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Open Information Extraction

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Proseminar *Text Mining*
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Papers

Identifying Relations for Open Information Extraction (Fader et al., 2011)

LODifier: Generating Linked Data from Unstructured Text
(Augenstein et al., 2012)

Strukturierung

- 1 Introduction to Information Extraction
- 2 OIE - Principles
- 3 Example: LODifier
- 4 Conclusion

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Introduction to Information Extraction

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What is Information Extraction?

Information Extraction

Goal of Information Extraction is automatically extracting information from unseen text

Information: entities, relations, events...

To make the dough for a good pizza, we start with putting 1kg of flour into the mixing bowl.
(1kg of flour, put into, mixing bowl)

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Problems of Information Extraction

- Named Entity Recognition
- Relationship Extraction
- Coreference Resolution
- Comment Extraction
- many more..

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OIE - Principles

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OIE - Principles

Open Information Extraction



Open Information Extraction

IE: Extractor for each target relation

Open: No pre-specified extractors

Unsupervised learning of relation phrases

Extraction of information on every given domain



Problems of Open Information Extraction

■ Incoherent extractions:

This guide contains dead links and omits sites
contains omits

■ Uninformative extractions:

Faust made a deal with the devil
(Faust, made, a deal)

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OIE - Principles

Methods

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Text Runner and WOE

- 1 *Label*: Automatic sentence labeling by heuristics
- 2 *Learn*: A relation phrase extractor is learned
- 3 *Extract*: Identifying NP pairs and searching relations words between

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Problems

- Large number of labeled training examples required
- Alternative heuristic labeling leads to huge noise and stacked uncertainty
- Ignores both holistic and lexical aspects

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Methods

Syntactic constraint

- Limits relations to those matching a certain POS Tag pattern:
- $V \mid VP \mid VW^*P$
- Always chooses longest possible match
- Merge adjacent matches together

$$V \mid VP \mid VW^*P$$

V = verb particle? adv?
 W = (noun | adj | adv | pron | det)
 P = (prep | particle | inf. marker)

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Lexical constraint

- Only assume relations that appear in the corpus for a certain amount
- The Obama administration is **offering only modest greenhouse gas reduction targets** at the conference

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Methods

Limitations of those constraints

- In a set of 300 hand-annotated sentences 85% relations fell into those constraints
- Model is not complete and has its flaws

Binary Verbal Relation Phrases	
85%	Satisfy Constraints
8%	Non-Contiguous Phrase Structure Coordination: X <u>is produced</u> and maintained <u>by</u> Y Multiple Args: X <u>was founded</u> in 1995 <u>by</u> Y Phrasal Verbs: X <u>turned</u> Y <u>off</u>
4%	Relation Phrase Not Between Arguments Intro. Phrases: <u>Discovered by</u> Y, X ... Relative Clauses: ... the Y that X <u>discovered</u>
3%	Do Not Match POS Pattern Interrupting Modifiers: X <u>has a lot of faith in</u> Y Infinitives: X <u>to attack</u> Y



ReVerb Extraction Algorithm

- *Relation Extraction*: Find the longest possible string of words that match the relation constraints, merge adjacents
- *Argument Extraction*: Find the nearest NP left and right to the relation that is not a relativ pronoun, WHO-adverb or existential-there.
- How is the lexical constraint being checked? By creating a list of relational phrases by applying this algorithm on a 500 million Web sentences.

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ReVerb Confidence Function

- The Algorithm has a high recall, but low precision
- Now the extracted relation is weighted by a confidence function:

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ReVerb Confidence Function

Weight	Feature
1.16	(x, r, y) covers all words in s
0.50	The last preposition in r is <i>for</i>
0.49	The last preposition in r is <i>on</i>
0.46	The last preposition in r is <i>of</i>
0.43	$len(s) \leq 10$ words
0.43	There is a WH-word to the left of r
0.42	r matches VW*P from Figure 1
0.39	The last preposition in r is <i>to</i>
0.25	The last preposition in r is <i>in</i>
0.23	$10 \text{ words} < len(s) \leq 20 \text{ words}$
0.21	s begins with x
0.16	y is a proper noun
0.01	x is a proper noun
-0.30	There is an NP to the left of x in s
-0.43	$20 \text{ words} < len(s)$
-0.61	r matches V from Figure 1
-0.65	There is a preposition to the left of x in s
-0.81	There is an NP to the right of u in s

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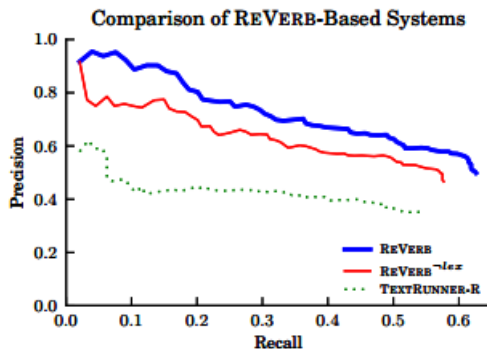
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Evaluation



Better results than TextRunner through lexical features, but still low recall.

