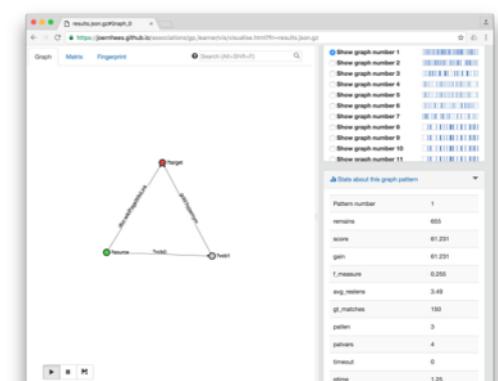
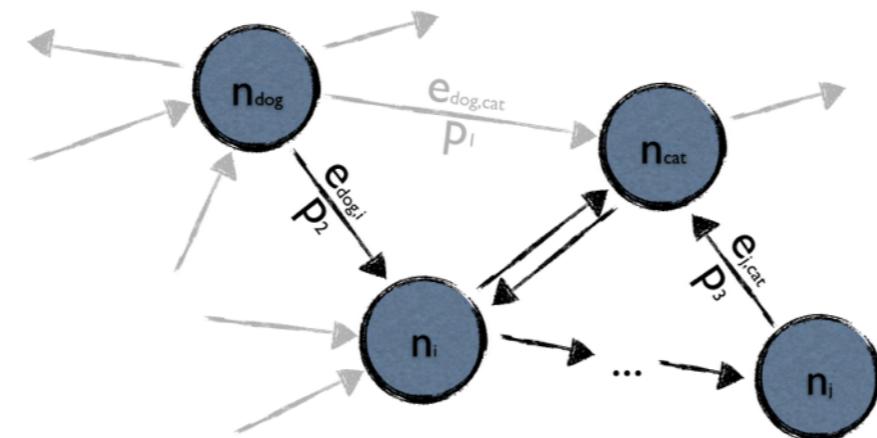
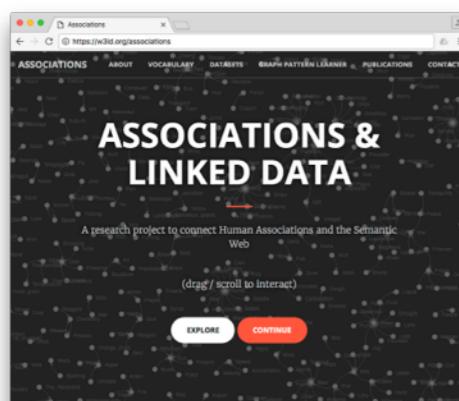


# Human Associations in the Semantic Web and DBpedia



Jörn Hees

2016-09-15  
DBpedia Community Meeting Leipzig

# Jörn Hees



- PhD Student at DFKI & TU Kaiserslautern
- Blog: Setting up a Linked Data mirror from RDF dumps (DBpedia, Freebase, Wikidata, LinkedGeoData, ...) with Virtuoso
- RDFLib maintainer (Python)
- <http://joernhees.de>
- <https://w3id.org/associations>

# Outline

- Background
- My Research
  - Human Association Datasets
  - Graph Pattern Learning
- Discussion

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- Mental connections between concepts
- What's the first thing that comes to your mind when thinking about ... ?
- Example:
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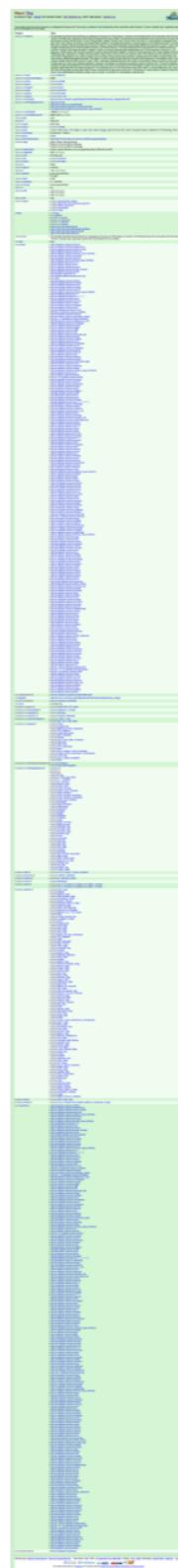
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- Example:
  - Dog: Cat, collar, leash, walk, fur, bark
  - House: Roof, door, window, flat, live

# Example: DBpedia:Dog



# Example: DBpedia:Dog

- Basic information (description, types)

| About: Dog  |  |       |                                      |  |                                   |  |  |   |                                    |   |                                   |   |                                     |  |                                   |   |                                    |  |                                     |   |                                       |   |  |  |  |   |  |   |
|---|--|-------|--------------------------------------|--|-----------------------------------|--|--|---|------------------------------------|---|-----------------------------------|---|-------------------------------------|--|-----------------------------------|---|------------------------------------|--|-------------------------------------|---|---------------------------------------|---|--|--|--|---|--|---|
| An Entity of Type : <a href="#">animal</a> , from Named Graph : <a href="http://dbpedia.org">http://dbpedia.org</a> , within Data Space : <a href="http://dbpedia.org">dbpedia.org</a>  |   |       |                                      |  |                                   |  |  |   |                                    |   |                                   |   |                                     |  |                                   |   |                                    |  |                                     |   |                                       |   |  |  |  |   |  |   |
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| <a href="#">dbpedia-owl:phylum</a>  | <ul style="list-style-type: none"> <li><a href="#">dbpedia:Chordate</a></li> </ul>   |       |                                      |  |                                   |  |  |   |                                    |   |                                   |   |                                     |  |                                   |   |                                    |  |                                     |   |                                       |   |  |  |  |   |  |   |
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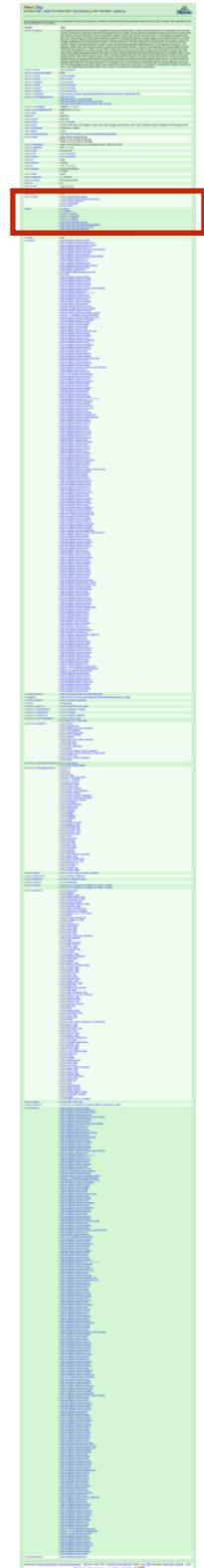


# Example: DBpedia:Dog



- Basic information (description, types)
- Categorisation (categories & types)

|                 |  |
|-----------------|--|
| dcterms:subject | <ul style="list-style-type: none"><li>▪ category:Cosmopolitan_species</li><li>▪ category:Mammals_with_sequenced_genomes</li><li>▪ category:Model_organisms</li><li>▪ category:Scavengers</li><li>▪ category:Dogs</li></ul>   |
| rdf:type        | <ul style="list-style-type: none"><li>▪ owl:Thing</li><li>▪ dul:Organism</li><li>▪ dbpedia-owl:Animal</li><li>▪ dbpedia-owl:Eukaryote</li><li>▪ dbpedia-owl:Mammal</li><li>▪ dbpedia-owl:Species</li><li>▪ <a href="http://umbel.org/umbel/rc/Animal">http://umbel.org/umbel/rc/Animal</a></li><li>▪ <a href="http://umbel.org/umbel/rc/BiologicalLivingObject">http://umbel.org/umbel/rc/BiologicalLivingObject</a></li><li>▪ <a href="http://umbel.org/umbel/rc/EukaryoticCell">http://umbel.org/umbel/rc/EukaryoticCell</a></li><li>▪ <a href="http://umbel.org/umbel/rc/Mammal">http://umbel.org/umbel/rc/Mammal</a></li></ul> |



# Example: DBpedia:Dog



- Basic information (description, types)
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- Links to other datasets (also Freebase)

|            |   |
|------------|---|
| owl:sameAs | <ul style="list-style-type: none"><li>▪ <a href="http://fr.dbpedia.org/resource/Chien">http://fr.dbpedia.org/resource/Chien</a></li><li>▪ <a href="http://de.dbpedia.org/resource/Haushund">http://de.dbpedia.org/resource/Haushund</a></li><li>▪ <a href="http://cs.dbpedia.org/resource/Pes_domácí">http://cs.dbpedia.org/resource/Pes_domácí</a></li><li>▪ <a href="http://el.dbpedia.org/resource/Σκύλος">http://el.dbpedia.org/resource/Σκύλος</a></li><li>▪ <a href="http://es.dbpedia.org/resource/Canis_lupus_familiaris">http://es.dbpedia.org/resource/Canis_lupus_familiaris</a></li><li>▪ <a href="http://eu.dbpedia.org/resource/Txakur">http://eu.dbpedia.org/resource/Txakur</a></li><li>▪ <a href="http://id.dbpedia.org/resource/Anjing">http://id.dbpedia.org/resource/Anjing</a></li><li>▪ <a href="http://it.dbpedia.org/resource/Canis_lupus_familiaris">http://it.dbpedia.org/resource/Canis_lupus_familiaris</a></li><li>▪ <a href="http://ja.dbpedia.org/resource/犬">http://ja.dbpedia.org/resource/犬</a></li><li>▪ <a href="http://ko.dbpedia.org/resource/개">http://ko.dbpedia.org/resource/개</a></li><li>▪ <a href="http://nl.dbpedia.org/resource/Hond">http://nl.dbpedia.org/resource/Hond</a></li><li>▪ <a href="http://pl.dbpedia.org/resource/Pies_domowy">http://pl.dbpedia.org/resource/Pies_domowy</a></li><li>▪ <a href="http://pt.dbpedia.org/resource/Cão">http://pt.dbpedia.org/resource/Cão</a></li><li>▪ <a href="http://wikidata.org/entity/Q144">http://wikidata.org/entity/Q144</a></li><li>▪ <a href="http://wikidata.dbpedia.org/resource/Q144">http://wikidata.dbpedia.org/resource/Q144</a></li><li>▪ <a href="#">fbase:Dog</a></li><li>▪ <a href="http://ab.dbpedia.org/resource/Ana">http://ab.dbpedia.org/resource/Ana</a></li><li>▪ <a href="http://ace.dbpedia.org/resource/Asèë">http://ace.dbpedia.org/resource/Asèë</a></li><li>▪ <a href="http://af.dbpedia.org/resource/Hond">http://af.dbpedia.org/resource/Hond</a></li><li>▪ <a href="http://als.dbpedia.org/resource/Hund">http://als.dbpedia.org/resource/Hund</a></li><li>▪ <a href="http://am.dbpedia.org/resource/Ռազը">http://am.dbpedia.org/resource/Ռազը</a></li><li>▪ <a href="http://an.dbpedia.org/resource/Canis_lupus_familiaris">http://an.dbpedia.org/resource/Canis_lupus_familiaris</a></li><li>▪ <a href="http://ar.dbpedia.org/resource/كلب">http://ar.dbpedia.org/resource/كلب</a></li></ul> |
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- Inverse links (redirects, link from other datasets)

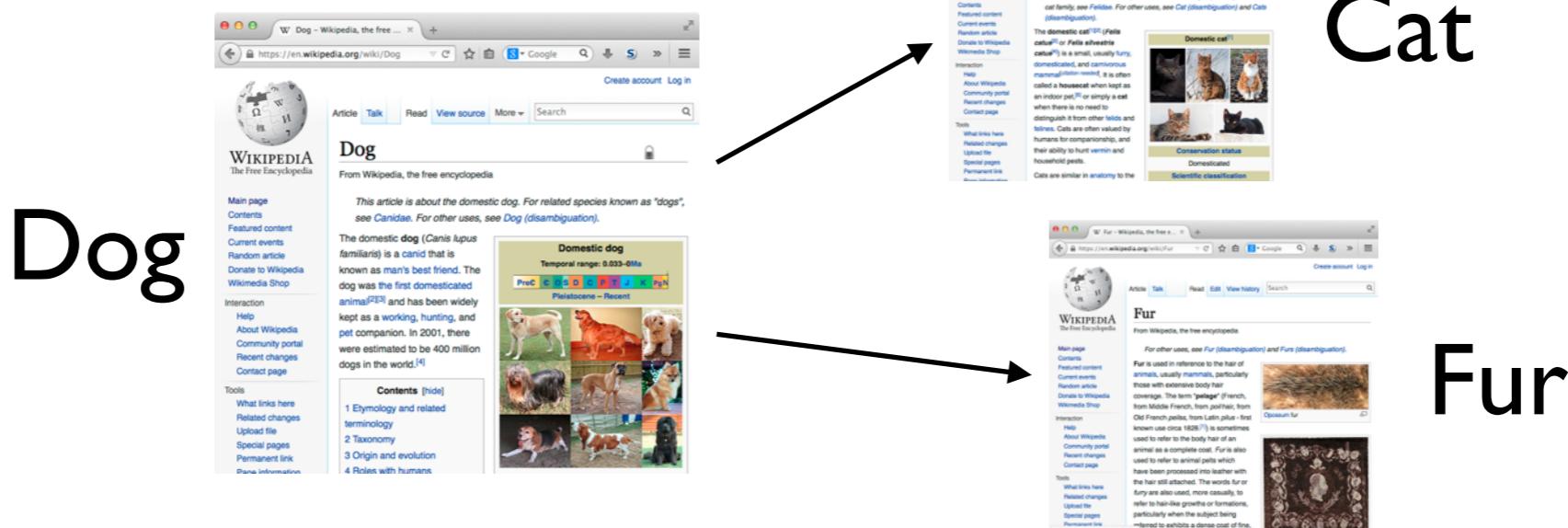
is dbpedia-owl:wikiPageRedirects of

- [dbpedia:כלב](#)
- [dbpedia:汪星人](#)
- [dbpedia:狗](#)
- [dbpedia:A\\_dog](#)
- [dbpedia:A\\_man's\\_best\\_friend](#)
- [dbpedia:C.\\_I.\\_familiaris](#)
- [dbpedia:C.I.\\_familiaris](#)
- [dbpedia:Canine\\_lupus](#)
- [dbpedia:Canis\\_Canis](#)
- [dbpedia:Canis\\_Familiaris](#)
- [dbpedia:Canis\\_Lupus\\_Familiaris](#)
- [dbpedia:Canis\\_familiaris](#)
- [dbpedia:Canis\\_familiaris\\_domesticus](#)
- [dbpedia:Canis\\_familiarus\\_domesticus](#)
- [dbpedia:Canis\\_lupus\\_familiaris](#)
- [dbpedia:DigitalDog](#)
- [dbpedia:Dog\\_\(Domestic\)](#)
- [dbpedia:Dog\\_groups](#)
- [dbpedia:Dog\\_hood](#)
- [dbpedia:Doggies](#)
- [dbpedia:Doggy](#)
- [dbpedia:Doghood](#)
- [dbpedia:Dogness](#)
- [dbpedia:Dogs](#)
- [dbpedia:Dogs\\_\(Animals\)](#)



