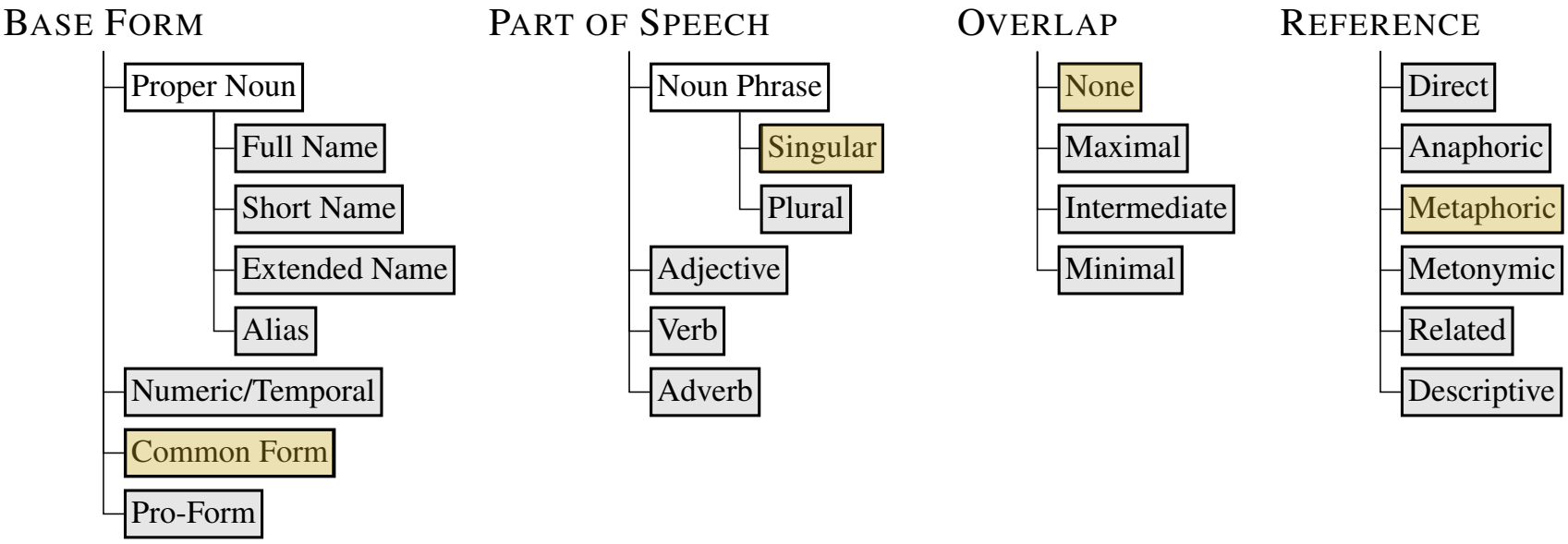
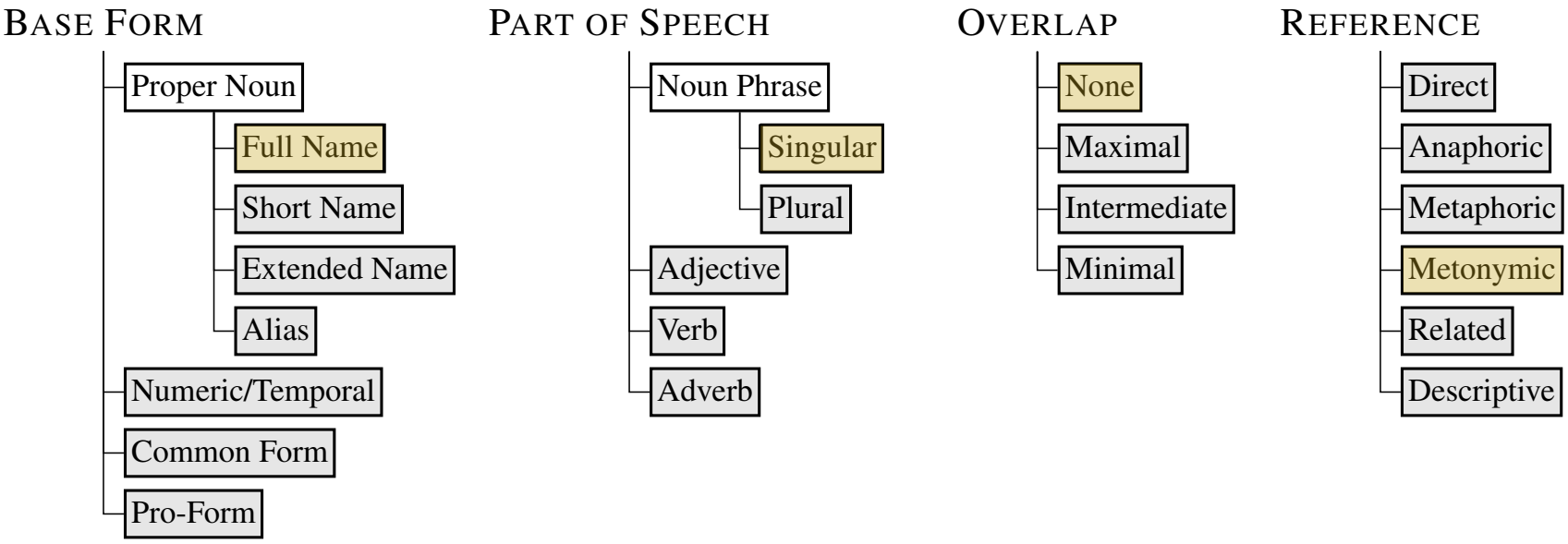


David and Victoria added spice to their marriage.

https://en.wikipedia.org/wiki/Spice

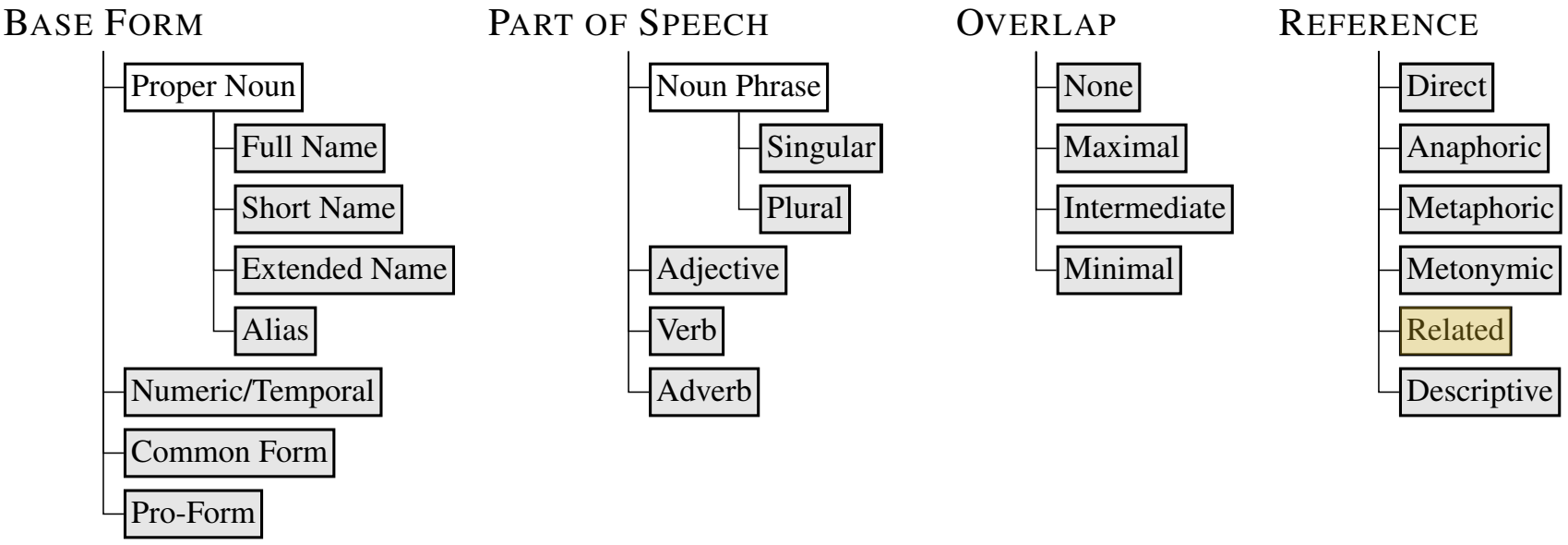
Categories



Greece beat England in the Euro Finals.