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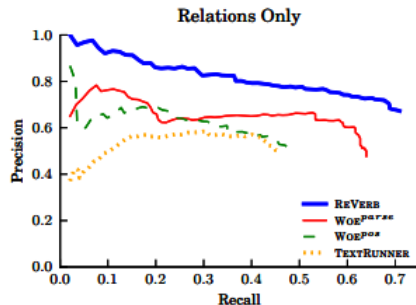
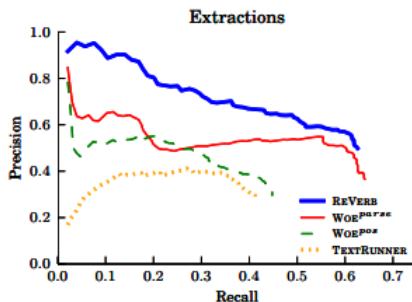
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Methods

Why?



Argument extraction is open to improvements



Methods

Why?

Evaluating the evaluation:

REVERB - Incorrect Extractions

65%	Correct relation phrase, incorrect arguments
16%	N-ary relation
8%	Non-contiguous relation phrase
2%	Imperative verb
2%	Overspecified relation phrase
7%	Other, including POS/chunking errors

REVERB - Missed Extractions

52%	Could not identify correct arguments
23%	Relation filtered out by lexical constraint
17%	Identified a more specific relation
8%	POS/chunking error

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Conclusion

Acceptable results on easy sentences. Fails on more complex sentences. *Possible improvements:*

- Does not support n-ary relations
- Relations seem overly specific in many results
- Coordination is not in all cases correctly recognized
- Coreference is not predicted by the system

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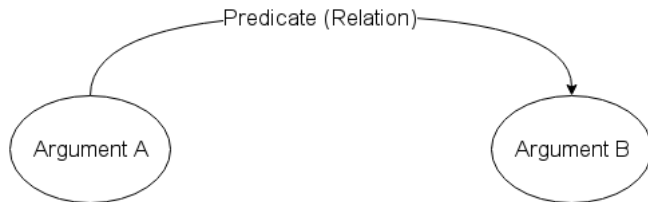
OIE - Principles

Data Representation

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Standard Patterns



Argument A is in a directed relation to **Argument B**.

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Unnormalized Annotation

(argument_a, predicate_x, argument_b)
(argument_a, predicate_y, argument_c)
(argument_a, predicate_y, argument_d)

Problems

- redundant
- unnormalized
- can only produce binary predicates

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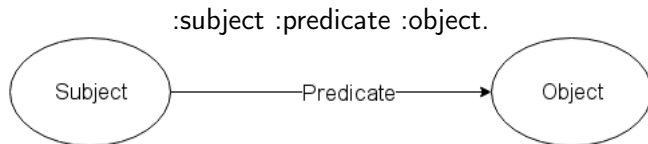
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RDF and Linked Data

Resource Description Framework

Models propositions by constructing *triples* including **Subjects**, **Objects** and **Predicates**

Generates a directed graph





RDF Concepts and Notation

- **URIs**
identifies resources (S, R, O) distinctively and references further informations (triples)
- **Conclusions**
allows to draw conclusions using rules
- **Turtle**
allows syntax abbreviations
- **Blanknodes**
placeholder for something without a URI
- **Queries**
can be searched by querying (eg SPARQL)

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RDF Reification

Motivation: How can I realize embedded propositions?

Example: Peter said, he watched the movie.

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RDF Reification

Motivation: How can I realize embedded propositions?

Example: Peter said, he watched the movie.

Wrong proposition

:Peter :watched :movie

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RDF Reification

Motivation: How can I realize embedded propositions?

Example: Peter said, he watched the movie.

