Creating a Commonsense Knowledge Base about Objects

Valerio Basile (University of Turin)

SAILab, Siena
12/2/2020

whoami

Valerio Basile

Assistant professor @ Unito
Previously:

- PhD @ RUG Groningen
- Postdoc @ Inria

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, Social Media, Hate Speech, ...

Today

Robotics and **A**rtificial **I**ntelligence

Objects

Linguistics and **S**emantics

Machine **L**earning and **C**lustering

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

TU WIEN

Inria

UNIVERSITÉ CÔTE D'AZUR

SAPIENZA UNIVERSITÀ DI ROMA

UNIVERSITY OF BIRMINGHAM

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

Deploy robots in human-inhabited environments.

The robots autonomously collect real-world data.

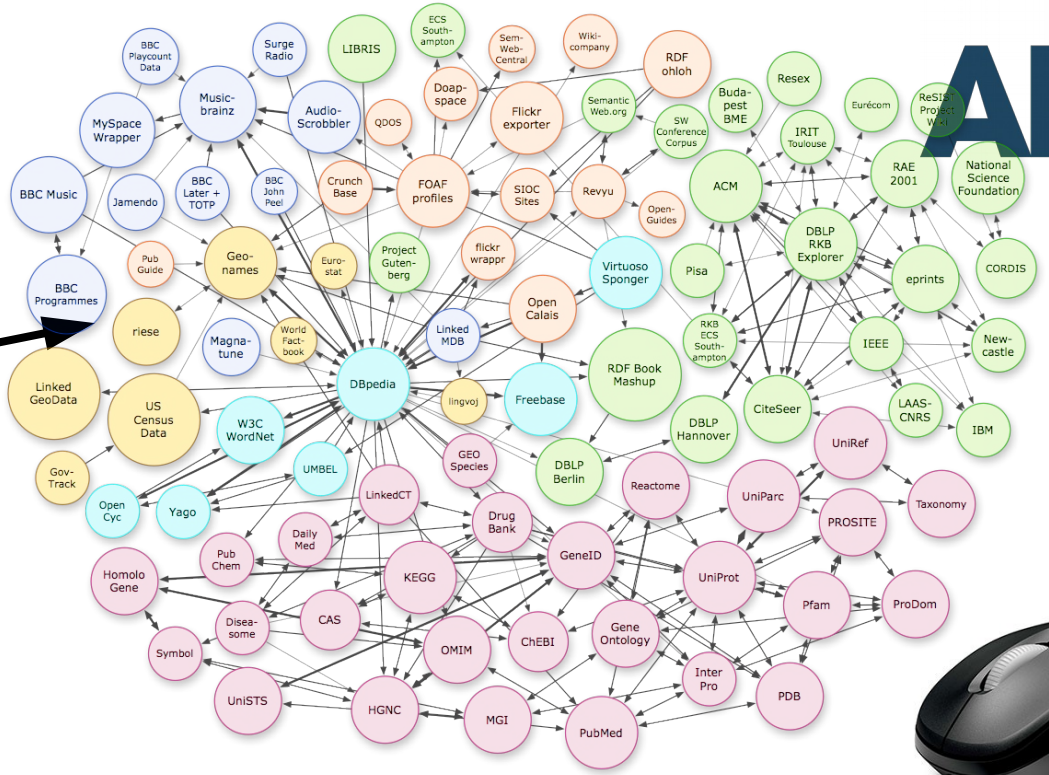
We use information available on the Semantic Web to identify the semantics of objects.

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF



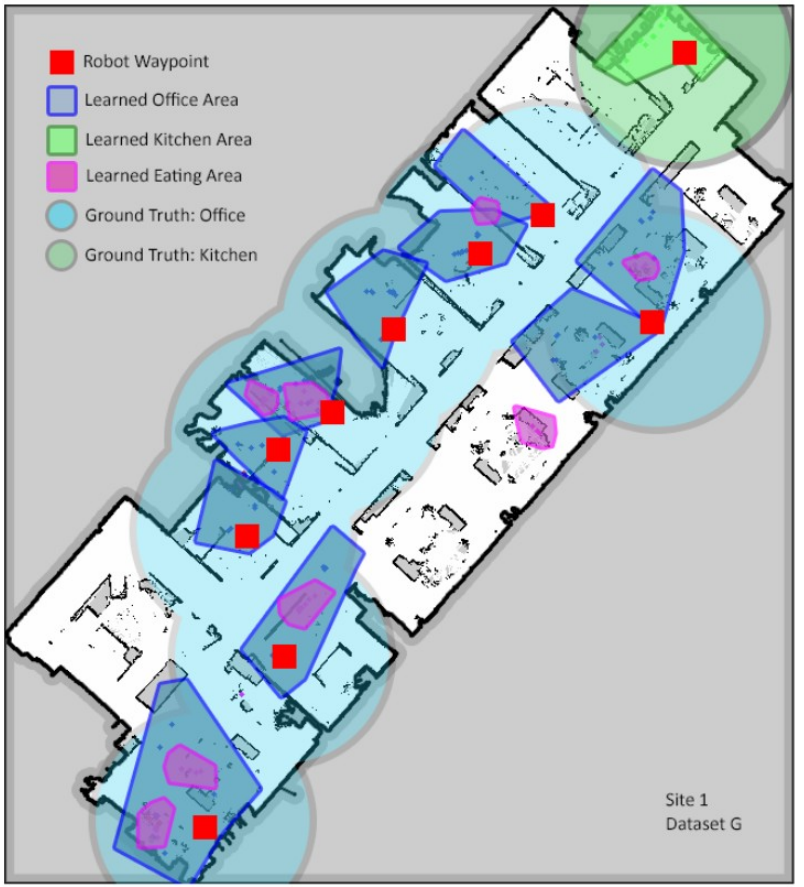
AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