https://en.wikipedia.org/wiki/Greece_national_football_team

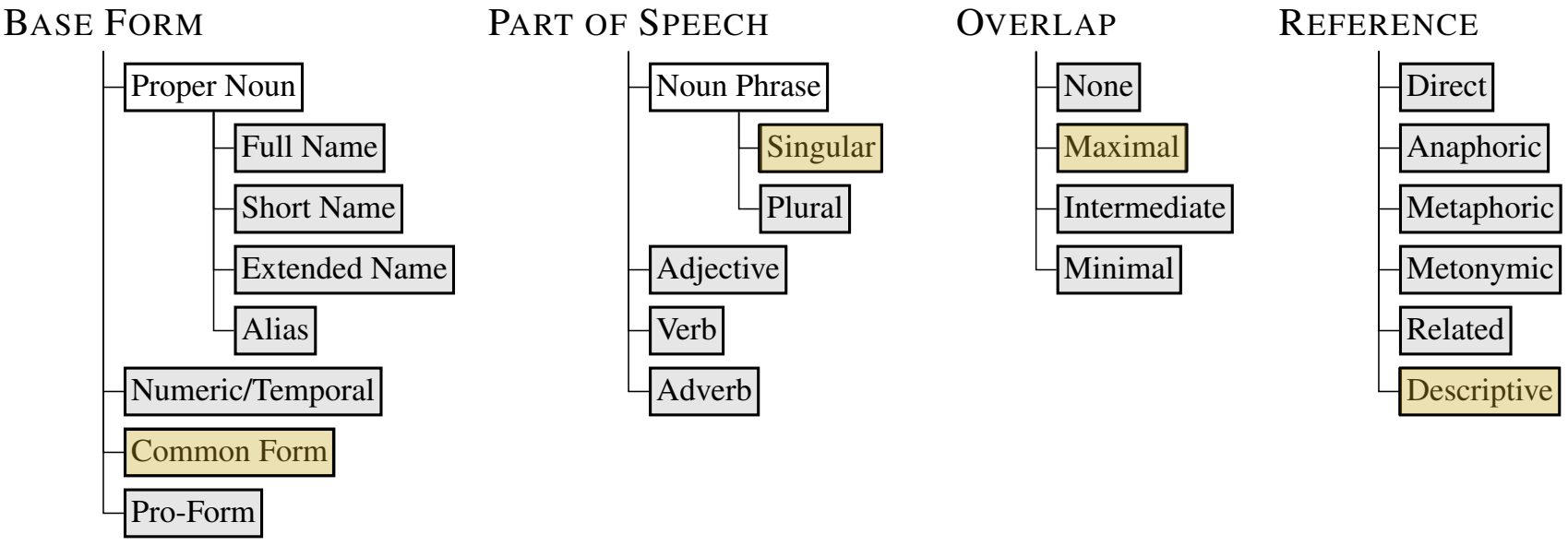
Categories



Today I am presenting my Dissertation Defense

`https://en.wikipedia.org/wiki/Present`

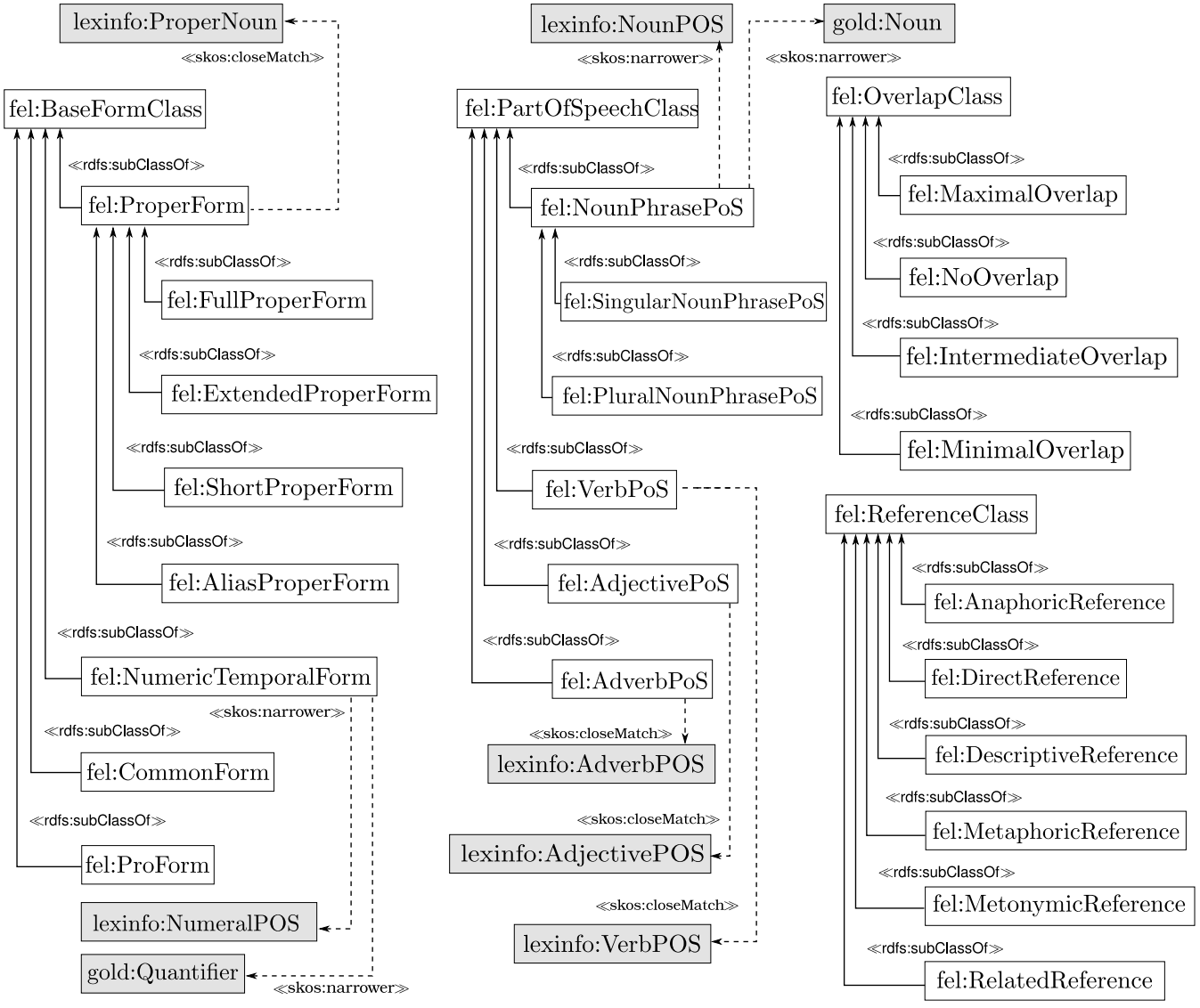
Categories



The capital of Chile is an incredible city.