Reification

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:Peter :said __:prop.  
__:prop rdf:subject :Peter.  
__:prop rdf:predicate :watched.  
__:prop rdf:object :movie.
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Vocabularies & Ontologies

Several vocabularies provide useful relations and functionality, eg.:

- RDF (rdf:type, ...)
- RDFS (rdfs:subClassOf, rdfs:domain, rdfs:range, ...)
- OWL (owl:sameAs, owl:SymmetricProperty, ...)
- FOAF

Ontologies are huge RDF Graphs containing many triples, eg.:

- DBpedia
- Wikidata
- WordNet


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RDF Syntax

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dbr:Barack_Obama a foaf:person, :President;
    dbo:spouse dbr:Michelle_Obama.
dbr:Bernie_Sanders dbo:birthPlace dbr:New_York,
    dbr:Brooklyn;
dbr:Brooklyn dbo:isPartOf dbr:New_York

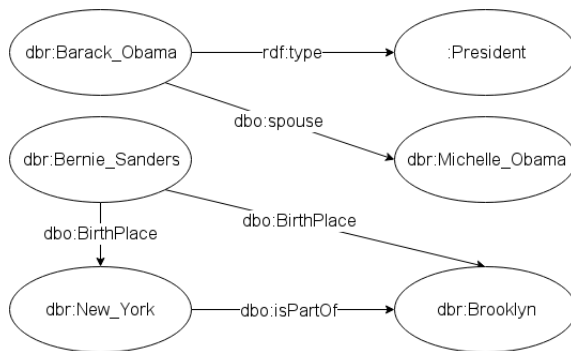
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Data Representation

... as Graph



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Example: LODifier

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LODifier: Generating Linked Data from Unstructured Text (Augenstein et al., 2012)

Generate an RDF Graph from unstructured Text

Past Approaches: Use Patterns to trade recall for precision

LODifier: Process the entire text

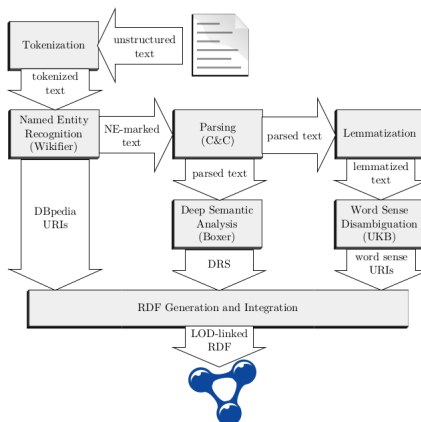
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Example: LODifier Architecture

Architecture

Architecture



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Approach

- 1 **Parse** the input text (POS, Treetagging, NER)
- 2 Apply **Deep Semantic Analysis** to get relations
- 3 Enrich NEs and words with **URIs** (DBpedia and WordNet)
- 4 Forge an **RDF Graph** of this information

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Architecture

How does it happen?

Lets go through the process step-by-step!

Example Text:

The New York Times reported that John McCarthy died. He invented the programming language LISP.

example taken from Augenstein et al., 2012

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Example: LODifier

Preprocessing

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Named Entity Recognition - Wikifier

Wikifier

Recognizes NE and replaces them with the Wikipedia Page Link
Disambiguates by comparing links between pages.

Example Text Output:

[The New York Times] reported that [John McCarthy (computer scientist)|John McCarthy] died. He invented the [Programming language|programming language] [Lisp (programming language)|LISP].

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Parsing Syntax - C&C

C&C Parser

Syntactical Parser that tags POS and builds Parse Trees in CCG.

Combinatory Categorical Grammar (CCG)

Grammatical formalism allows parallel analysis of syntax and semantics

Associates words with categories that can be combined (rule-based) to form a sentence