# Example: DBpedia:Dog

- Basic information (description, types)
- Categorisation (categories & types)
- Links to other datasets (also Freebase)
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- Wiki-page-links (377 for Dog)



# Example: DBpedia:Dog

- Basic information (description, types)
- Categorisation (categories & types)
- Links to other datasets (also Freebase)
- Inverse links (redirects, link from other datasets)
- Wiki-page-links (377 for Dog)
- Associations?
  - Dog:  
Cat (✓), collar (✗), leash (✗), walk (✗), fur (✓), bark (✗)



# Outline

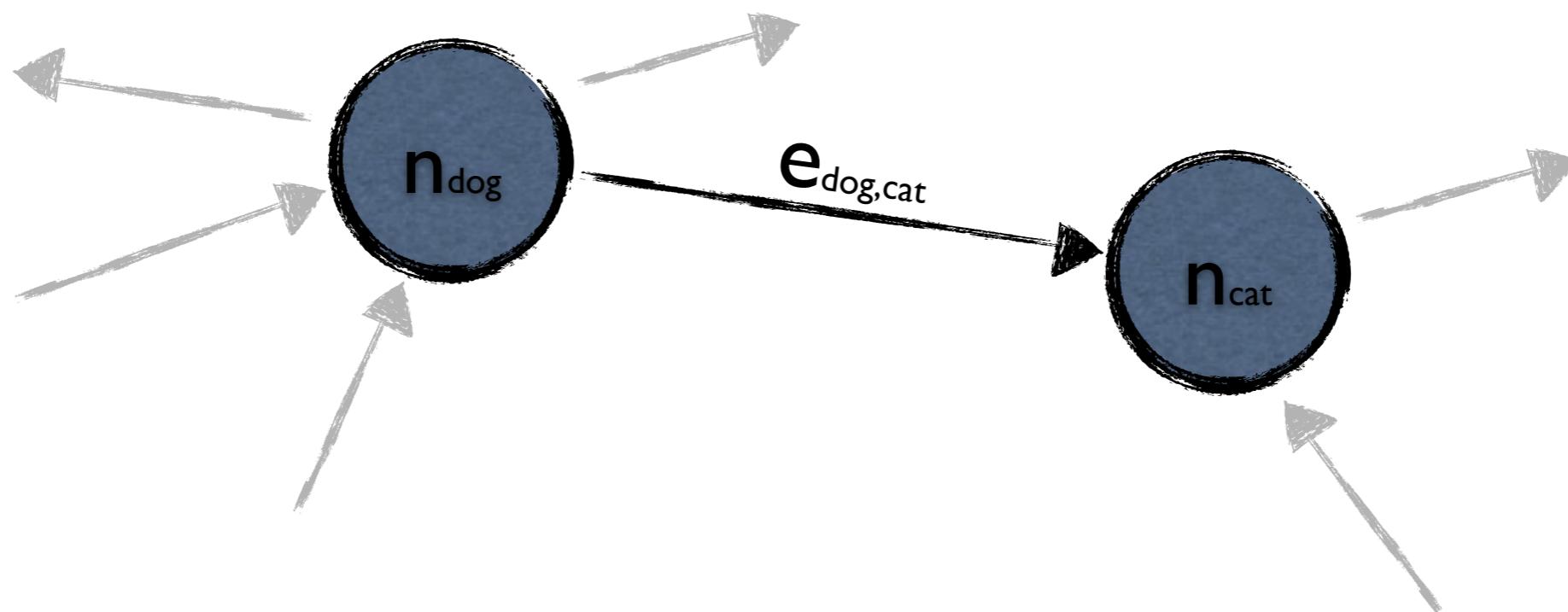
- Background
- My Research
  - Human Association Datasets
  - Graph Pattern Learning
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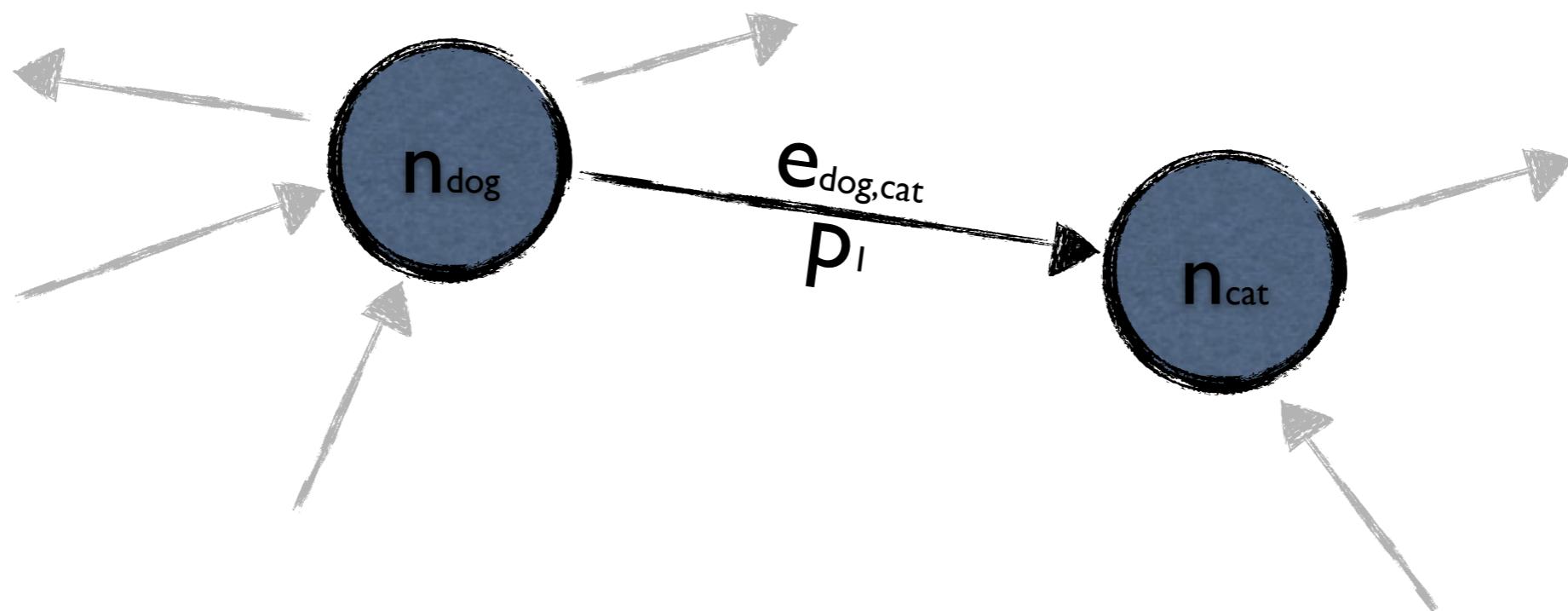
# My Research

- Research Question:
  - Is it possible to learn patterns for Human Associations from Linked Data?



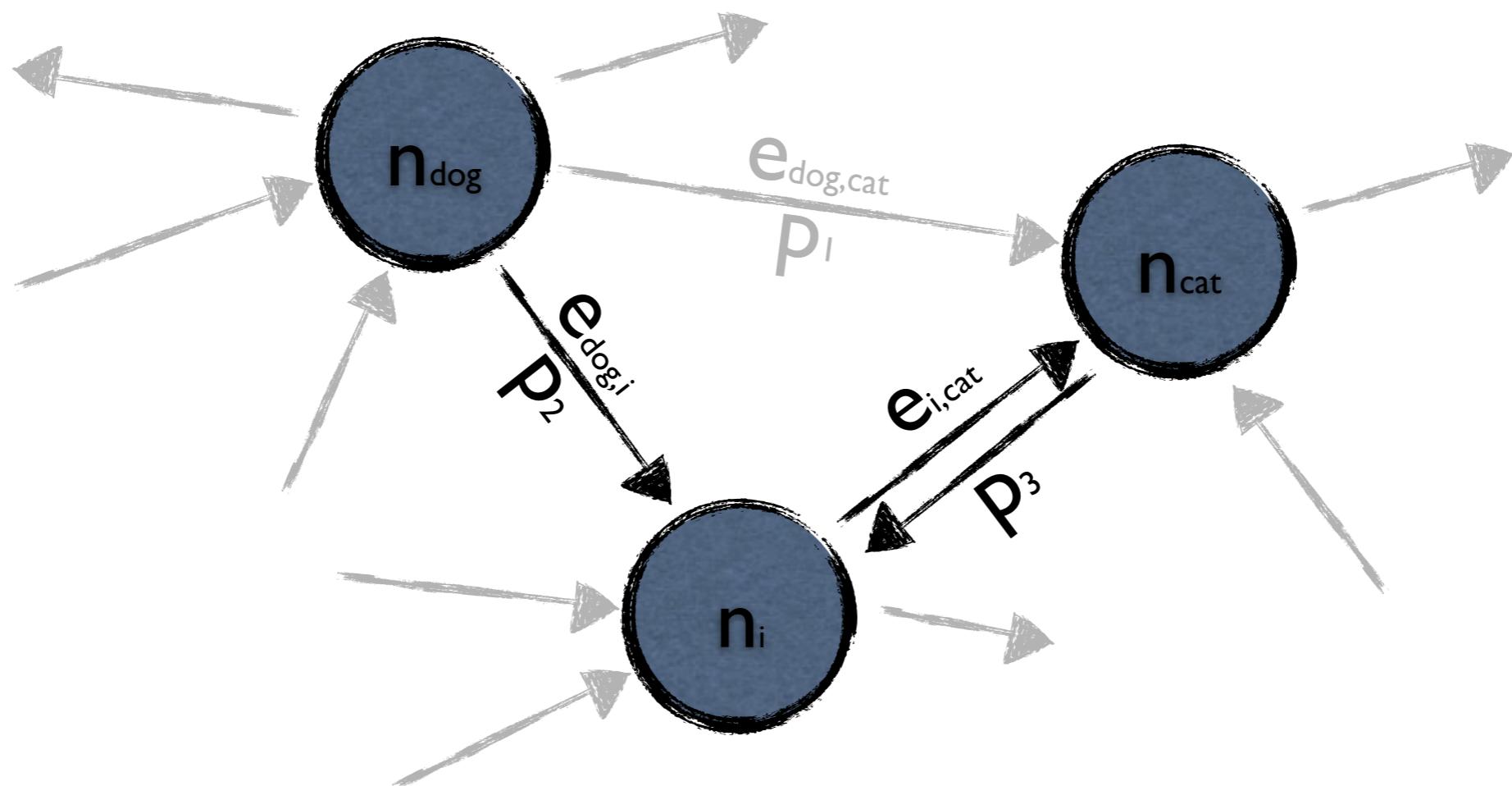
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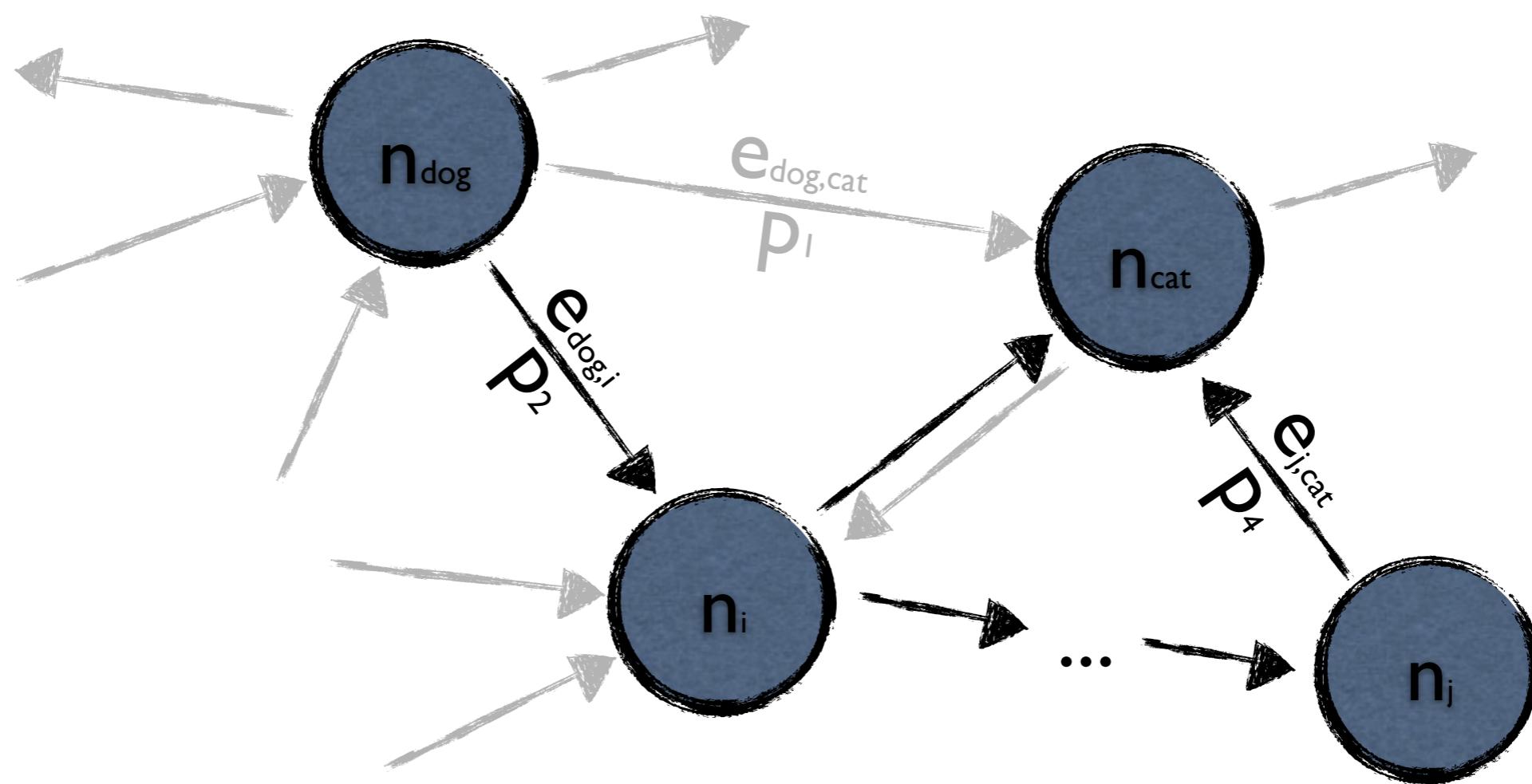
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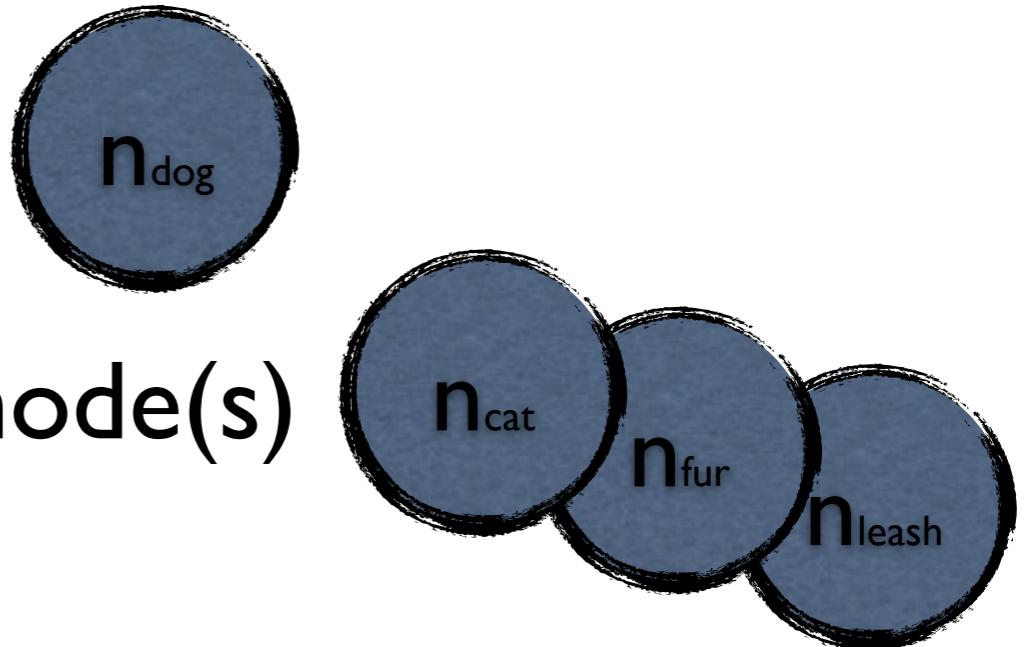
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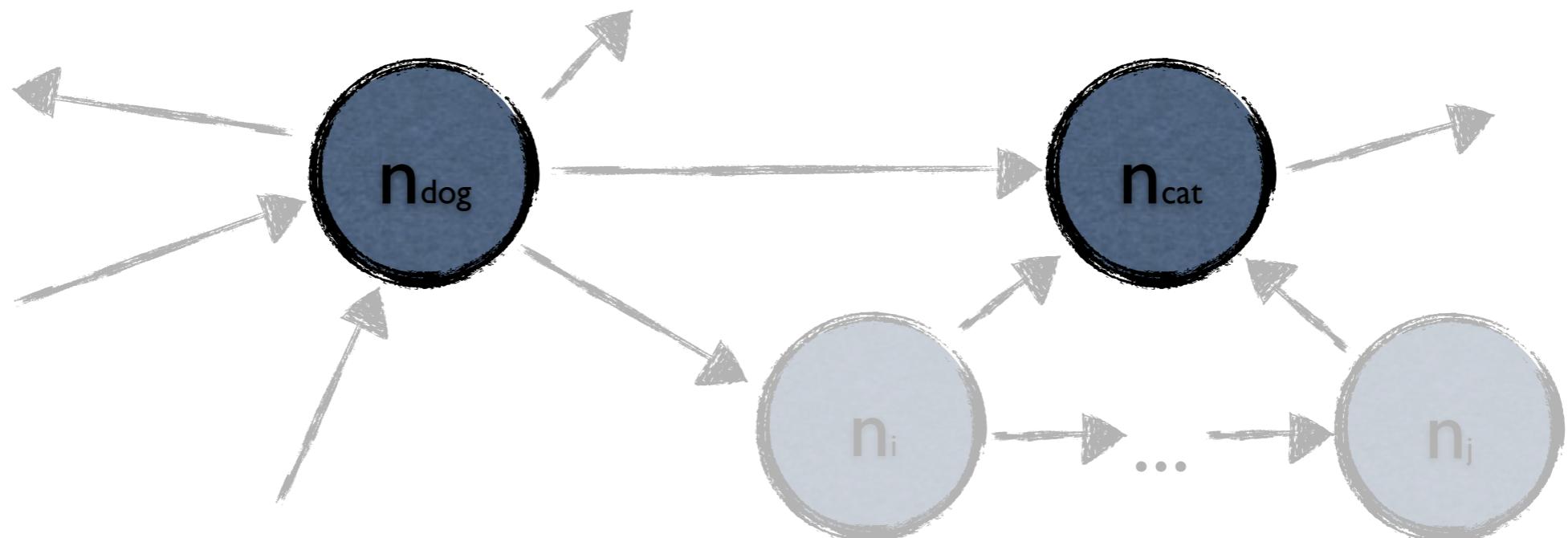
# My Research