https://en.wikipedia.org/wiki/Santiago

FEL Ontology



Re-annotation and categorization

1. KORE50: 1 doc, 50 sentences
2. VoxEL: 15 doc, 94 sentences
3. ACE04: first 20 doc, 214 sentences

Validating by tag

		B_s			B_r			T			D			A			F		
	$\|A\|$	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1
Full Mention	766	0.93	0.46	0.61	0.75	0.53	0.62	0.82	0.59	0.69	0.84	0.57	0.68	0.78	0.57	0.66	0.82	0.55	0.65
Short Mention	497	0.44	0.16	0.23	0.37	0.24	0.29	0.54	0.44	0.48	0.5	0.30	0.37	0.50	0.36	0.42	0.39	0.28	0.33
Extended Mention	9	1.00	0.56	0.71	0.83	0.56	0.67	1.00	0.44	0.62	1.00	0.44	0.62	1.00	0.44	0.62	0.80	0.44	0.57
Alias	112	0.56	0.16	0.25	0.33	0.21	0.25	0.52	0.32	0.40	0.67	0.38	0.48	0.60	0.29	0.40	0.55	0.29	0.38
Numeric/Temporal	404	0.45	0.01	0.02	0.82	0.24	0.37	0.14	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Form	2,452	0.21	0.00	0.01	0.66	0.33	0.44	0.49	0.28	0.35	0.88	0.04	0.08	0.43	0.00	0.00	0.56	0.00	0.01
Pro-form	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singular Noun	2,623	0.79	0.17	0.28	0.73	0.45	0.56	0.62	0.38	0.47	0.87	0.24	0.38	0.79	0.20	0.32	0.74	0.19	0.31
Plural Noun	746	0.33	0.01	0.02	0.61	0.33	0.43	0.56	0.28	0.37	0.83	0.03	0.06	0.70	0.03	0.07	0.66	0.04	0.07
Adjective	516	0.77	0.02	0.04	0.26	0.07	0.11	0.56	0.24	0.34	0.65	0.14	0.23	0.72	0.21	0.32	0.60	0.14	0.22
Verb	334	0.00	0.00	0.00	0.86	0.02	0.04	0.37	0.17	0.23	1.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Adverb	12	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2,871	0.75	0.12	0.20	0.67	0.33	0.45	0.58	0.38	0.46	0.84	0.19	0.32	0.78	0.19	0.30	0.71	0.17	0.27
Maximal Overlap	464	0.87	0.17	0.29	0.85	0.36	0.50	0.73	0.34	0.46	0.89	0.19	0.32	0.84	0.08	0.15	0.84	0.12	0.22
Intermediate Overlap	71	0.76	0.18	0.30	0.71	0.52	0.60	0.57	0.30	0.39	0.56	0.13	0.21	0.54	0.10	0.17	0.78	0.10	0.17
Minimal Overlap	825	0.82	0.04	0.09	0.61	0.37	0.46	0.50	0.15	0.23	0.80	0.09	0.17	0.72	0.09	0.16	0.66	0.06	0.12
Direct	3,106	0.79	0.13	0.23	0.71	0.43	0.53	0.63	0.38	0.47	0.83	0.21	0.33	0.76	0.19	0.30	0.70	0.17	0.27
Anaphoric	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metaphoric	69	0.00	0.00	0.00	0.57	0.29	0.38	0.43	0.35	0.38	0.91	0.14	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Metonymic	73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Related	829	0.64	0.06	0.11	0.36	0.14	0.20	0.39	0.24	0.30	0.76	0.10	0.18	0.81	0.08	0.15	0.83	0.09	0.16
Descriptive	189	0.33	0.01	0.01	0.44	0.02	0.04	0.16	0.02	0.03	0.60	0.02	0.03	0.00	0.00	0.00	0.6	0.02	0.03
All	4231	0.77	0.11	0.19	0.67	0.35	0.46	0.59	0.33	0.42	0.84	0.17	0.29	0.77	0.16	0.26	0.72	0.14	0.24

Results per category for Babelfy (strict/relaxed), TagME, DBpedia Spotlight, AIDA and FREME

Validating by tag

		B_s			B_r			T			D			A			F		
	$\|A\|$	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1
Full Mention	766	0.93	0.46	0.61	0.75	0.53	0.62	0.82	0.59	0.69	0.84	0.57	0.68	0.78	0.57	0.66	0.82	0.55	0.65
Short Mention	497	0.44	0.16	0.23	0.37	0.24	0.29	0.54	0.44	0.48	0.5	0.30	0.37	0.50	0.36	0.42	0.39	0.28	0.33
Extended Mention	9	1.00	0.56	0.71	0.83	0.56	0.67	1.00	0.44	0.62	1.00	0.44	0.62	1.00	0.44	0.62	0.80	0.44	0.57
Alias	112	0.56	0.16	0.25	0.33	0.21	0.25	0.52	0.32	0.40	0.67	0.38	0.48	0.60	0.29	0.40	0.55	0.29	0.38
Numeric/Temporal	404	0.45	0.01	0.02	0.82	0.24	0.37	0.14	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Form	2,452	0.21	0.00	0.01	0.66	0.33	0.44	0.49	0.28	0.35	0.88	0.04	0.08	0.43	0.00	0.00	0.56	0.00	0.01
Pro-form	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singular Noun	2,623	0.79	0.17	0.28	0.73	0.45	0.56	0.62	0.38	0.47	0.87	0.24	0.38	0.79	0.20	0.32	0.74	0.19	0.31
Plural Noun	746	0.33	0.01	0.02	0.61	0.33	0.43	0.56	0.28	0.37	0.83	0.03	0.06	0.70	0.03	0.07	0.66	0.04	0.07
Adjective	516	0.77	0.02	0.04	0.26	0.07	0.11	0.56	0.24	0.34	0.65	0.14	0.23	0.72	0.21	0.32	0.60	0.14	0.22
Verb	334	0.00	0.00	0.00	0.86	0.02	0.04	0.37	0.17	0.23	1.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Adverb	12	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2,871	0.75	0.12	0.20	0.67	0.33	0.45	0.58	0.38	0.46	0.84	0.19	0.32	0.78	0.19	0.30	0.71	0.17	0.27
Maximal Overlap	464	0.87	0.17	0.29	0.85	0.36	0.50	0.73	0.34	0.46	0.89	0.19	0.32	0.84	0.08	0.15	0.84	0.12	0.22
Intermediate Overlap	71	0.76	0.18	0.30	0.71	0.52	0.60	0.57	0.30	0.39	0.56	0.13	0.21	0.54	0.10	0.17	0.78	0.10	0.17
Minimal Overlap	825	0.82	0.04	0.09	0.61	0.37	0.46	0.50	0.15	0.23	0.80	0.09	0.17	0.72	0.09	0.16	0.66	0.06	0.12
Direct	3,106	0.79	0.13	0.23	0.71	0.43	0.53	0.63	0.38	0.47	0.83	0.21	0.33	0.76	0.19	0.30	0.70	0.17	0.27
Anaphoric	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metaphoric	69	0.00	0.00	0.00	0.57	0.29	0.38	0.43	0.35	0.38	0.91	0.14	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Metonymic	73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Related	829	0.64	0.06	0.11	0.36	0.14	0.20	0.39	0.24	0.30	0.76	0.10	0.18	0.81	0.08	0.15	0.83	0.09	0.16
Descriptive	189	0.33	0.01	0.01	0.44	0.02	0.04	0.16	0.02	0.03	0.60	0.02	0.03	0.00	0.00	0.00	0.6	0.02	0.03
All	4231	0.77	0.11	0.19	0.67	0.35	0.46	0.59	0.33	0.42	0.84	0.17	0.29	0.77	0.16	0.26	0.72	0.14	0.24

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	$\|A\|$	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1
Full Mention	766	0.93	0.46	0.61	0.75	0.53	0.62	0.82	0.59	0.69	0.84	0.57	0.68	0.78	0.57	0.66	0.82	0.55	0.65
Short Mention	497	0.44	0.16	0.23	0.37	0.24	0.29	0.54	0.44	0.48	0.5	0.30	0.37	0.50	0.36	0.42	0.39	0.28	0.33
Extended Mention	9	1.00	0.56	0.71	0.83	0.56	0.67	1.00	0.44	0.62	1.00	0.44	0.62	1.00	0.44	0.62	0.80	0.44	0.57
Alias	112	0.56	0.16	0.25	0.33	0.21	0.25	0.52	0.32	0.40	0.67	0.38	0.48	0.60	0.29	0.40	0.55	0.29	0.38
Numeric/Temporal	404	0.45	0.01	0.02	0.82	0.24	0.37	0.14	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Form	2,452	0.21	0.00	0.01	0.66	0.33	0.44	0.49	0.28	0.35	0.88	0.04	0.08	0.43	0.00	0.00	0.56	0.00	0.01
Pro-form	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singular Noun	2,623	0.79	0.17	0.28	0.73	0.45	0.56	0.62	0.38	0.47	0.87	0.24	0.38	0.79	0.20	0.32	0.74	0.19	0.31
Plural Noun	746	0.33	0.01	0.02	0.61	0.33	0.43	0.56	0.28	0.37	0.83	0.03	0.06	0.70	0.03	0.07	0.66	0.04	0.07
Adjective	516	0.77	0.02	0.04	0.26	0.07	0.11	0.56	0.24	0.34	0.65	0.14	0.23	0.72	0.21	0.32	0.60	0.14	0.22
Verb	334	0.00	0.00	0.00	0.86	0.02	0.04	0.37	0.17	0.23	1.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Adverb	12	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2,871	0.75	0.12	0.20	0.67	0.33	0.45	0.58	0.38	0.46	0.84	0.19	0.32	0.78	0.19	0.30	0.71	0.17	0.27
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Anaphoric	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metaphoric	69	0.00	0.00	0.00	0.57	0.29	0.38	0.43	0.35	0.38	0.91	0.14	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Metonymic	73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Related	829	0.64	0.06	0.11	0.36	0.14	0.20	0.39	0.24	0.30	0.76	0.10	0.18	0.81	0.08	0.15	0.83	0.09	0.16
Descriptive	189	0.33	0.01	0.01	0.44	0.02	0.04	0.16	0.02	0.03	0.60	0.02	0.03	0.00	0.00	0.00	0.6	0.02	0.03
All	4231	0.77	0.11	0.19	0.67	0.35	0.46	0.59	0.33	0.42	0.84	0.17	0.29	0.77	0.16	0.26	0.72	0.14	0.24

