

Semantic web-mining and deep vision for lifelong object discovery

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Data Science Meetup
Learning Center Sophia Polytech
20/6/2017

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Moi

Valerio Basile

From: Italy

PhD in Groningen (NL)

Postdoc at WIMMICS, 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, Math, Pasta, Videogames, ...

Today

Robots

Computer vision

Objects

Semantics

Learning

Data

Part I: Motivation

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOOF



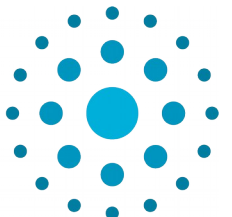
SAPIENZA
UNIVERSITÀ DI ROMA



**UNIVERSITY OF
BIRMINGHAM**



Inria

**UNIVERSITÉ
CÔTE D'AZUR** 

AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS



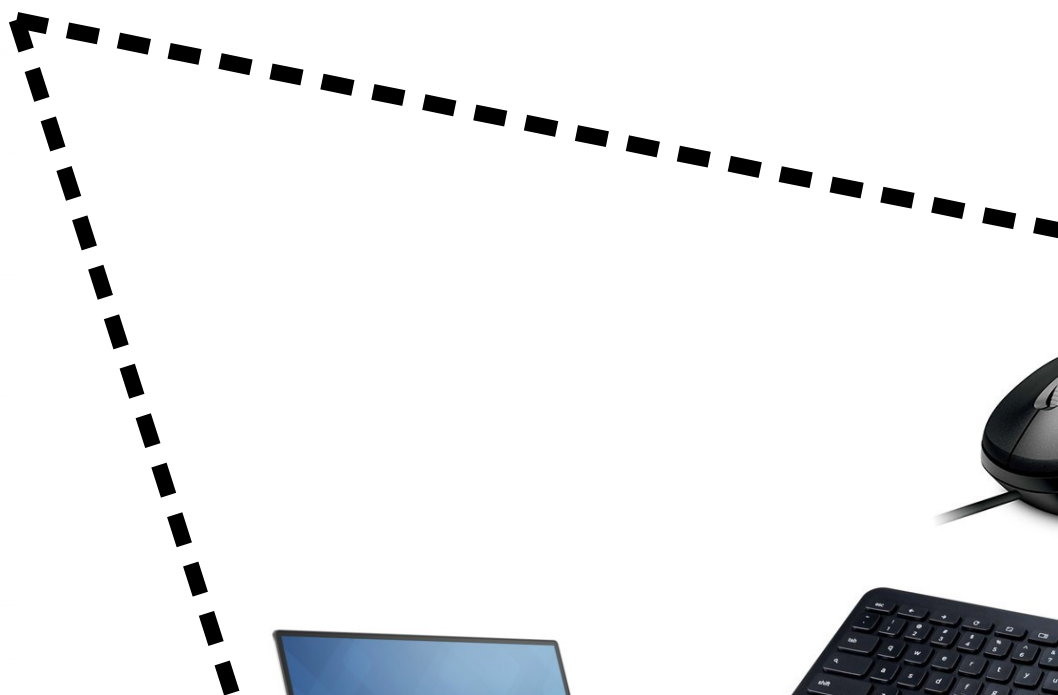
We deploy **robots** in human-inhabited environments.

Our 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



ALOO



AUTONOMOUS
LEARNING
OF THE MEANING
OF OBJECTS

ALOOF



- Background Knowledge
- Room detection
- Object classification
- Frame semantics
- ...

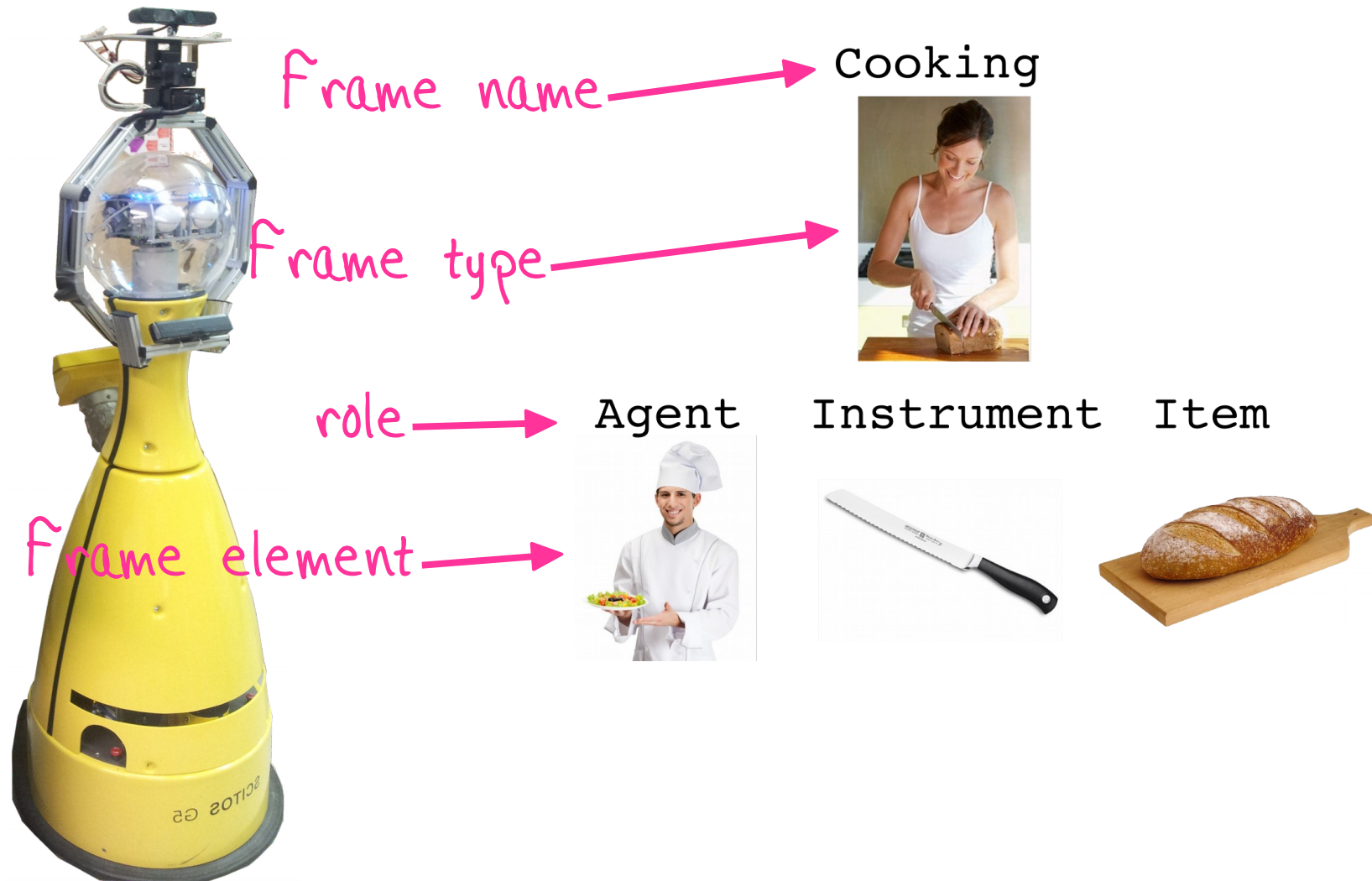
Frame Semantics



Bob, du pain svp!



