

Semantic Parsing and Beyond to Create a Commonsense Knowledge Base

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Computational Semantics, Semantic Web, Natural Language Generation, Information Extraction, Linguistic Annotation, Distributional Semantics, General Knowledge Bases, Gamification, Social Media, Sentiment Analysis, Legal Informatics, Argument Mining, Math, Pasta, Videogames, ...

Today

Robotics and Artificial Intelligence

Objects

Linguistics and Semantics

Machine Learning and Clustering

Today

- I Motivation: The Semantics of Objects
- II Objects, Knowledge and The Web
- III Objects, Words and Vectors
- IV Frames and Prototypical Knowledge
- V Default Knowledge about Objects

Part I

Motivation:

The Semantics of Objects

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

5-year CHIST-ERA funded project (2014-2018)

4 EU partners



AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

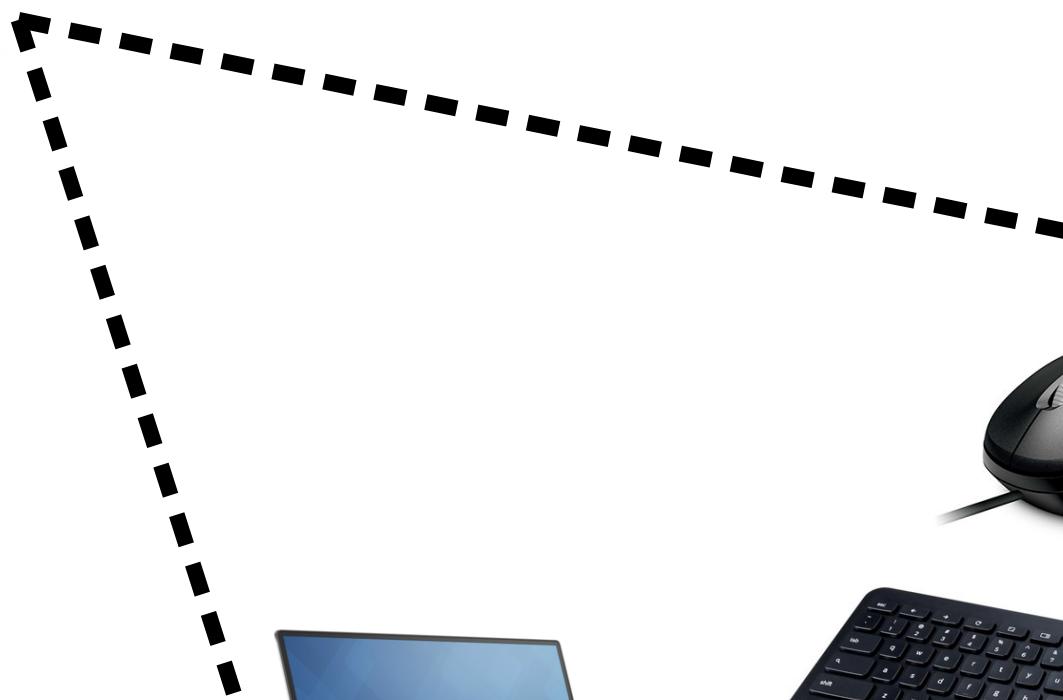
Deploy **robots** in human-inhabited environments.

The robots **autonomously** collect real-world data.

We use information available on the **Semantic Web** to identify the semantics of objects.

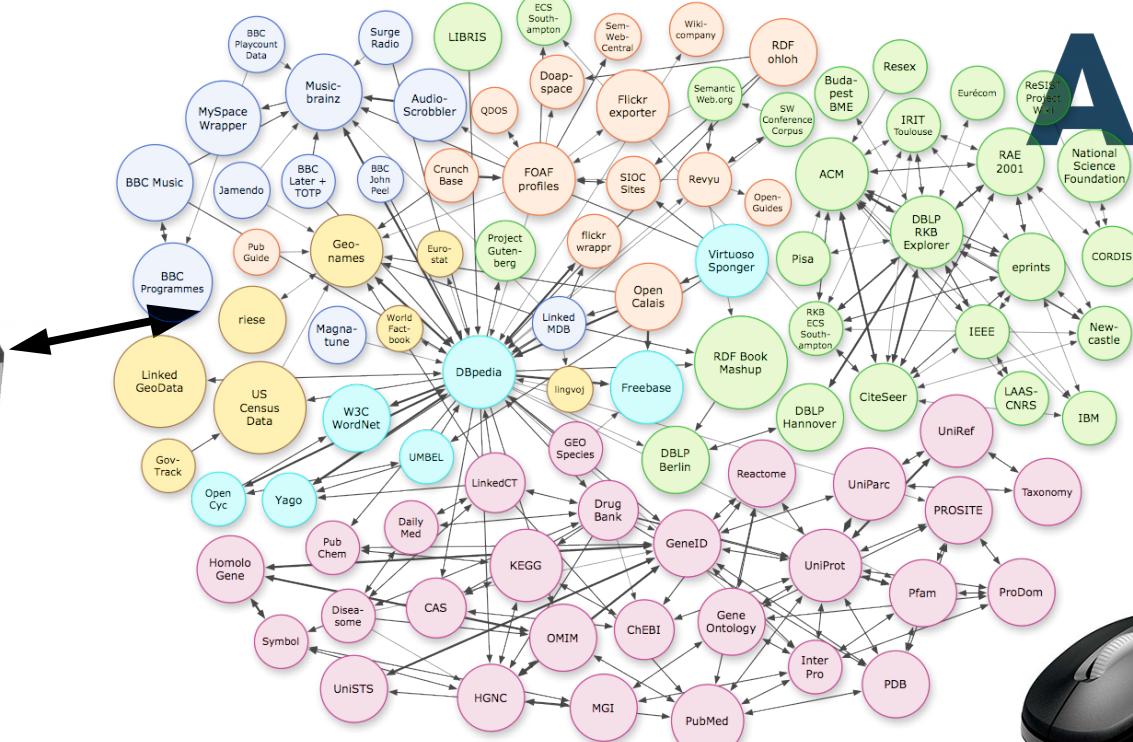
AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF



AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF



AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF





- Object classification
- Room detection
- Frame detection
- Inference
- ...

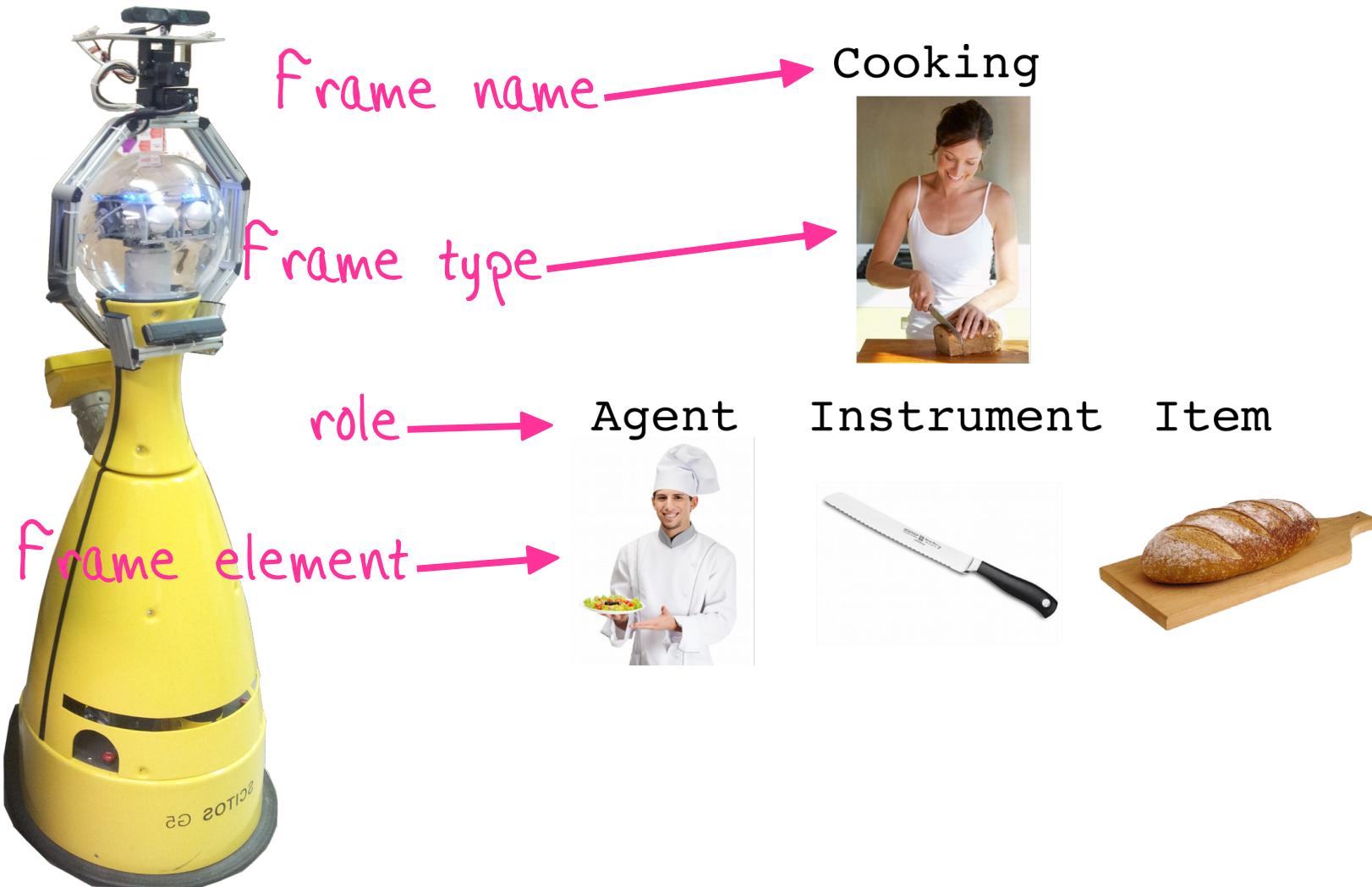
Frame Semantics



Bob, I want some pane!



Frame Semantics



Frame Semantics



Part II

Objects, Knowledge and The Web

Object Knowledge

Classification

What is (not) an object?

What type is an object?

What is a room?

...

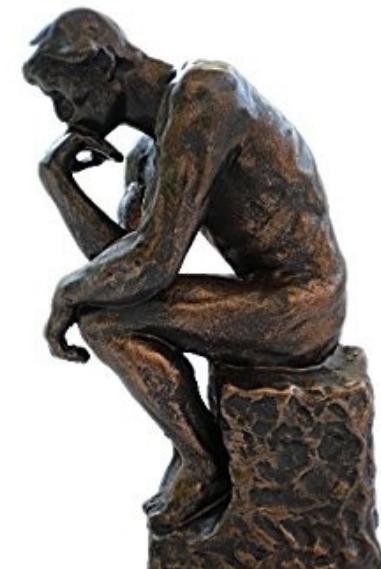
Relations

How are objects related?