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Common Form	2,452	0.21	0.00	0.01	0.66	0.33	0.44	0.49	0.28	0.35	0.88	0.04	0.08	0.43	0.00	0.00	0.56	0.00	0.01
Pro-form	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singular Noun	2,623	0.79	0.17	0.28	0.73	0.45	0.56	0.62	0.38	0.47	0.87	0.24	0.38	0.79	0.20	0.32	0.74	0.19	0.31
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Adjective	516	0.77	0.02	0.04	0.26	0.07	0.11	0.56	0.24	0.34	0.65	0.14	0.23	0.72	0.21	0.32	0.60	0.14	0.22
Verb	334	0.00	0.00	0.00	0.86	0.02	0.04	0.37	0.17	0.23	1.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Adverb	12	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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Anaphoric	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metaphoric	69	0.00	0.00	0.00	0.57	0.29	0.38	0.43	0.35	0.38	0.91	0.14	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Metonymic	73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Related	829	0.64	0.06	0.11	0.36	0.14	0.20	0.39	0.24	0.30	0.76	0.10	0.18	0.81	0.08	0.15	0.83	0.09	0.16
Descriptive	189	0.33	0.01	0.01	0.44	0.02	0.04	0.16	0.02	0.03	0.60	0.02	0.03	0.00	0.00	0.00	0.6	0.02	0.03
All	4231	0.77	0.11	0.19	0.67	0.35	0.46	0.59	0.33	0.42	0.84	0.17	0.29	0.77	0.16	0.26	0.72	0.14	0.24

Results per category for Babelfy (strict/relaxed), TagME, DBpedia Spotlight, AIDA and FREME

Outline

- Introduction
- Problem
- Hypothesis
- Consensus about Entity Linking
- Multilingualism
- Fine-Grained Entity Linking
- Fine-Grained Entity Linking Systems
- Conclusions

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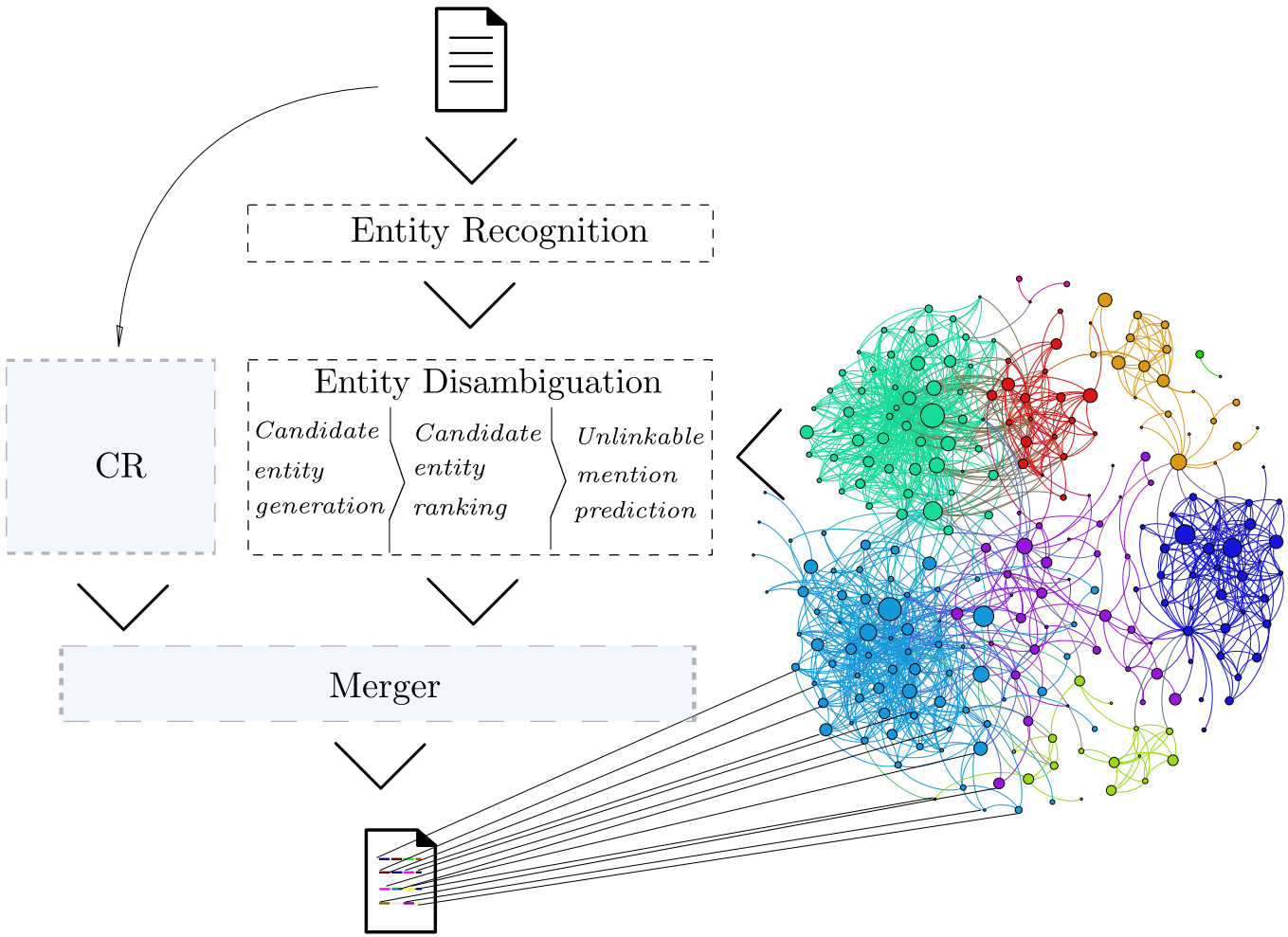
Fine-Grained Entity Linking Systems

Adding Coreference Resolution

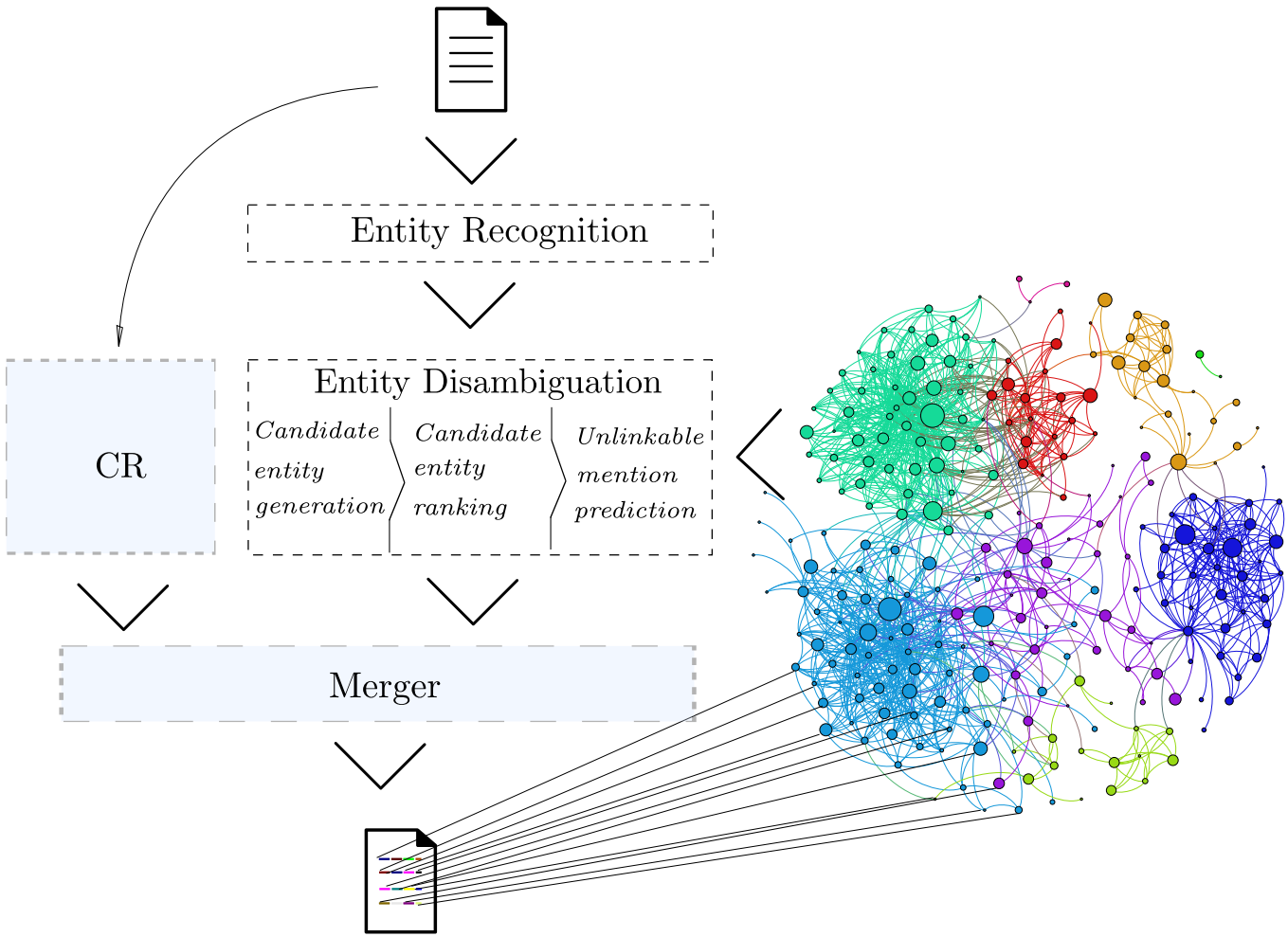
- Could we combine EL and CR to improve the quality of linking *Pro-Form* mentions?

