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# Artificial Intelligence

## 3rd year, 1st semester

### Knowledge representation and inference systems

“We are drowning in information but starved for knowledge.”—
John Naisbitt

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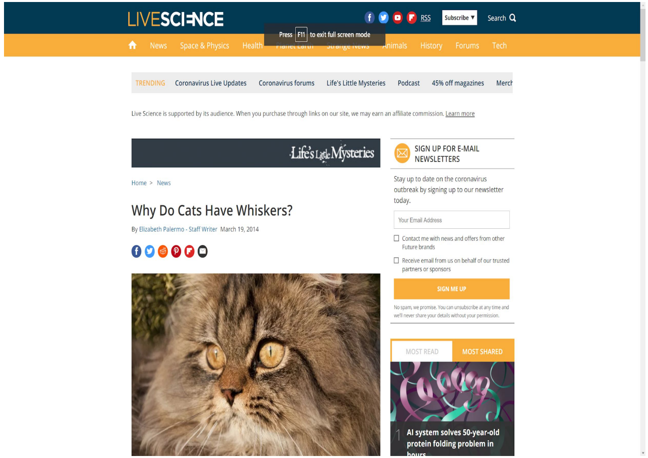
# How did you learn that a cat has whiskers?




# Does it matter?

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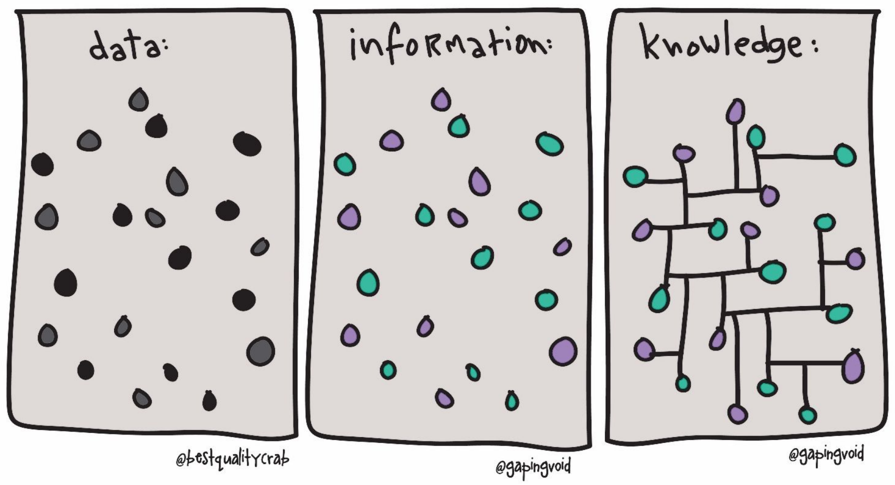
# What is knowledge?

Intelligence applied to information produces knowledge.

Knowledge supplements intelligence.

Intelligence is asking the right question, knowledge is having the right answer.



# Is knowledge useful to a computer?

Knowledge can supplement a slow or insufficient intelligence.
Example: chatbot templates and the Turing test.

Knowledge is a product, not a process (like intelligence), so it can be provided ready-made to the computer.

Knowledge is built on facts, heuristics and intuition and **can change**.

Let’s look at unambiguous and easily parse-able representations.

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Linnaeus, C. (1753). *Species Plantarum*. Stockholm: Laurentii Salvii.

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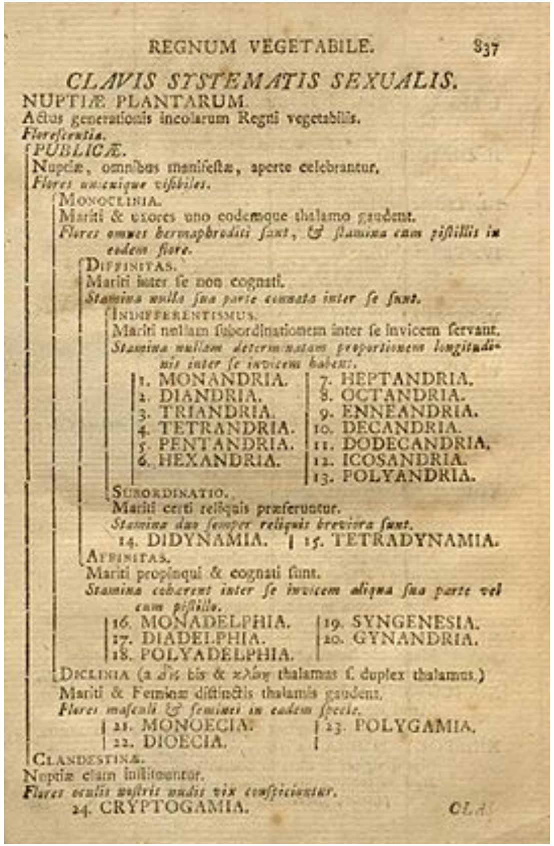
REGNUM VEGETABILE. 837