Frame Semantics



Frame Semantics

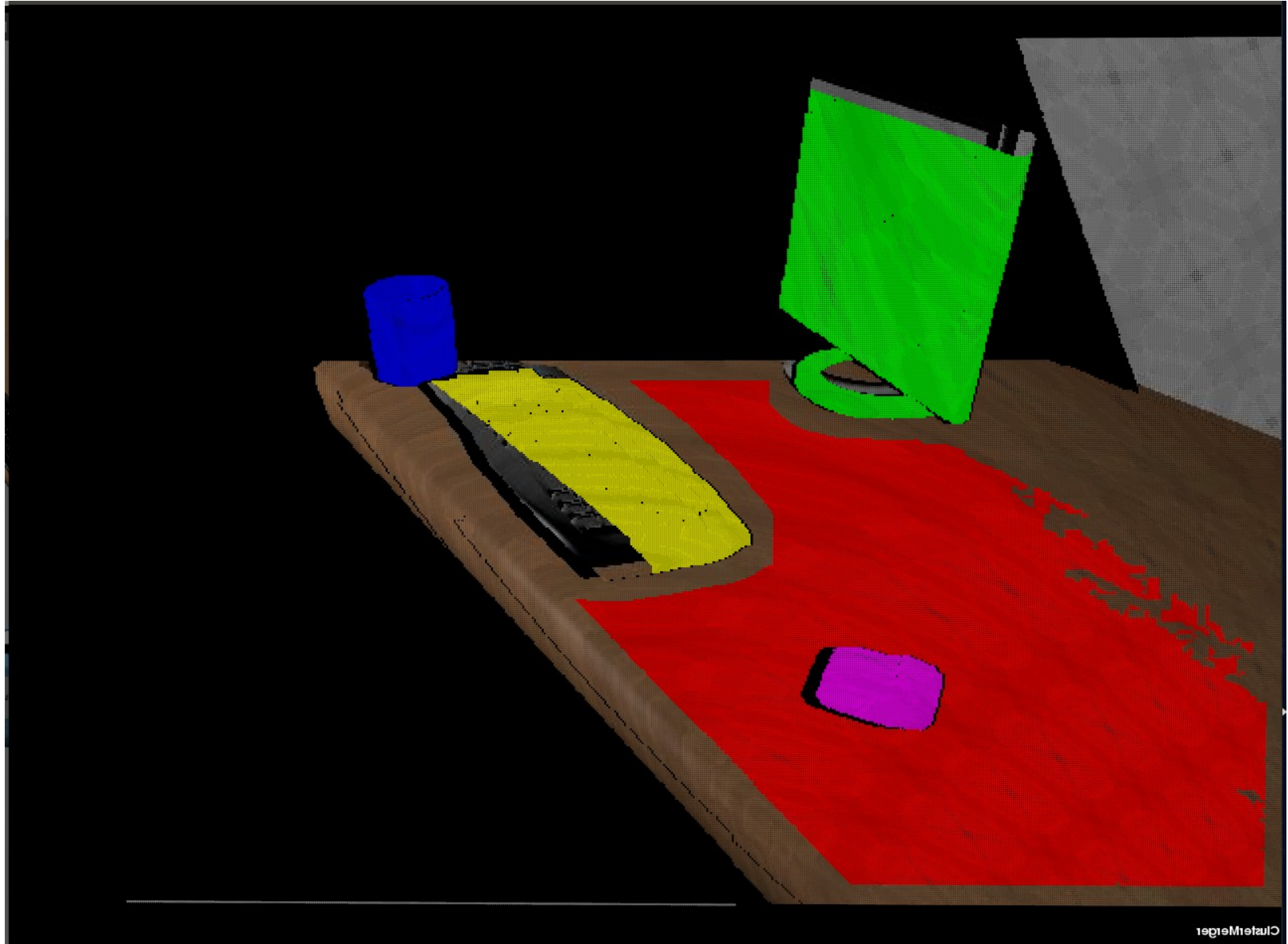


Part II: Deep Vision

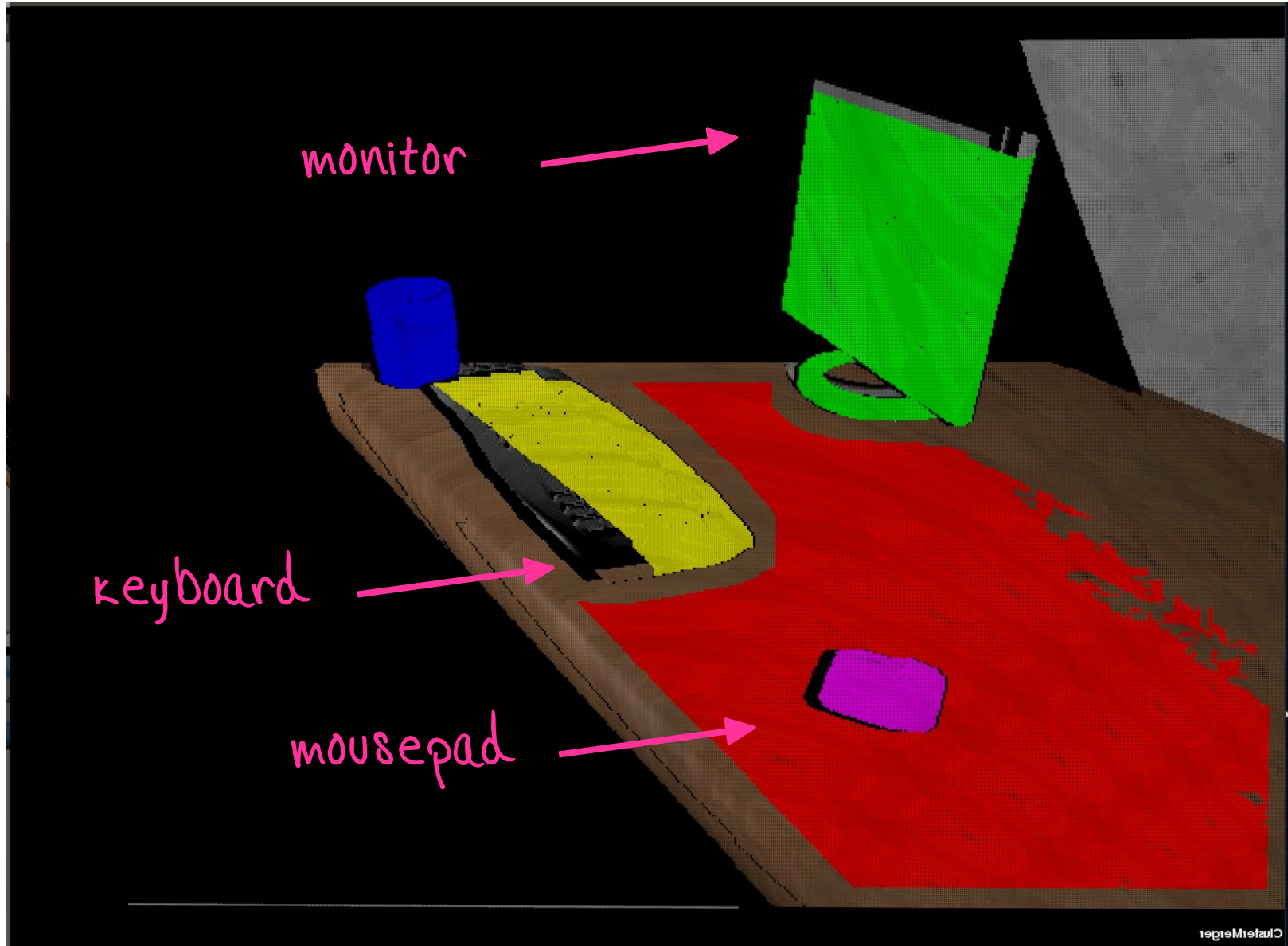
Perception and Identification



Perception and Identification

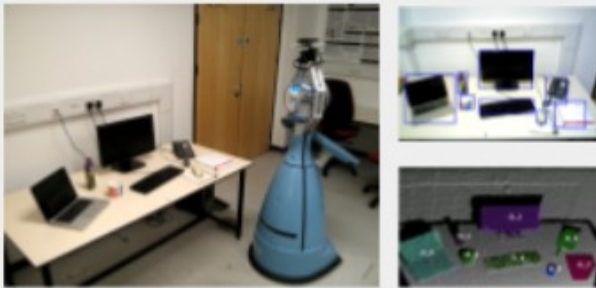


Perception and Identification

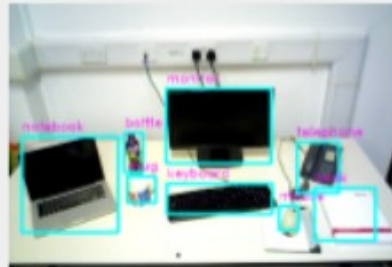


Perception and Identification

Step 1 Situated Robot Perception



Step 2 Object Classification



Step 3 Place Classification



Situated Robot Perception

Robot deployments in office environments

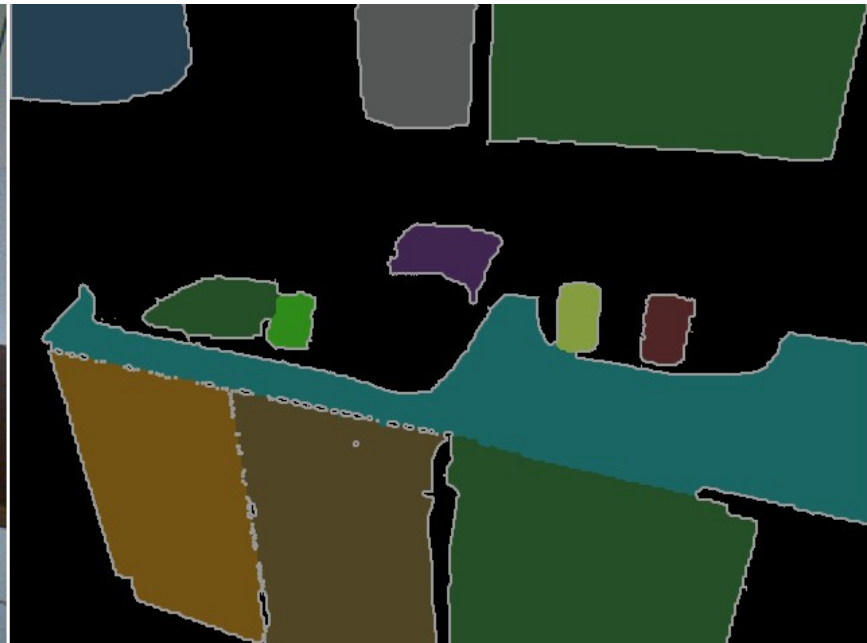
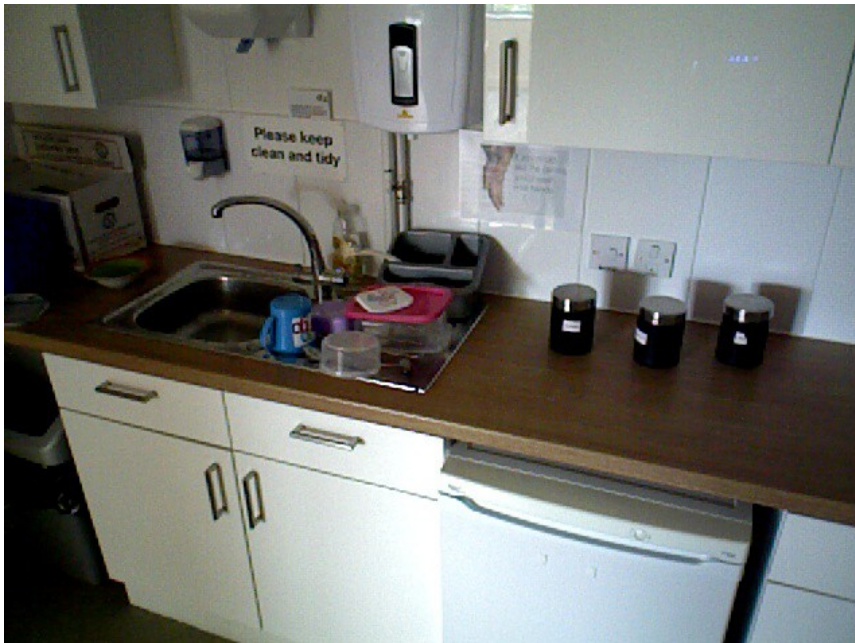
The robot visits fixed waypoints on the map, taking full 360° RGB-D scans



Situated Robot Perception

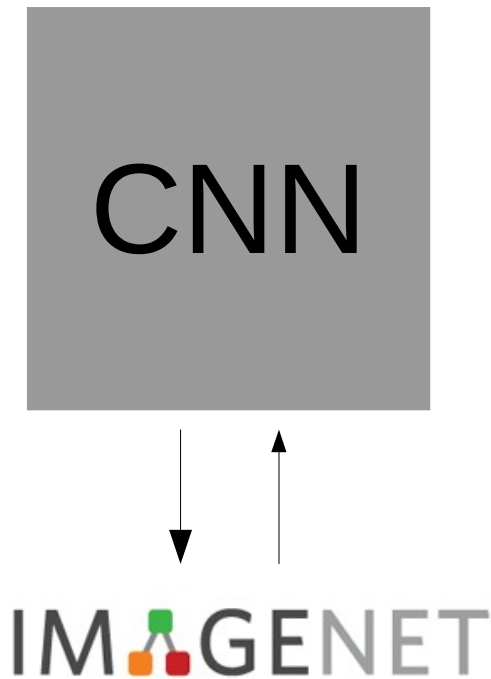
RGB-D depth **segmentation** algorithm
(Potapova et al., 2014)

Pictures→Point clouds→Patches→
→Surfaces→Clustering→Filtering→
→Candidate objects

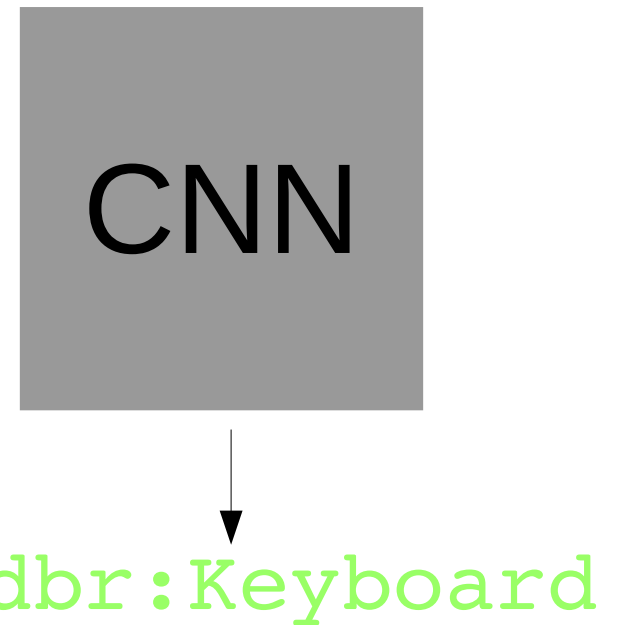


Supervised Object Recognition

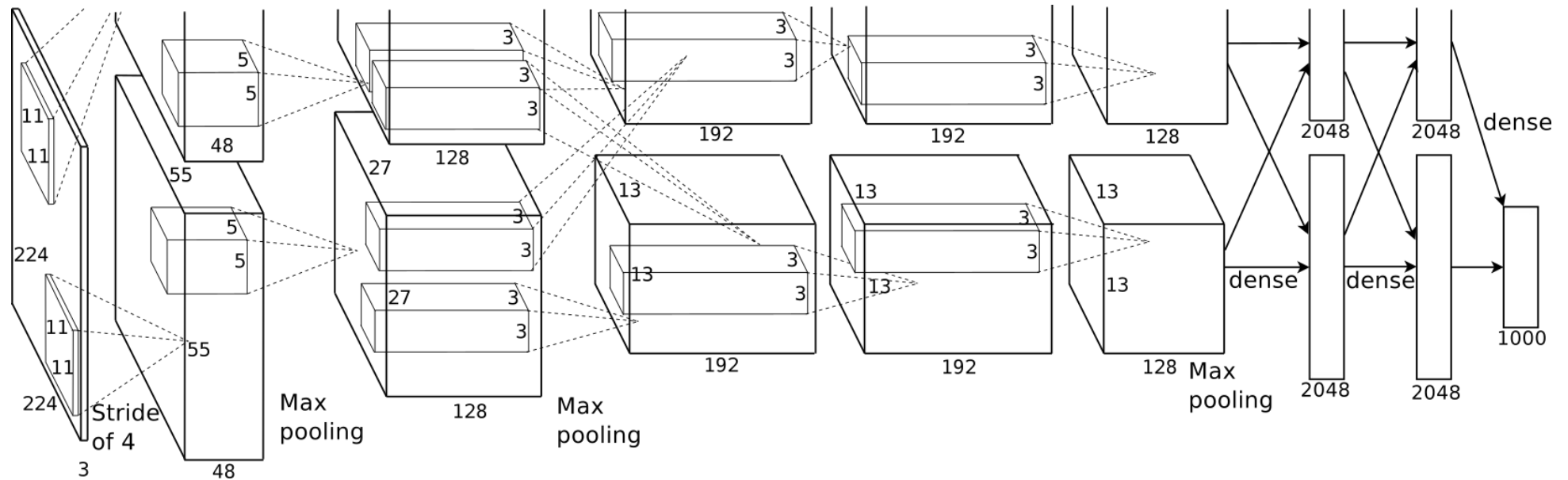
Training



Prediction



Supervised Object Recognition



Convolutional Neural Network model trained
on 1,000 object classes
(More detail in Young et al., ICRA 2017)



21,841 WordNet Synsets (1,000 with SIFT features)

14,197,122 images (1,034,908 with bounding box)

<http://image-net.org/>
<http://wordnet-rdf.princeton.edu/>

Supervised Object Recognition

SEARCH

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14,197,122 images, 21841 synsets indexed

Not logged in. [Login](#) | [Signup](#)

Your query "robot" matches 3 synsets.



Synset: [automaton](#), [robot](#), [golem](#)

Definition: a mechanism that can move automatically.

Popularity percentile:: 75%

Depth in WordNet: 7



Synset: [buzz bomb](#), [robot bomb](#), [flying bomb](#), [doodlebug](#), [V-1](#)

Definition: a small jet-propelled winged missile that carries a bomb.

Popularity percentile:: 74%

Depth in WordNet: 10



Synset: [autopilot](#), [automatic pilot](#), [robot pilot](#)

Definition: a navigational device that automatically keeps ships or planes or spacecraft on a steady course.