CR + FEL experiment

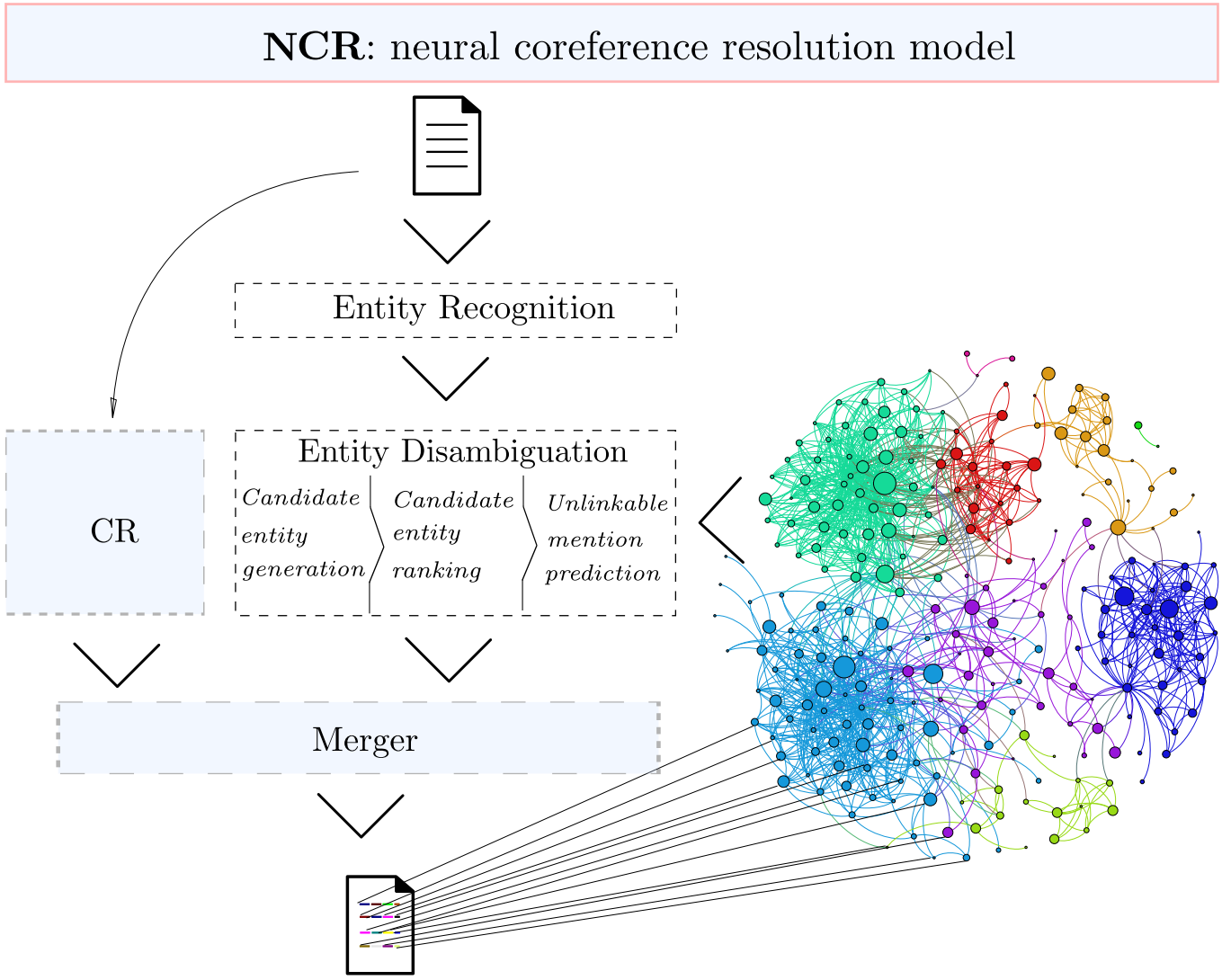


CR + FEL experiment

SCR: statistical CR model trained on the CoNLL 2012



CR + FEL experiment



SCR + FEL experiment

	$\|A\|$	$\mathbf{B}_s$			$\mathbf{B}_r$			$\mathbf{T}$			$\mathbf{D}$			$\mathbf{A}$			$\mathbf{F}$	
		P	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$
Pro-form	153	0.44	0.18	0.26	0.55	0.24	0.33	0.52	0.27	0.36	0.60	0.24	0.34	0.55	0.27	0.36	0.44	0.22	0.30
Singular Noun	2623	0.77	0.18	0.29	0.72	0.45	0.56	0.62	0.39	0.48	0.86	0.25	0.39	0.78	0.21	0.33	0.73	0.20	0.31
Adjective	518	0.49	0.05	0.09	0.33	0.12	0.17	0.55	0.29	0.38	0.64	0.18	0.28	0.67	0.25	0.37	0.54	0.18	0.27
Non-Overlapping	2871	0.71	0.13	0.21	0.67	0.34	0.45	0.58	0.40	0.47	0.82	0.20	0.33	0.76	0.20	0.32	0.68	0.18	0.28
Minimal Overlap	826	0.78	0.05	0.09	0.62	0.38	0.47	0.51	0.15	0.24	0.81	0.10	0.18	0.72	0.10	0.17	0.66	0.07	0.13
Anaphoric	153	0.44	0.18	0.26	0.55	0.24	0.33	0.52	0.27	0.36	0.60	0.24	0.34	0.55	0.27	0.36	0.44	0.22	0.30
All	4231	0.74	0.12	0.20	0.67	0.36	0.46	0.59	0.34	0.43	0.82	0.18	0.30	0.76	0.17	0.27	0.69	0.15	0.25

Results per category for Babelfy, TagME, DBpedia Spotlight, AIDA and FREME extended with SCR

NCR + FEL experiment

	$\|A\|$	$\mathbf{B}_s$			$\mathbf{B}_r$			$\mathbf{T}$			$\mathbf{D}$			$\mathbf{A}$			$\mathbf{F}$		
		P	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$
Short Mention	497	0.46	0.17	0.25	0.37	0.25	0.30	0.54	0.44	0.49	0.50	0.31	0.38	0.50	0.37	0.42	0.39	0.29	0.34
Common Form	2452	0.21	0.00	0.01	0.66	0.34	0.44	0.49	0.28	0.36	0.88	0.04	0.08	0.69	0.00	0.01	0.67	0.01	0.01
Pro-form	153	0.39	0.15	0.22	0.39	0.16	0.23	0.47	0.22	0.30	0.55	0.20	0.30	0.51	0.23	0.32	0.42	0.18	0.25
Singular Noun	2623	0.77	0.18	0.29	0.72	0.46	0.56	0.62	0.39	0.48	0.86	0.25	0.39	0.78	0.21	0.33	0.73	0.20	0.32
Adjective	518	0.48	0.04	0.07	0.29	0.10	0.15	0.55	0.28	0.37	0.63	0.17	0.27	0.66	0.24	0.36	0.55	0.17	0.26
Non-Overlapping	2871	0.72	0.13	0.22	0.66	0.34	0.45	0.58	0.40	0.47	0.83	0.21	0.33	0.76	0.20	0.32	0.69	0.18	0.29
Maximal Overlap	464	0.83	0.17	0.29	0.83	0.36	0.50	0.73	0.35	0.47	0.90	0.20	0.33	0.86	0.09	0.17	0.85	0.14	0.23
Intermediate Overlap	71	0.78	0.20	0.31	0.72	0.54	0.61	0.57	0.30	0.39	0.59	0.14	0.23	0.57	0.11	0.19	0.80	0.11	0.20
Minimal Overlap	826	0.72	0.05	0.09	0.60	0.38	0.46	0.50	0.15	0.24	0.77	0.10	0.18	0.68	0.09	0.16	0.63	0.07	0.12
Anaphoric	153	0.39	0.15	0.22	0.39	0.16	0.23	0.47	0.22	0.30	0.55	0.20	0.30	0.51	0.23	0.32	0.42	0.18	0.25
Descriptive	189	0.25	0.01	0.02	0.40	0.03	0.06	0.32	0.04	0.07	0.82	0.05	0.09	1.00	0.03	0.06	0.82	0.05	0.09
All	4231	0.73	0.12	0.20	0.67	0.35	0.46	0.59	0.34	0.43	0.82	0.18	0.30	0.76	0.17	0.27	0.70	0.15	0.25