- Research Question:
  - Is it possible to learn patterns for Human Associations from Linked Data?
- Goal:
  - Given an input node predict the output node(s) we would associate



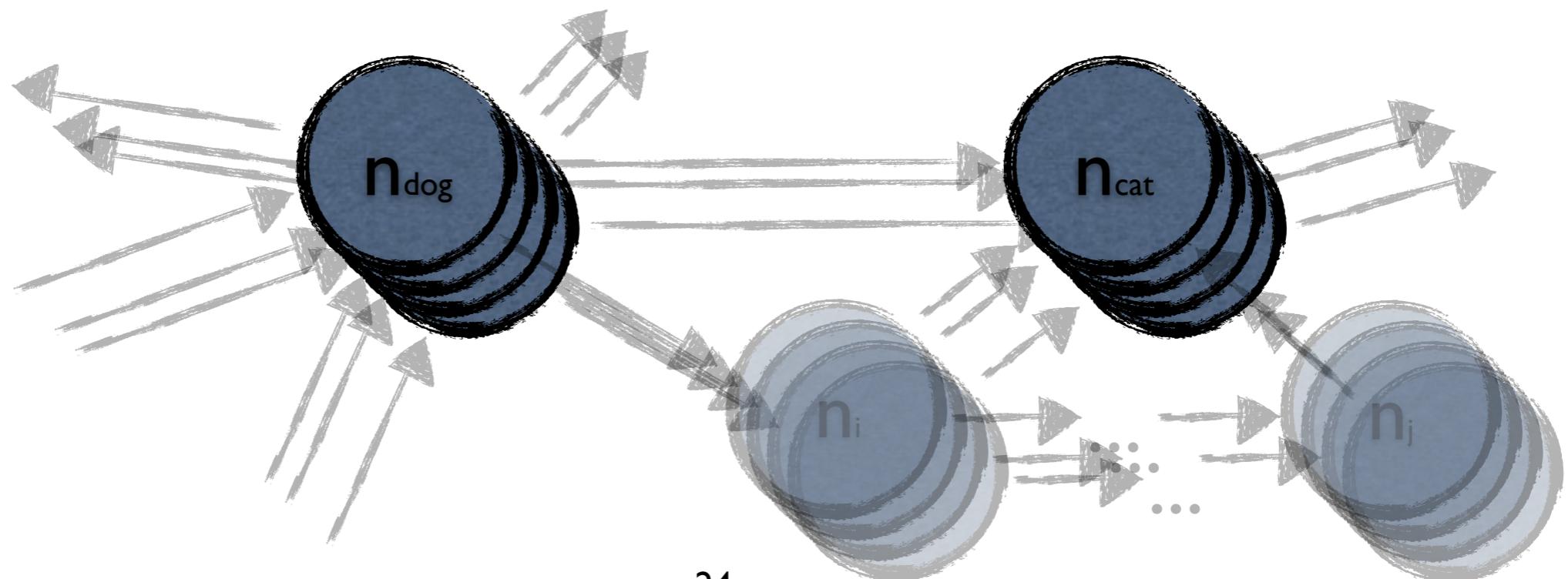
# My Research

- Research Question:
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- Dataset of "Semantic Associations" needed



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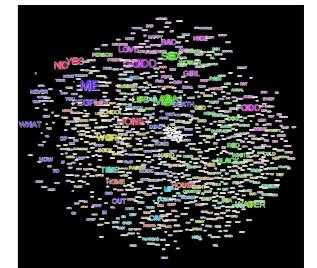
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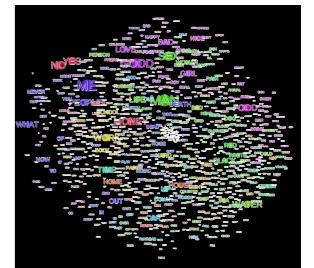
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# Edinburgh Associative Thesaurus



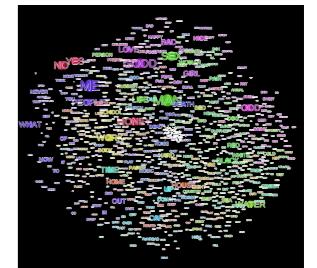
- Association corpus (1973) G. Kiss, C. Armstrong, R. Milroy, J. Piper
  - For each stimulus asked 100 ppl for a response
  - Strong responses became stimuli of next round

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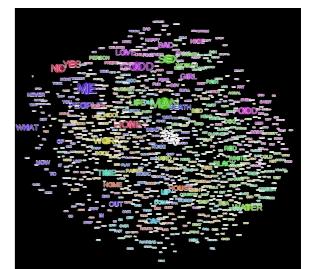
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- Graph: ( $|V| = 23\text{ K}$ ,  $|E| = 325\text{ K}$ )

# Edinburgh Associative Thesaurus



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- ~ 790 K associations (free text)
- Graph: ( $|V| = 23\text{ K}$ ,  $|E| = 325\text{ K}$ )
  - ~ 5000 strong associations ( $>19\times$ )
    - ~167.4 K raw associations

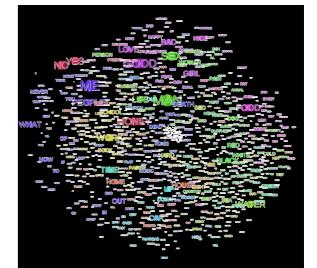
# Edinburgh Associative Thesaurus



- ## ● Examples:

| <b>dog</b> | <b>cat</b> | <b>man</b> | <b>woman</b> | <b>bank</b> | <b>money</b> |
|------------|------------|------------|--------------|-------------|--------------|
| cat        | 57         | dog        | 49           | woman       | 66           |
| collar     | 5          | mouse      | 8            | strong      | 3            |
| bark       | 3          | black      | 4            | human       | 2            |
| leg        | 2          | mat        | 3            | hole        | 2            |
|            |            | tom        | 2            | boy         | 2            |
|            |            |            |              | child       | 2            |
|            |            |            |              | clerk       | 5            |

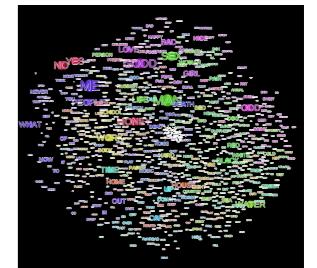
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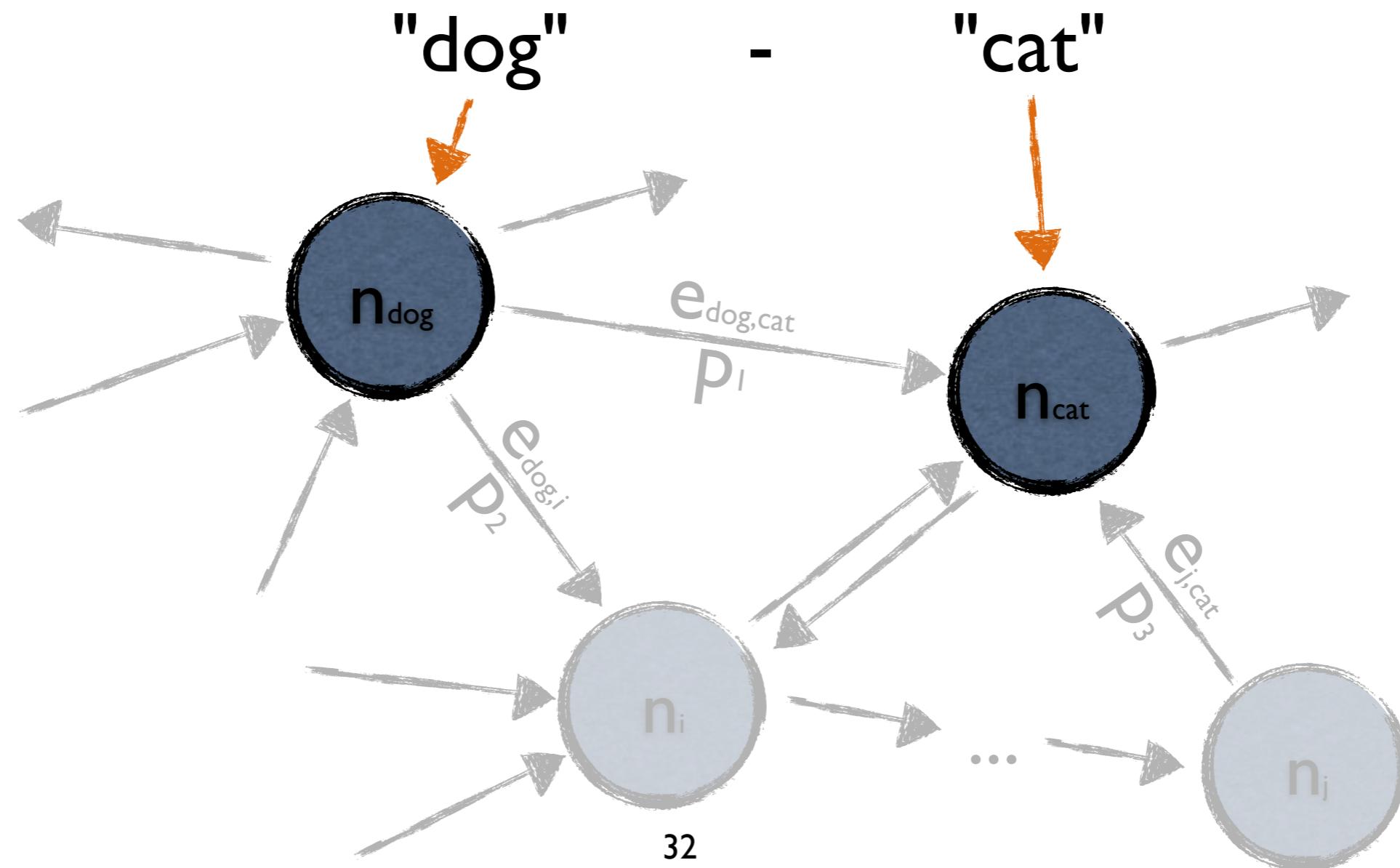
- Difficulty: Free text
  - Mapping to Semantic Entities

"dog" - "cat"