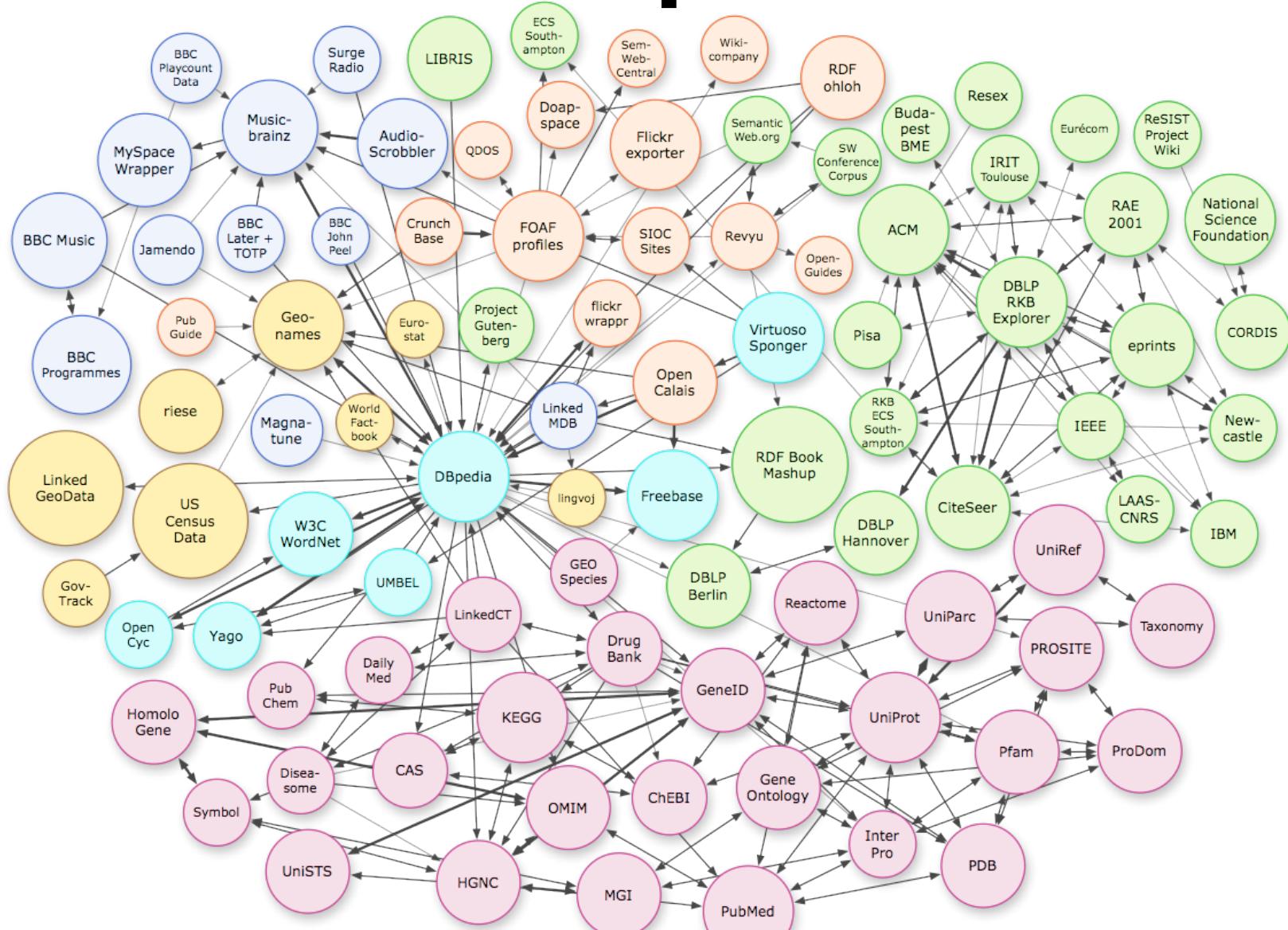
Where is an object?

What can I do with an object?

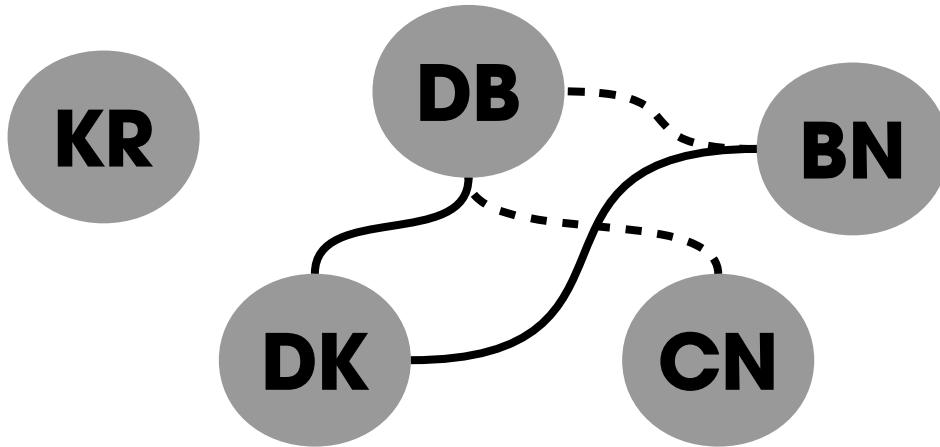
...



Linked Open Data



<http://lod-cloud.net/>



	Taxonomy	Function	Location	Linked Data
DBpedia	✓	✗	✗	✓
ConceptNet	✓	✓	✓	partly
KnowRob	✓	✓	partly	✗
BabelNet	✓	✗	✗	✓
SUN	✗	✗	✓	✗

Keyword Linking Methods

DBpedia Lookup

“official” search API of DBpedia

String Match (+redirect)

Try <http://dbpedia.org/resource/{KEYWORD}>

Babelfy

State of the art algorithm for Word Sense
Disambiguation/Entity Linking

Keyword Linking Methods

Vector-based Contextual disambiguation

- Run String Match on the keywords
- Split the missed keywords into tokens
- Run String Match on the tokens
- Compute the semantic similarity of each token-entity with all the previously recognized entities
- Select the highest scoring token-entity

e.g., basket_of_banana → dbr:Basket

The SUN database



BEDROOM

Definition (WordNet): A room in a house used primarily for sleeping

2117 images
1043 annotated
18331 objects

Objects

List of most common objects found in this place sorted by frequency.

 Wall 2561 in this scene 20213 total	 Bed 1144 in this scene 1617 total	 Cushion 1043 in this scene 2091 total	 Pillow 1008 in this scene 1359 total	 Floor 991 in this scene 7227 total	 Desk lamp 953 in this scene 1702 total	 Night table 867 in this scene 1054 total
 Window 845 in this scene 16080 total	 Curtain 838 in this scene 2525 total	 Painting 651 in this scene 2784 total	 Ceiling 623 in this scene 5284 total	 Picture 457 in this scene 1822 total	 Chair 275 in this scene 7971 total	 Door 265 in this scene 4135 total
 Ceiling lamp 243 in this scene 6268 total	 Cabinet 229 in this scene 3102 total	 Mirror 200 in this scene 954 total	 Sconce 189 in this scene 1054 total	 Plant 176 in this scene 3095 total	 Armchair 167 in this scene 1080 total	

Similar scenes

List of places with the most similar object distributions. The list is sorted by similarity.

 Hotel room 499 images 113 annotated 1908 objects	 Childs room 163 images 77 annotated 1723 objects	 Alcove 66 images 29 annotated 433 objects	 Parlor 338 images 66 annotated 1459 objects	 Dorm room 167 images 50 annotated 957 objects	 Youth hostel 139 images 27 annotated 388 objects	 Attic 375 images 48 annotated 779 objects
 Bow window indoor 217 images 33 annotated 497 objects	 Nursery 258 images 65 annotated 952 objects					

Annotated images

 basket, bed skirt, books, box, chair, comforter, cow on wheels, decorative	 basket, bed skirt, bench, blanket, book, ceiling, chair, chest, chimney, coat rack	 beam, bed, bowl, ceiling, ceiling lamp, chair, coffee maker, coffee table	 basket, bedpost, bench, books, box, cabinet, candleholder, chair, comforter	 armchair, bed, ceiling, ceiling lamp, cushion, door, floor, floor lamp, flowers, grille, night	 armchair, bed, bottle, box, cabinet, ceiling, ceiling fan, clock, curtain, cushion, desk	 bed, book, ceiling, ceiling fan, ceiling lamp, chest, curtain, cushion, floor, floor	 bag, bed, bookcase, books, box, carpet, ceiling, chandelier, cuddly toy, cushion	 bed, bookcase, books, cabinet, ceiling, ceiling fan, ceiling lamp, chair, cushion
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<https://groups.csail.mit.edu/vision/SUN/>

The SUN database

131,067 Images

908 Scene categories

313,884 Segmented objects

4,479 Object categories

Table 3: Results of the systems on the *objects* dataset.

Method	Precision	Recall	F-score
DBpedia Lookup	0.397	0.272	0.322
String Match	0.523	0.327	0.402
Babelfy	0.780	0.418	0.544
String Match + Redirect	0.861	0.538	0.662
VCD (aggr.=AVG, T=0.3)	0.736	0.650	0.691

Table 4: Results of the systems on the *scenes* dataset.