Results per category for Babelfy, TagME, DBpedia Spotlight, AIDA and FREME extended with SCR

WSD + FEL experiment

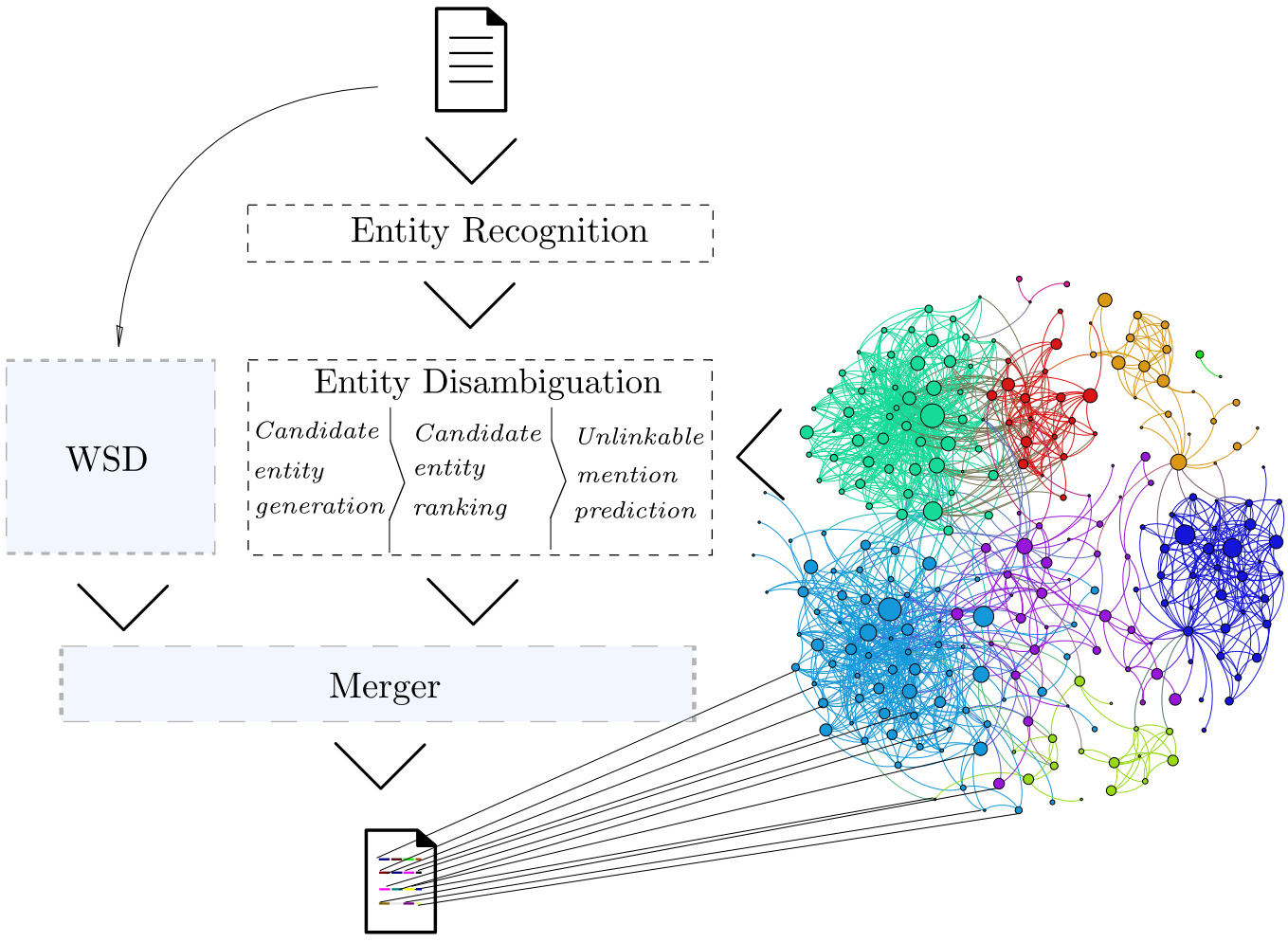
		B_s			B_r			T			D			A			F		
	$\|A\|$	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1	P	R	F_1
Full Mention	766	0.93	0.46	0.61	0.75	0.53	0.62	0.82	0.59	0.69	0.84	0.57	0.68	0.78	0.57	0.66	0.82	0.55	0.65
Short Mention	497	0.44	0.16	0.23	0.37	0.24	0.29	0.54	0.44	0.48	0.5	0.30	0.37	0.50	0.36	0.42	0.39	0.28	0.33
Extended Mention	9	1.00	0.56	0.71	0.83	0.56	0.67	1.00	0.44	0.62	1.00	0.44	0.62	1.00	0.44	0.62	0.80	0.44	0.57
Alias	112	0.56	0.16	0.25	0.33	0.21	0.25	0.52	0.32	0.40	0.67	0.38	0.48	0.60	0.29	0.40	0.55	0.29	0.38
Numeric/Temporal	404	0.45	0.01	0.02	0.82	0.24	0.37	0.14	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common Form	2,452	0.21	0.00	0.01	0.66	0.33	0.44	0.49	0.28	0.35	0.88	0.04	0.08	0.43	0.00	0.00	0.56	0.00	0.01
Pro-form	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singular Noun	2,623	0.79	0.17	0.28	0.73	0.45	0.56	0.62	0.38	0.47	0.87	0.24	0.38	0.79	0.20	0.32	0.74	0.19	0.31
Plural Noun	746	0.33	0.01	0.02	0.61	0.33	0.43	0.56	0.28	0.37	0.83	0.03	0.06	0.70	0.03	0.07	0.66	0.04	0.07
Adjective	516	0.77	0.02	0.04	0.26	0.07	0.11	0.56	0.24	0.34	0.65	0.14	0.23	0.72	0.21	0.32	0.60	0.14	0.22
Verb	334	0.00	0.00	0.00	0.86	0.02	0.04	0.37	0.17	0.23	1.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Adverb	12	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2,871	0.75	0.12	0.20	0.67	0.33	0.45	0.58	0.38	0.46	0.84	0.19	0.32	0.78	0.19	0.30	0.71	0.17	0.27
Maximal Overlap	464	0.87	0.17	0.29	0.85	0.36	0.50	0.73	0.34	0.46	0.89	0.19	0.32	0.84	0.08	0.15	0.84	0.12	0.22
Intermediate Overlap	71	0.76	0.18	0.30	0.71	0.52	0.60	0.57	0.30	0.39	0.56	0.13	0.21	0.54	0.10	0.17	0.78	0.10	0.17
Minimal Overlap	825	0.82	0.04	0.09	0.61	0.37	0.46	0.50	0.15	0.23	0.80	0.09	0.17	0.72	0.09	0.16	0.66	0.06	0.12
Direct	3,106	0.79	0.13	0.23	0.71	0.43	0.53	0.63	0.38	0.47	0.83	0.21	0.33	0.76	0.19	0.30	0.70	0.17	0.27
Anaphoric	153	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metaphoric	69	0.00	0.00	0.00	0.57	0.29	0.38	0.43	0.35	0.38	0.91	0.14	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Metonymic	73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Related	829	0.64	0.06	0.11	0.36	0.14	0.20	0.39	0.24	0.30	0.76	0.10	0.18	0.81	0.08	0.15	0.83	0.09	0.16
Descriptive	189	0.33	0.01	0.01	0.44	0.02	0.04	0.16	0.02	0.03	0.60	0.02	0.03	0.00	0.00	0.00	0.6	0.02	0.03
All	4231	0.77	0.11	0.19	0.67	0.35	0.46	0.59	0.33	0.42	0.84	0.17	0.29	0.77	0.16	0.26	0.72	0.14	0.24

Results per category for Babelfy (strict/relaxed), TagME, DBpedia Spotlight, AIDA and FREME