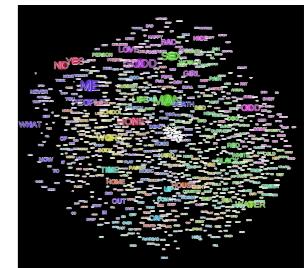
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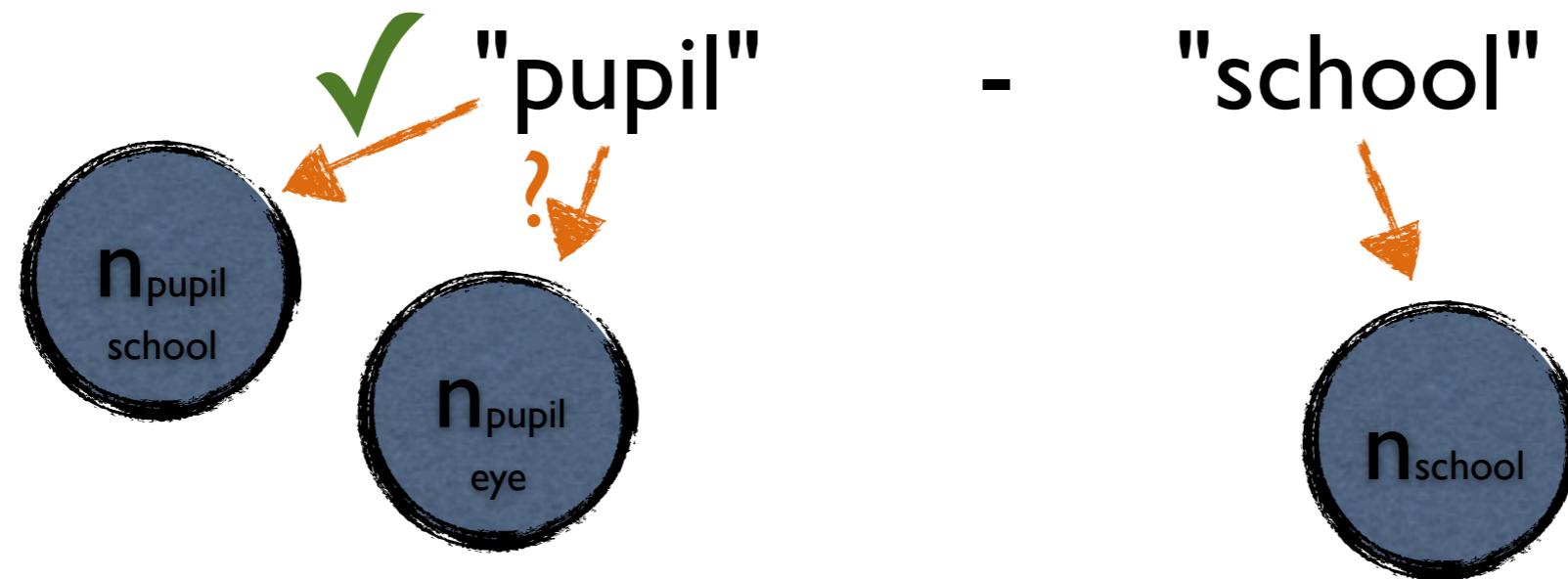
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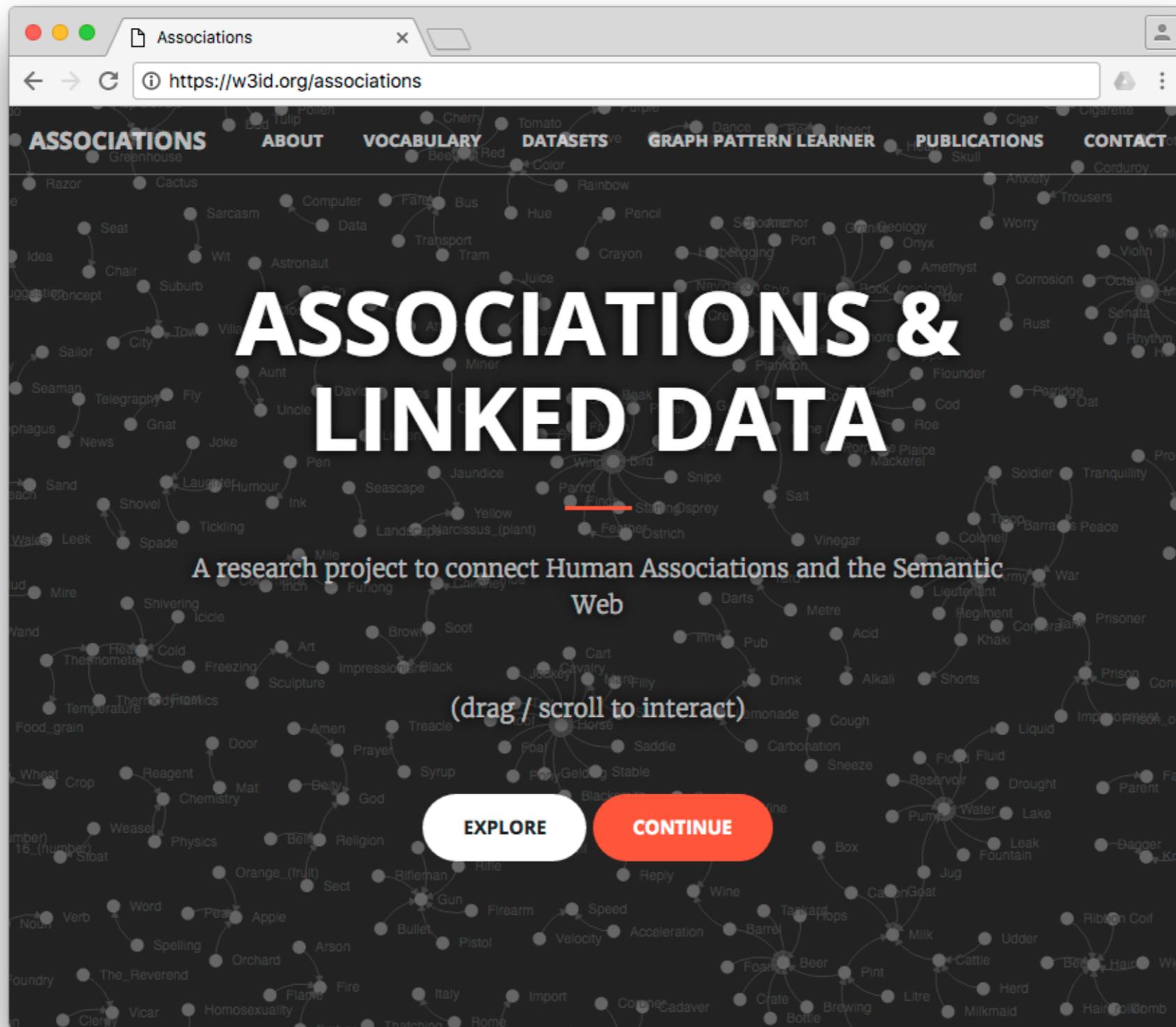


- Difficulty: Free text
  - Mapping to Semantic Entities



- Semi-Automatic Mapping Approach
  - 727 verified "Semantic Associations"

# Associations & Linked Data



# Outline

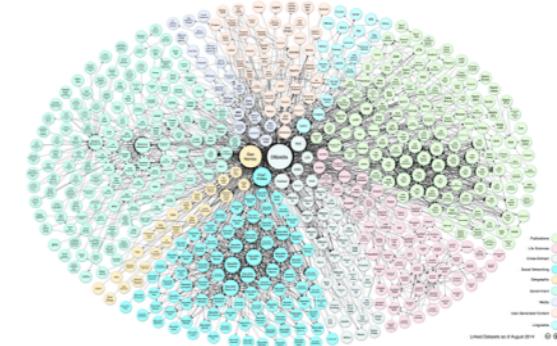
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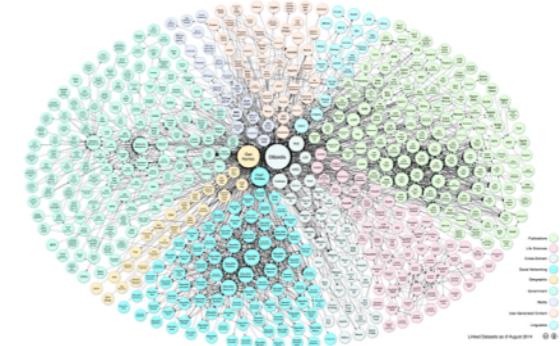
# Data Analysis

- Local Linked Data Endpoint:
  - Central Datasets
  - ~8 G triples
  - SPARQL Queries



# Data Analysis

- Local Linked Data Endpoint:
  - Central Datasets
  - ~8 G triples
  - SPARQL Queries
  - Scalability Issues



# First Analysis

- Node Degrees:
- Avg: 3643

| Node            | Degree |
|-----------------|--------|
| dbp:Animal      | 400624 |
| dbp:Insect      | 195058 |
| dbp:France      | 190047 |
| dbp:India       | 181119 |
| dbp:Italy       | 132719 |
| dbp:Village     | 132400 |
| dbp:Plant       | 126731 |
| dbp:Scotland    | 71828  |
| dbp:Paris       | 64232  |
| dbp:Switzerland | 55471  |

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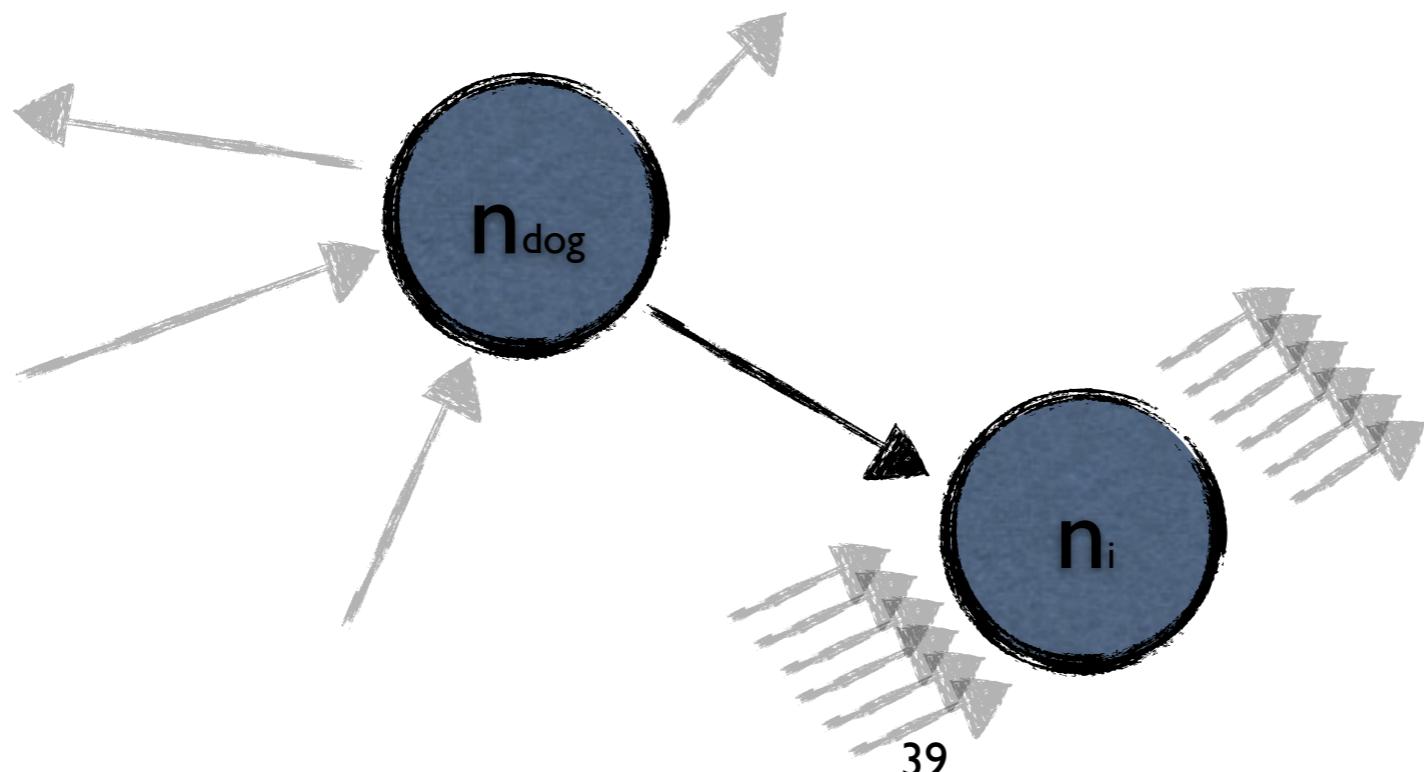
# First Analysis

- Node Degrees:
  - Avg: 3643
  - Excluding big nodes?
  - Would cause bias!
  - Exclude in-links?
  - Directionality depends on modelling!

| Node            | Degree |
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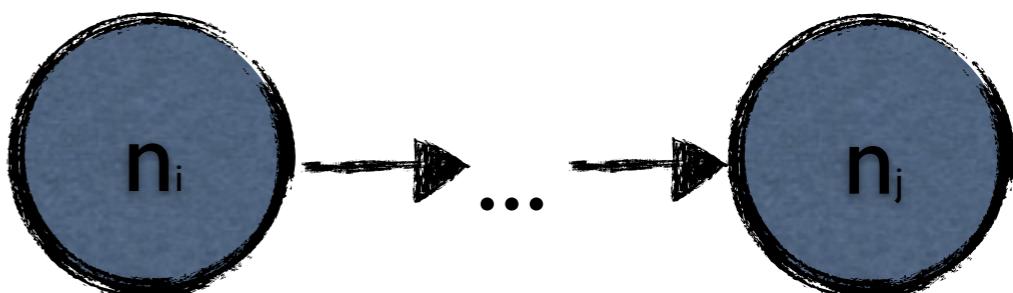
# Graph Pattern Learning

- First idea: Shortest paths
  - Many false positives (associations)
  - Problems with high degrees
    - Super-nodes (`owl:Thing`, countries, cities)
      - Everything is connected with paths of length 2 ;)



# Graph Pattern Learning

- First idea: Shortest paths
  - Many false positives (associations)
  - Problems with high degrees
    - Super-nodes (owl:Thing, countries, cities)
      - Everything is connected with paths of length 2 ;)
  - Problems due to modelling
    - Nearly linear parts / chains
      - (owl:sameAs, freebase, temporal properties)