Method	Precision	Recall	F-score
DBpedia Lookup	0.449	0.412	0.430
String Match	0.598	0.535	0.564
Babelfy	0.754	0.569	0.649
String Match + Redirect	0.839	0.750	0.792
VCD (aggr.=MAX, T=0.8)	0.811	0.786	0.798

The SUN database

Results

2,493 objects in DBpedia

679 locations in DBpedia

2,935 object-location relations

Classification



Relations



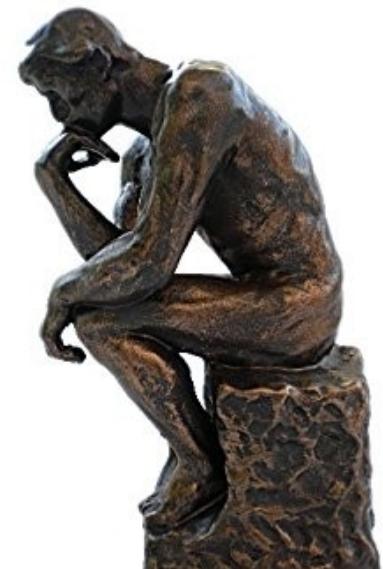
Part III

Objects, Words and Vectors

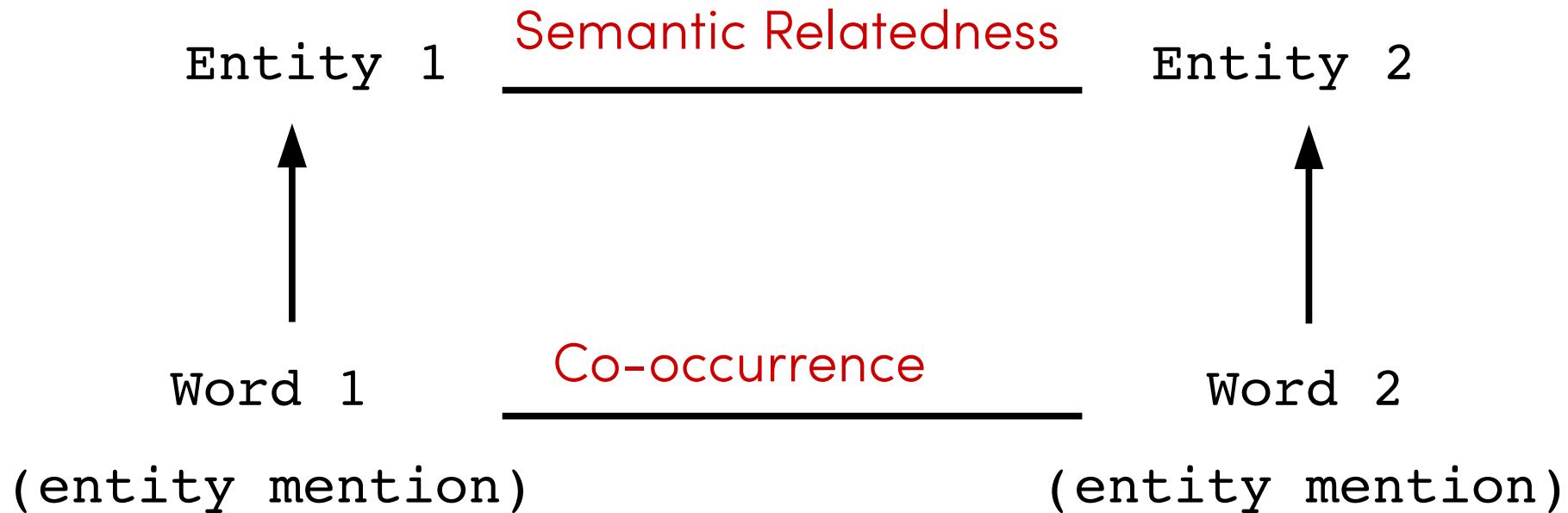
Object Knowledge

Problem

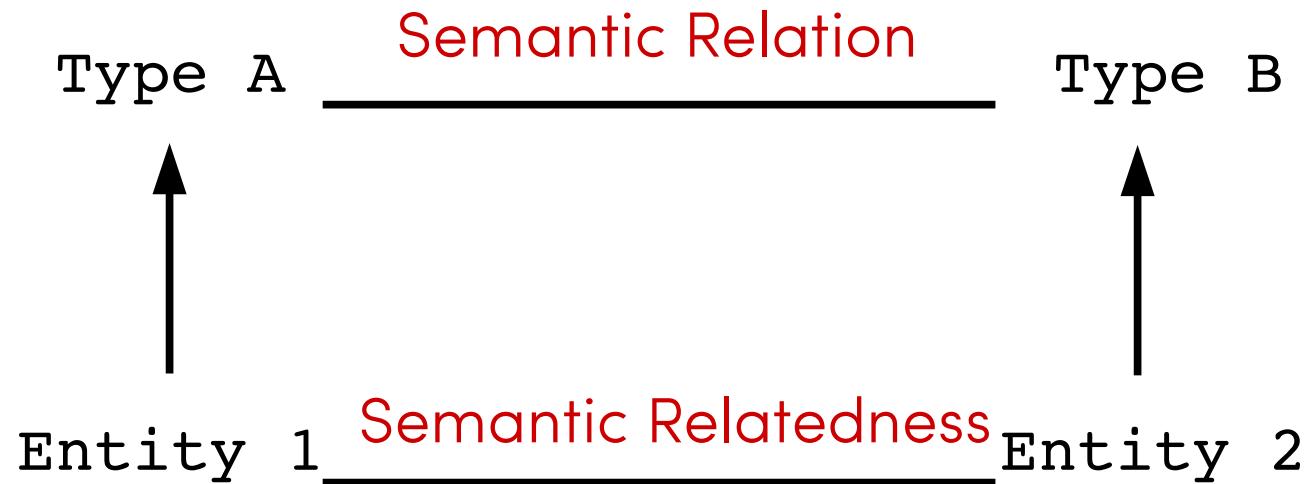
Classification is good, but relations are sparse



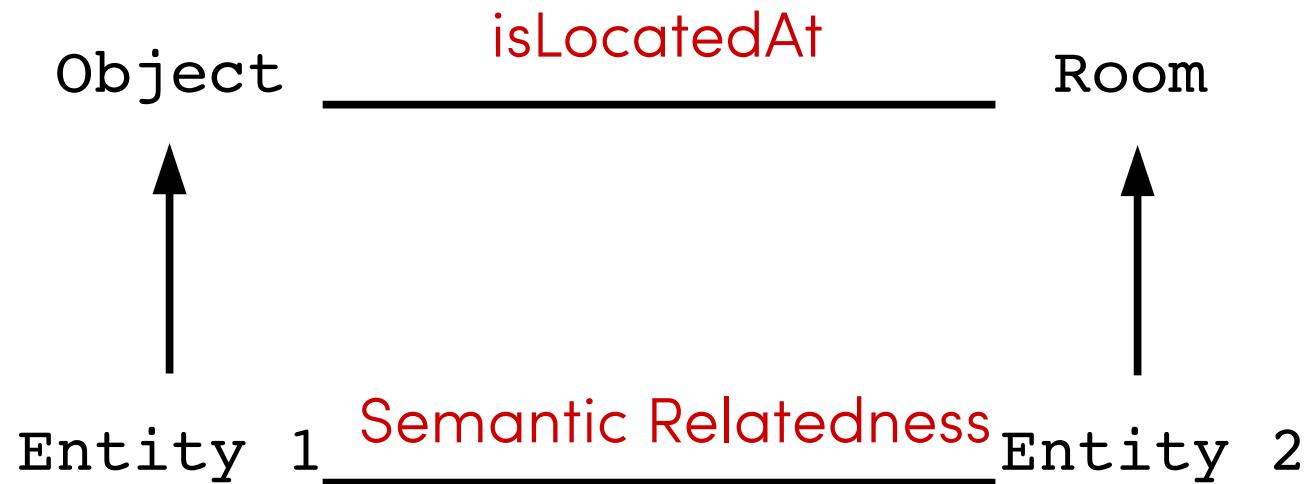
Distributional Hypothesis



Distributional Relational Hypothesis



Distributional Relational Hypothesis



Semantic Relatedness

QUESTION

Is it legal to fit a washing machine in the bathroom?

Hi all, I would like to fit a washing machine in the the bathroom. The power cable will be fed through a small hole in the wall with the outlet socket on the outside of the bathroom and the machine will be +1200mm from the edge of the bath and 500mm from the toilet. My question is, is this legal?

Asked by: edward_88 29th Dec, 2012 Electrical AddThis



washing machine, washer, automatic washer

A home appliance for washing clothes and linens automatically

ID: 00007365n | Concept



bathroom, bath, full bathroom

A room (as in a residence) containing a bathtub or shower and usually a washbasin and toilet

ID: 00008995n | Concept

Co-occurrence matrix

	Washing_machine	Ashtray
Bathroom	5	2
Bedroom	0	1
Living_room	1	6

Singular value decomposition

$$M = U \Sigma V^*$$

Low-rank approximation

$$U_k \Sigma_k V_k^* = M_k$$

NASARI: A Novel Approach to a Semantically-Aware Representation of Items
(Camacho-Collados, Pilehvar and Navigli, 2015)

Semantic Similarity

```
bn:00008995n Bathroom -0.03750793 0.06731935 -0.02334246 -0.02009913  
0.02251291 0.07689607 0.01527985 -0.10780967 0.18232885 0.1234034  
-0.0520944 -0.25805958 0.12200121 -0.04875973 -0.03544397 -0.03841146  
0.00970973 ...
```

```
bn:00007365n Washing_machine -0.00911299 0.11549547 -0.04274256 0.03672424  
-0.06627292 0.13761881 0.01171631 -0.08721243 0.08270955 0.13095092  
-0.00137408 -0.16226186 0.0422162 0.0545828 -0.01007292 0.10094466  
-0.05663372 0.09864459 0.10167608 7.534e-05 0.08067719 0.05527394
```

Cosine similarity:

$$\frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^n A_i B_i}{\sqrt{\sum_{i=1}^n A_i^2} \sqrt{\sum_{i=1}^n B_i^2}}$$