Perception and Identification

Robot deployments in office environments

The robot visits fixed waypoints on the map, taking full 360° RGB-D scans



AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF

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

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/

Web KBs

- DBpedia
  hub for LOD
- KnowRob
  smaller, manually crafted, robotic-oriented
- ConceptNet
  large, automatically built, not-LOD

The SUN database

BEDROOM

2117 images
1043 annotated
18331 objects

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

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,

https://groups.csail.mit.edu/vision/**SUN**/

Web KBs

	Taxonomy	Function	Location	Linked Data
DBpedia	✔	✘	✘	✔
ConceptNet	✔	✔	✔	partly
KnowRob	✔	✔	partly	✘
SUN	✘	✘	✔	✘

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

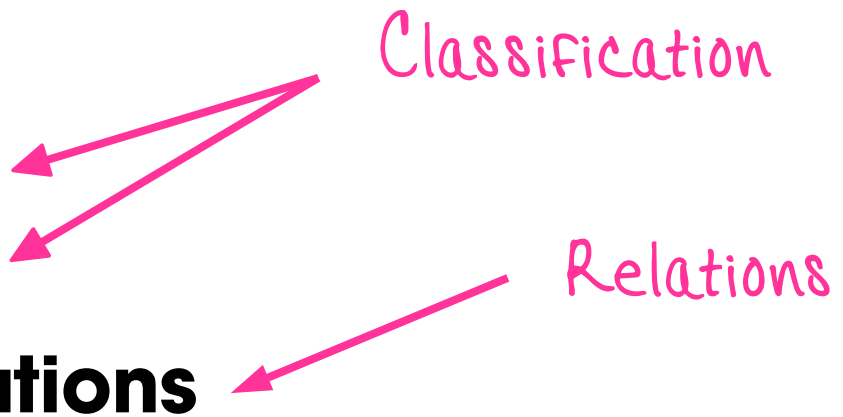
The SUN database

Results

2,493 objects in DBpedia

679 locations in DBpedia

2,935 object-location relations



Keyword	Entity
Objects	
stand_clothes	dbr:Clothes_horse
cold_meat	dbr:Lunch_meat
tree_stem_3	dbr:Plant_stem
deer	dbr:Deer
instrument_control	dbr:Instrument_control
volcano	dbr:Volcano
bass_drum	dbr:Bass_drum
building_arch	dbr:Arch
oyster_bank	dbr:Oyster_reef
observatory	dbr:Observatory
Scenes	
c/childs_room	dbr:Nursery_(room)
o/oil_refinery/indoor	dbr:Oil_refinery
m/mobile_home	dbr:Mobile_home
o/oyster_farm	dbr:Oyster_farming
z/zoo	dbr:Zoo
c/canteen	dbr:Cafeteria
d/donjon	dbr:Keep
p/parking_garage/indoor	dbr:Garage_(residential)
d/day_care_center	dbr:Day_care
s/skywalk/outdoor	dbr:Skyway