Syntax via Category Combination, Semantics via lambda calculus

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Preprocessing

Parsing - Output

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ccg(1, rp(s:dcl,
  ba(s:dcl,
    lx(np, n,
      t(n, 'The_New_York_Times', 'The_New_York_Times', 'NNS', 'I-NP', 'O')),
    fa(s:dcl\np,
      t((s:dcl\np)/s:em, 'reported', 'report', 'VBD', 'I-VP', 'O')),
    fa(s:em,
      t(s:em/s:dcl, 'that', 'that', 'IN', 'I-SBAR', 'O')),
    ba(s:dcl,
      lx(np, n,
        t(n, 'John_McCarthy', 'John_McCarthy', 'NNP', 'I-NP', 'I-PER')),
        t(s:dcl\np, 'died', 'die', 'VBD', 'I-VP', 'O')))),
  t(period, '.', '.', '.', 'O', 'O'))).
ccg(2, rp(s:dcl,
  ba(s:dcl,
    t(np, 'He', 'he', 'PRP', 'I-NP', 'O'),
    fa(s:dcl\np,
      t((s:dcl\np)/np, 'invented', 'invent', 'VBD', 'I-VP', 'O'),
      fa(np:nb,
        t(np:nb/n, 'the', 'the', 'DT', 'I-NP', 'O'),
        fa(n,
          t(n/n, 'programming_language', 'programming_language', 'NN', 'I-NP', 'O'),
          t(n, 'LISP', 'LISP', 'NNP', 'I-NP', 'O'))))),
  t(period, '.', '.', '.', 'O', 'O'))).

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Find Relations - Boxer

Boxer

Creates DRSs from C&C Output

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Find Relations - Boxer

Boxer

Creates DRSs from C&C Output

Discours Representation Structure (DRS)

Represents the discourse via *relations* between *entities*
Allows referencing over the entire discourse

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Find Relations - Boxer

Boxer

Creates DRSs from C&C Output

Discours Representation Structure (DRS)

Represents the discourse via *relations* between *entities*
Allows referencing over the entire discourse

Boxers DRS Relations (Conditions):

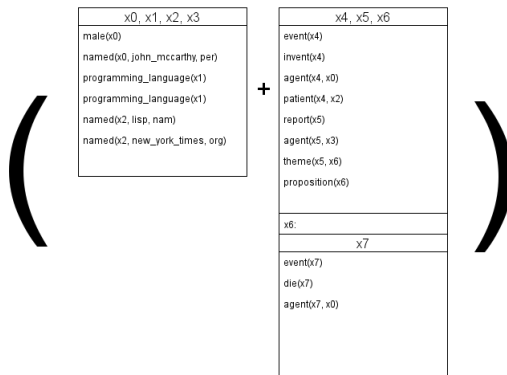
- **Unary Relations (Classes):** eg. *topic, person, event, male, ...*
+ all verbs
- **Binary Relations:** agent, patient, ... (semantic roles)

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Preprocessing

Boxer Output



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Assign WordNet URIs

RDF WordNet

WN: Lexicography containing senses linked by semantic relations

RDF WN: LD Representation of WN providing URIs for words

Steps:

- 1 Lemmatization
- 2 WSD (UKB)
- 3 Assign RDF WN URIs to word senses

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Preprocessing

Preprocessing Result

We now have ...

- URIs for all NEs
- URIs for all (disambiguated) words
- Relations between entities (those URIs)

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Example: LODifier

RDF Construction

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RDF Construction

What now?

Let's now construct the RDF Graph from this information!

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Namespaces/Vocabularies

LODifier introduces several namespaces:

- **drsclass**: contains Boxer classes (event, person, ...) and :named relation
- **drsrel**: contains Boxer relations (agent, patient, ...)
- **ne**: contains the named entity URLs
- **reify**: reification (embedding propositions into propositions)

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Namespaces/Vocabularies

And uses standard namespaces:

- **rdf:** mainly for `rdf:type` and reification
- **owl:** for `owl:sameAs`

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Namespaces/Vocabularies

Finally the two ontologies:

- **wn30**: contains all WordNet URIs
- **dbpedia**: contains the dbpedia URIs
- **class**: contains classes not in wn30 nor in dbpedia

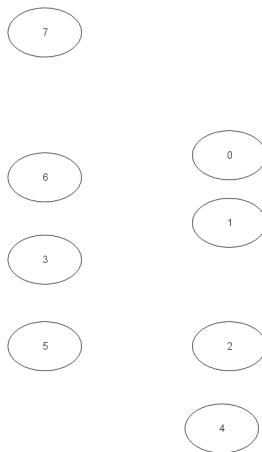
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RDF Construction Strategy I

Create a blanknode `_:x` for each discourse referent (`x0, x1, ...`)