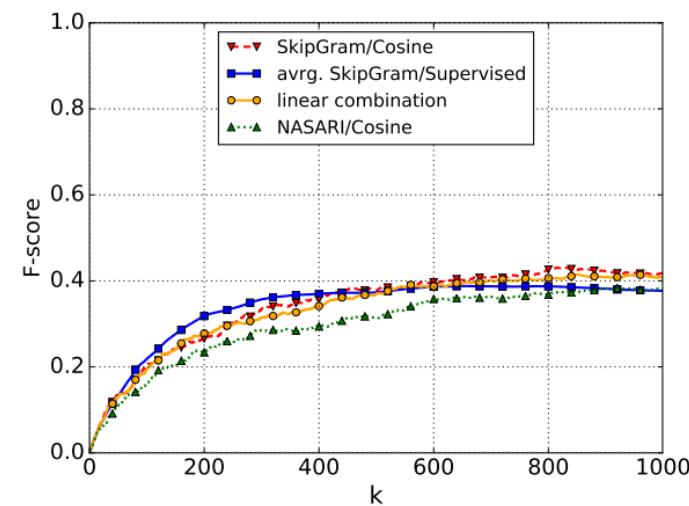
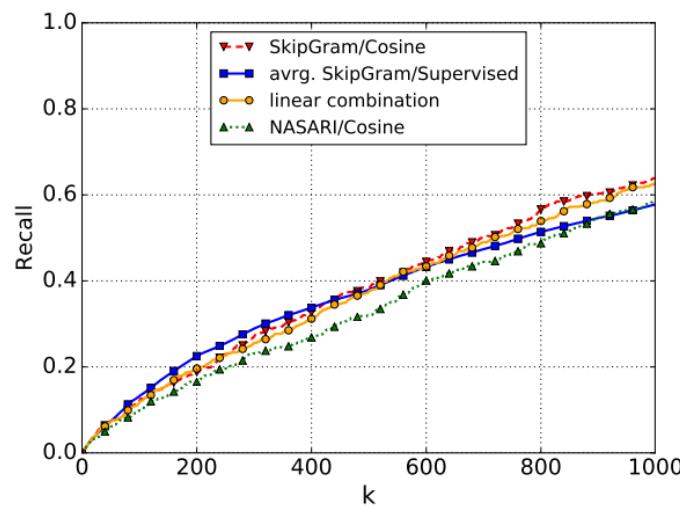
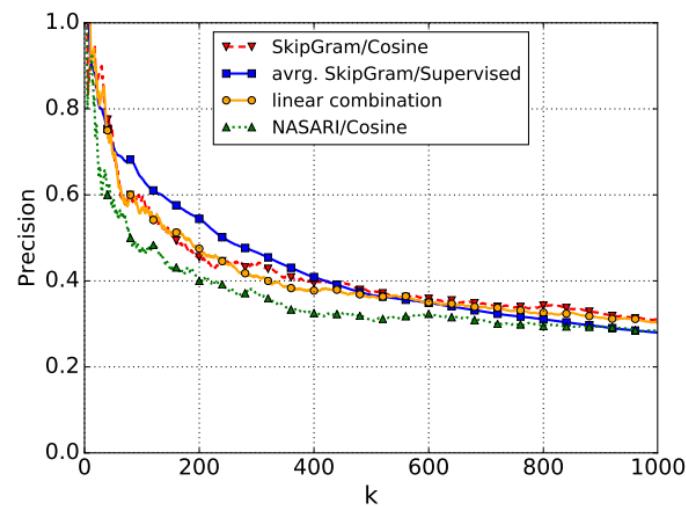
Semantic Similarity

Locations for a sample object, extracted by computing cosine similarity on NASARI vectors.

Object	Location	Cos. Similarity
Dishwasher	Kitchen	.803
	Air_shower_(room)	.788
	Utility_room	.763
	Bathroom	.758
	Furnace_room	.749
Paper_towel	Air_shower_(room)	.671
	Public_toilet	.634
	Bathroom	.632
	Mizuya	.597
	Kitchen	.589
Sump_pump	Furnace_room	.699
	Air_shower_(room)	.683
	Basement	.680
	Mechanical_room	.676

Evaluation: locatedAt

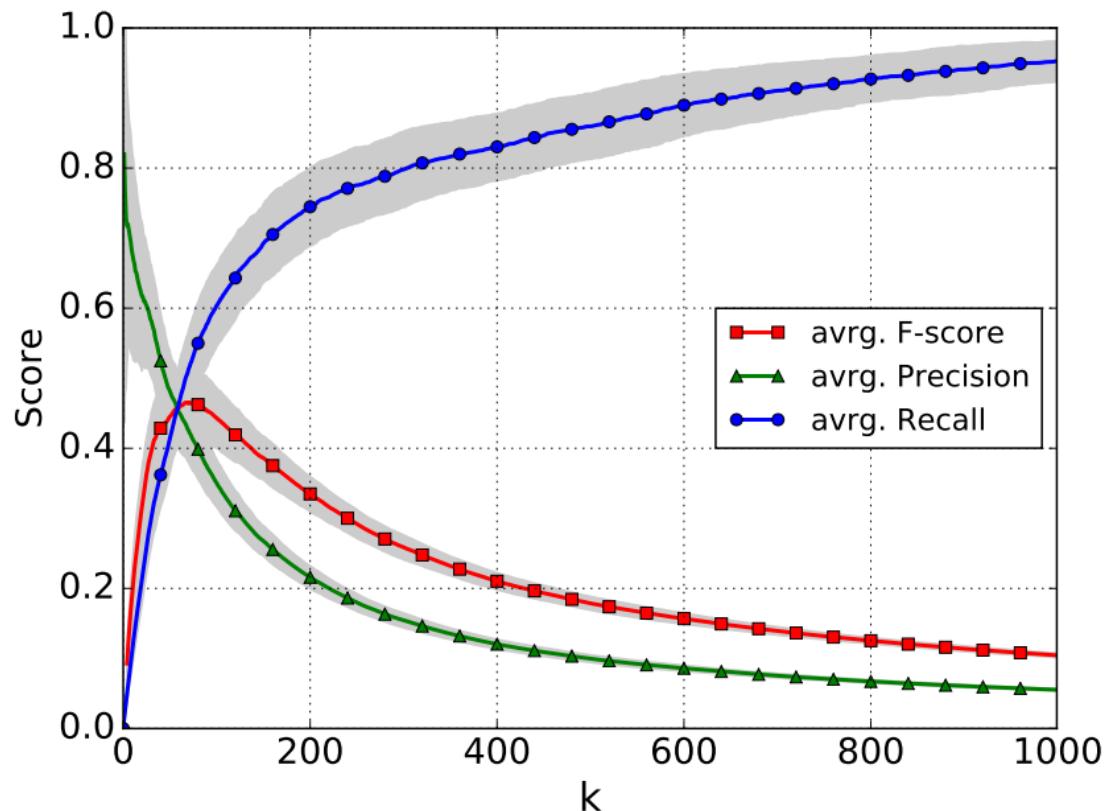
Extract the top k object-location pairs



Gold standard: SUN database linked to DBpedia

Evaluation: usedFor

Extract the top k object-action pairs



Gold standard: ConceptNet linked to DBpedia

Results

931 high confidence location relations

Only 52 were in the gold standard set

E.g.:

Trivet → Kitchen

Flight_bag → Airport_lounge

Soap_dispenser → Unisex_public_toilet

+ many related datasets:

<https://project.inria.fr/aloof/data/>

Distributional Relational Hypothesis

Object-action relation (usedFor)

Extracting common sense knowledge via triple ranking using supervised and unsupervised distributional models

S Jebbara, V Basile, E Cabrio, P Cimiano, Semantic Web 2018

Improving object detection

Semantic web-mining and deep vision for lifelong object discovery

J Young, L Kunze, V Basile, E Cabrio, N Hawes, B Caputo

Robotics and Automation, ICRA 2017

Object-location relation (locatedAt)

Populating a knowledge base with object-location relations using distributional semantics

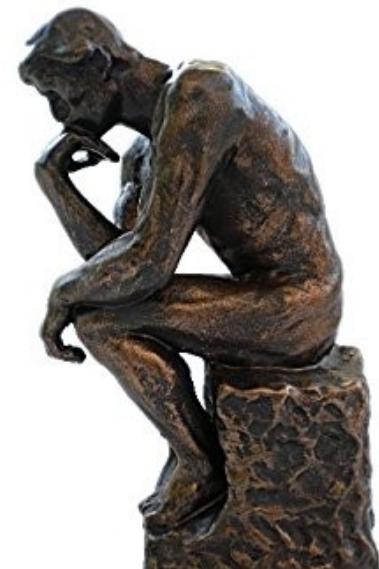
V Basile, S Jebbara, E Cabrio, P Cimiano, EKAW 2016

Part IV

Frames and Prototypical Knowledge

Problem

**The distributional relational hypothesis is limited
to specific relations**



Frame Semantics

Cooking



Agent

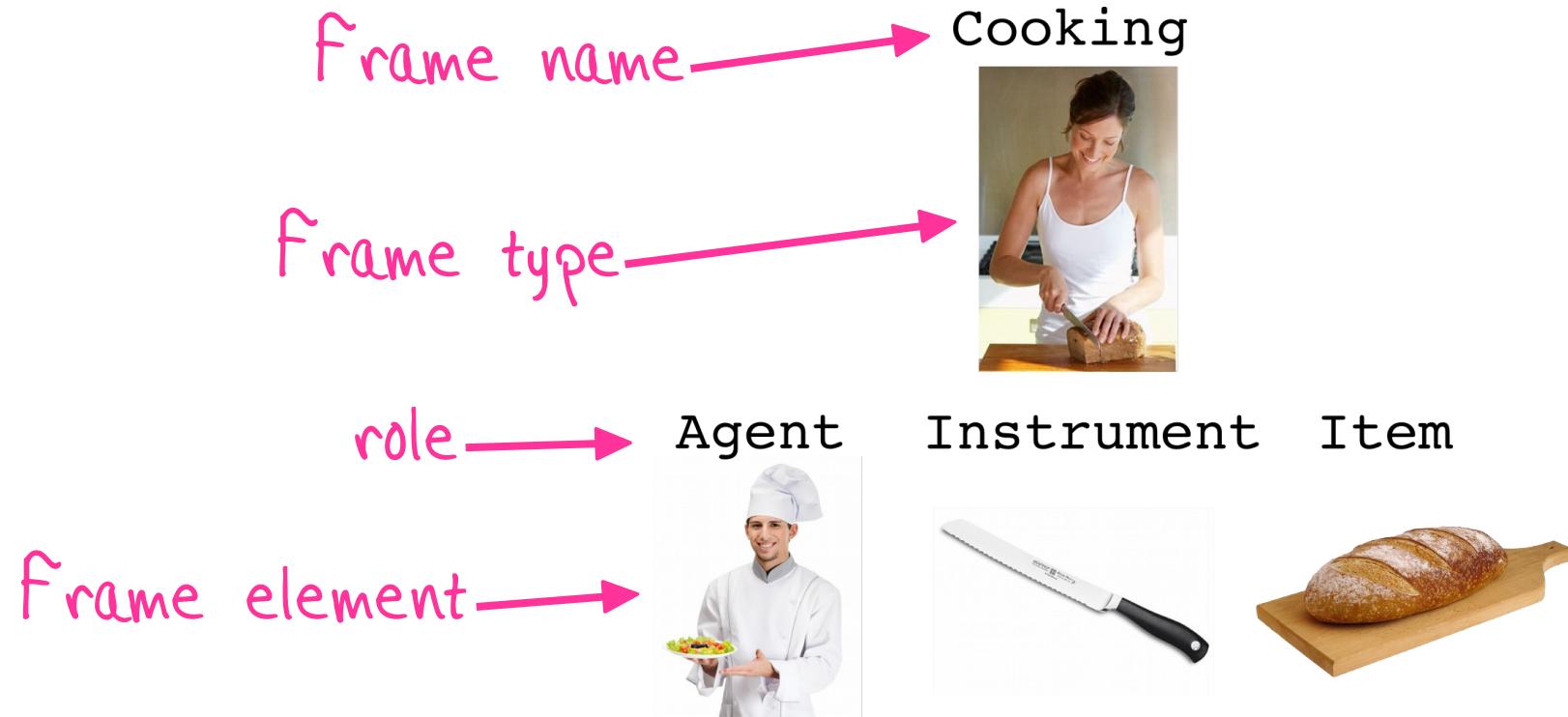


Instrument



Item

Frame Semantics



FrameNet (1997), Framester (2016), Framebase (2015)

Frame Instance

Instance id: <fi12345>

Frame type: fbframe:Cooking

Frame elements:

- fbfe:Instrument, dbr:Knife
- fbfe:Agent, dbr:Person
- ...