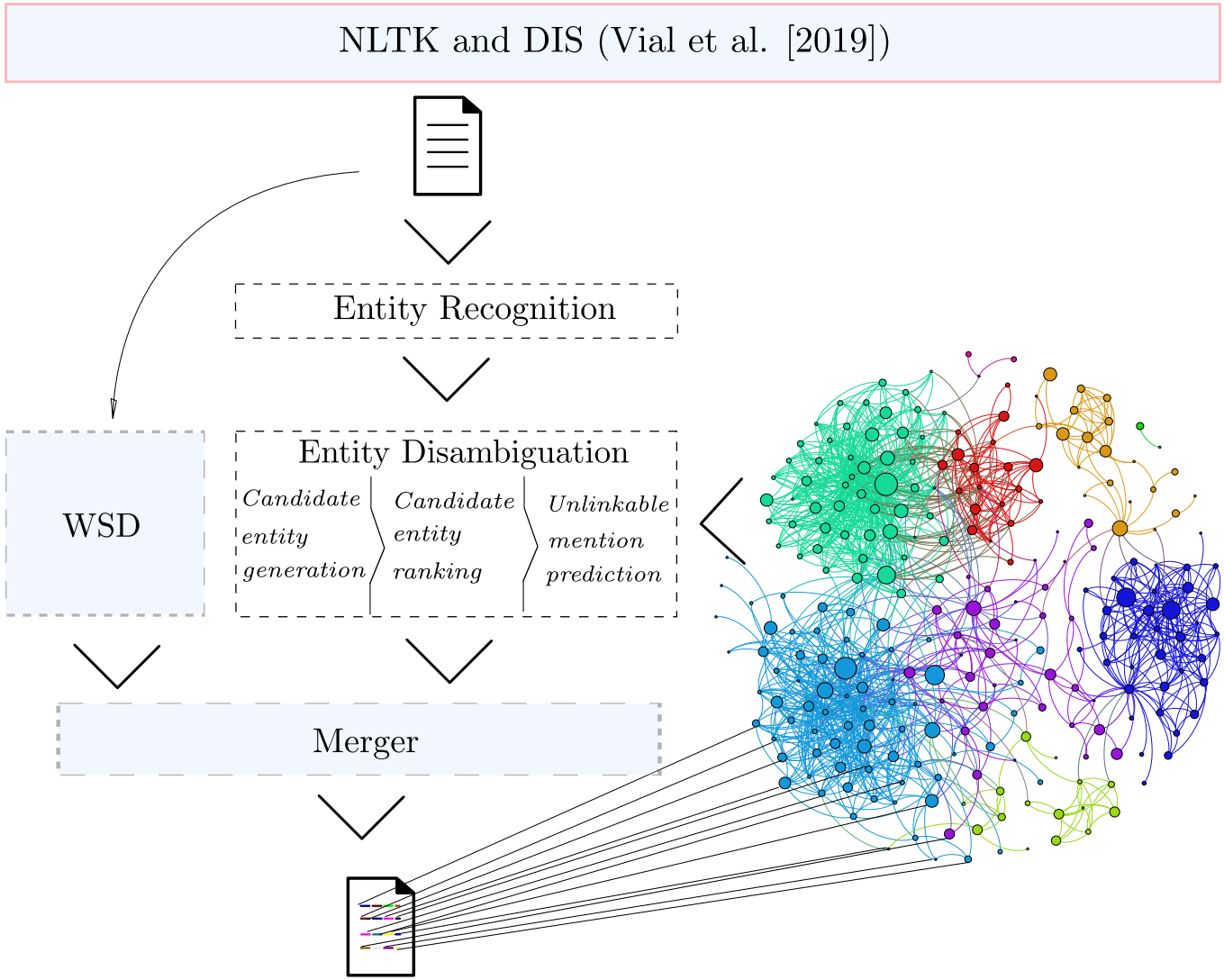
Adding Word Sense Disambiguation

- Could we combine EL and WSD to improve the performance of EL systems?

WSD + FEL experiment



WSD + FEL experiment



NLTK + FEL experiment

	$\|A\|$	$\mathbf{B}_s$			$\mathbf{B}_r$			$\mathbf{T}$			$\mathbf{D}$			$\mathbf{A}$			$\mathbf{F}$		
		P	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$
Full Mention	766	0.73	0.51	0.60	0.69	0.57	0.62	0.75	0.62	0.68	0.77	0.60	0.67	0.72	0.58	0.65	0.74	0.57	0.64
Short Mention	497	0.31	0.21	0.25	0.35	0.29	0.31	0.53	0.46	0.49	0.43	0.31	0.36	0.46	0.38	0.42	0.36	0.30	0.33
Alias	112	0.39	0.18	0.25	0.32	0.22	0.26	0.49	0.32	0.39	0.63	0.39	0.48	0.57	0.29	0.39	0.54	0.29	0.37
Numeric/Temporal	404	0.56	0.18	0.28	0.68	0.25	0.37	0.34	0.14	0.19	0.59	0.18	0.28	0.59	0.18	0.28	0.59	0.18	0.28
Common Form	2452	0.25	0.13	0.17	0.56	0.36	0.44	0.43	0.32	0.37	0.30	0.16	0.21	0.25	0.12	0.16	0.25	0.13	0.17
Singular Noun	2623	0.46	0.29	0.36	0.64	0.48	0.55	0.56	0.44	0.49	0.53	0.35	0.42	0.48	0.31	0.38	0.47	0.30	0.37
Plural Noun	746	0.25	0.14	0.17	0.51	0.34	0.41	0.45	0.31	0.37	0.29	0.16	0.20	0.28	0.16	0.20	0.28	0.16	0.20
Adjective	518	0.21	0.06	0.09	0.24	0.11	0.15	0.43	0.26	0.33	0.41	0.16	0.23	0.51	0.24	0.32	0.41	0.16	0.23
Verb	334	0.00	0.00	0.00	0.46	0.02	0.03	0.35	0.17	0.23	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2871	0.43	0.24	0.31	0.56	0.36	0.44	0.54	0.42	0.47	0.51	0.30	0.38	0.49	0.30	0.37	0.46	0.28	0.35
Minimal Overlap	826	0.23	0.15	0.18	0.54	0.41	0.46	0.33	0.23	0.28	0.28	0.19	0.23	0.28	0.19	0.23	0.25	0.17	0.20
Direct	3106	0.45	0.27	0.33	0.64	0.46	0.54	0.55	0.43	0.49	0.52	0.32	0.40	0.49	0.31	0.38	0.46	0.29	0.36
Metaphoric	69	0.14	0.07	0.10	0.42	0.30	0.35	0.40	0.36	0.38	0.42	0.22	0.29	0.16	0.07	0.10	0.16	0.07	0.10
Related	829	0.18	0.08	0.11	0.27	0.16	0.20	0.34	0.25	0.29	0.23	0.11	0.15	0.21	0.10	0.13	0.22	0.10	0.14
Descriptive	189	0.25	0.01	0.01	0.44	0.02	0.04	0.15	0.02	0.03	0.50	0.02	0.03	0.00	0.00	0.00	0.50	0.02	0.03
All	4231	0.40	0.21	0.28	0.58	0.37	0.45	0.52	0.37	0.43	0.48	0.26	0.34	0.45	0.25	0.32	0.43	0.24	0.30

Results per category for Babelfy, TagME, DBpedia Spotlight, AIDA and FREME extended with NLTK

NLTK + FEL experiment

	$\|A\|$	$\mathbf{B}_s$			$\mathbf{B}_r$			$\mathbf{T}$			$\mathbf{D}$			$\mathbf{A}$			$\mathbf{F}$		
		P	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$	**P**	**R**	$\mathbf{F}_1$
Full Mention	766	0.73	0.51	0.60	0.69	0.57	0.62	0.75	0.62	0.68	0.77	0.60	0.67	0.72	0.58	0.65	0.74	0.57	0.64
Short Mention	497	0.31	0.21	0.25	0.35	0.29	0.31	0.53	0.46	0.49	0.43	0.31	0.36	0.46	0.38	0.42	0.36	0.30	0.33
Alias	112	0.39	0.18	0.25	0.32	0.22	0.26	0.49	0.32	0.39	0.63	0.39	0.48	0.57	0.29	0.39	0.54	0.29	0.37
Numeric/Temporal	404	0.56	0.18	0.28	0.68	0.25	0.37	0.34	0.14	0.19	0.59	0.18	0.28	0.59	0.18	0.28	0.59	0.18	0.28
Common Form	2452	0.25	0.13	0.17	0.56	0.36	0.44	0.43	0.32	0.37	0.30	0.16	0.21	0.25	0.12	0.16	0.25	0.13	0.17
Singular Noun	2623	0.46	0.29	0.36	0.64	0.48	0.55	0.56	0.44	0.49	0.53	0.35	0.42	0.48	0.31	0.38	0.47	0.30	0.37
Plural Noun	746	0.25	0.14	0.17	0.51	0.34	0.41	0.45	0.31	0.37	0.29	0.16	0.20	0.28	0.16	0.20	0.28	0.16	0.20
Adjective	518	0.21	0.06	0.09	0.24	0.11	0.15	0.43	0.26	0.33	0.41	0.16	0.23	0.51	0.24	0.32	0.41	0.16	0.23
Verb	334	0.00	0.00	0.00	0.46	0.02	0.03	0.35	0.17	0.23	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non-Overlapping	2871	0.43	0.24	0.31	0.56	0.36	0.44	0.54	0.42	0.47	0.51	0.30	0.38	0.49	0.30	0.37	0.46	0.28	0.35
Minimal Overlap	826	0.23	0.15	0.18	0.54	0.41	0.46	0.33	0.23	0.28	0.28	0.19	0.23	0.28	0.19	0.23	0.25	0.17	0.20
Direct	3106	0.45	0.27	0.33	0.64	0.46	0.54	0.55	0.43	0.49	0.52	0.32	0.40	0.49	0.31	0.38	0.46	0.29	0.36
Metaphoric	69	0.14	0.07	0.10	0.42	0.30	0.35	0.40	0.36	0.38	0.42	0.22	0.29	0.16	0.07	0.10	0.16	0.07	0.10
Related	829	0.18	0.08	0.11	0.27	0.16	0.20	0.34	0.25	0.29	0.23	0.11	0.15	0.21	0.10	0.13	0.22	0.10	0.14
Descriptive	189	0.25	0.01	0.01	0.44	0.02	0.04	0.15	0.02	0.03	0.50	0.02	0.03	0.00	0.00	0.00	0.50	0.02	0.03
All	4231	0.40	0.21	0.28	0.58	0.37	0.45	0.52	0.37	0.43	0.48	0.26	0.34	0.45	0.25	0.32	0.43	0.24	0.30