RDF Construction Strategy II



RDF Construction Strategy III

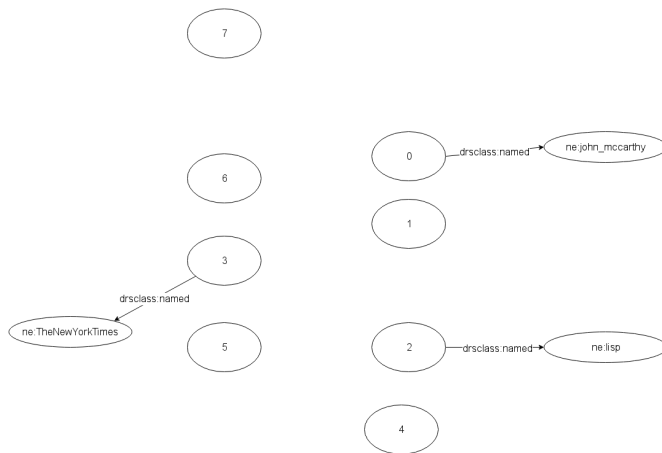
if NE, then create

`_:x drsclass:named ne:URI`



RDF Construction

RDF Construction Strategy IV

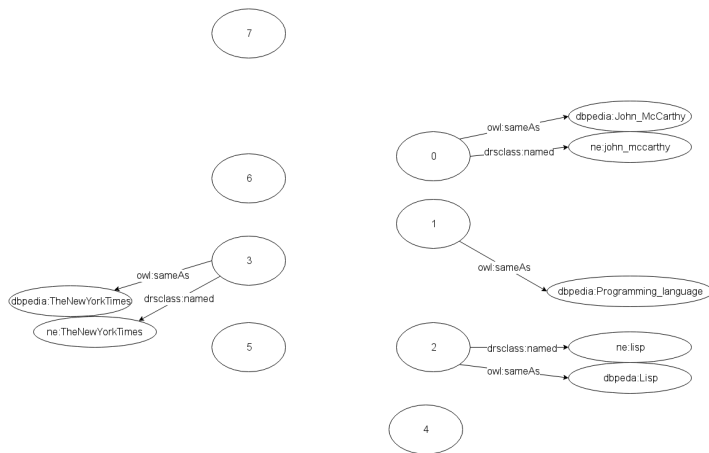


RDF Construction Strategy V

if NE and DBpedia URI exists create
__ :x owl:sameAs dbpedia:URI

RDF Construction

RDF Construction Strategy VI

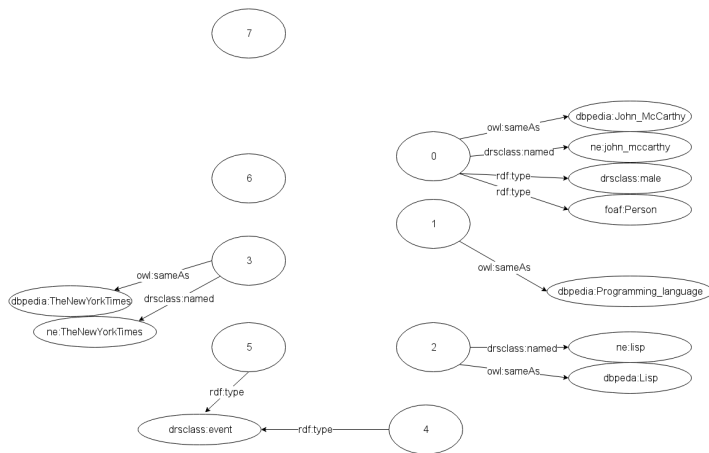


RDF Construction Strategy VII

via `rdf:type` assign closed classes (event, person, ...)
`_:x rdf:type drsclass:CLOSEDCLASS`

RDF Construction

RDF Construction Strategy VIII



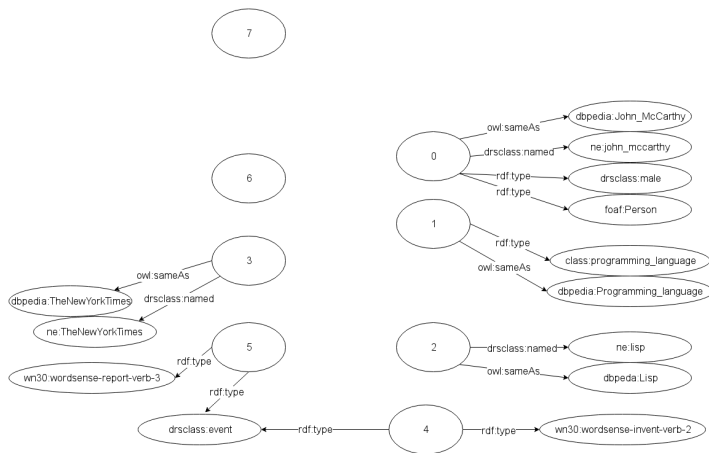


RDF Construction Strategy IX

via `rdf:type` assign open classes (die, programming_language, ...)
`_:x rdf:type wn30:OPENCLASS, class:OPENCLASS`