Popularity percentile:: 57%

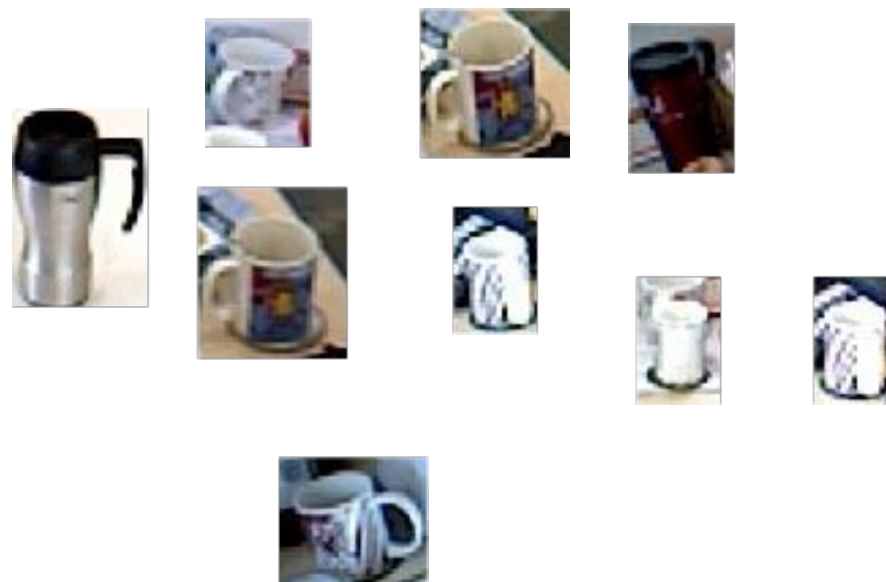
Depth in WordNet: 6

© 2016 Stanford Vision Lab, Stanford University, Princeton University support@image-net.org Copyright infringement

<http://image-net.org/>

Performance of Robot Vision

Good but not great

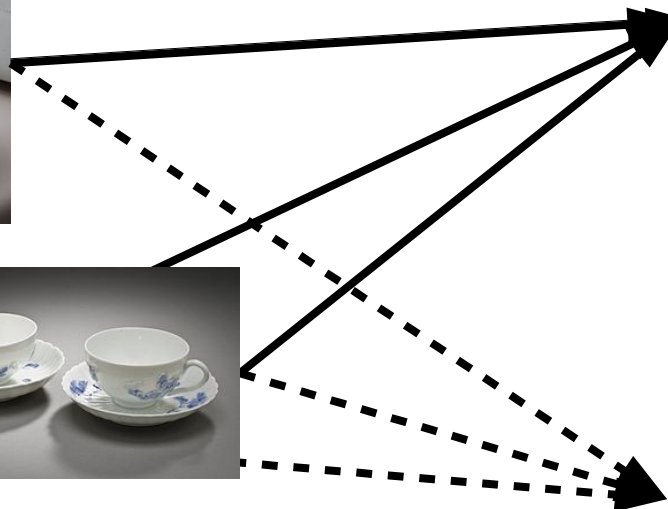


Mugs on ImageNet
(training data)

Mugs seen by a robot
(validation data)

Part III: Semantics and Vision

Object Identification



Place Classification



Semantic Relatedness

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** 

Semantic Relatedness

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Asked by: **edward_88** 29th Dec, 2012 **Electrical** 