*CLAVIS SYSTEMATIS SEXUALIS.*

NUPTIÆ PLANTARUM.
Actus generationis incolarum Regni vegetabilis.
*Florescentia.*

PUBLICÆ.
Nuptiæ, omnibus manifestæ, aperte celebrantur.
*Flores unicuique visibiles.*

MONOCLINIA.
Mariti & uxores uno eodemque thalamo gaudent.
*Flores omnes hermaphroditi sunt, & stamina cum pistillis in eodem flore.*

DIFFINITAS.
Mariti inter se non cognati.
*Stamina nulla sua parte connata inter se sunt.*

INDIFFERENTISMUS.
Mariti nullam subordinationem inter se invicem servant.
*Stamina nullam determinatam proportionem longitudinis inter se invicem habent.*

1. MONANDRIA.
2. DIANDRIA.
3. TRIANDRIA.
4. TETRANDRIA.
5. PENTANDRIA.
6. HEXANDRIA.
7. HEPTANDRIA.
8. OCTANDRIA.
9. ENNEANDRIA.
10. DECANDRIA.
11. DODECANDRIA.
12. ICOSANDRIA.
13. POLYANDRIA.

SUBORDINATIO.
Mariti certi reliquis præferuntur.
*Stamina duo semper reliquis breviora sunt.*

14. DIDYNAMIA.
15. TETRADYNAMIA.

AFFINITAS.
Mariti propinqui & cognati sunt.
*Stamina cohærent inter se invicem aliqua sua parte vel cum pistillo.*

16. MONADELPHIA.
17. DIADELPHIA.
18. POLYADELPHIA.
19. SYNGENESIA.
20. GYNANDRIA.

DICLINIA (a δὶς bis & κλίνη thalamus s. duplex thalamus.)
Mariti & Feminæ distinctis thalamis gaudent.
*Flores masculi & feminei in eadem specie.*

21. MONOECIA.
22. DIOECIA.
23. POLYGAMIA.

CLANDESTINÆ.
Nuptiæ clam instituuntur.
*Flores oculis nostris nudis vix conspiciuntur.*

24. CRYPTOGAMIA.

*CLA*

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# Taxonomy

Greek: taxis (arrangement) nomia (method)

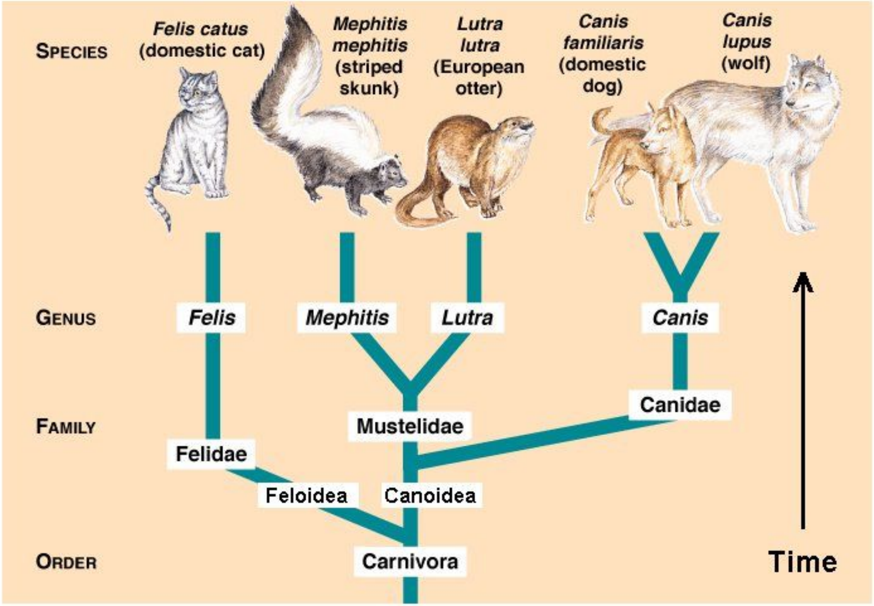
A taxonomy is language independent (as is all knowledge).

Nodes are concepts.

No ambiguity due to careful lexicalisations and domain focus.

Relations are semantic.