Part III

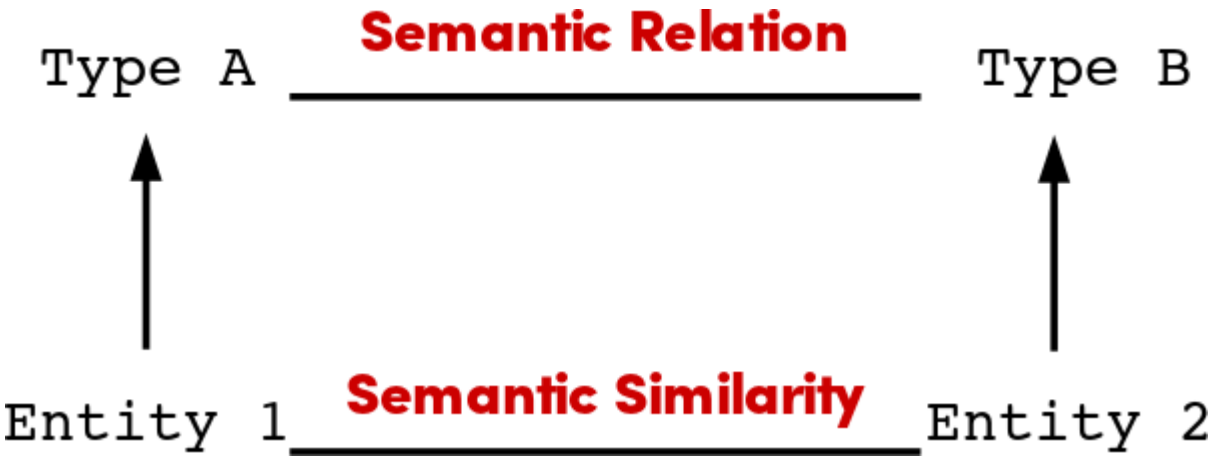
Objects, Words and Vectors

Object Knowledge

Problem

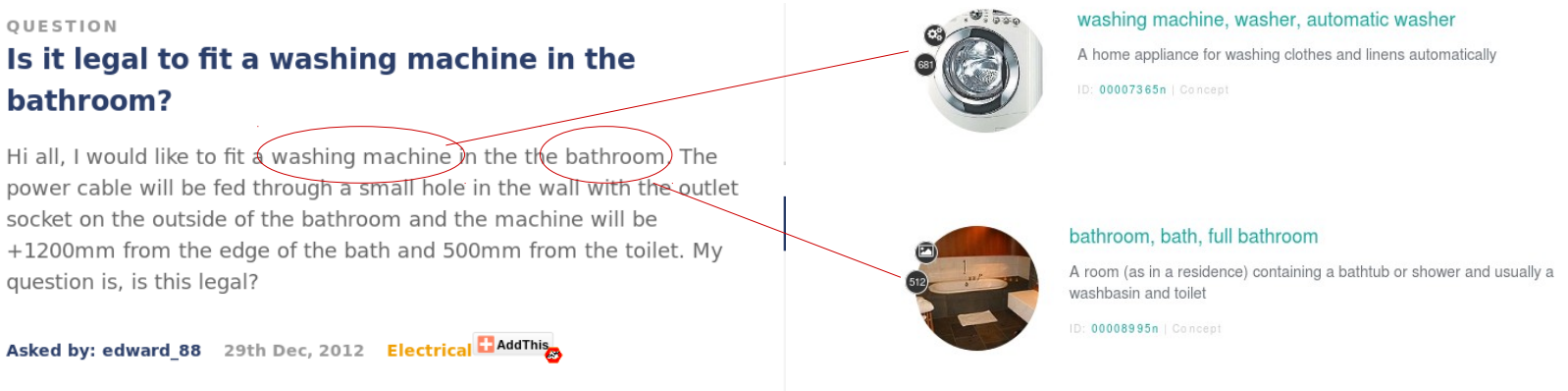
Classification is good, but relations are sparse