RDF Construction

RDF Construction Strategy X





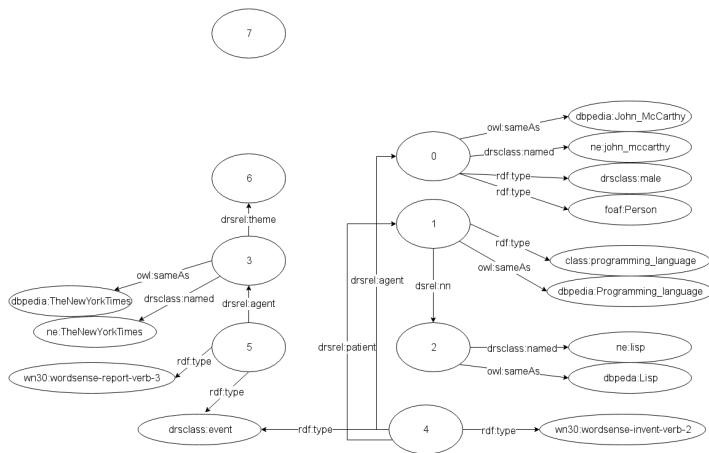
RDF Construction Strategy XI

create triples from binary relations (agent, theme, ...)

`_:x drsrel:RELATION _:y`

RDF Construction

RDF Construction Strategy XII



RDF Construction Strategy XIII

recursive reification of embedded propositions (eg. by *report* or *says*)

RDF Construction Strategy XIV



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RDF Construction

RDF Construction: Output

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_:var0x0 drsclass:named ne:john_mccarthy ;
        rdf:type drsclass:male , foaf:Person ;
        owl:sameAs dbpedia:John_McCarthy_(computer_scientist) .
_:var0x1 rdf:type class:programming_language ;
        owl:sameAs dbpedia:Programming_language .
_:var0x2 drsrel:nn _:var0x1 .
_:var0x2 drsclass:named ne:lisp ;
        owl:sameAs dbpedia:Lisp_(programming_language) .
_:var0x3 drsclass:named ne:the_new_york_times ;
        owl:sameAs dbpedia:The_New_York_Times .
_:var0x4 rdf:type drsclass:event , wn30:wordsense-invent-verb-2 .
        drsrel:agent _:var0x0 ; drsrel:patient _:var0x2 .
_:var0x5 rdf:type drsclass:event , wn30:wordsense-report-verb-3 ;
        drsrel:agent _:var0x3 ; drsrel:theme _:var0x6 .
_:var0x6 rdf:type drsclass:proposition , reify:proposition , reify:conjunction ;
        reify:conjunct [ rdf:subject _:var0x7 ;
                        rdf:predicate rdf:type ;
                        rdf:object drsclass:event . ]
        reify:conjunct [ rdf:subject _:var0x7 ;
                        rdf:predicate rdf:type ;
                        rdf:object wn30:wordsense-die-verb-1 . ]
        reify:conjunct [ rdf:subject _:var0x7 ;
                        rdf:predicate drsrel:agent ;
                        rdf:object _:var0x0 . ]

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Example: LODifier Experiments

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Method

- Evaluate by testing similarity of two given documents:
- *the problem of deciding whether two randomly selected stories discuss the same news topic*
- TDT-2 benchmark dataset: 84.000 news documents
- Extract 183 positive and 183 negative pairs (avg. 11.2 per topic)
- Calculate similarity and evaluate the system on the result

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Similarity measurements

- 1 NEs identified by Wikifier and successfully disambiguated words in UKB
- 2 add NEs recognized by Boxer
- 3 add URIs of unrecognized words

Further add structural features: Measurement of the similarity of the RDF graphs of the two documents