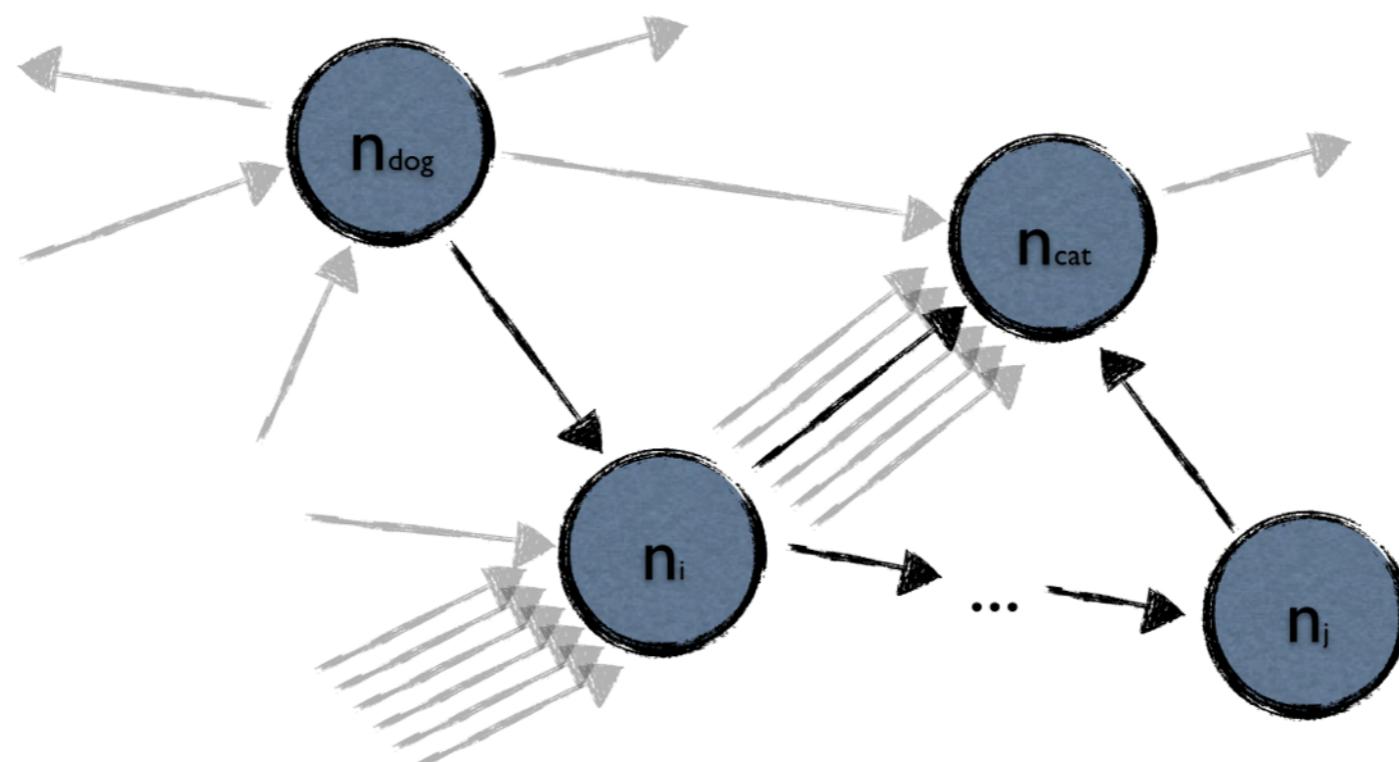


# Good Graph Patterns?

- How often is a response reached? **max**
- How many other nodes are reached? **min**
- How many nodes need to be expanded? **min**
- How long does a query take? **min**

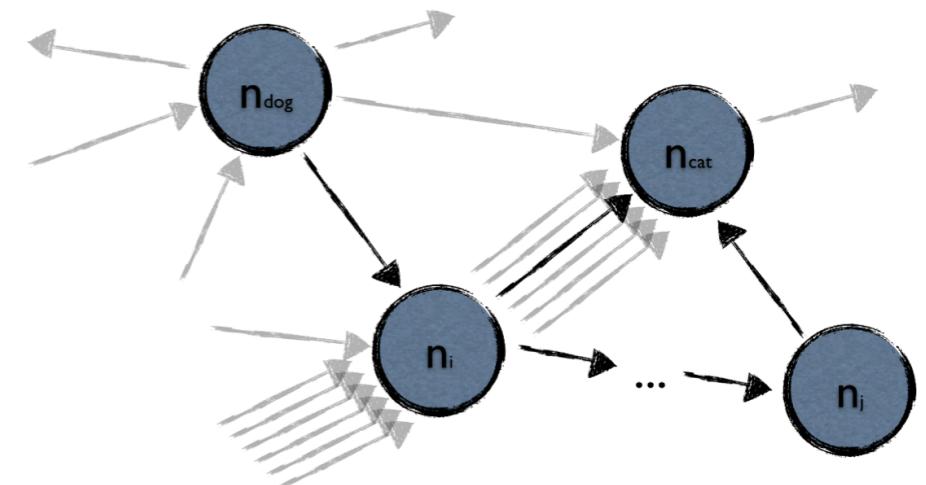
# Graph Pattern Learning

- Idea: Shortest ~~paths~~



# Graph Pattern Learning

- Idea: Shortest ~~paths~~
- Idea: Constrained Subgraphs
  - Don't model cost as hops, but
  - number of expanded nodes
    - Property based look-ahead
    - Prefer keeping the search corridor narrow
    - "Spreading activation" like



# Graph Pattern Learning

- Genetic algorithm (genetic programming)
  - Individuals: SPARQL BGP patterns

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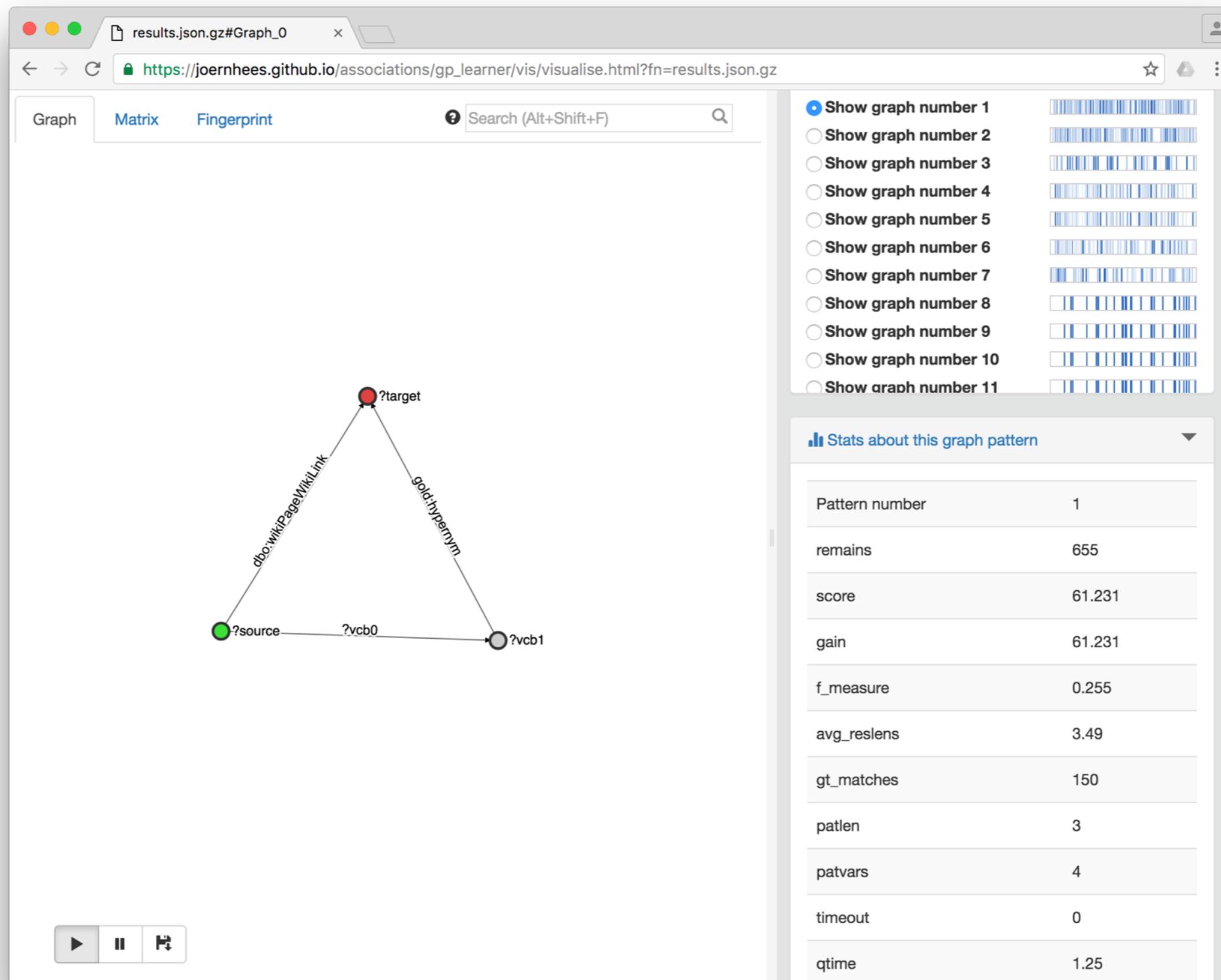
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  - Fitness function: Good pattern?

# Learned Graph Patterns



results.json.gz#Graph\_0

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 1

Show graph number 2

Show graph number 3

Show graph number 4

Show graph number 5

Show graph number 6

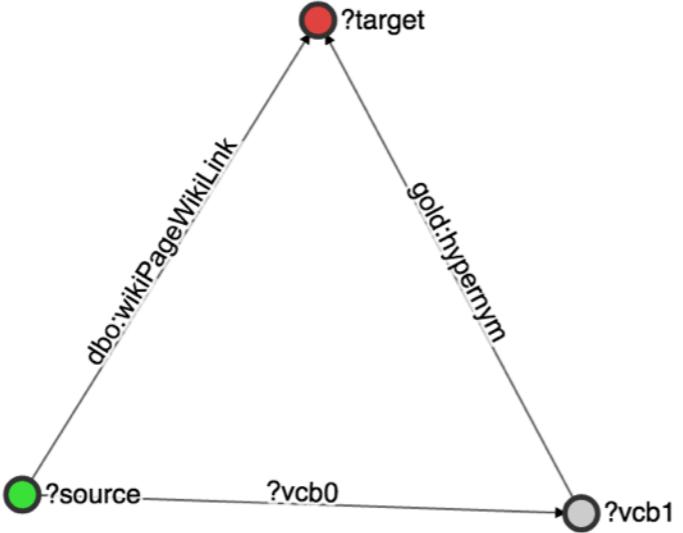
Show graph number 7

Show graph number 8

Show graph number 9

Show graph number 10

Show graph number 11



```
graph TD; ?source((?source)) -- "?vcb0" --> ?vcb1((?vcb1)); ?source -- "dbo:wikiPageWikiLink" --> ?target((?target)); ?vcb1 -- "gold:hyponym" --> ?target;
```

 Stats about this graph pattern

|                |        |
|----------------|--------|
| Pattern number | 1      |
| remains        | 655    |
| score          | 61.231 |
| gain           | 61.231 |
| f_measure      | 0.255  |
| avg_reslens    | 3.49   |
| gt_matches     | 150    |
| patlen         | 3      |
| patvars        | 4      |
| timeout        | 0      |
| qtime          | 1.25   |

▶ □ ↻

results.json.gz#Graph\_1

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 2

Show graph number 1

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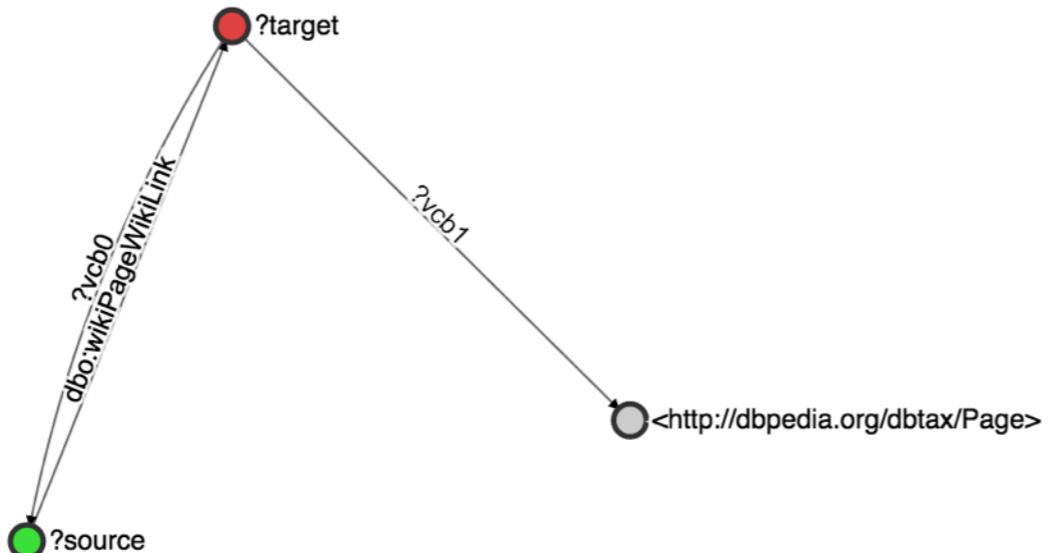
Show graph number 7

Show graph number 8

Show graph number 9

Show graph number 10

Show graph number 11



**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 2      |
| remains        | 655    |
| score          | 52.954 |
| gain           | 52.954 |
| f_measure      | 0.227  |
| avg_reslens    | 4.573  |
| gt_matches     | 155    |
| patlen         | 3      |
| patvars        | 4      |
| timeout        | 0      |
| qtime          | 0.819  |

▶ □ ↻

results.json.gz#Graph\_2

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 3

Show graph number 1

Show graph number 2

Show graph number 4

Show graph number 5

Show graph number 6

Show graph number 7

Show graph number 8

Show graph number 9

Show graph number 10

Show graph number 11

**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 3      |
| remains        | 655    |
| score          | 30.495 |
| gain           | 30.495 |
| f_measure      | 0.129  |
| avg_reslens    | 2.683  |
| gt_matches     | 51     |
| patlen         | 3      |
| patvars        | 4      |
| timeout        | 0      |
| qtime          | 0.768  |

```

graph LR
    target((?target)) -- "dbo:wikiPageWikiLink ?vcb0" --> source((?source))
    target -- "2vcb1" --> template((<http://dbpedia.org/resource/Template:Sister_project_links>))
    source --> template
  
```

▶ ■ ↻

results.json.gz#Graph\_3

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 1 

Show graph number 2 

Show graph number 3 

Show graph number 4 

Show graph number 5 

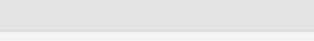
Show graph number 6 

Show graph number 7 

Show graph number 8 

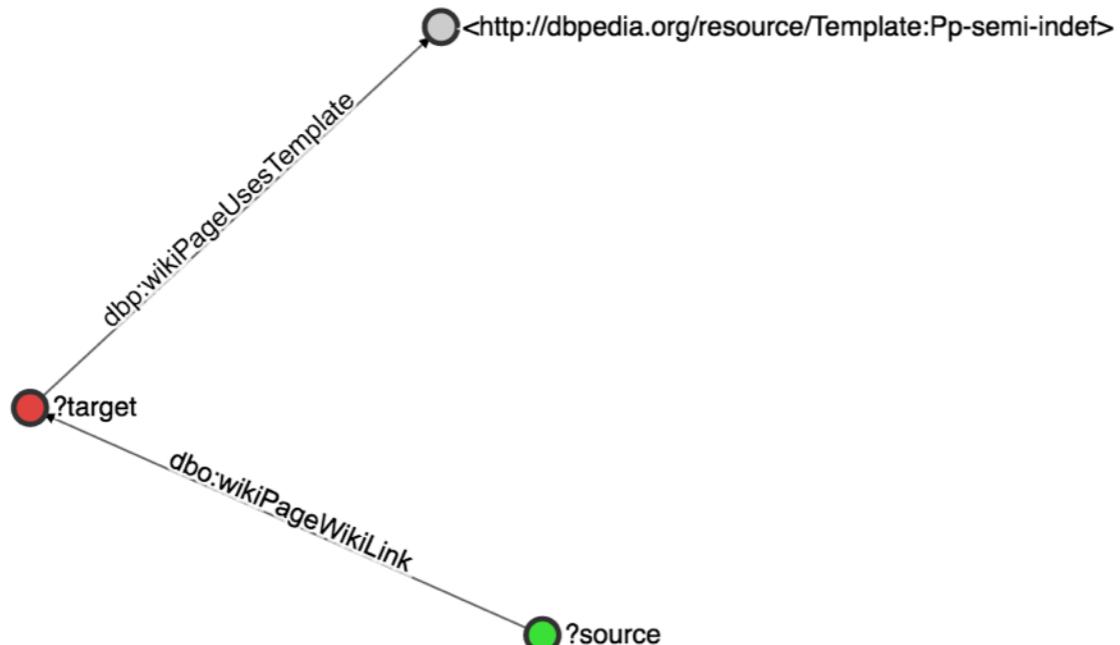
Show graph number 9 

Show graph number 10 

Show graph number 11 

**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 4      |
| remains        | 655    |
| score          | 28.765 |
| gain           | 28.765 |
| f_measure      | 0.15   |
| avg_reslens    | 5.562  |
| gt_matches     | 84     |
| patlen         | 2      |
| patvars        | 2      |
| timeout        | 0      |
| qtime          | 0.798  |