Frame Instance

Instance id: <fi12345>

Frame type: fbframe:Cooking

Frame elements:

- fbfe:Instrument, dbr:Knife
- fbfe:Agent, dbr:Person
- ...

Default Knowledge → Prototypical Frame Instances

Frame Instance

Instance id: <fi12345>

Frame type: fbframe:Cooking

Frame elements:

- fbfe:Instrument, dbr:Knife
- fbfe:Agent, dbr:Person
- ...

Default Knowledge → Prototypical Frame Instances
= F.I. extraction + F.I. clustering

Knowledge Extraction

Semantic Parsing

+

Word Sense Disambiguation & linking

+

Alignment

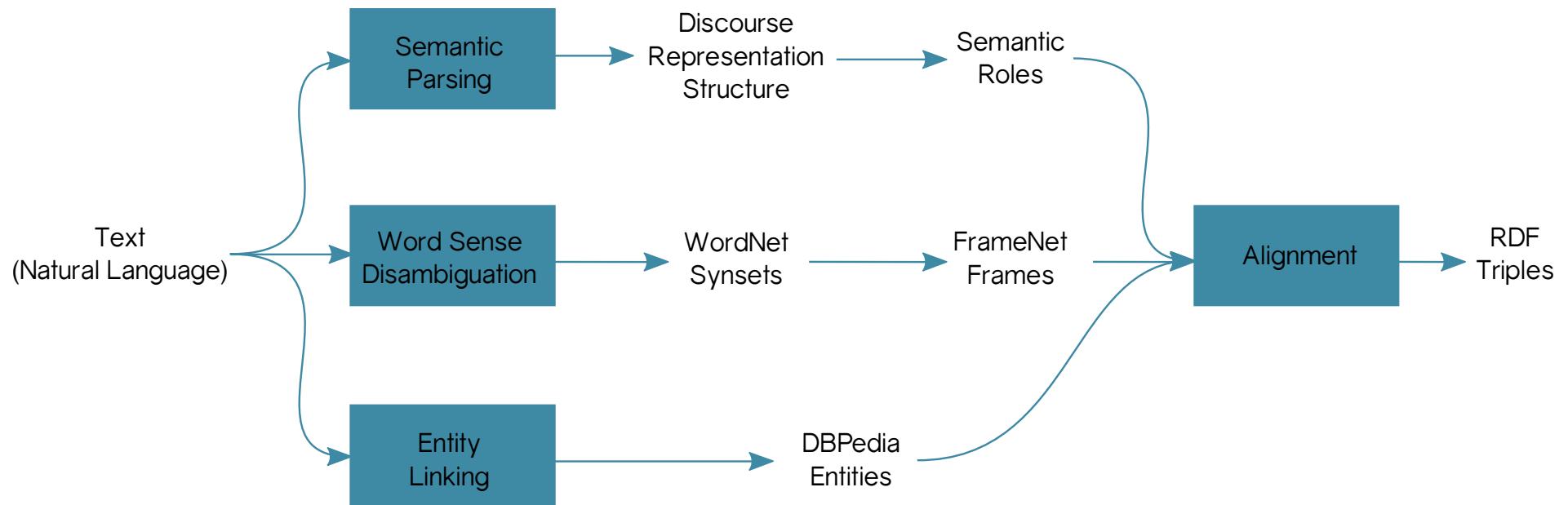
V. Basile, E. Cabrio, C. Schon

KNEWS: Using Logical and Lexical Semantics to Extract Knowledge from Natural Language