Only one type of relation: “is-a”



X IS-A Y: X is a specific type of Y, with additional properties

- Symmetry: if a bear IS-A mammal, a mammal IS-A bear?
- Reflexivity: bear IS-A bear?
- Transitivity: if a black bear IS-A bear and a bear IS-A mammal, a black bear IS-A mammal?
- Connectivity: cat IS-A bear or bear IS-A cat?

"is-a" is asymmetric, irreflexive, transitive and not connected, thus is a strict order relation over the set of concepts (no cycles in a taxonomy).

Are taxonomies enough?

Can you represent all your computer science knowledge in a taxonomy?

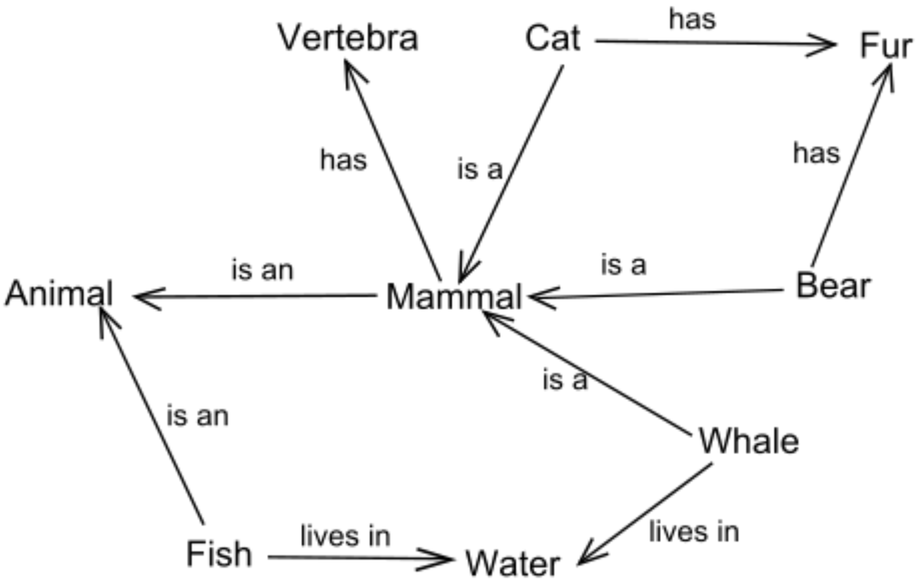
Is IS-A enough?

How adaptable is a taxonomy to new knowledge?

# Semantic networks

Directed graphs with concepts as nodes and semantic relations labeling edges.

Can also be represented as a list of predicates: `has (Cat, Fur), lives in (Fish, Water)`



# Semantic frames

*John drives a car.*

Identified by an action (event) OR a type reference: *Fluffy the cat*

| "Cat" frame | |
|---|---|
| Name | Fluffy |
| Age | ? |
| Weight | ? |

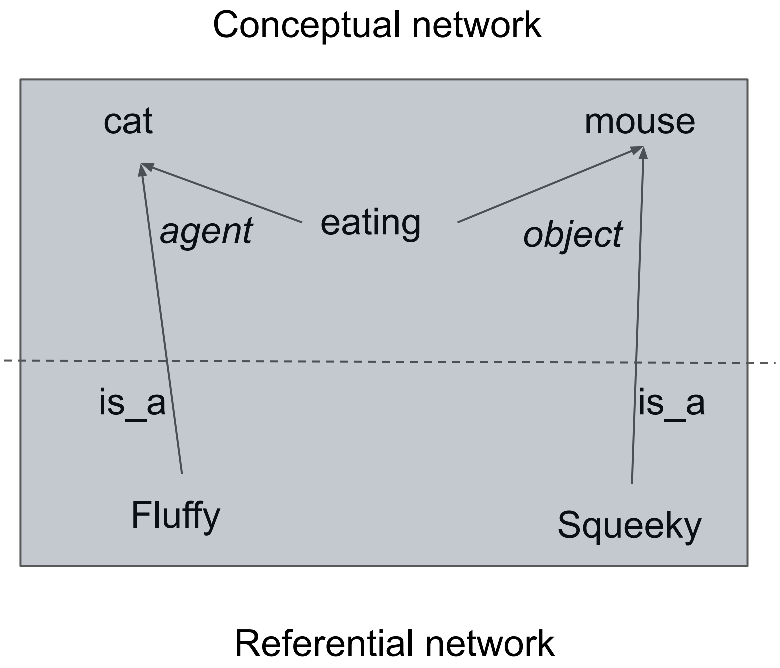
| "to drive" frame | |
|---|---|
| Agent | John |
| Object | a car |
| Starting point | ? |
| Ending point | ? |
| Reason | ? |
| Beneficiary | ? |
| Modal | ? |

# Events and referential networks

Referential network: part of a semantic network in which nodes identify actual objects, not concepts.