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

Semantic Relatedness

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Co-occurrence matrix

	Washing_machine	Ashtray
Bathroom	5	2
Bedroom	0	1
Living_room	1	6

Semantic Relatedness

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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 ...
```

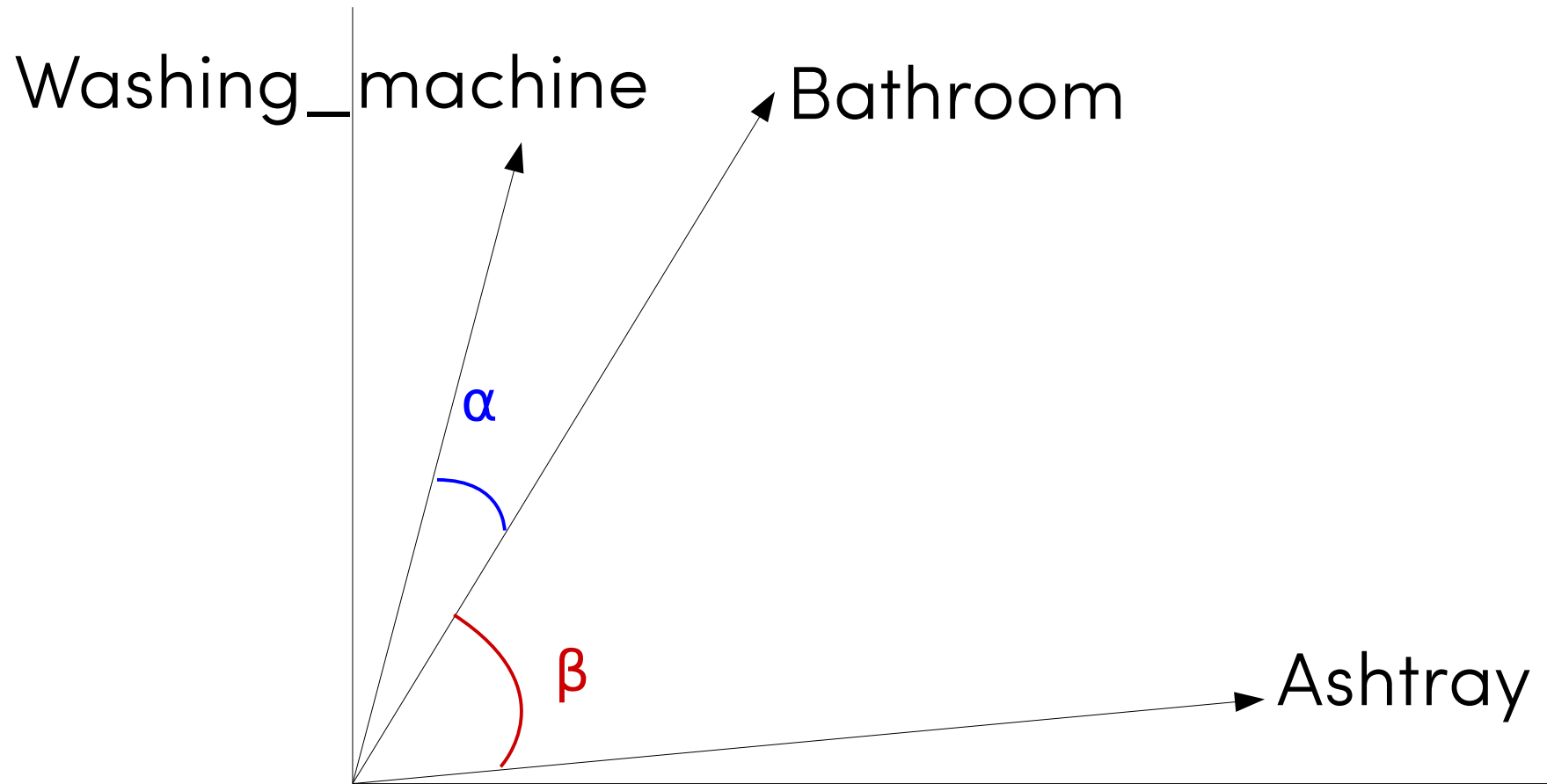
```
bn:00007365n Washing_machine -0.00911299 0.11549547 -0.04274256 0.03672424  
-0.06627292 0.13761881 0.01171631 -0.08721243 0.08270955 0.13095092  
-0.00137408 -0.16226186 0.0422162 0.0545828 -0.01007292 0.10094466  
-0.05663372 0.09864459 0.10167608 7.534e-05 0.08067719 0.05527394
```

Cosine similarity:

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

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

Semantic Similarity



$$\text{sim}(\text{Bathroom}, \text{Washing_machine}) = \cos(\alpha) \approx 0.71$$

$$\text{sim}(\text{Bathroom}, \text{Ashtray}) = \cos(\beta) \approx 0.37$$

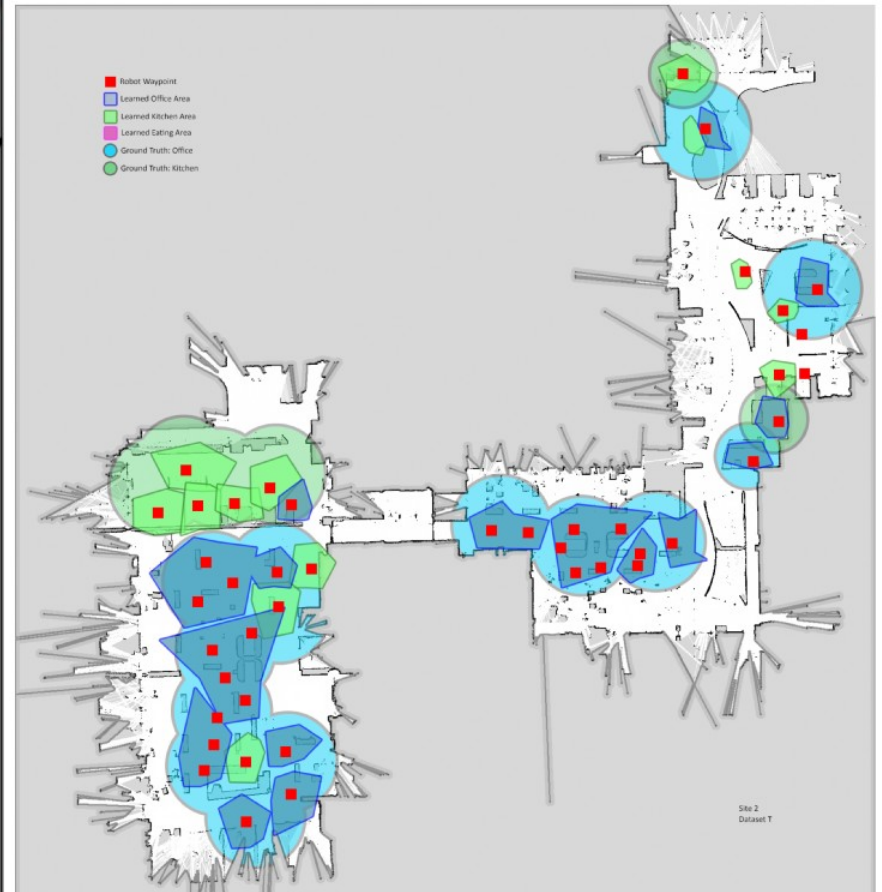
Place Classification

→ = Cosine similarity on NASARI

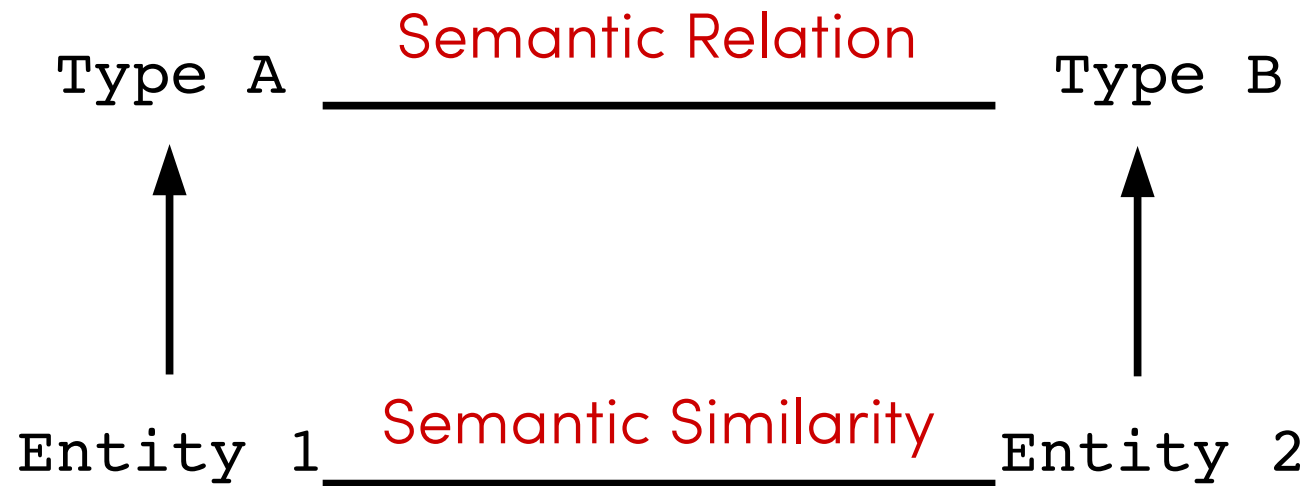


+ aggregation, weighting by distance, ...

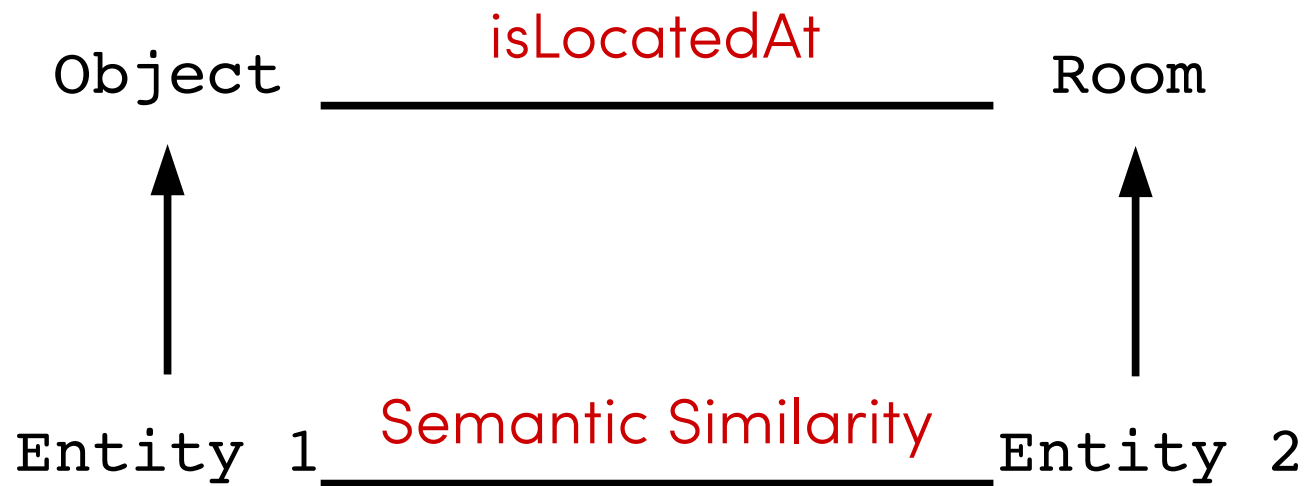
Place Classification



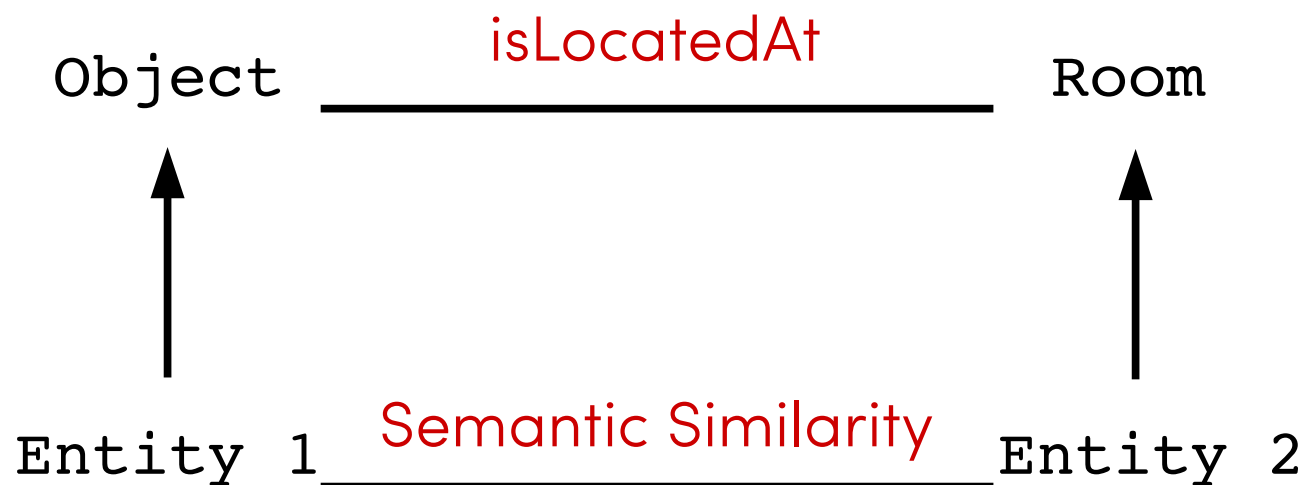
Distributional Relational Hypothesis



Distributional Relational Hypothesis



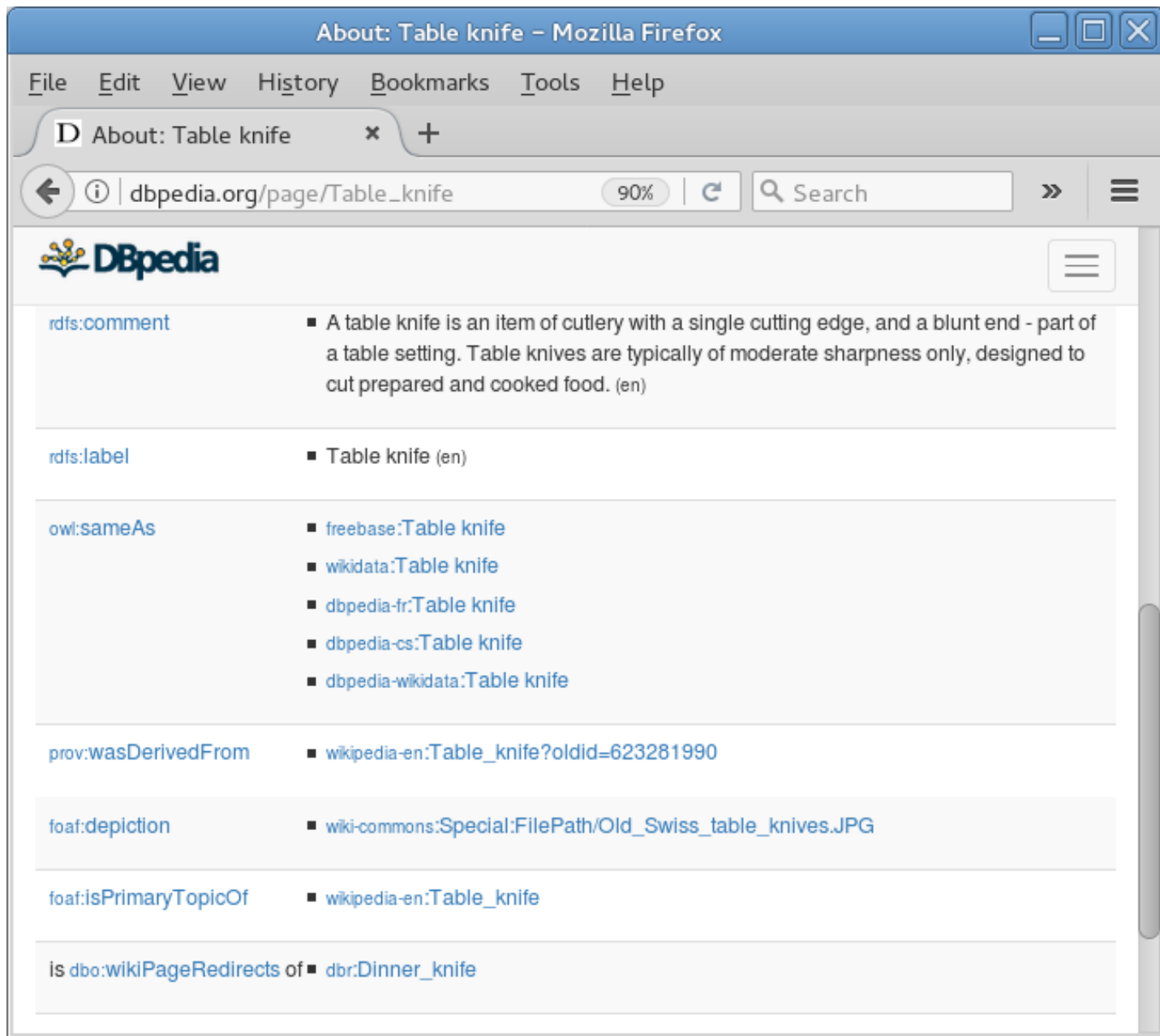
Distributional Relational Hypothesis



Successfully applied to **object-location** relation extraction (Basile et al, EKAW 2016) and improving **object detection** (Young et al., ICRA 2017)