Distributional Relational Hypothesis



$$isa(E1, A) \land isa(E2, B) \land S(E1, E1) \rightarrow R(A, B) \ ?$$

Semantic Relatedness



Co-occurrence matrix

	Washing_machine	Ashtray
Bathroom	5	2
Bedroom	0	1
Living_room	1	6

Singular value decomposition

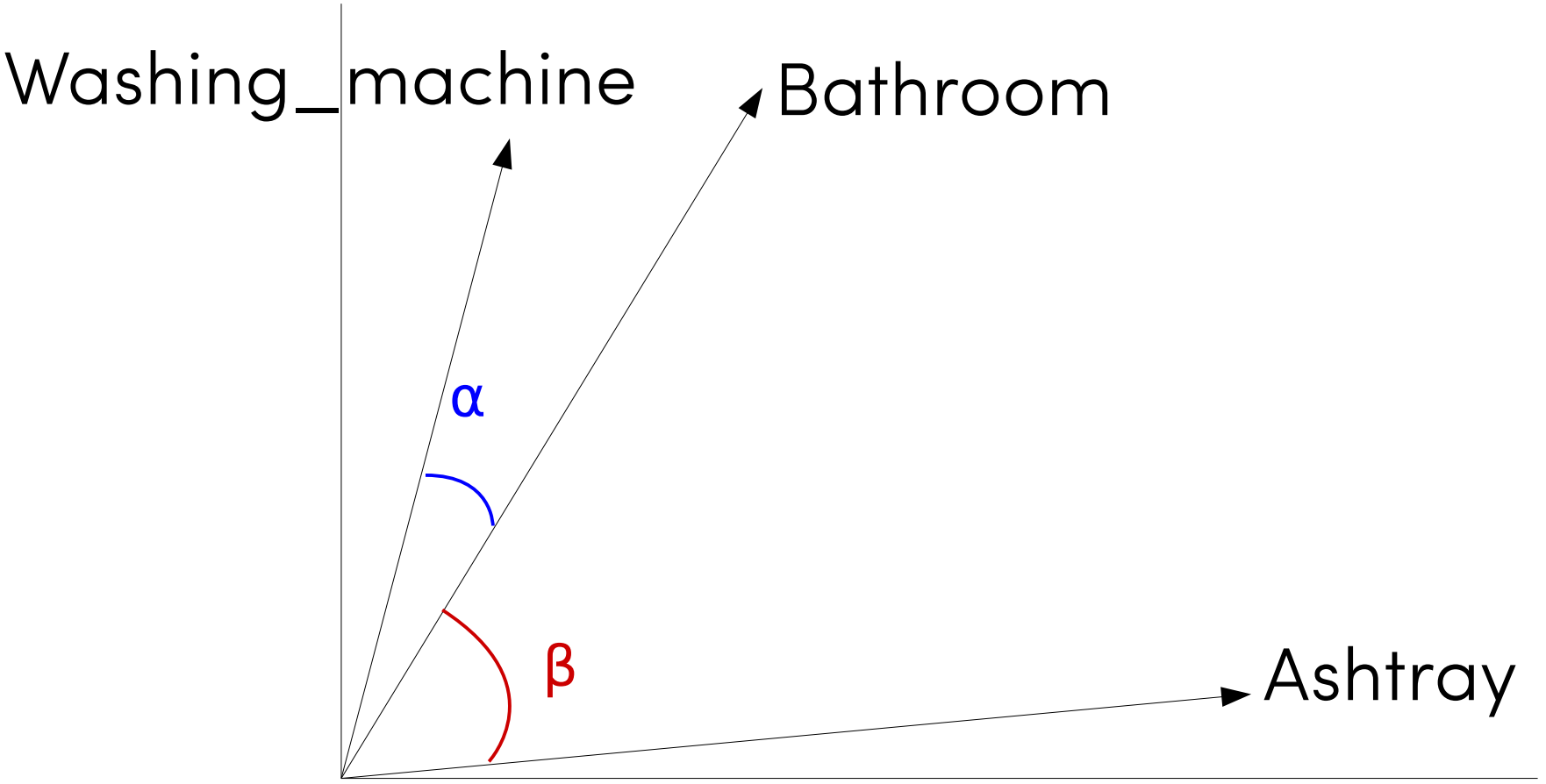
$$M = U \Sigma V^*$$

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



sim(Bathroom, Washing_machine) = cos(α) ≈ 0.71

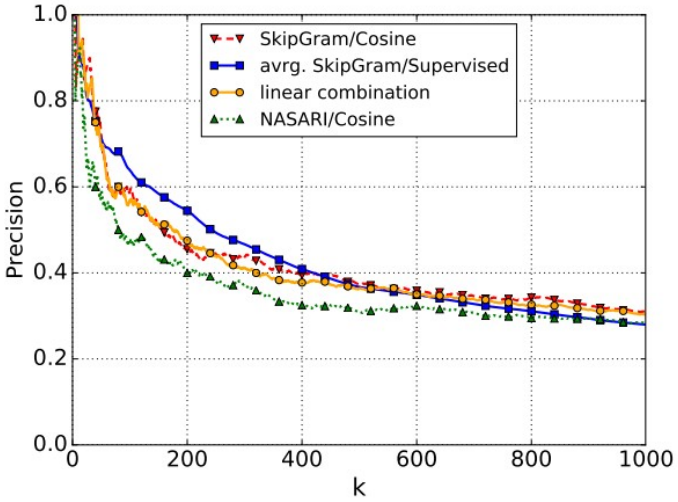
sim(Bathroom, Ashtray) = cos(β) ≈ 0.37

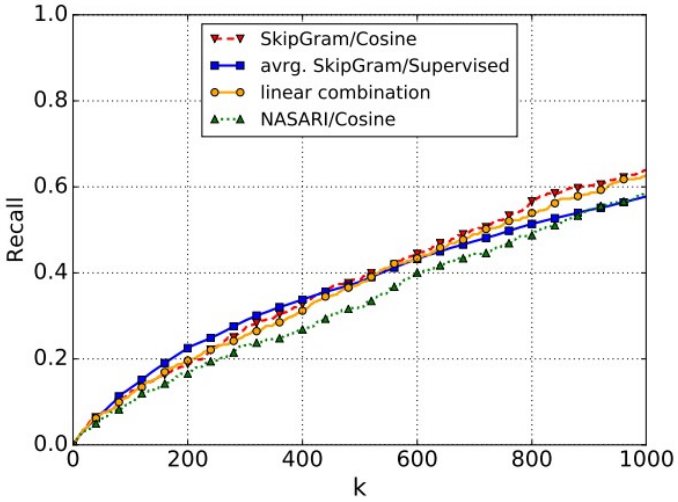
Place Classification

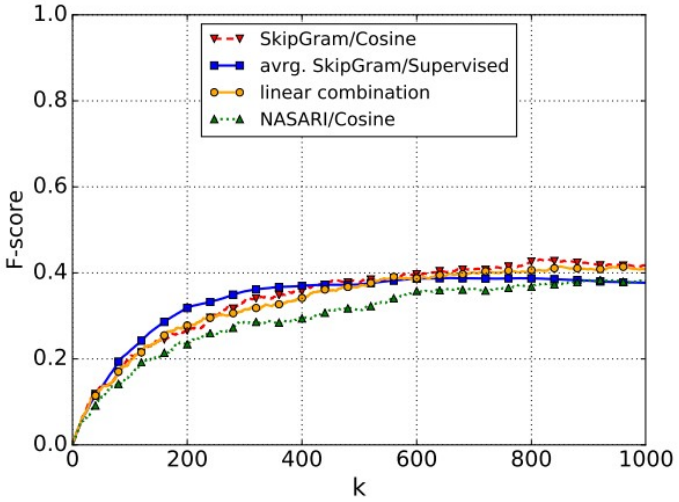
= Cosine similarity on NASARI

+ aggregation, weighting by distance, ...