?target

dbo:wikiPageWikiLink

?source

dbp:wikiPageUsesTemplate

<http://dbpedia.org/resource/Template:Pp-semi-indef>

▶ ■ ↻

results.json.gz#Graph\_4

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 1 

Show graph number 2 

Show graph number 3 

Show graph number 4 

Show graph number 5 

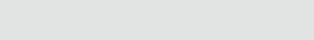
Show graph number 6 

Show graph number 7 

Show graph number 8 

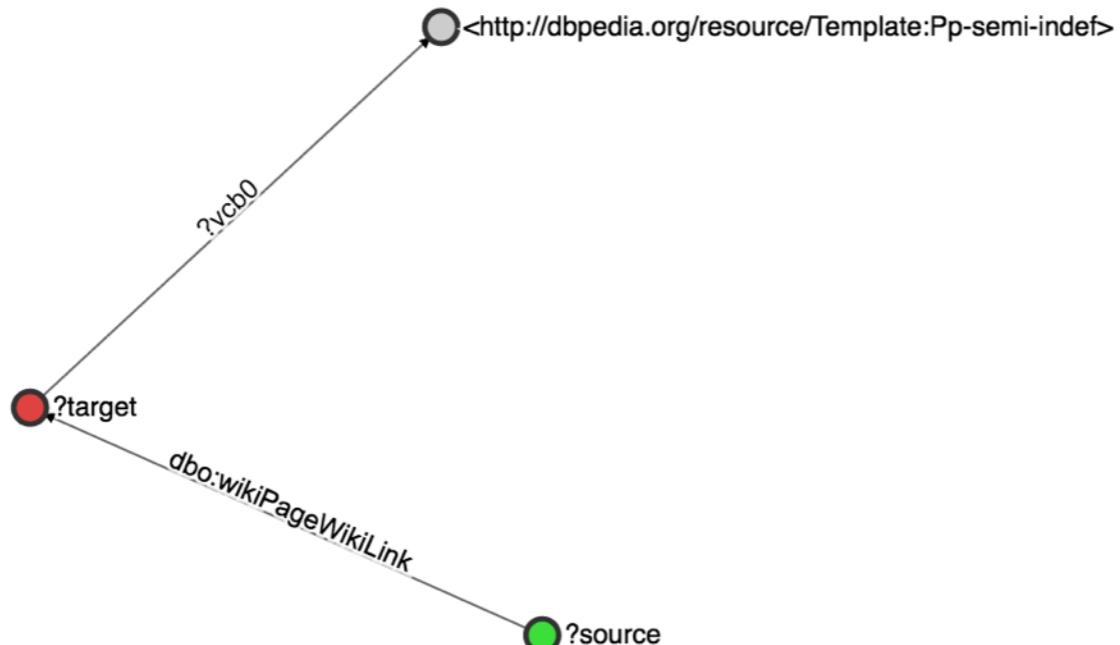
Show graph number 9 

Show graph number 10 

Show graph number 11 

**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 5      |
| remains        | 655    |
| score          | 28.765 |
| gain           | 28.765 |
| f_measure      | 0.15   |
| avg_reslens    | 5.562  |
| gt_matches     | 84     |
| patlen         | 2      |
| patvars        | 3      |
| timeout        | 0      |
| qtime          | 0.421  |



?source

?target

?vcb0

dbo:wikiPageWikiLink

<http://dbpedia.org/resource/Template:Pp-semi-indef>

▶ ■ ↻

results.json.gz#Graph\_5

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 2 

Show graph number 3 

Show graph number 4 

Show graph number 5 

Show graph number 6 

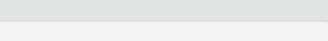
Show graph number 7 

Show graph number 8 

Show graph number 9 

Show graph number 10 

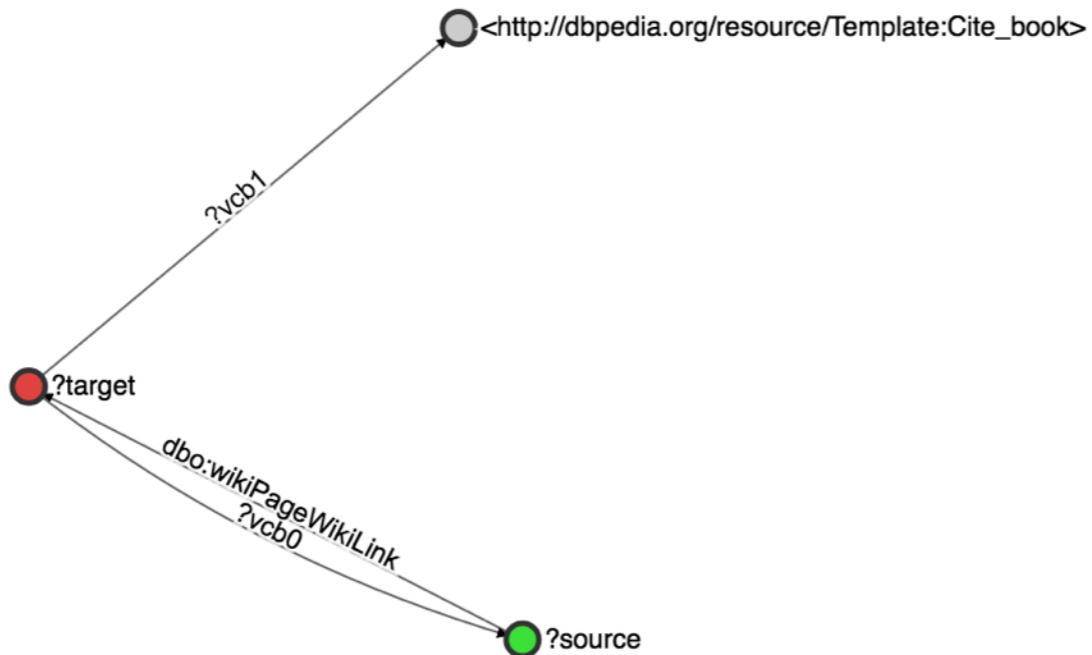
Show graph number 11 

Show graph number 12 

**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 6      |
| remains        | 655    |
| score          | 28.685 |
| gain           | 28.685 |
| f_measure      | 0.14   |
| avg_reslens    | 8.124  |
| gt_matches     | 106    |
| patlen         | 3      |
| patvars        | 4      |
| timeout        | 0      |
| qtime          | 1.382  |

?target  
?source  
?vcb1  
?vcb0  
dbo:wikiPageWikiLink



▶ ■ ↻

results.json.gz#Graph\_6

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 3 

Show graph number 4 

Show graph number 5 

Show graph number 6 

Show graph number 7 

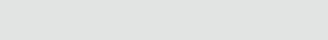
Show graph number 8 

Show graph number 9 

Show graph number 10 

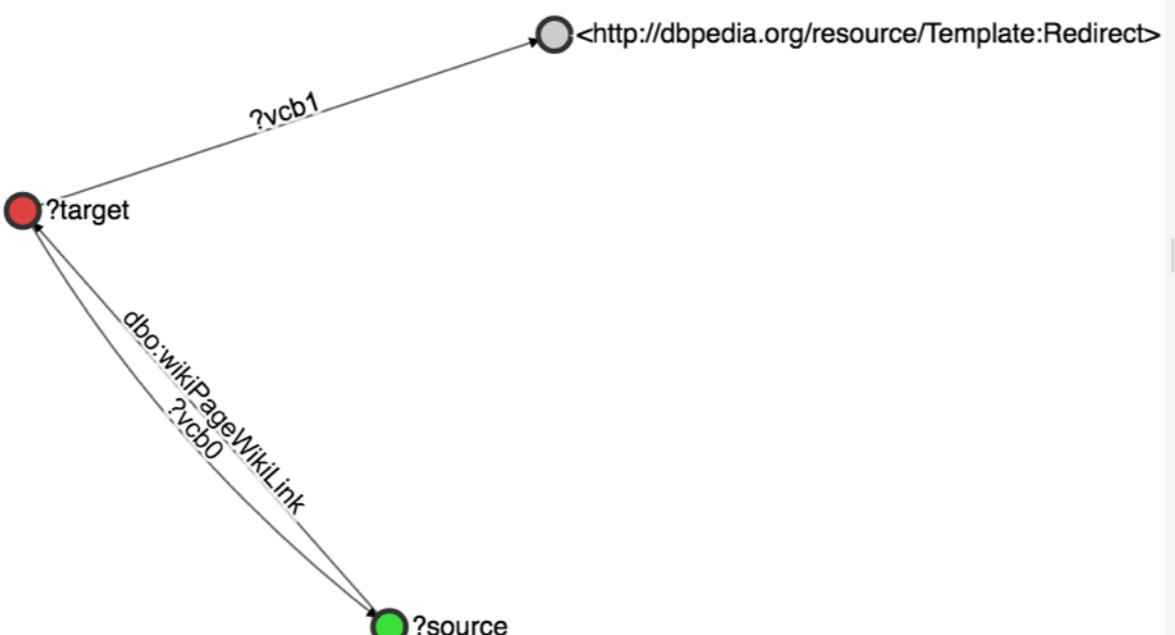
Show graph number 11 

Show graph number 12 

Show graph number 13 

**Stats about this graph pattern**

|                |        |
|----------------|--------|
| Pattern number | 7      |
| remains        | 655    |
| score          | 28.634 |
| gain           | 28.634 |
| f_measure      | 0.148  |
| avg_reslens    | 4.198  |
| gt_matches     | 70     |
| patlen         | 3      |
| patvars        | 4      |
| timeout        | 0      |
| qtime          | 0.967  |



► ▶ ↻

results.json.gz#Graph\_7

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 8

Show graph number 4

Show graph number 5

Show graph number 6

Show graph number 7

Show graph number 9

Show graph number 10

Show graph number 11

Show graph number 12

Show graph number 13

Show graph number 14

**Stats about this graph pattern**

|                |       |
|----------------|-------|
| Pattern number | 8     |
| remains        | 655   |
| score          | 28    |
| gain           | 28    |
| f_measure      | 0.082 |
| avg_reslens    | 1     |
| gt_matches     | 28    |
| patlen         | 1     |
| patvars        | 2     |
| timeout        | 0     |
| qtime          | 0.271 |

?target

gold:hypernym

?source

▶ ▶ ↻

results.json.gz#Graph\_8

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 5 

Show graph number 6 

Show graph number 7 

Show graph number 8 

Show graph number 9 

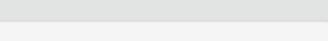
Show graph number 10 

Show graph number 11 

Show graph number 12 

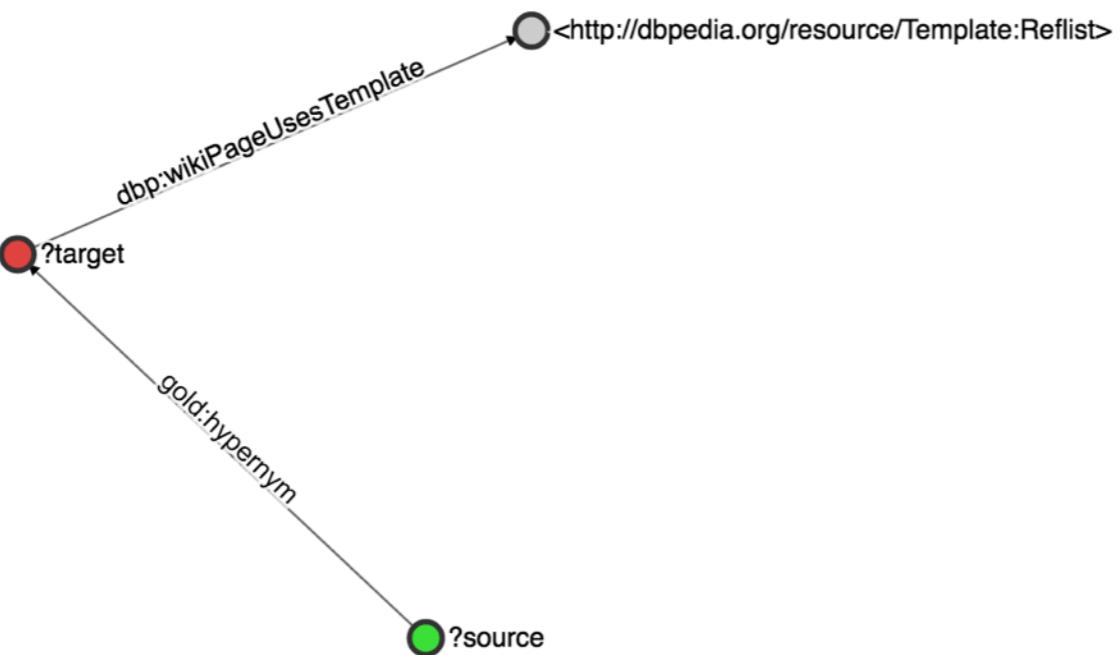
Show graph number 13 

Show graph number 14 

Show graph number 15 

**Stats about this graph pattern**

|                |       |
|----------------|-------|
| Pattern number | 9     |
| remains        | 655   |
| score          | 28    |
| gain           | 28    |
| f_measure      | 0.082 |
| avg_reslens    | 1     |
| gt_matches     | 28    |
| patlen         | 2     |
| patvars        | 2     |
| timeout        | 0     |
| qtime          | 0.25  |



```

graph LR
    A((?target)) -- "dbpedia:wikiPageUsesTemplate" --> B((<http://dbpedia.org/resource/Template:Reflist>))
    A((?target)) -- "gold:hyponym" --> C((?source))
    
```