More on this later

Part IV: More Semantics



http://dbpedia.org/page/Table_knife

ConceptNet 5: knife – Mozilla Firefox

File Edit View History Bookmarks Tools Help

ConceptNet 5: knife x +

conceptnet.io/c/en/knife Search ☆ 📖 🔍 » ☰



knife

An English term in ConceptNet 5.5

Sources: Open Mind Common Sense contributors, DBPedia 2015, JMDict 1.07, OpenCyc 2012, Verbosity players, German Wiktionary, English Wiktionary, French Wiktionary, and Open Multilingual WordNet

[View this term in the API](#)

[Documentation](#)
[FAQ](#)
[Chat](#)
[Blog](#)

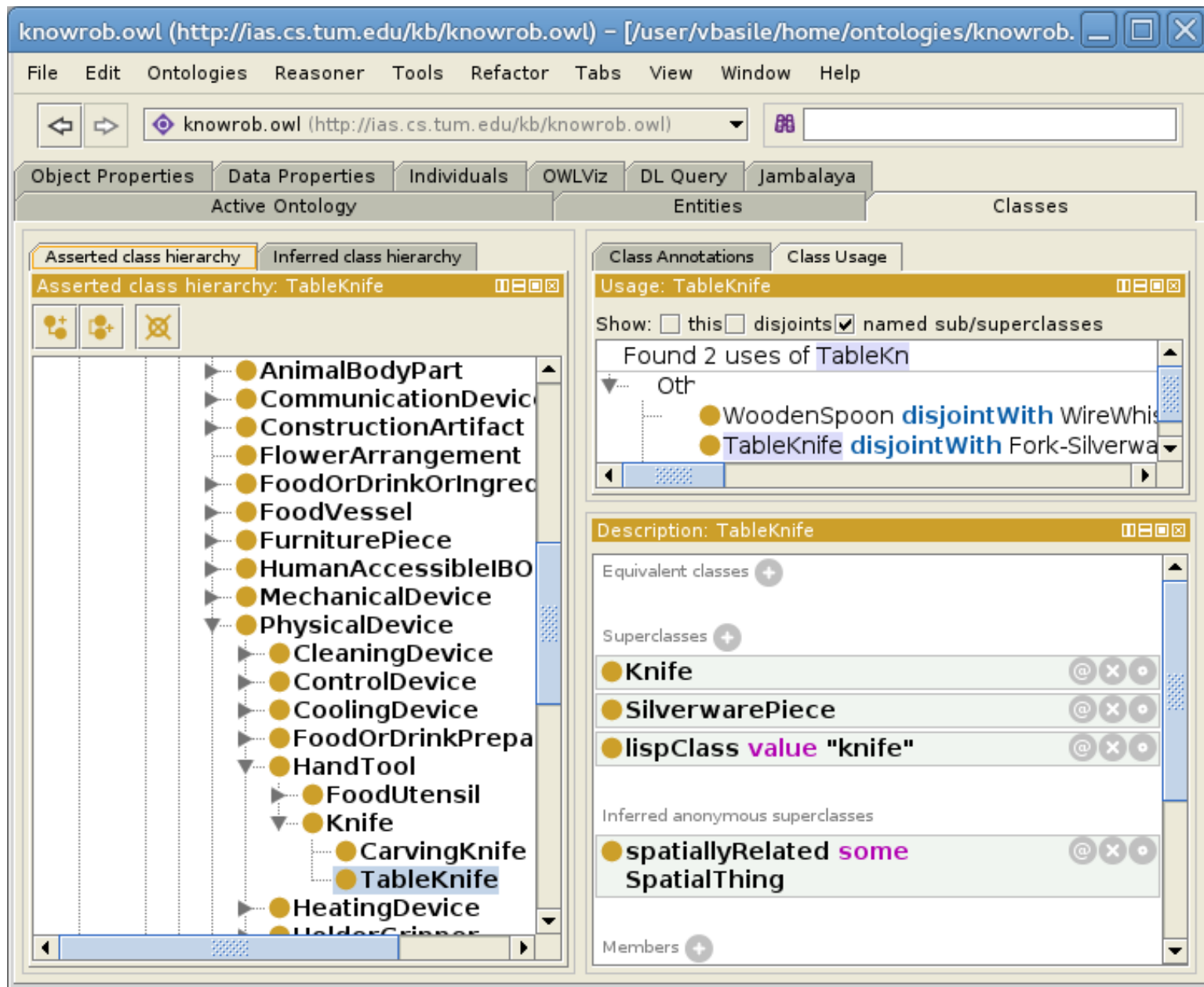
knife is used for...

- [en cut^{\(n\)} →](#)
- [en stabbing →](#)
- [en cut^{\(v\)} →](#)
- [en butter →](#)
- [en stab^{\(v\)} →](#)
- [en cutting food →](#)
- [en carving wood →](#)
- [en slicing →](#)

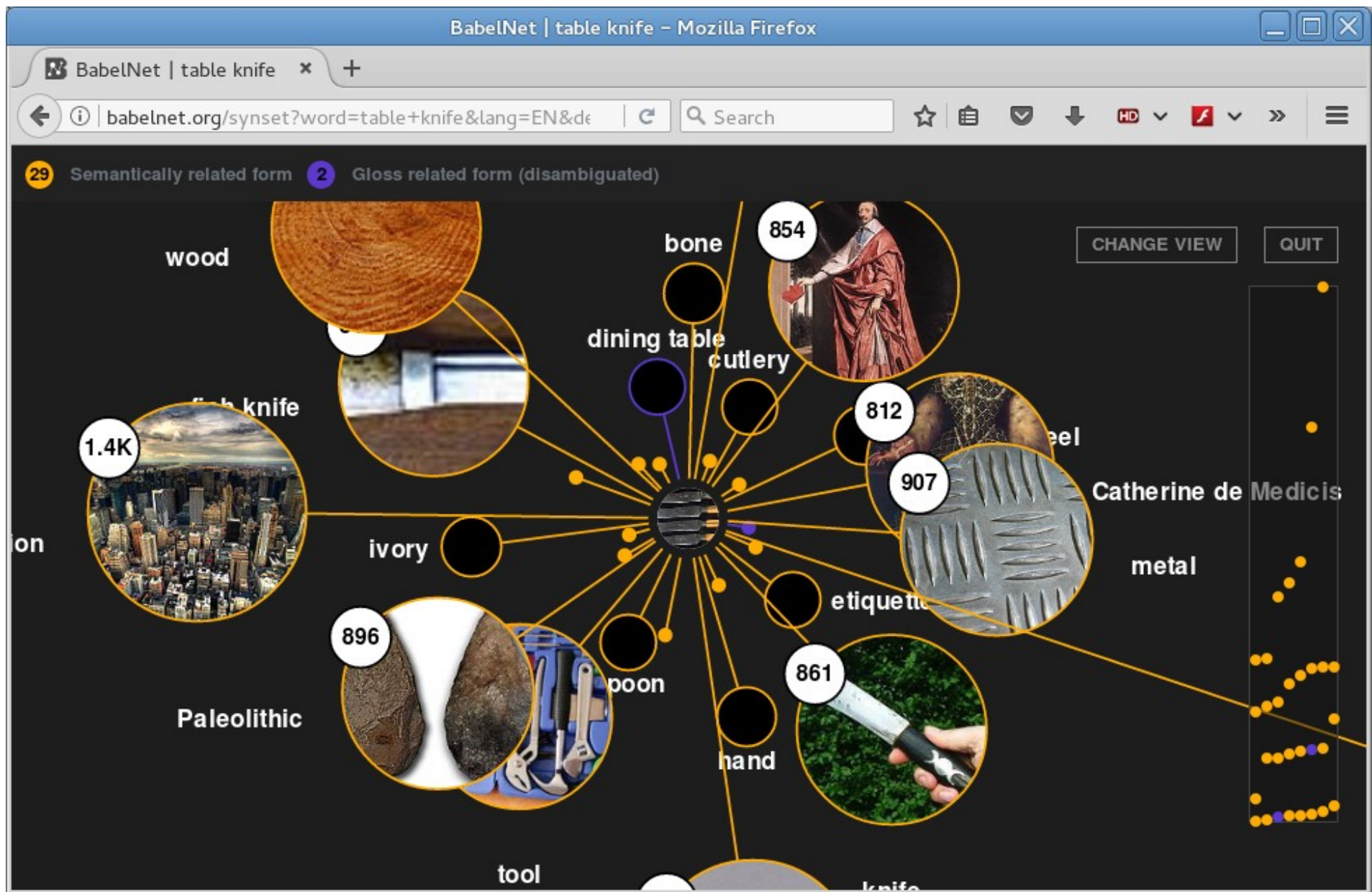
Types of knife

- [en barong^{\(n\)} →](#)
- [en bayonet^{\(v\)} →](#)
- [en machete^{\(n\)} →](#)
- [en A mind that is all logic →](#)
- [en bayonet^{\(n\)} →](#)
- [en poniard^{\(v\)} →](#)
- [en scalpel^{\(n\)} →](#)
- [en bolo^{\(n\)} →](#)

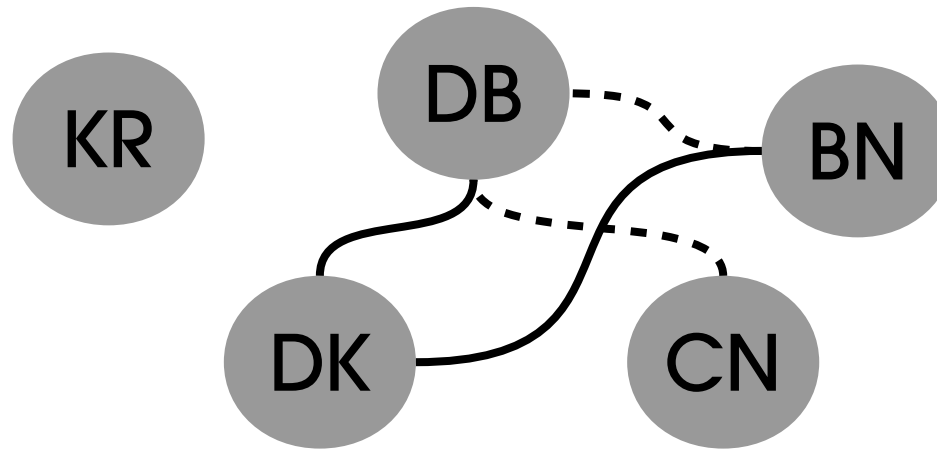
<http://conceptnet.io/c/en/knife>



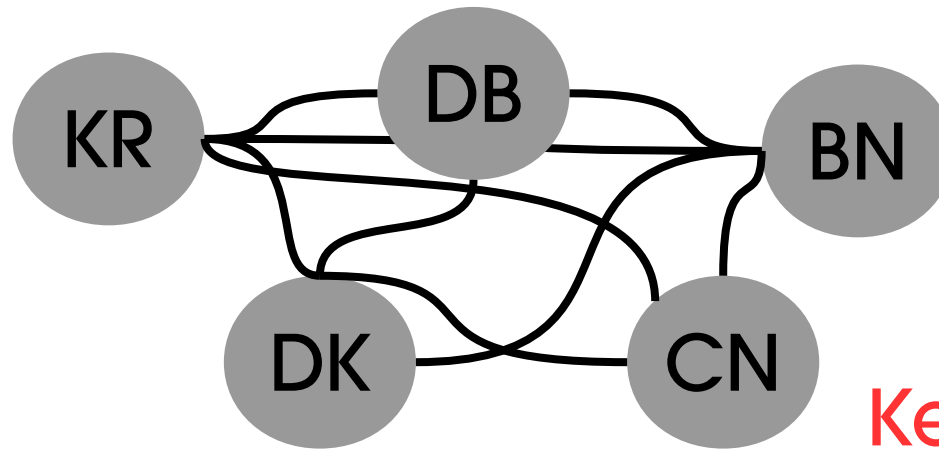
<http://knowrob.org/kb/knowrob.owl>



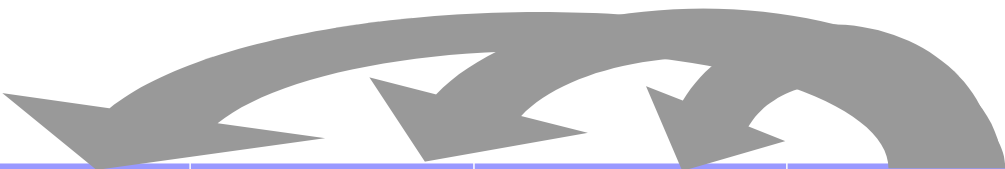
<http://babelnet.org/synset?word=table+knife>



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



Keyword Linking



	Taxonomy	Function	Location	Linked Data
DBpedia	✓	✓	✓	✓
ConceptNet	✓	✓	✓	✓
KnowRob	✓	✓	✓	✓
BabelNet	✓	✓	✓	✓
DeKO	✓	✓	✓	✓

Keyword Linking Methods

DBpedia Lookup

“official” search API of DBpedia