ECAI 2016

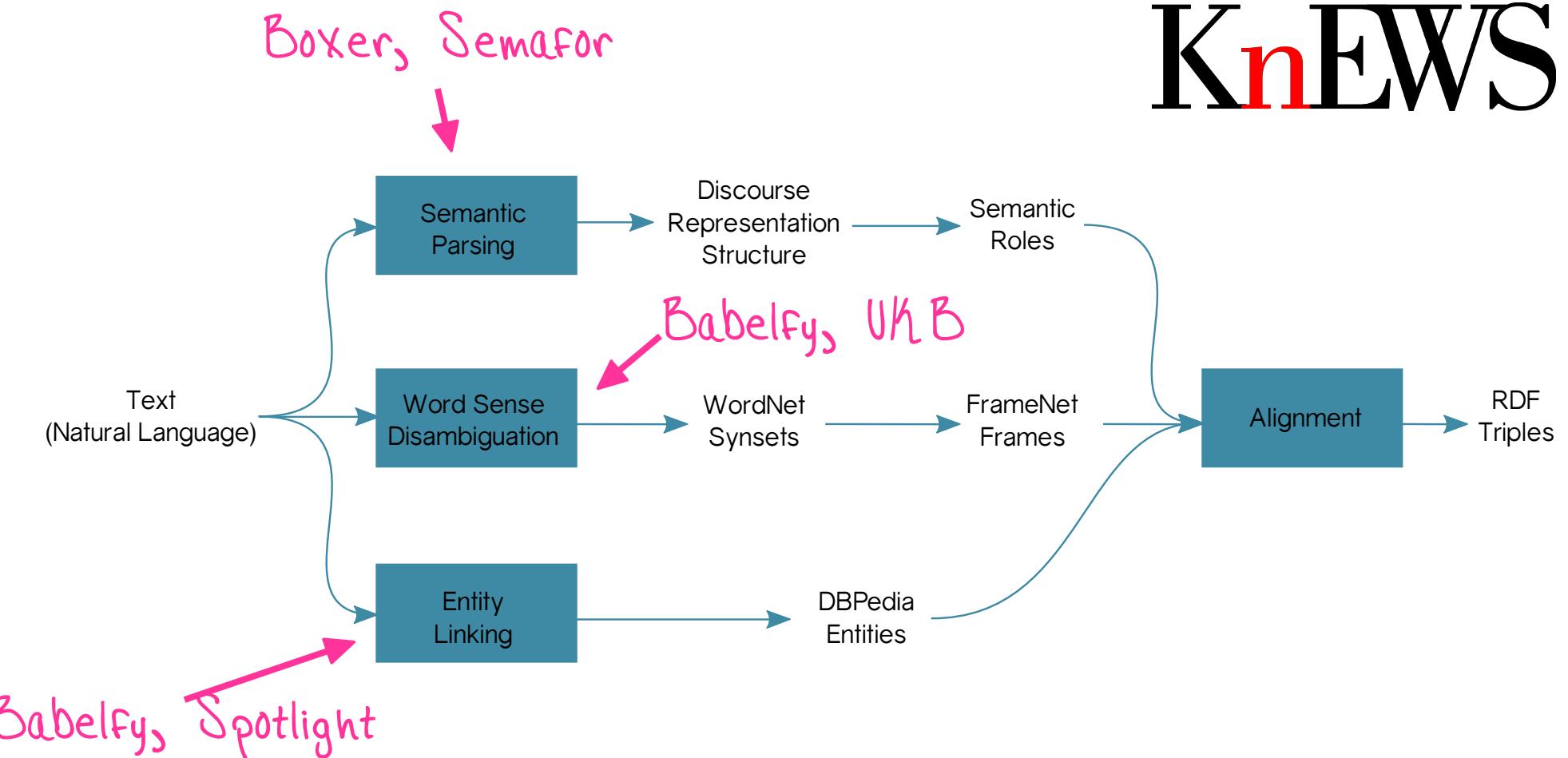
Knowledge Extraction

KnEWS

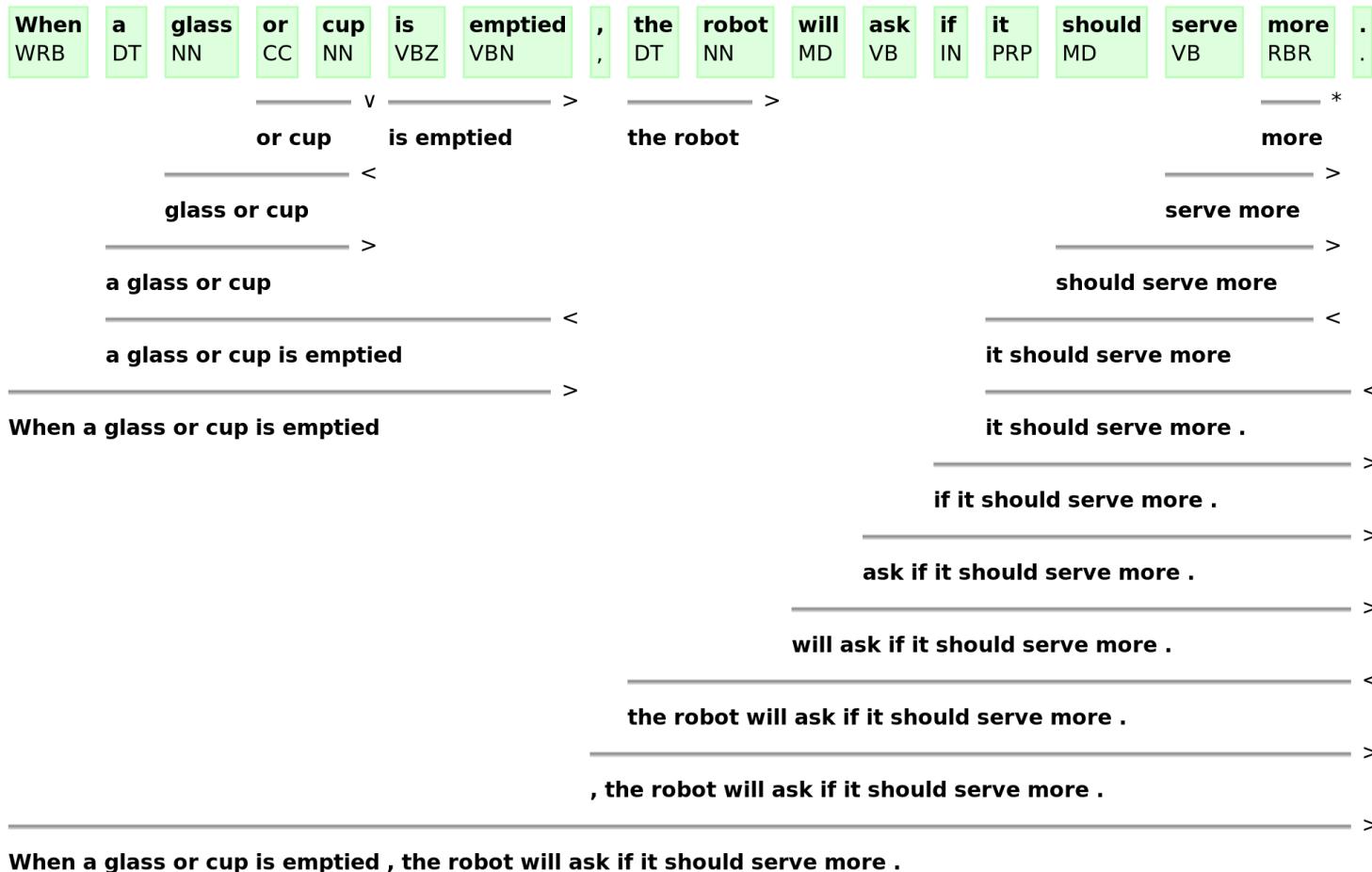


<https://github.com/valeriobasile/learningbyreading>

Knowledge Extraction



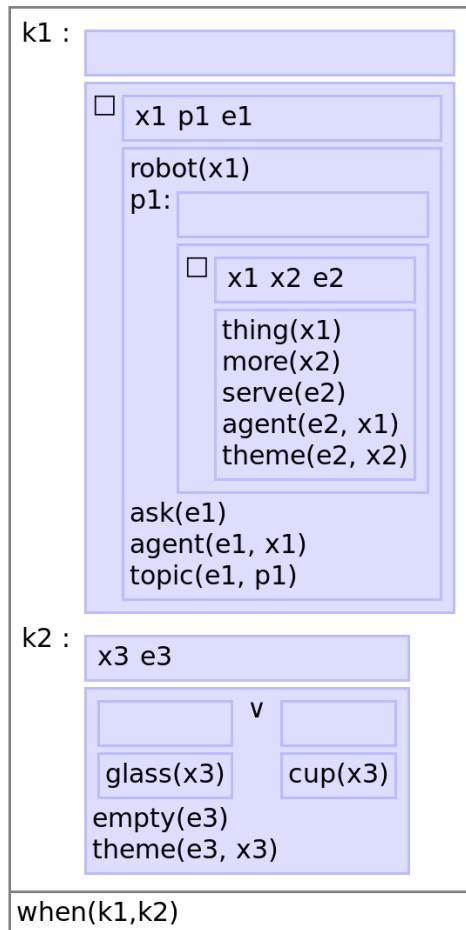
Deeper Natural Language Processing



C&C Tools, Boxer (Curran, Clark and Bos 2007)

<http://valeriobasile.github.io/candcapi/>

Deeper Natural Language Processing



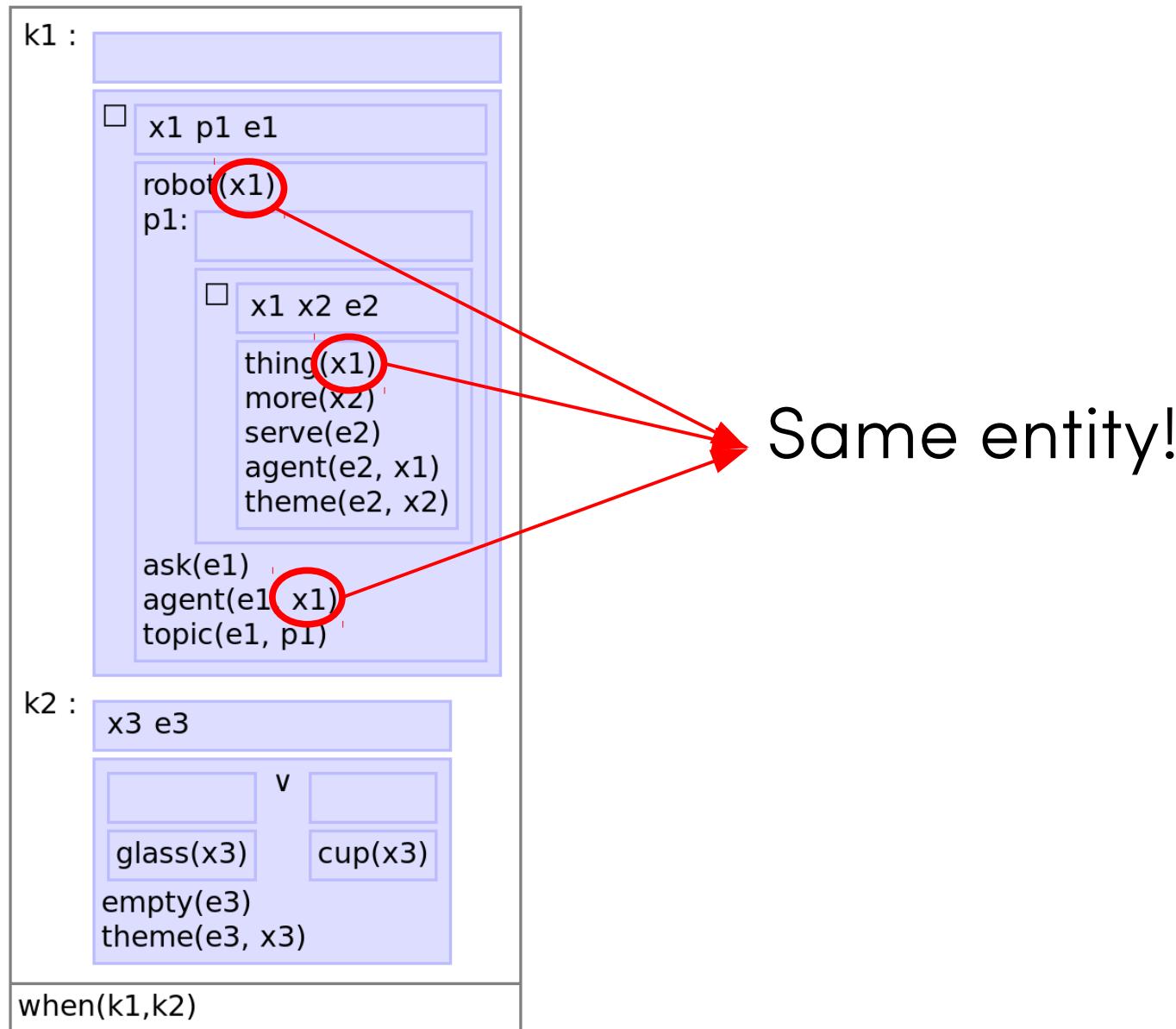
Discourse
Representation
Structure



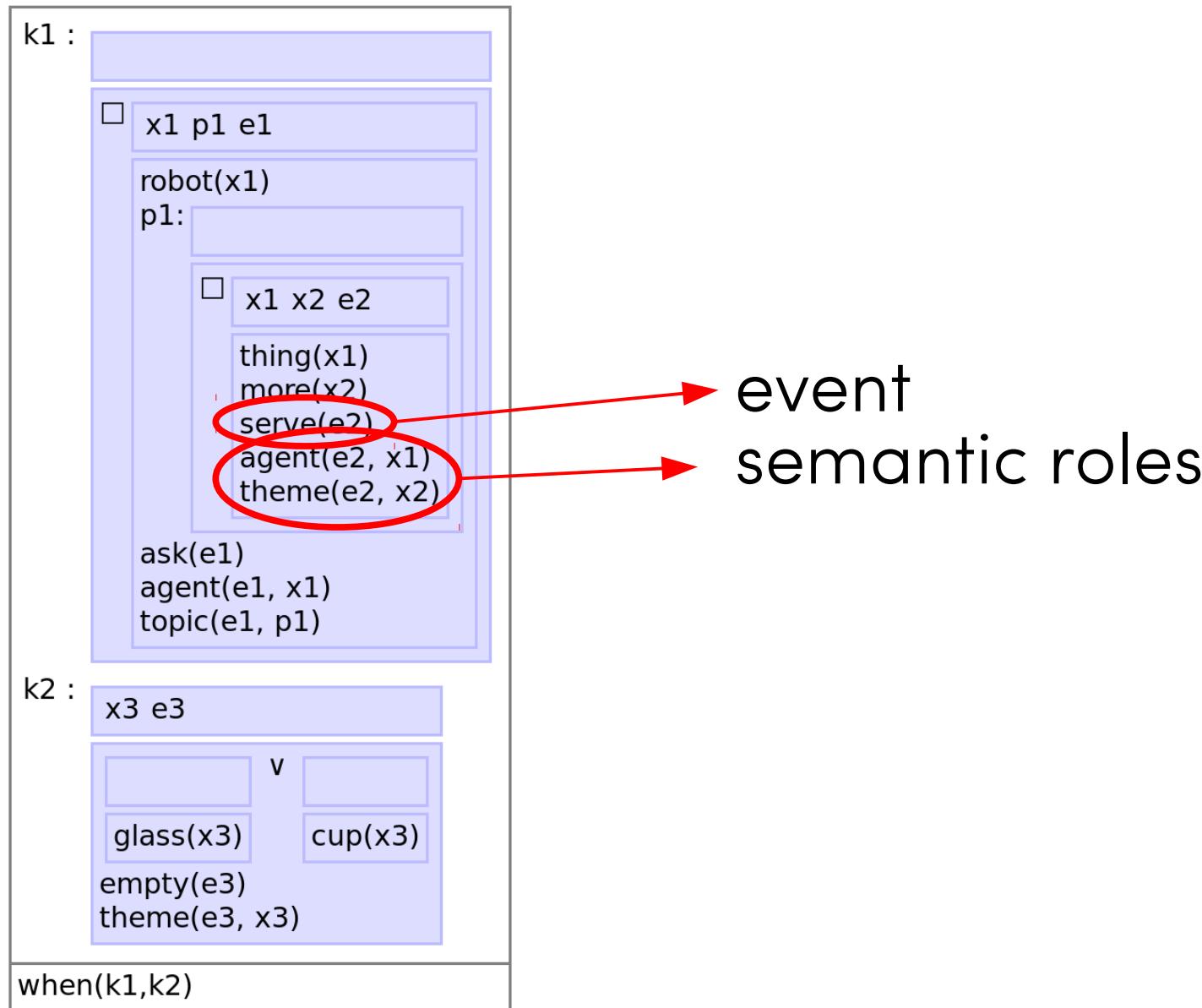
C&C Tools, Boxer (Curran, Clark and Bos 2007)