Event: defined as a set of relations with referential network connections. Frames ca be references and marked in a semantic network.

```
Eating:
agent(is_a(Fluffy, cat)) ∧
object(is_a(Squeeky, mouse))
```



# Reasoning on semantic networks(I)

Relations are inherited.

```
   IS-A(cat, mammal) AND IS-A(mammal, animal)
=> IS-A(cat, animal)
```

Answering queries.

```
Eating: agent (Fluffy) ∧ object (?x)
```

# Reasoning on semantic networks(II)

Daemons: procedures used to automatically maintain and enhance a semantic network.

```
If (IS-A(Fluffy, animal)) ∧ (length(Fluffy, ?x)) ∧ ?x ∈ [50,100] => size(Fluffy, medium)
```

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# WordNet

Nodes? Synsets = lists of synonymic senses of different words (over 120.000)

S: (n) **student**, pupil, educatee (a learner who is enrolled in an educational institution)

Relations? 6 types of semantic relations:

- Antonymy: opposite meaning of — good - bad
- Hyponymy: IS-A (is a specific kind of…) — student - person
- Meronymy: part of (is structurally included in…) — head - student
- Troponymy: identifies a manner of… — whisper - speak
- Entailment: identifies requirements — divorce - marriage
- Derivation: related to, produced by — product - factory

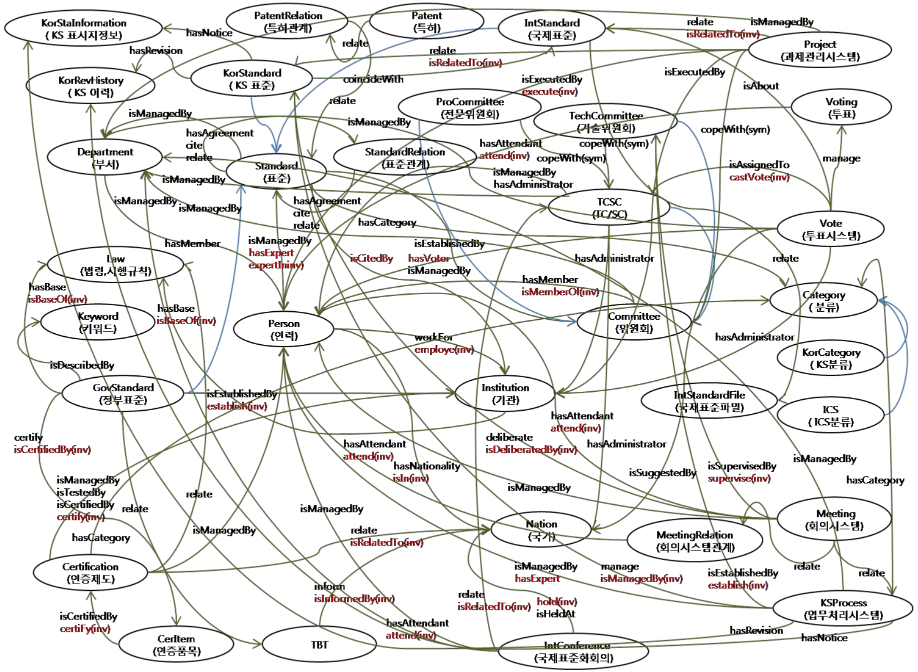
# Ontology

## Definitions (courtesy of Merriam-Webster):

**1**: a branch of metaphysics concerned with the nature and relations of being

**2**: a particular theory about the nature of being or the kinds of things that have existence

## Unambiguous representation of knowledge, more expressive than a taxonomy.



# Ontology: attempt of a formal definition

A hypergraph O(C, R) and a set I where:

- C is a set of concepts c, where c is defined as a tuple (i, d, l, r, p, r), where:
    - i is an unique identifier;
    - d is a list of definitions;
    - l is a list of lexicalisations;
    - r is a list of references to other related sources;
    - p is a list of property identifiers (relations with one member);
    - r is a list of relation identifiers with c as a member.

# Ontology: attempt of a formal definition

- R is a set of semantic relations r, each defined as a triple (i, m, b), where:
  - i is an unique identifier;
  - m is the number of members of that relation;
  - b indicates whether the relation is bidirectional.

- I is a set of inferences (rules) over the ontology performing changes to it.

Instance: concept to which no other concept can be related by IS-A.