String Match (+redirect)

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

Babelify

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

Keyword Linking Methods

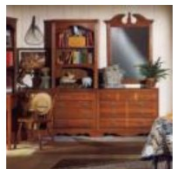
Vector-based Contextual disambiguation

- 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

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

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.

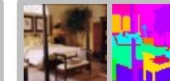
 Wall 2561 in this scene 20213 total	 Bed 1144 in this scene 1617 total	 Cushion 1043 in this scene 2091 total	 Pillow 1008 in this scene 1359 total	 Floor 991 in this scene 7227 total	 Desk lamp 953 in this scene 1702 total	 Night table 867 in this scene 1054 total
 Window 845 in this scene 16080 total	 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
---	---	--	--	--	---	---	---	--

The SUN database

<http://groups.csail.mit.edu/vision/SUN>

131,067 Images

908 Scene categories

313,884 Segmented objects

4,479 Object categories

After linking

2,493 objects in DBpedia

679 locations in DBpedia

2,935 object-location relations

The SUN database

<http://groups.csail.mit.edu/vision/SUN>

131,067 Images

908 Scene categories

313,884 Segmented objects

4,479 Object categories

After linking

2,493 objects in DBpedia

679 locations in DBpedia

2,935 object-location relations

Yes, this is hard



Epilogue: Putting it all together

Default Knowledge about Objects



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

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

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