Evluation: locatedAt

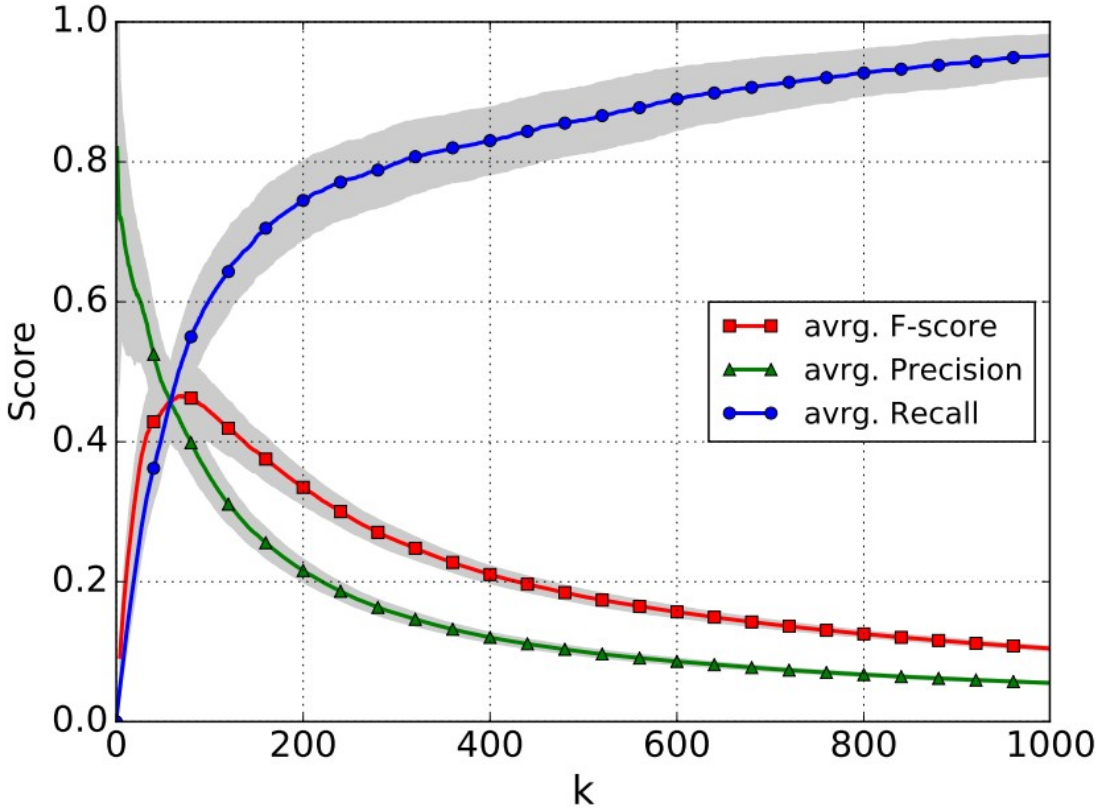






Gold standard: SUN database linked to DBpedia

Evluation: usedFor



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)