Results per category for Babelfy, TagME, DBpedia Spotlight, AIDA and FREME extended with NLTK

DIS + FEL experiment

	$\|A\|$	B_s			B_r			T			D			A			F		
		P	**R**	**F_1**	**P**	**R**	**F_1**	**P**	**R**	**F_1**	**P**	**R**	**F_1**	**P**	**R**	**F_1**	**P**	**R**	**F_1**
Full Mention	766	0.80	0.48	0.60	0.71	0.54	0.62	0.77	0.60	0.68	0.80	0.58	0.68	0.74	0.57	0.65	0.76	0.55	0.64
Short Mention	497	0.34	0.17	0.23	0.36	0.26	0.30	0.52	0.45	0.48	0.47	0.30	0.37	0.49	0.38	0.43	0.38	0.30	0.34
Extended Mention	9	0.83	0.56	0.67	0.83	0.56	0.67	0.80	0.44	0.57	0.80	0.44	0.57	1.00	0.44	0.62	0.80	0.44	0.57
Alias	112	0.42	0.16	0.23	0.33	0.21	0.25	0.50	0.32	0.39	0.65	0.38	0.47	0.58	0.29	0.39	0.53	0.29	0.37
Numeric/Temporal	404	0.58	0.06	0.12	0.81	0.24	0.37	0.25	0.07	0.11	0.64	0.06	0.10	0.64	0.06	0.10	0.64	0.06	0.10
Common Form	2452	0.21	0.04	0.07	0.62	0.34	0.44	0.46	0.29	0.35	0.34	0.08	0.13	0.21	0.04	0.07	0.22	0.04	0.07
Singular Noun	2623	0.55	0.21	0.30	0.69	0.46	0.55	0.58	0.40	0.47	0.66	0.28	0.39	0.59	0.23	0.33	0.56	0.23	0.32
Plural Noun	746	0.22	0.05	0.08	0.59	0.34	0.43	0.52	0.29	0.37	0.33	0.07	0.11	0.32	0.07	0.11	0.32	0.07	0.12
Adjective	518	0.31	0.04	0.07	0.29	0.09	0.14	0.53	0.26	0.35	0.56	0.15	0.24	0.65	0.22	0.33	0.52	0.15	0.23
Verb	334	0.25	0.00	0.01	0.75	0.02	0.04	0.37	0.17	0.23	0.40	0.01	0.01	0.25	0.00	0.01	0.25	0.00	0.01
Non-Overlapping	2871	0.51	0.15	0.24	0.63	0.34	0.44	0.57	0.40	0.47	0.64	0.23	0.34	0.60	0.22	0.32	0.55	0.20	0.30
Minimal Overlap	826	0.28	0.08	0.12	0.59	0.39	0.47	0.38	0.18	0.24	0.39	0.13	0.19	0.36	0.12	0.18	0.32	0.10	0.15
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Metaphoric	69	0.19	0.04	0.07	0.53	0.29	0.37	0.43	0.35	0.38	0.65	0.19	0.29	0.25	0.04	0.07	0.25	0.04	0.07
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Traditional F1

$$P = \frac{|TP|}{|TP| + |FP|}$$

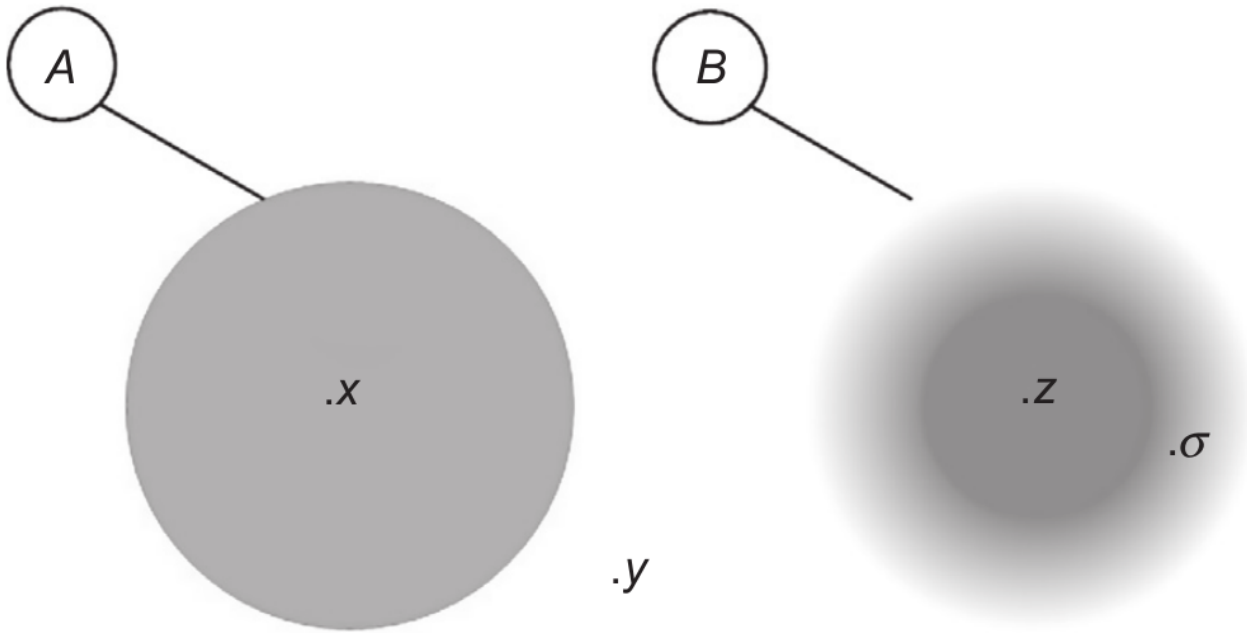
$$R = \frac{|TP|}{|TF| + |FN|}$$

$$F_1 = \frac{2 \cdot P \cdot R}{P + R}$$

Traditional F1

- Some EL annotations might be more important in certain application scenarios than others.

Fuzzy set



A: Crisp set

B: Fuzzy set

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Modifications to F1

$$P = \frac{|TP|}{|S|}$$

$$R* = \frac{\sum_{a \in S} \mu_{G^*}(a)}{\sum_{a \in G} \mu_{G^*}(a)}$$

$$F_1^* = \frac{2 \cdot P \cdot R^*}{P + R^*}$$

- PROP1: the values for R^* and F_1^* both range between 0 and 1, inclusive.
- PROP2: when $\mu_{G^*} : G \rightarrow \{1\}$ (i.e., when memberships are binary), R^* and F_1^* correspond to R and F_1.
- PROP3: missing annotations with higher membership degree are penalized more in R^* and F_1^* than those with lower degree.

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- Problem
- Hypothesis
- Consensus about Entity Linking
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- Combine CR/WSD with EL helps to fill gaps of some EL systems for specific applications.

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- In our fine-grained EL evaluation, we include the results of two CR systems and two WSD systems.

Towards a Fine-Grained Entity Linking Approach

Henry Rosales-Méndez

Supervisors: Aidan Hogan and Barbara Poblete

Dissertation Defense

June 11th, 2021