<http://valeriobasile.github.io/candcapi/>

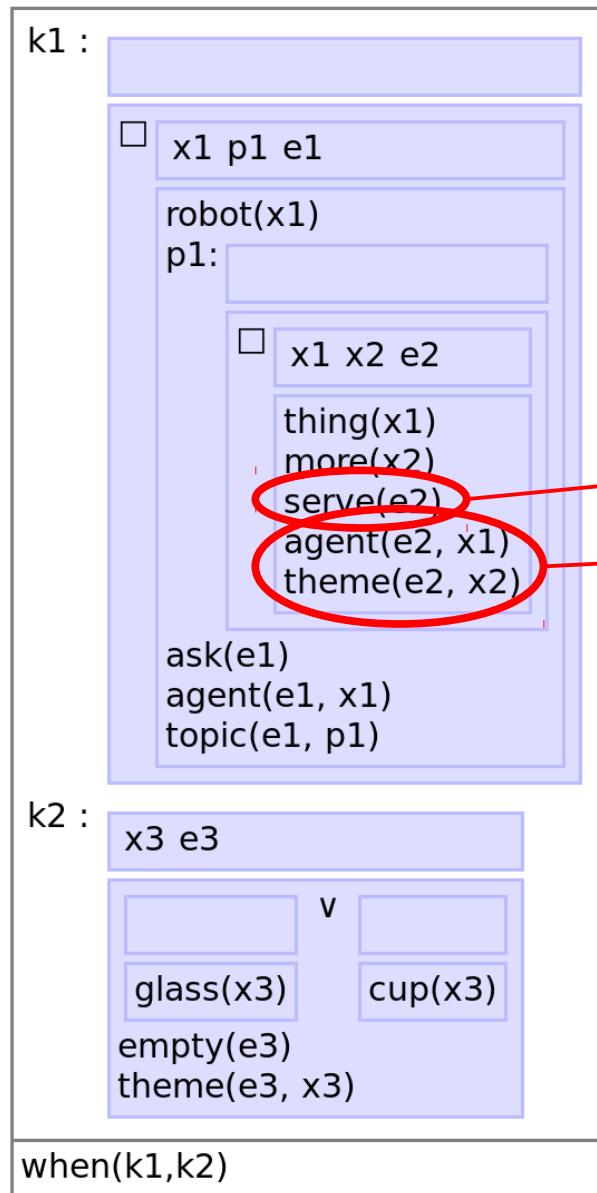
Deeper Natural Language Processing



Deeper Natural Language Processing



Deeper Natural Language Processing



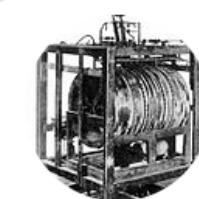
event → **Frame**
semantic roles
→ **Frame elements**

Word Sense Disambiguation

We start with having the robot to assist in cleaning various planar

start

Take the first step or steps in carrying out an action



robot

A mechanism that can move automatically

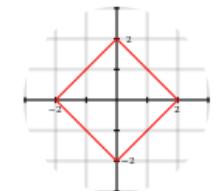


assist

Give help or assistance; be of service

cleaning

Clean one's body or parts thereof, as by washing



planar

Involving two dimensions

surfaces

in the

bathroom

, e.g. a

mirror

or a

tiled

wall

surfaces

The outer boundary of an artifact or a material layer constituting or



bathroom

A room (as in a residence) containing a bathtub or shower and usually a



mirror

Polished surface that forms images by reflecting light

tiled

Covered or furnished with tiles



wall

An architectural partition with a height and length greater than its thickness;

Deeper Natural Language Processing

Framebase mapping

Event → Word sense → FrameNet Frame

SemLink mapping

VerbNet role + FrameNet frame → FrameNet role

Example:

serve(e2) → serve.v.01 → Offering

agent(x1, e2) + Offering → Offerer*

empty(e3) → empty.a.01 → Fullness

cup(x3) + Fullness → Container*

Frame Instance Extraction

@prefix fbfi: <http://framebase.org/ns/fi->

@prefix fbframe: <http://framebase.org/ns/frame->

@prefix fbfe: <{http://framebase.org/ns/fe->

@prefix rdfs: <http://www.w3.org/1999/02/22-rdf-syntax-ns\#>

@prefix bn: <http://babelnet.org/rdf/>

fbfi:People_01b52400 rdfs:type fbframe:People.

fbfi:People_01b52400 fbfe:Person bn:s00001533n.

fbfi:Cardinal_numbers_3faa6c9c rdfs:type fbframe:Cardinal_numbers.

fbfi:Cardinal_numbers_3faa6c9c fbfe:Entity bn:s00001533n.

fbfi:Being_located_079aed4d rdfs:type fbframe:Being_located.

fbfi:Being_located_079aed4d fbfe:Theme bn:s00001533n.

fbfi:Being_located_079aed4d fbfe:Location bn:s00009850n.

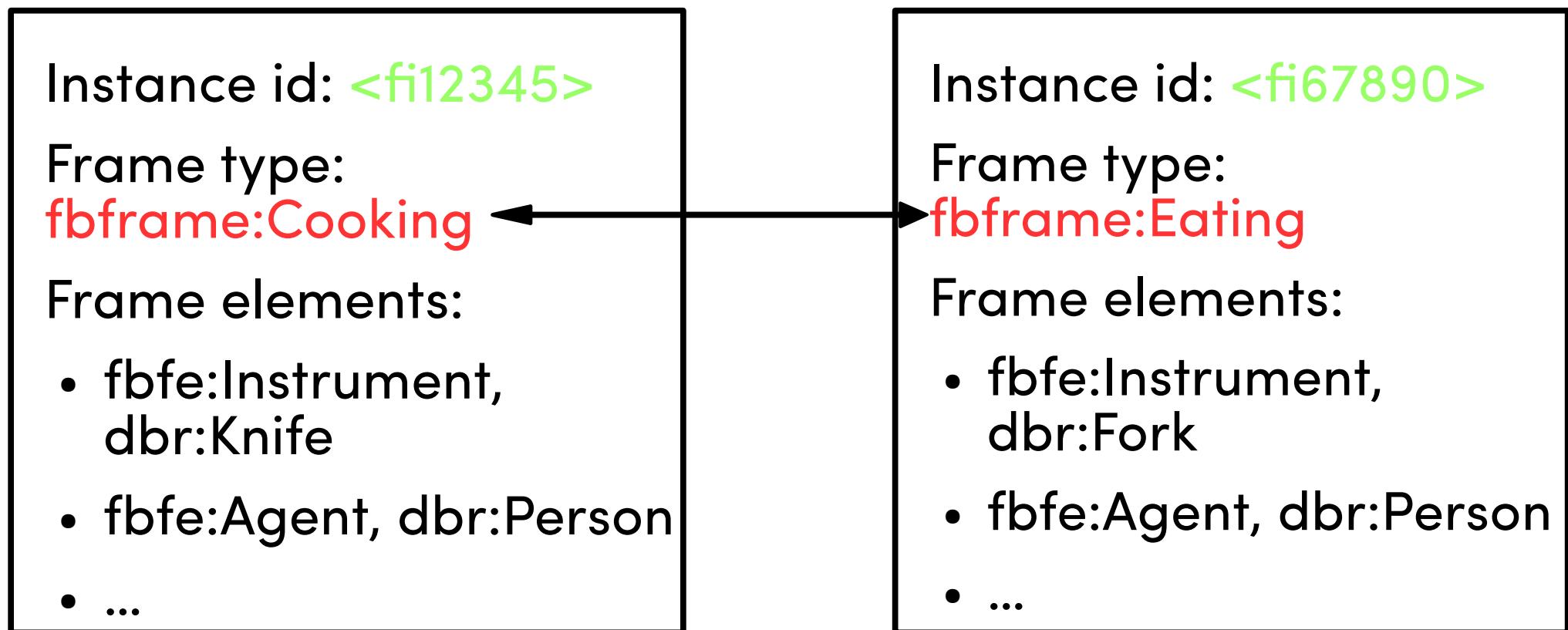
“Two men are sleeping on a bench”

Frame Instance Extraction

```
<frameinstance id="Operate_vehicle_ce746f21 2d8d 4fe8 8981  
df95c9b0eb07" type="Operate_vehicle drive.v" internalvariable="e1">  
  <framelexicalization>k3:x1 is driving k3:x2</framelexicalization>  
  <instancelexicalization>  
    The robot is driving the car .  
  </instancelexicalization>  
  <frameelements>  
    <frameelement role="Driver" internalvariable="x1">  
      <concept>  
        http://dbpedia.org/resource/Robot  
      </concept>  
      <rolelexicalization>  
        The robot is driving x2  
      </rolelexicalization>  
      <conceptlexicalization>The robot</conceptlexicalization>  
    </frameelement>  
    <frameelement role="Vehicle" internalvariable="x2">  
      <concept>  
        http://wordnet rdf.princeton.edu/wn31/02961779 n  
      </concept>  
      <rolelexicalization>  
        x1 is driving the car .  
      </rolelexicalization>  
      <conceptlexicalization>the car .</conceptlexicalization>  
    </frameelement>  
  </frameelements>  
</frameinstance>
```