▶ ■ ↻

results.json.gz#Graph\_9

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 6 

Show graph number 7 

Show graph number 8 

Show graph number 9 

Show graph number 10 

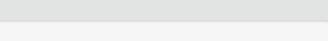
Show graph number 11 

Show graph number 12 

Show graph number 13 

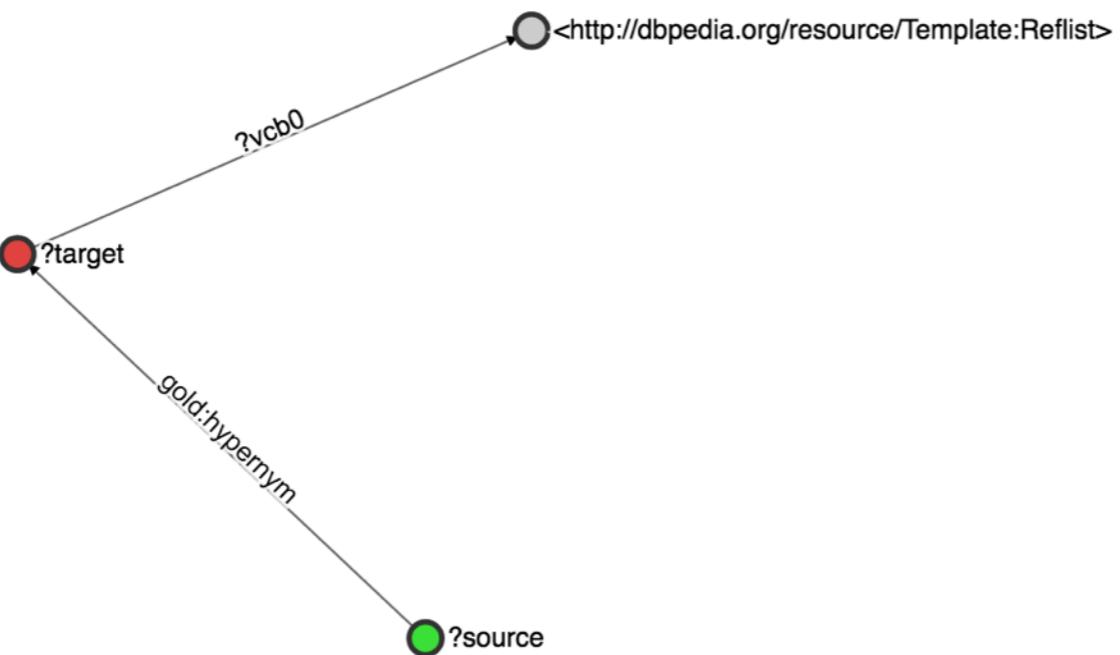
Show graph number 14 

Show graph number 15 

Show graph number 16 

**Stats about this graph pattern**

|                |       |
|----------------|-------|
| Pattern number | 10    |
| remains        | 655   |
| score          | 28    |
| gain           | 28    |
| f_measure      | 0.082 |
| avg_reslens    | 1     |
| gt_matches     | 28    |
| patlen         | 2     |
| patvars        | 3     |
| timeout        | 0     |
| qtime          | 0.231 |



?target

?source

?vcbo

gold:hyponym

<http://dbpedia.org/resource/Template:Reflist>

▶ □ ↻

results.json.gz#Graph\_69

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 66

Show graph number 67

Show graph number 68

Show graph number 69

Show graph number 70

Show graph number 71

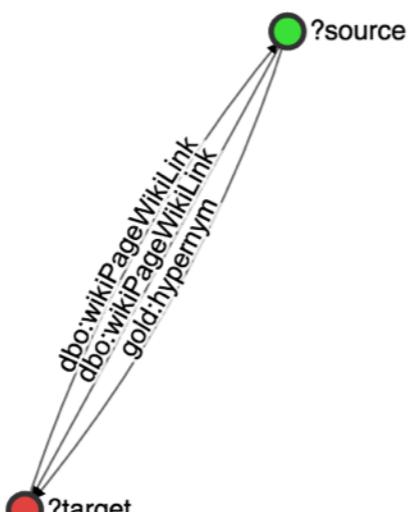
Show graph number 72

Show graph number 73

Show graph number 74

Show graph number 75

Show graph number 76

 A graph pattern diagram showing three nodes: a green source node at the top, a red target node at the bottom, and a blue middle node. Three arrows point from the source to the target, labeled with predicates: 'dbo:wikiPageWikiLink', 'dbo:wikiPageWikiLink', and 'gold:hypernym'. The middle node is connected to both the source and target nodes.

 Stats about this graph pattern

|                |       |
|----------------|-------|
| Pattern number | 70    |
| remains        | 655   |
| score          | 21    |
| gain           | 21    |
| f_measure      | 0.062 |
| avg_reslens    | 1     |
| gt_matches     | 21    |
| patlen         | 3     |
| patvars        | 2     |
| timeout        | 0     |
| qtime          | 0.308 |

▶ □ ↻

results.json.gz#Graph\_71

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 68

Show graph number 69

Show graph number 70

Show graph number 71

Show graph number 72

Show graph number 73

Show graph number 74

Show graph number 75

Show graph number 76

Show graph number 77

Show graph number 78

**Stats about this graph pattern**

|                |         |
|----------------|---------|
| Pattern number | 72      |
| remains        | 478.434 |
| score          | 8.667   |
| gain           | 8.667   |
| f_measure      | 0.07    |
| avg_reslens    | 1.214   |
| gt_matches     | 24      |
| patlen         | 4       |
| patvars        | 4       |
| timeout        | 0       |
| qtime          | 0.257   |

```

graph LR
    source((?source)) -- "dbo:wikiPageWikiLink" --> target((?target))
    source((?source)) -- "dct:subject" --> vcb1((?vcb1))
    vcb0((?vcb0)) -- "owl:sameAs" --> vcb1((?vcb1))
  
```

▶ ■ ↻

results.json.gz#Graph\_132

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

?

Show graph number 129  
Show graph number 130  
Show graph number 131  
Show graph number 132  
 Show graph number 133  
Show graph number 134  
Show graph number 135  
Show graph number 136  
Show graph number 137  
Show graph number 138  
Show graph number 139

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 133     |
| remains        | 478.434 |
| score          | 6.36    |
| gain           | 6.36    |
| f_measure      | 0.102   |
| avg_reslens    | 1.868   |
| gt_matches     | 37      |
| patlen         | 2       |
| patvars        | 3       |
| timeout        | 0       |
| qtime          | 0.318   |

?source

?target

?vcb0

dct:subject

skos:subject

▶ ■ ↻

```
graph LR; ?source((?source)) -- dct:subject --> ?vcb0((?vcb0)); ?target((?target)) -- skos:subject --> ?vcb0
```

results.json.gz#Graph\_194

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 191

Show graph number 192

Show graph number 193

Show graph number 194

Show graph number 195

Show graph number 196

Show graph number 197

Show graph number 198

Show graph number 199

Show graph number 200

Show graph number 201

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 195     |
| remains        | 385.048 |
| score          | 3.583   |
| gain           | 3.583   |
| f_measure      | 0.042   |
| avg_reslens    | 1.198   |
| gt_matches     | 14      |
| patlen         | 3       |
| patvars        | 5       |
| timeout        | 0       |
| qtime          | 0.474   |

?source

?vcb0

?vcb2

?vcb1

?target

dbo:label

dbp:description

▶ ■ ↻

results.json.gz#Graph\_281

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

?

Show graph number 278  
Show graph number 279  
Show graph number 280  
Show graph number 281  
**Show graph number 282**  
Show graph number 283  
Show graph number 284  
Show graph number 285  
Show graph number 286  
Show graph number 287  
Show graph number 288

Info from BabelNet

?vcb1 ?vcb0  
?target ?source  
dbp:species skos:exactMatch  
dbpedia.org/resource/Template:Cite\_book  
dbp:wikiPageUsesTemplate dbo:wikiPageWikiLink

Pattern number 282  
remains 377.948  
score 5.842  
gain 5.842  
f\_measure 0.084  
avg\_reslens 1.919  
gt\_matches 30  
patlen 4  
patvars 4  
timeout 0  
qtime 0.682

```
graph LR; ?vcb1 -- dbp:species --> ?target; ?vcb0 -- skos:exactMatch --> ?target; ?target -- dbo:wikiPageWikiLink --> ?source; ?target -- dbpedia.org/resource/Template:Cite_book --> ?target;
```

results.json.gz#Graph\_293

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Info from WikiData

?source

dbo:wikiPageWikiLink

?target

dbp:species

?vcb1

<[http://dbpedia.org/resource/Template:Cite\\_book](http://dbpedia.org/resource/Template:Cite_book)>

?vcb0

?vcb2

wd:Q95074

Show graph number 290  
Show graph number 291  
Show graph number 292  
Show graph number 293  
**Show graph number 294**  
Show graph number 295  
Show graph number 296  
Show graph number 297  
Show graph number 298  
Show graph number 299  
Show graph number 300

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 294     |
| remains        | 377.948 |
| score          | 4.909   |
| gain           | 4.909   |
| f_measure      | 0.079   |
| avg_reslens    | 1.856   |
| gt_matches     | 28      |
| patlen         | 4       |
| patvars        | 5       |
| timeout        | 0       |
| qtime          | 0.52    |

results.json.gz#Graph\_295

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

?source

?target

?vcb1

?vcb2

dbo:wikiPageWikiLink

dbp:species

?vcb0

wd:Q5

Info from  
WikiData

Show graph number 292

Show graph number 293

Show graph number 294

Show graph number 295

Show graph number 296

Show graph number 297

Show graph number 298

Show graph number 299

Show graph number 300

Show graph number 301

Show graph number 302

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 296     |
| remains        | 377.948 |
| score          | 4.909   |
| gain           | 4.909   |
| f_measure      | 0.079   |
| avg_reslens    | 1.856   |
| gt_matches     | 28      |
| patlen         | 4       |
| patvars        | 5       |
| timeout        | 0       |
| qtime          | 0.559   |

results.json.gz#Graph\_302

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 299  
Show graph number 300  
Show graph number 301  
Show graph number 302  
**Show graph number 303**  
Show graph number 304  
Show graph number 305  
Show graph number 306  
Show graph number 307  
Show graph number 308  
Show graph number 309

**Stats about this graph pattern**

|                |         |
|----------------|---------|
| Pattern number | 303     |
| remains        | 377.948 |
| score          | 4.242   |
| gain           | 4.242   |
| f_measure      | 0.05    |
| avg_reslens    | 1.422   |
| gt_matches     | 17      |
| patlen         | 5       |
| patvars        | 6       |
| timeout        | 0       |
| qtime          | 0.474   |

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results.json.gz#Graph\_316

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

Show graph number 313  Show graph number 314  Show graph number 315  Show graph number 316  Show graph number 317  Show graph number 318  Show graph number 319  Show graph number 320  Show graph number 321  Show graph number 322  Show graph number 323

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 317     |
| remains        | 377.948 |
| score          | 3.759   |
| gain           | 3.759   |
| f_measure      | 0.122   |
| avg_reslens    | 2.746   |
| gt_matches     | 48      |
| patlen         | 3       |
| patvars        | 4       |
| timeout        | 0       |
| qtime          | 0.517   |

Info from BabelNet

?source — dbo:wikiPageWikiLink — ?vcb1  
?vcb0 — skos:exactMatch — ?target

▶ ■ ↻

results.json.gz#Graph\_343

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

```

graph TD
    source((?source)) -- "?vcbo" --> vcb1((?vcb1))
    target((?target)) -- "dbo:type" --> target
    vcb1 -- "?vcbo" --> vcb1
  
```

Show graph number 340  
Show graph number 341  
Show graph number 342  
Show graph number 343  
**Show graph number 344**  
Show graph number 345  
Show graph number 346  
Show graph number 347  
Show graph number 348  
Show graph number 349  
Show graph number 350

**Stats about this graph pattern**

|                |         |
|----------------|---------|
| Pattern number | 344     |
| remains        | 364.049 |
| score          | 3.667   |
| gain           | 3.667   |
| f_measure      | 0.024   |
| avg_reslens    | 2.806   |
| gt_matches     | 8       |
| patlen         | 3       |
| patvars        | 5       |
| timeout        | 0       |
| qtime          | 0.84    |

results.json.gz#Graph\_397

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

?

dbr>List\_of\_Latin\_words\_with\_English\_derivatives

?target

?source

dbo:wikiPageWikiLink

dbo:wikiPageWikiLink

Show graph number 394

Show graph number 395

Show graph number 396

Show graph number 397

Show graph number 398

Show graph number 399

Show graph number 400

Show graph number 401

Show graph number 402

Show graph number 403

Show graph number 404

Stats about this graph pattern

|                |         |
|----------------|---------|
| Pattern number | 398     |
| remains        | 320.612 |
| score          | 5.801   |
| gain           | 5.801   |
| f_measure      | 0.172   |
| avg_reslens    | 6.511   |
| gt_matches     | 128     |
| patlen         | 2       |
| patvars        | 2       |
| timeout        | 0       |
| qtime          | 1.071   |

▶ ■ ↻

results.json.gz#Graph\_404

[https://joernhees.github.io/associations/gp\\_learner/vis/visualise.html?fn=results.json.gz](https://joernhees.github.io/associations/gp_learner/vis/visualise.html?fn=results.json.gz)

Graph Matrix Fingerprint Search (Alt+Shift+F)