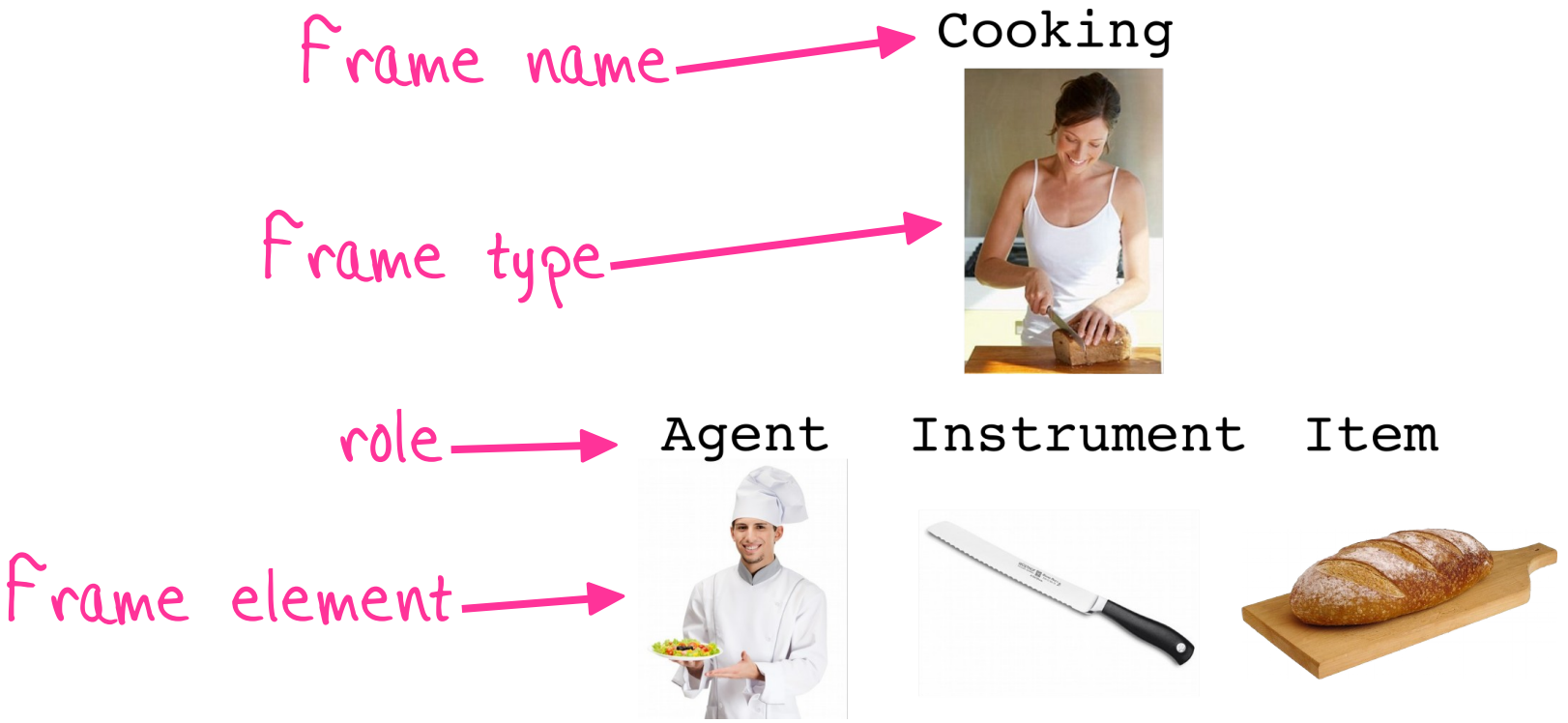
Populating a knowledge base with object-location relations using distributional semantics
V Basile, S Jebbara, E Cabrio, P Cimiano, EKAW 2016

Part IV
Frames and Prototypical Knowledge

Problem

The distributional relational hypothesis is limited to specific relations

Frame Semantics



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
- ...

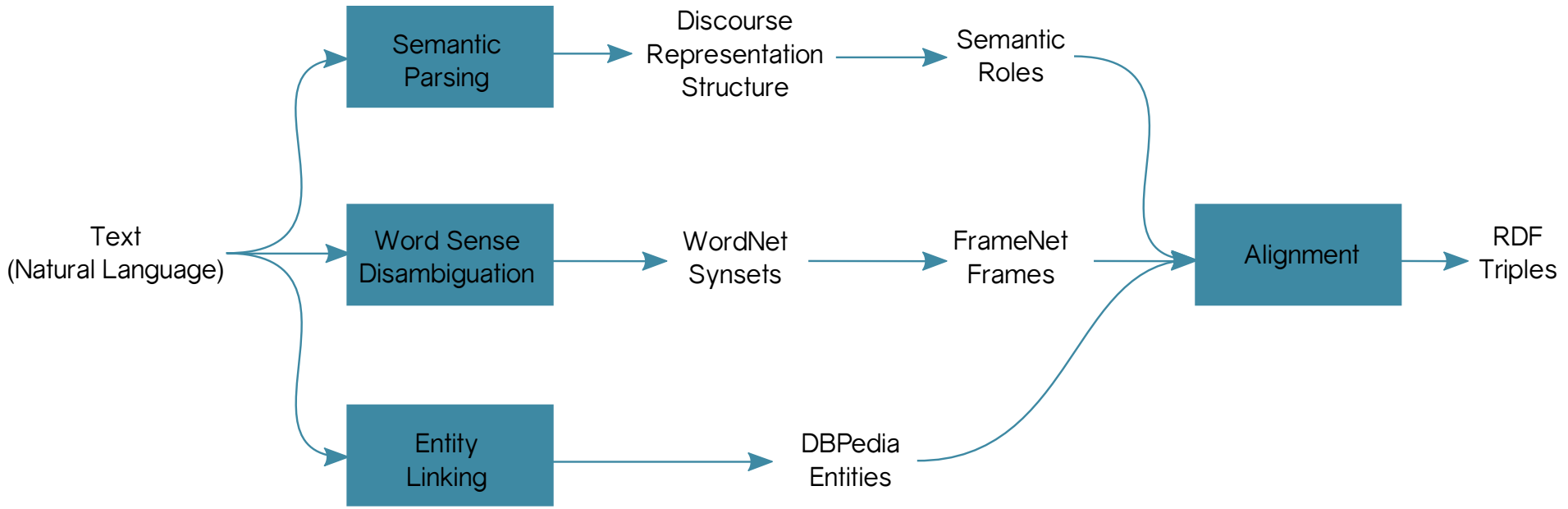
Default Knowledge → Prototypical Frame Instances