```
<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> .
```

Autonomous Learning

Task-level Loop



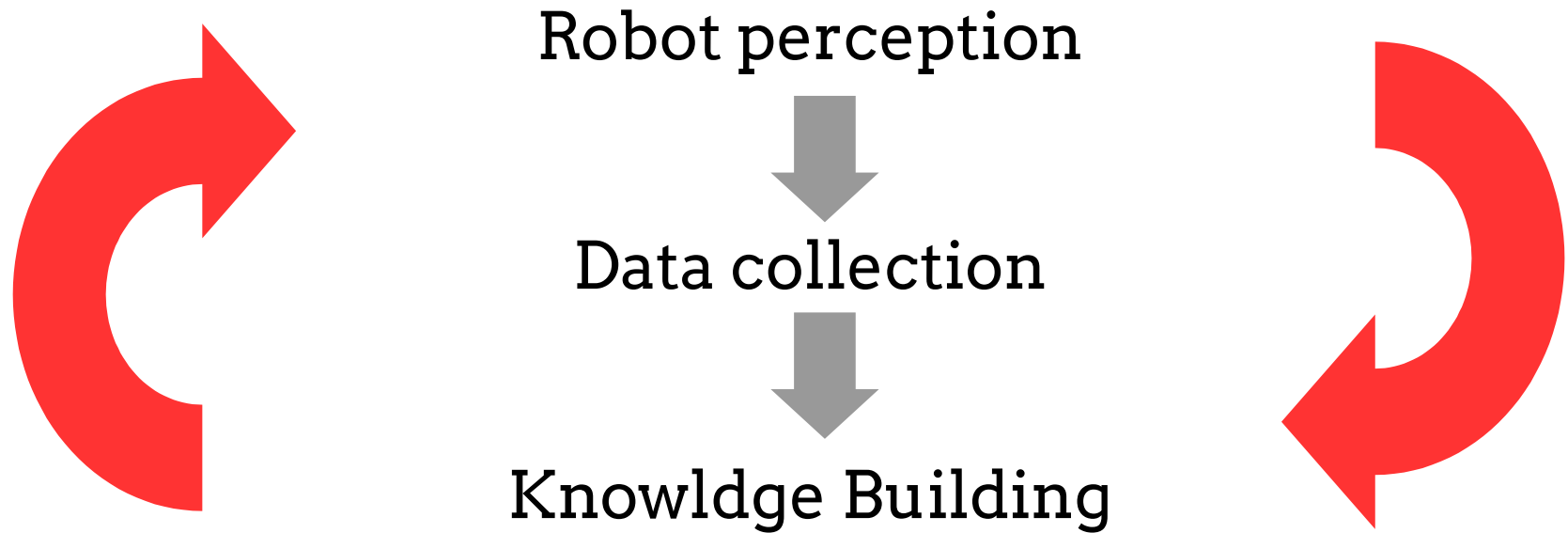
DeKO

Keyword Linking
Distributional Relational Hypothesis

...

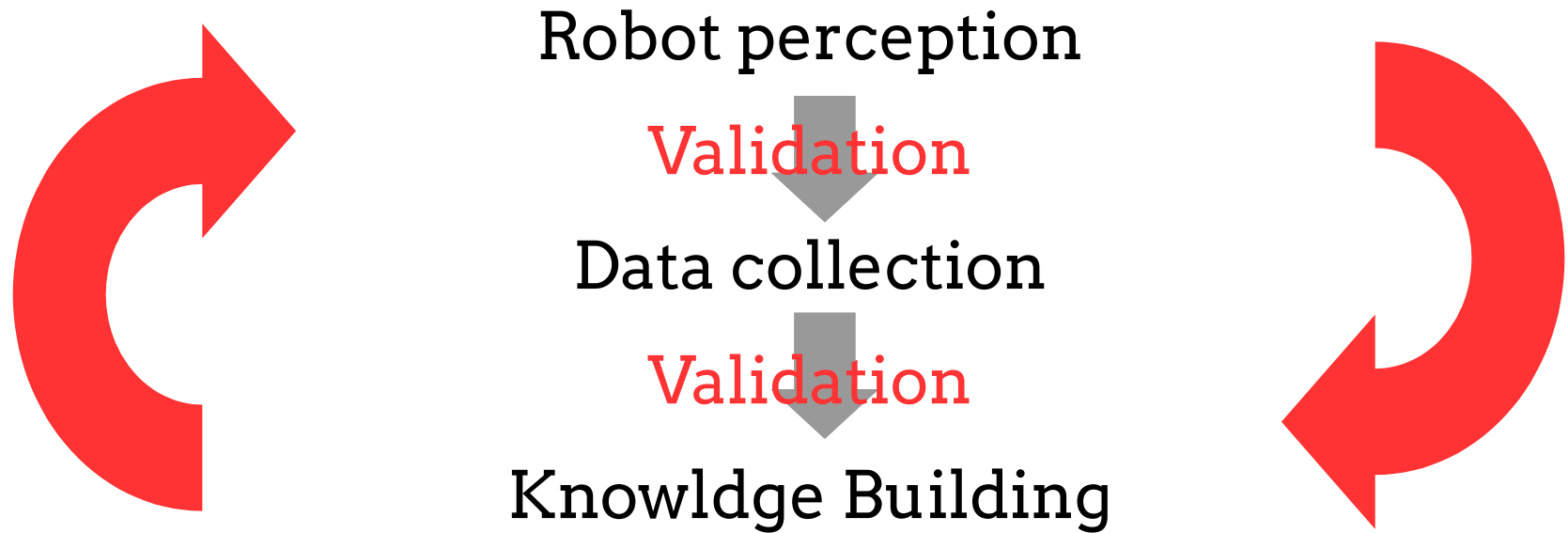
Autonomous Learning

Learning-level Loop



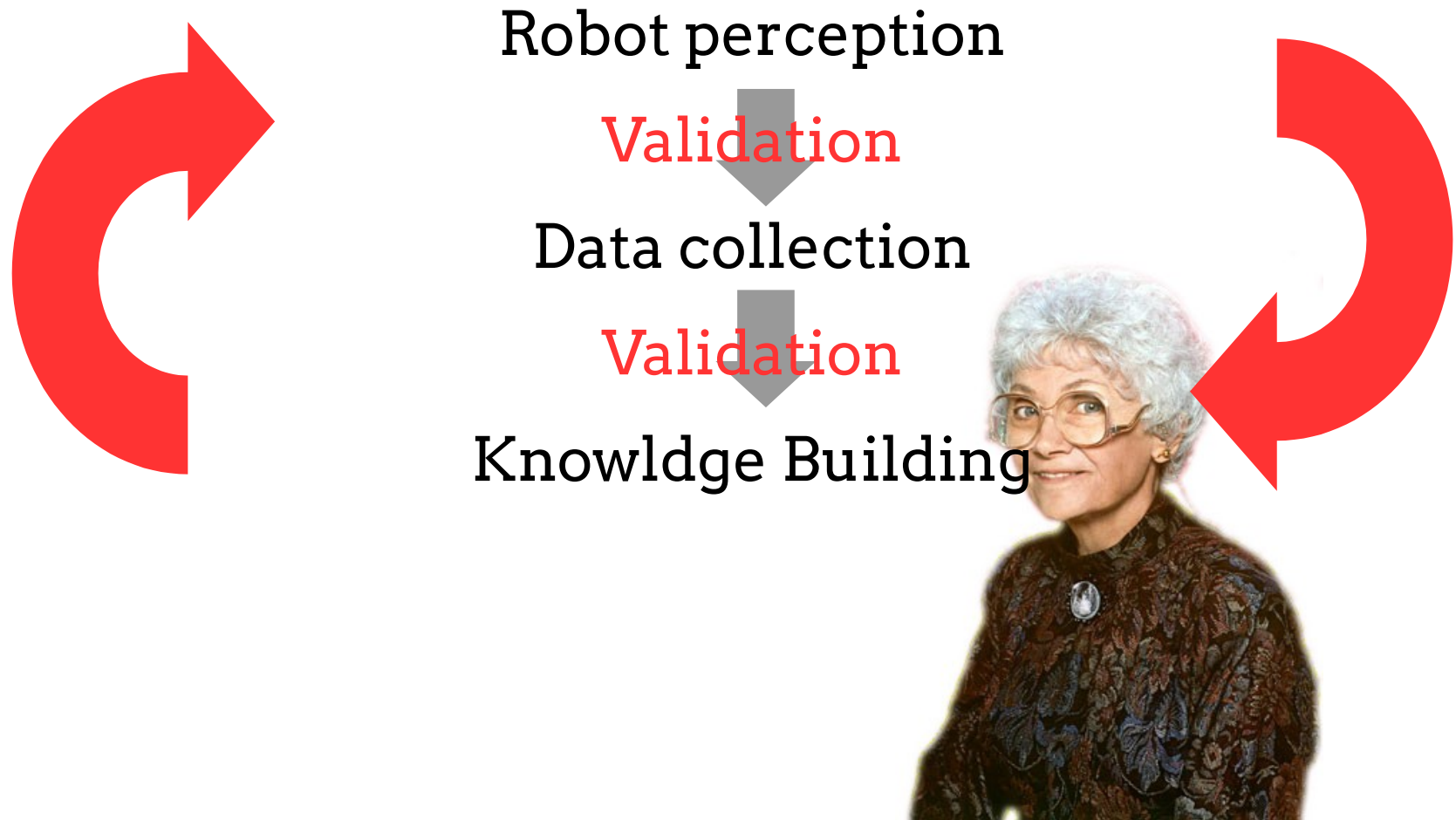
Autonomous Learning

Learning-level Loop



Autonomous Learning

Learning-level Loop



Fin
(Q/A)



Links

Me

<http://valeribasile.github.io/>

Project

<https://project.inria.fr/alooof/>

Databases & Resources

<http://image-net.org/>

<http://groups.csail.mit.edu/vision/SUN>

<http://knowrob.org/kb/knowrob.owl>

<http://dbpedia.org/page/>

<http://babelnet.org/>

<http://conceptnet.io/>

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