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Experiments

Accuracy

Table 1. Accuracy on Story Link Detection Task

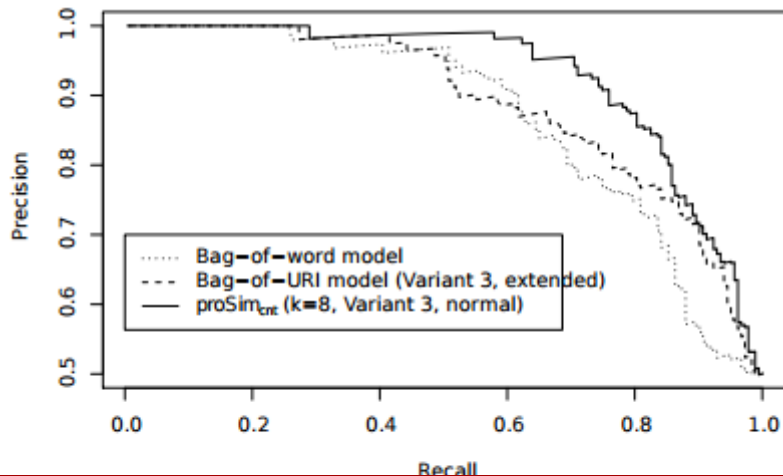
Model	normal extended	
Similarity measures without structural knowledge		
Random Baseline	50.0	–
Bag of Words	63.0	–
Bag of URIs (Variant 1)	61.6	75.1
Bag of URIs (Variant 2)	70.6	76.0
Bag of URIs (Variant 3)	73.4	76.4
Similarity measures with structural knowledge		
proSim _{cut} (k=6, Variant 1)	79.0	78.9
proSim _{cut} (k=6, Variant 2)	80.3	80.3
proSim _{cut} (k=6, Variant 3)	81.6	81.6
proSim _{cut} (k=8, Variant 1)	77.7	77.6
proSim _{cut} (k=8, Variant 2)	79.2	79.0
proSim _{cut} (k=8, Variant 3)	82.1	81.9
proSim _{len} (k=6, Variant 3)	81.5	81.4
proSim _{len} (k=8, Variant 3)	80.3	80.1
proSim _{len} (k=10, Variant 3)	80.0	79.8
proSim _{sqen} (k=6, Variant 3)	80.4	80.4
proSim _{sqen} (k=8, Variant 3)	81.1	80.9
proSim _{sqen} (k=10, Variant 3)	80.5	80.4

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Experiments

Precision - Recall



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Example: LODifier

Conclusions

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Conclusions

What to draw from this?

- deep semantic analysis can work for OIE
- information gained by unsupervised OIE can already improve real world tasks

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What we liked

- full-text OIE

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Conclusions

What we liked

- full-text OIE
- uses many strengths of RDF

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Conclusions

What we liked

- full-text OIE
- uses many strengths of RDF
- relations aren't overspecified

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Conclusions

What we liked

- full-text OIE
- uses many strengths of RDF
- relations are not overspecified
- extendable/improvable by improving/swapping Systems in the architecture

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What we liked

- full-text OIE
- uses many strengths of RDF
- relations are not overspecified
- extendable/improvable by improving/swapping Systems in the architecture
- Part of the LOD-Cloud

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What we liked

- full-text OIE
- uses many strengths of RDF
- relations are not overspecified
- extendable/improvable by improving/swapping Systems in the architecture
- Part of the LOD-Cloud
- results in standardized notation

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Conclusions

What we liked

- full-text OIE
- uses many strengths of RDF
- relations are not overspecified
- extendable/improvable by improving/swapping Systems in the architecture
- Part of the LOD-Cloud
- results in standardized notation
- domain-independent

What we didnt like

- Redundant processes like NER

What we didnt like

- Redundant processes like NER
- BlankNode Massacre

Conclusions

What we didnt like

- Redundant processes like NER
- BlankNode Massacre
- confusing boxer relations not simplified for RDF (will be hard to search through)

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Conclusions

What we didnt like

- Redundant processes like NER
- BlankNode Massacre
- confusing boxer relations not simplified for RDF (will be hard to search through)
- Paper scratches only the surface of the system

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Conclusions

What we didnt like

- Redundant processes like NER
- BlankNode Massacre
- confusing boxer relations not simplified for RDF (will be hard to search through)
- Paper scratches only the surface of the system
- Some points are unclear / not even described

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Conclusion

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Weaknesses and Strengths of OIE

- trades precision for recall
- $OIE > IE$ if no special task/domain is defined
- theory independent
- relations may be redundant/overspecified/unintended
- restricted usability of results due to low precision

Future Opportunities

- better subsystems
 - Coreference Resolution
 - NER
 - Disambiguation
- improve semantic analysis

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