=

F.I. extraction + F.I. clustering

Knowledge Extraction

KnEWS



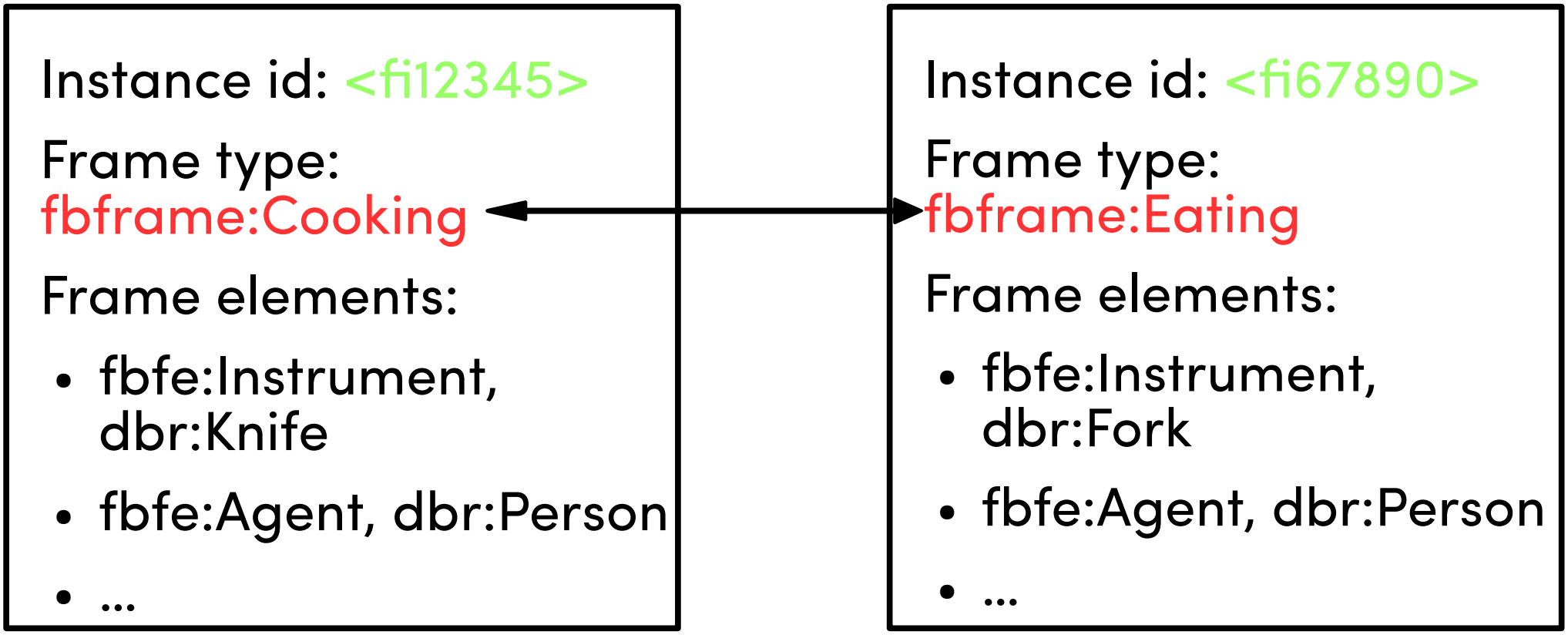
https://github.com/valeriobasile/learningbyreading