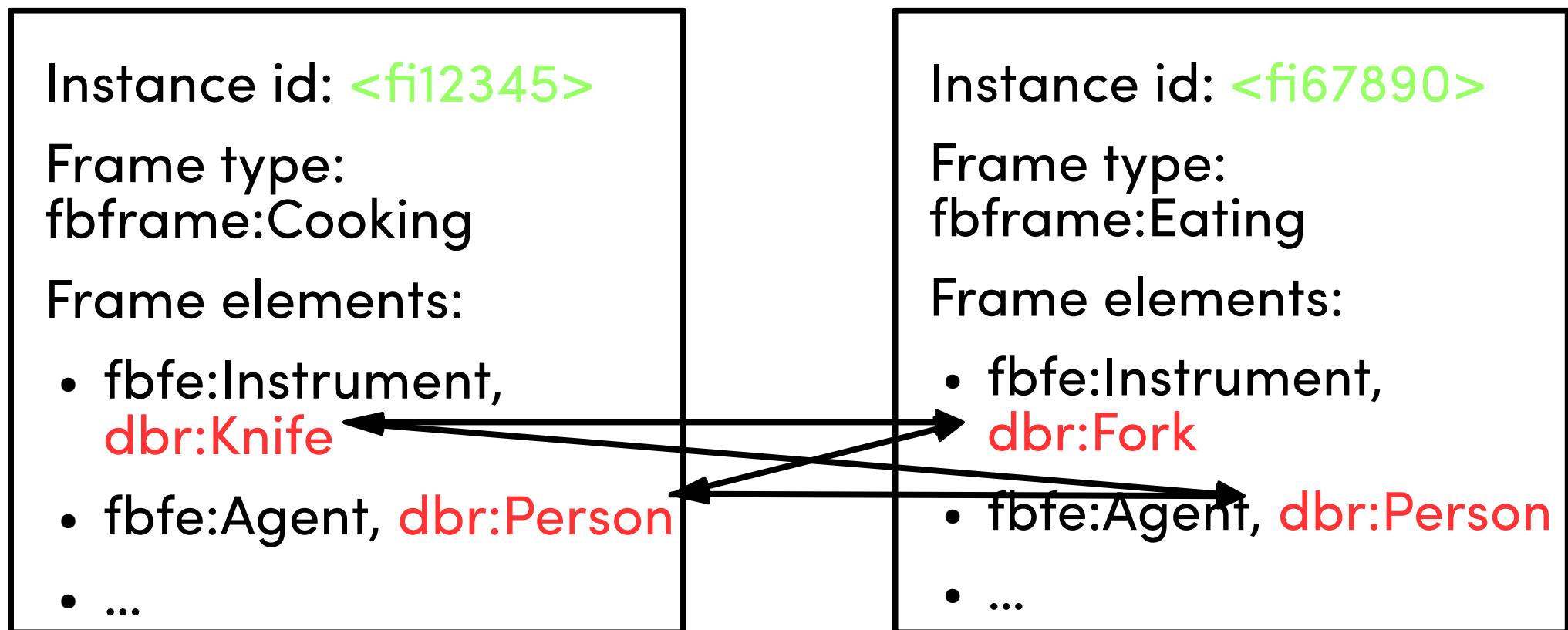
Frame Similarity

frame types



Frame Similarity

frame elements



Frame Similarity

$$\begin{aligned} fisim(fi_1, fi_2) &= \\ &= \alpha ftsim(fi_1, fi_2) + (1 - \alpha) fesim(fi_1, fi_2) \end{aligned}$$

$$ftsim_{occ}(fi_1, fi_2) = \log_2 \frac{|C_{ft_1, ft_2}|}{|C_{ft_1}| |C_{ft_2}|} \quad (2) \quad \begin{aligned} C_{ft_i} &= \{c \in C : \exists l_{ft_i} \in c\} \\ C_{ft_1, ft_2} &= \{c \in C : \exists l_{ft_1} \in c \wedge \exists l_{ft_2} \in c\} \end{aligned}$$

$$\begin{aligned} fesim(fi_1, fi_2) &= \\ &= \frac{1}{2} \left(\frac{1}{|fi_1|} \sum_{fe_i \in fi_1} \max_{fe_j \in fi_2} csim(fe_i, fe_j) + \right. \\ &\quad \left. + \frac{1}{|fi_2|} \sum_{fe_i \in fi_2} \max_{fe_j \in fi_1} csim(fe_i, fe_j) \right) \quad (4) \end{aligned}$$

Measuring Frame Instance Relatedness
V. Basile, R. Lopez Condori, E. Cabrio
*SEM 2018 (accepted)

Frame Similarity

Sentence Textual Similarity shared task dataset

250 sentence pairs

1,650 frame instances with KNEWS

178 frame types, ~1.2 frame elements each

457 concepts

Table 1: Examples of the sentence pairs in the SemEval 2017 STS dataset, with numbers indicating their relatedness on a scale from 1 to 5.

Relatedness	Sentence pair
4.0	There are dogs in the forest. The dogs are alone in the forest.
3.4	The boy is raising his hand. The man is raising his hand.
1.0	A woman supervisor is instructing the male workers. A woman is working as a nurse.
0.2	Our current vehicles will be in museums when everyone has their own aircraft. The car needs to some work.

Table 2: Pearson correlation between sentence pair similarity scores predicted by frame instance relatedness and the SemEval STS reference set.

ftsim: alpha	without role filter		with role filter	
	occ	dist	occ	dist
1.0	0.526	0.455	0.526	0.455
0.9	0.529	0.465	0.536	0.477
0.8	0.529	0.471	0.544	0.495
0.7	0.525	0.473	0.550	0.510
0.6	0.517	0.471	0.555	0.522
0.5	0.503	0.463	0.558	0.531
0.4	0.484	0.451	0.558	0.538
0.3	0.461	0.436	0.557	0.542
0.2	0.436	0.418	0.554	0.544
0.1	0.410	0.400	0.550	0.545
0.0	0.381	0.381	0.543	0.543

Clustering Frame Instances

Table 4: Clustroids of randomly selected clusters from the STS dataset.

Cluster size	3
Frame type	Emotion_directed (The adjectives and nouns in this frame describe an Experiencer who is feeling or experiencing a particular emotional response to a Stimulus or about a Topic)
Role	Experiencer (the Experiencer is the person or sentient entity that experiences or feels the emotions)
Concept	Woman (an adult female person -as opposed to a man-)
Cluster size	6
Frame type	Using (An Agent manipulates an Instrument in order to achieve a Purpose)
Role	Agent (the Agent uses the Instrument to achieve their Purpose)
Concept	Man (an adult person who is male -as opposed to a woman-)
Cluster size	17
Frame type	Roadways (This frame involves stable Roadways which connect two stable Endpoints, the Source and the Goal)
Role	Roadway (the Roadway is the roadway that connects locations)
Concept	Road (a way or means to achieve something)

Table 5: Clustroids of the three largest clusters in the dataset.

Cluster size	203
Frame type	People (this frame contains general words for Individuals, i.e. humans.)
Role	Person (the Person is the human being)
Concept	Man (an adult person who is male -as opposed to a woman-)
Cluster size	68
Frame type	People_by_age (this frame contains words for individuals as viewed in terms of their age.)
Role	Person (the human being of a certain age)
Concept	Boy (a friendly informal reference to a grown man)
Cluster size	44
Frame type	Clothing (this frame refers to clothing and its characteristics, including anything that people conventionally wear.)
Role	Garment (this FE identifies the clothing worn)
Concept	Shirt (a garment worn on the upper half of the body)

Pilot Study

Text for language learners (**1,653** short stories)

114,536 frame instances, **154,422** frame elements,
686 frame types, **222** roles filled by **3,398** types
of concepts.

Hierarchical clustering with our distance metric:
complete-linkage agglomerative (SciPy)

Frame Instance Extraction and Clustering for Default Knowledge Building

A. Shah, V. Basile, E. Cabrio, S. Kamath S.

Applications of Semantic Web technologies in Robotics - ANSWER 17

Pilot Study

Similarity metric	Frame types	Frame elements
Based on frame types $(\alpha = 1)$	Commerce-buy (75)	<i>Goods</i> thing-n#8-n (11) <i>Goods</i> star+sign-n#1-n (4) <i>Goods</i> ticket-n#1-n (3) <i>Goods</i> book-n#1-n (2) <i>Goods</i> clothes-n#1-n (2) <i>Goods</i> placard-n#1-n (2) <i>Goods</i> cycle-n#6-n (2) <i>Buyer</i> thing-n#8-n (2) <i>Goods</i> machine-n#6-n (2) <i>Goods</i> shirt-n#1-n (2) <i>Goods</i> filter-n#2-n (2) <i>Goods</i> pellet-n#2-n (2) <i>Buyer</i> male-n#2-n (2)
Based on frame elements $(\alpha = 0)$	Stimulus-focus (8) Categorization (4) Hear (4) Reading (4) Reading_aloud (4)	<i>vn-Theme</i> book-n#1-n (24) <i>Item</i> book-n#1-n (4) <i>vn-Patient</i> book-n#1-n (2)

Pilot Study

Most frequent frame type, role and element from each cluster

```
<http://framebase.org/fbframe/Ride_vehicle>
<http://framebase.org/fbfe/Vehicle>
<http://wordnet-rdf.princeton.edu/wn31/02837983-n>
```

~300 triples, available at
<http://project.inria.fr/aloof/data/>



Bicycle

Part V

Default Knowledge about Objects

Default Knowledge about Objects



<http://deko.inria.fr/>

RDF dataset of **common sense** knowledge about objects.

Object classification, prototypical location, actions, frames...

Knowledge extracted from parsing, crowdsourcing, distributional semantics, **keyword linking**

Default Knowledge about Objects

```
<http://dbpedia.org/resource/Knife> a ns1:Object ;
  ns1:locatedAt <http://dbpedia.org/resource/Beer_hall>,
    <http://dbpedia.org/resource/Dining_car>,
    <http://dbpedia.org/resource/Dining_room>,
    <http://dbpedia.org/resource/Galley>,
    <http://dbpedia.org/resource/Kitchen>,
    <http://dbpedia.org/resource/Restaurant> ;
  ns1:usedFor <http://dbpedia.org/resource/Carving>,
    <http://dbpedia.org/resource/Collecting>,
    <http://dbpedia.org/resource/Cooking>,
    <http://dbpedia.org/resource/Coring>,
    <http://dbpedia.org/resource/Counting>,
    <http://dbpedia.org/resource/Eating>,
    <http://dbpedia.org/resource/Engraving>,
    <http://dbpedia.org/resource/Gashing>,
    <http://dbpedia.org/resource/Hunting>,
    <http://dbpedia.org/resource/Mashing>,
    <http://dbpedia.org/resource/Notching>,
    <http://dbpedia.org/resource/Pricking>,
    <http://dbpedia.org/resource/Scratching>,
    <http://dbpedia.org/resource/Shaving>,
    <http://dbpedia.org/resource/Spearling>,
    <http://dbpedia.org/resource/Throwing>,
    <http://dbpedia.org/resource/Turning>,
    <http://dbpedia.org/resource/Writing> .
```

Default Knowledge about Objects

Bicycle

<http://dbpedia.org/resource/Bicycle>



A Bicycle is:

- | [locatedAt Alley](#)
- | of type [Object](#)
- | [VehicleOf Ride vehicle](#)
- | [usedFor Driving](#)
- | [usedFor Racing](#)
- | [usedFor Welding](#)

also:

- | [Ride vehicle](#) [Vehicle](#) [Bicycle](#)

Graph:

KeywordLinking DistributionalRelationalHypothesis KNEWS Crowdsourcing

Default Knowledge about Objects



<http://deko.inria.fr/>

10,990 nquads (named graphs)

603 from crowdsourcing

1,221 from distributional relational hypothesis

8,046 from keyword kinking

1,120 from KNEWS/frame instance clustering

+ DeKO ontology

The End **(Q/A)**