?target

?source

?vcb0

<http://dbpedia.org/resource/QI\_(J\_series)>

dbo:wikiPageWikiLink

dbo:wikiPageWikiLink

dbo:wikiPageDisambiguates

Show graph number 405

Show graph number 402

Show graph number 403

Show graph number 404

Show graph number 406

Show graph number 407

Show graph number 408

Show graph number 409

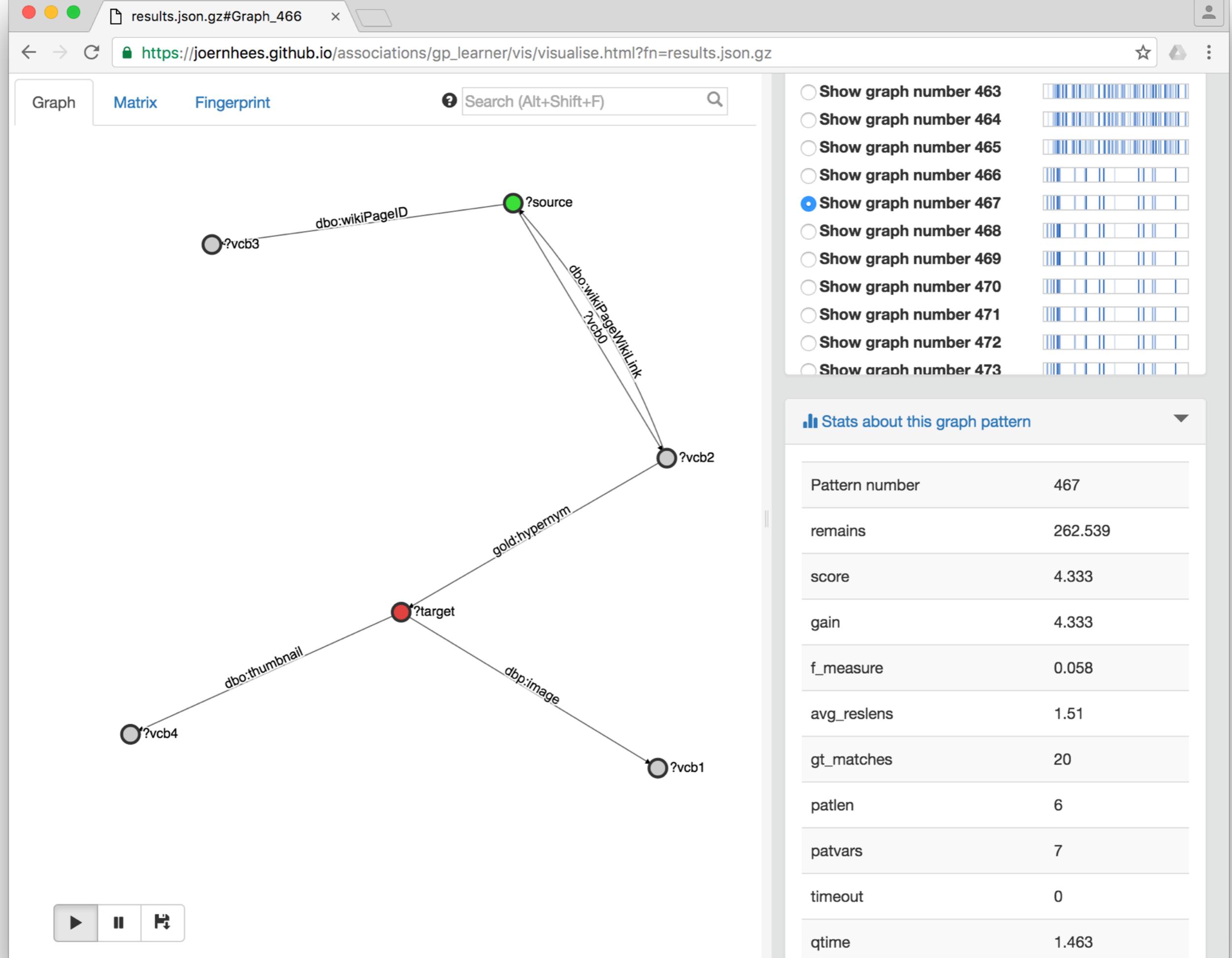
Show graph number 410

Show graph number 411

**Stats about this graph pattern**

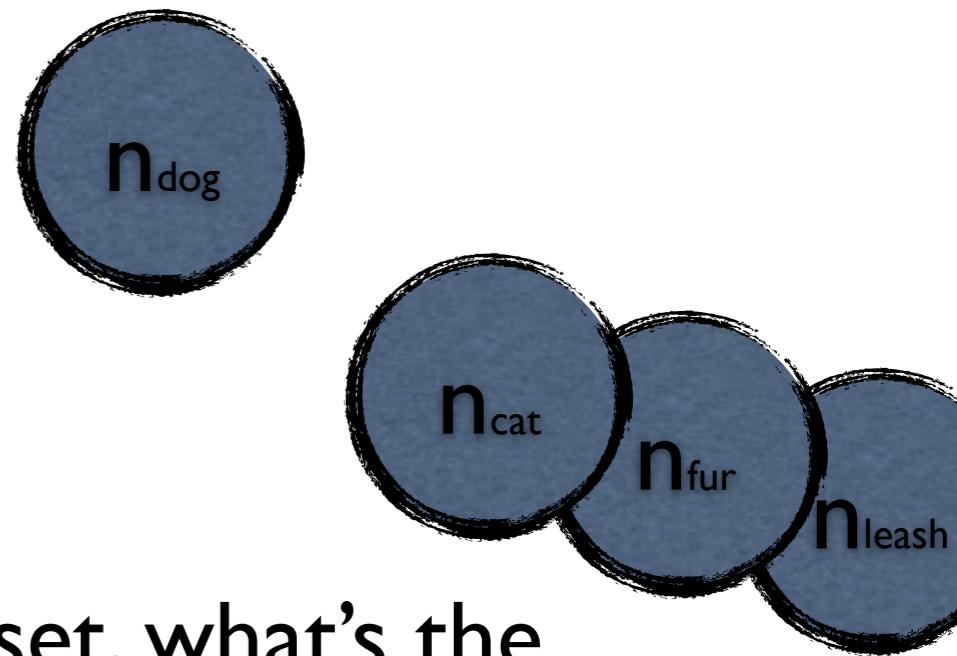
|                |         |
|----------------|---------|
| Pattern number | 405     |
| remains        | 320.612 |
| score          | 4.764   |
| gain           | 4.764   |
| f_measure      | 0.204   |
| avg_reslens    | 2.006   |
| gt_matches     | 84      |
| patlen         | 4       |
| patvars        | 3       |
| timeout        | 0       |
| qtime          | 0.42    |

▶ ■ 🔍

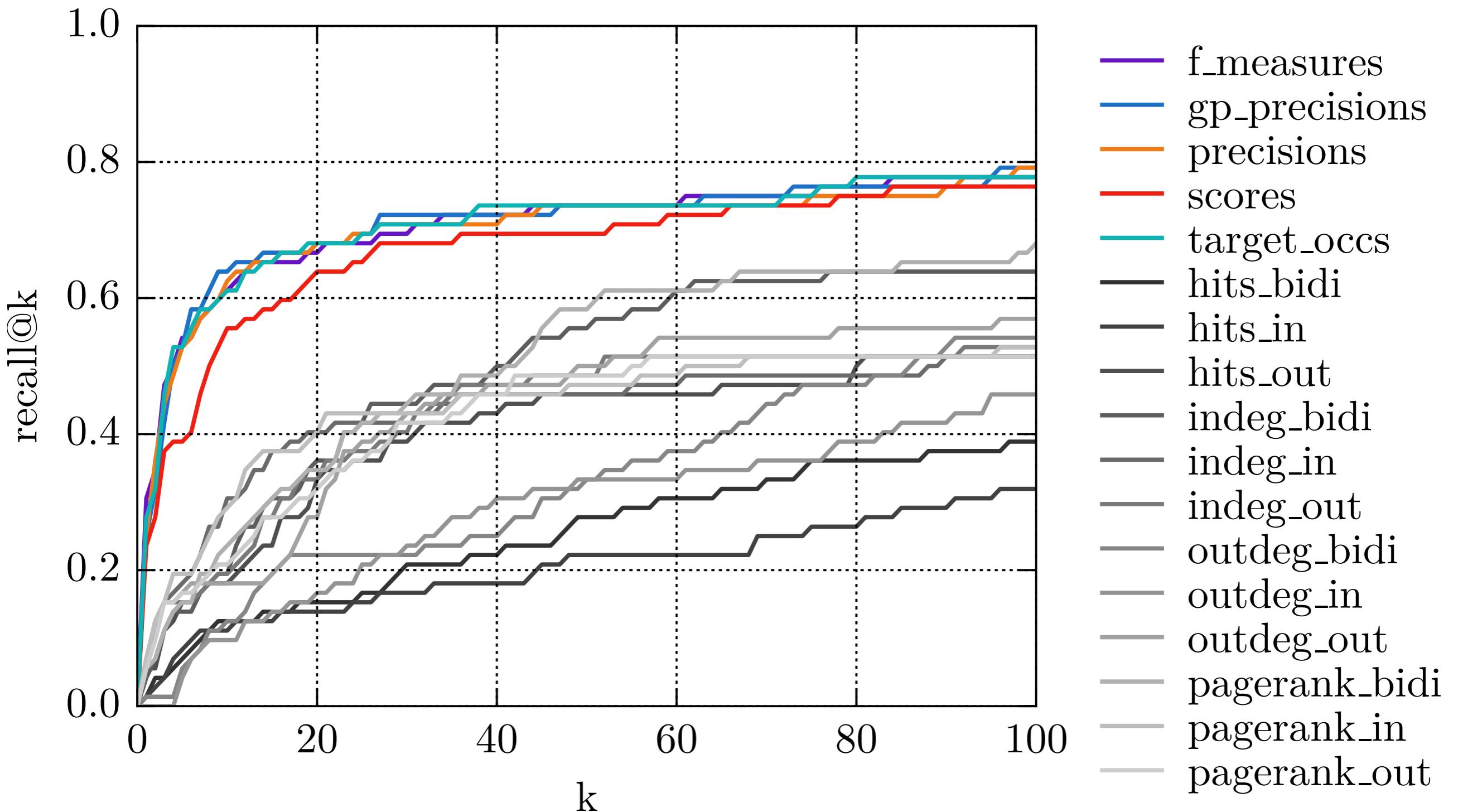


# Evaluation

- How good are the learned patterns?
  - Difficult to evaluate directly
- Indirect objective approach:
  - Are they good for prediction?
  - Training/Test set split
  - Clustered similar GPs
  - Given a stimulus from the test set, what's the rank of the true response in the prediction results?



# Evaluation Results

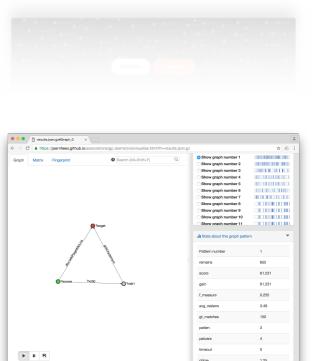
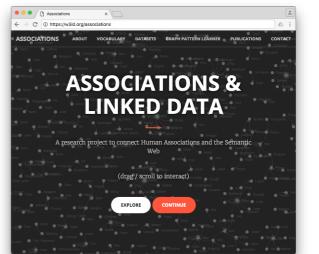
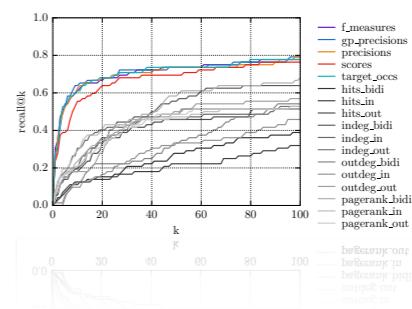
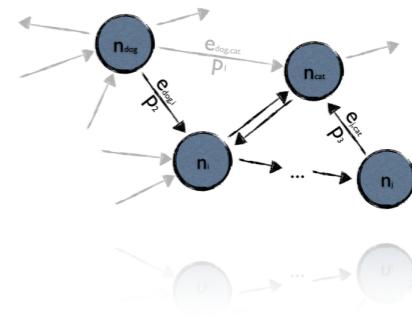


# Evaluation Results

|               | Recall@1     | Recall@2     | Recall@3     | Recall@4     | Recall@5     | Recall@10    | MAP          | NDCG         |
|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| outdeg in     | 0.000        | 0.000        | 0.000        | 0.000        | 0.042        | 0.097        | 0.029        | 0.105        |
| outdeg out    | <b>0.069</b> | <b>0.125</b> | <b>0.153</b> | 0.153        | 0.167        | 0.181        | 0.126        | 0.209        |
| outdeg bidi   | 0.014        | 0.014        | 0.014        | 0.014        | 0.056        | 0.125        | 0.045        | 0.131        |
| indeg in      | 0.056        | 0.111        | <b>0.153</b> | 0.167        | 0.181        | <b>0.306</b> | 0.129        | 0.207        |
| indeg out     | 0.056        | <b>0.125</b> | <b>0.153</b> | 0.153        | 0.153        | 0.194        | 0.121        | 0.200        |
| indeg bidi    | 0.042        | 0.069        | 0.111        | 0.139        | 0.139        | 0.194        | 0.104        | 0.205        |
| pagerank in   | <b>0.069</b> | <b>0.125</b> | <b>0.153</b> | <b>0.194</b> | <b>0.194</b> | 0.292        | <b>0.140</b> | <b>0.219</b> |
| pagerank out  | 0.056        | 0.097        | <b>0.153</b> | 0.153        | 0.167        | 0.208        | 0.117        | 0.195        |
| pagerank bidi | 0.056        | 0.069        | 0.111        | 0.139        | 0.153        | 0.236        | 0.113        | <b>0.219</b> |
| hits in       | 0.014        | 0.028        | 0.042        | 0.069        | 0.083        | 0.111        | 0.046        | 0.095        |
| hits out      | 0.056        | 0.056        | 0.111        | 0.125        | 0.153        | 0.181        | 0.102        | 0.181        |
| hits bidi     | 0.014        | 0.042        | 0.042        | 0.056        | 0.069        | 0.125        | 0.050        | 0.110        |
| scores        | 0.236        | 0.278        | 0.375        | 0.389        | 0.389        | 0.556        | 0.323        | 0.413        |
| gp precisions | 0.250        | 0.319        | 0.417        | 0.500        | 0.528        | <b>0.639</b> | 0.365        | 0.457        |
| precisions    | 0.250        | <b>0.361</b> | 0.444        | 0.486        | 0.528        | 0.625        | 0.371        | 0.460        |
| target occs   | 0.278        | 0.319        | 0.458        | <b>0.528</b> | 0.528        | 0.611        | 0.381        | 0.466        |
| f measures    | <b>0.306</b> | 0.347        | <b>0.472</b> | 0.500        | <b>0.542</b> | 0.611        | <b>0.399</b> | <b>0.479</b> |

# Summary

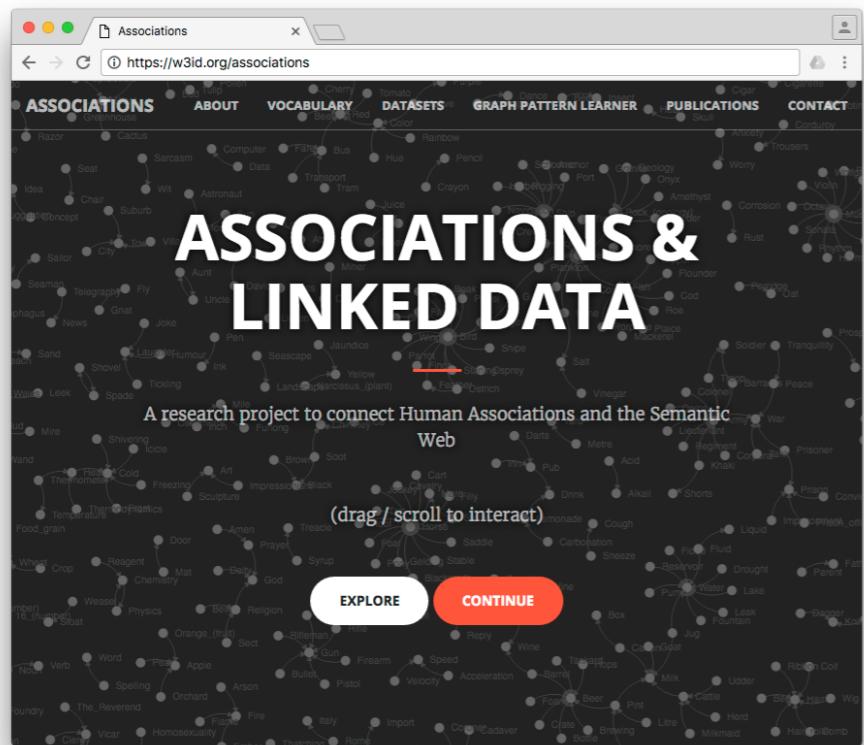
- Goal  
Learning Graph Patterns for Associations
  - Datasets
  - Graph Pattern Learning



# Discussion

Thanks for your attention

Questions?



<https://w3id.org/associations>