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>
```

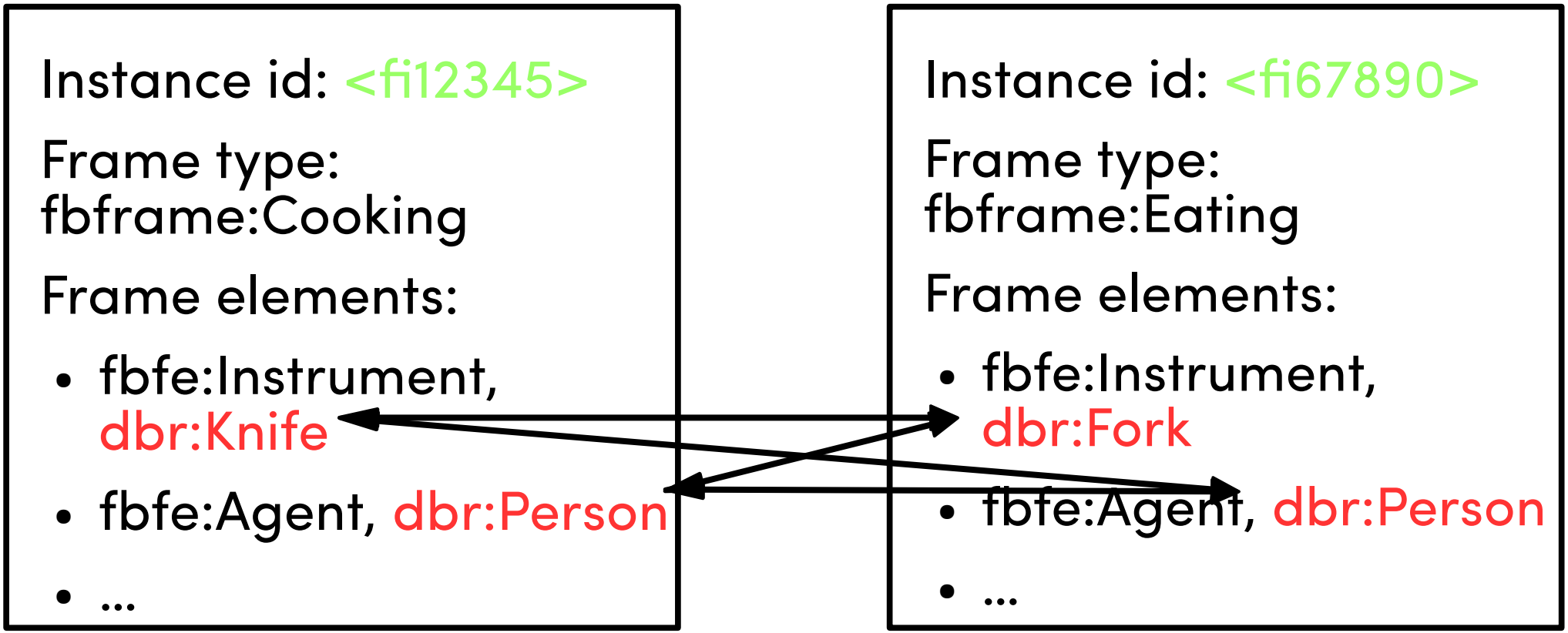
Frame Similarity

frame types



Frame Similarity

frame elements



Frame Similarity

$$fisim(fi_1, fi_2) =$$
$$= \alpha ftsim(fi_1, fi_2) + (1 - \alpha) fesim(fi_1, fi_2)$$

$$ftsim_{occ}(fi_1, fi_2) = log_2 \frac{|C_{ft_1,ft_2}|}{|C_f t_1||C_f t_2|} \quad (2)$$

$$C_{ft_i} = \{c \in C : \exists l_{ft_i} \in c\}$$
$$C_{ft_1,ft_2} = \{c \in C : \exists l_{ft_1} \in c \wedge \exists l_{ft_2} \in c\}$$

$$fesim(fi_1, fi_2) =$$
$$= \frac{1}{2}\Big(\frac{1}{|fi_1|} \sum_{fe_i \in fi_1} \max_{fe_j \in fi_2} csim(fe_i, fe_j) +$$
$$+ \frac{1}{|fi_2|} \sum_{fe_i \in fi_2} \max_{fe_j \in fi_1} csim(fe_i, fe_j)\Big) \quad (4)$$

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

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

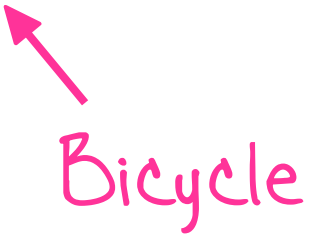
Pilot Study

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

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/

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://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

```
    <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/Spearing>,
            <http://dbpedia.org/resource/Throwing>,
            <http://dbpedia.org/resource/Turning>,
            <http://dbpedia.org/resource/Writing> .
```

Left out

... but open for discussion

- Fundational distinctions
  Class vs. Instance in DBpedia
  Asprino L., Basile V., Ciancarini P., Presutti
  Empirical Analysis of Foundational Distinctions in Linked Open Data
  (IJCAI 2018)
- Nature of prototypical relations
  Default Logic and RDF

The End
(Q/A)

- Valerio Basile, Elena Cabrio, Fabien Gandon, Debora Nozza:
  Mapping Natural Language Labels to Structured Web Resources
  NL4AI 2018
- Valerio Basile, Roque Lopez Condori, Elena Cabrio:
  Measuring Frame Instance Relatedness.
  *SEM 2018
- Soufian Jebbara, Valerio Basile, Elena Cabrio, Philip Cimiano (2018):
  Extracting common sense knowledge via triple ranking using supervised and unsupervised distributional models
  Semantic Web
- Avijit Shah, Valerio Basile, Elena Cabrio, Sowmya Kamath S.:
  Frame Instance Extraction and Clustering for Default Knowledge Building.
  AnSWeR 2017.
- Jay Young, Valerio Basile, Markus Suchi, Lars Kunze, Nick Hawes, Markus Vincze, Barbara Caputo:
  Making sense of indoor spaces using semantic web mining and situated robot perception
  ESWC 2017
- Jay Young, Lars Kunze, Valerio Basile, Elena Cabrio, Nick Hawes, Barbara Caputo:
  Semantic Web-Mining and Deep Vision for Lifelong Object Discovery.
  ICRA 2017
- Valerio Basile, Soufian Jebbara, Elena Cabrio, Philipp Cimiano:
  Populating a Knowledge Base with Object-Location Relations Using Distributional Semantics
  EKAW 2016
- Jay Young, Valerio Basile, Lars Kunze, Elena Cabrio, Nick Hawes:
  Towards Lifelong Object Learning by Integrating Situated Robot Perception and Semantic Web Mining
  ECAI 2016
- Valerio Basile, Elena Cabrio, Fabien Gandon:
  Building a General Knowledge Base of Physical Objects for Robots.
  ESWC 2016