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# Viewers and editors

- OWLGReD
- PuffinSemantics
- WebVowl

- Protégé
- Fluent Editor

Most common format: RDF

# Ontologies: unlimited expressiveness

- Anything can be included as a concept/instance
- Concepts/instances can have any properties
- Any semantic relation can be included
- Consistent relations/properties are not mandatory (but highly recommended)
- Built for continuous maintenance and development - use inferences!

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# Potential difficulties in knowledge representation

- Semantic parasitism: externally inferred semantics

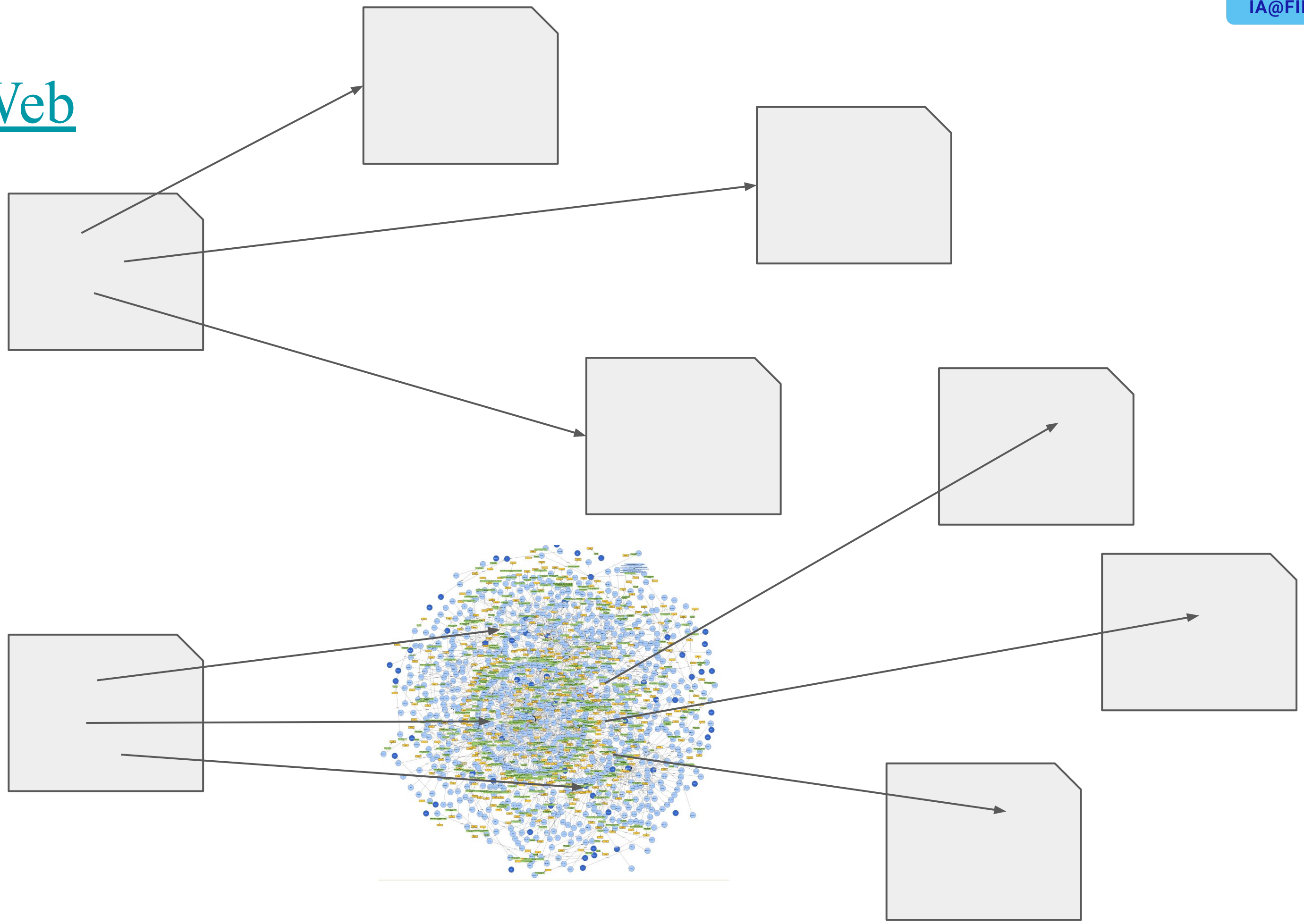
  Metaphors: is “semantic parasitism” something positive or negative in an AI ontology?

- Semantic subjectivity: different semantics for different contexts

# The Semantic Web

Classic web

Semantic web



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# Semantic web: current state

Describe linked data?

[JSON-LD](#) [Open Graph](#)

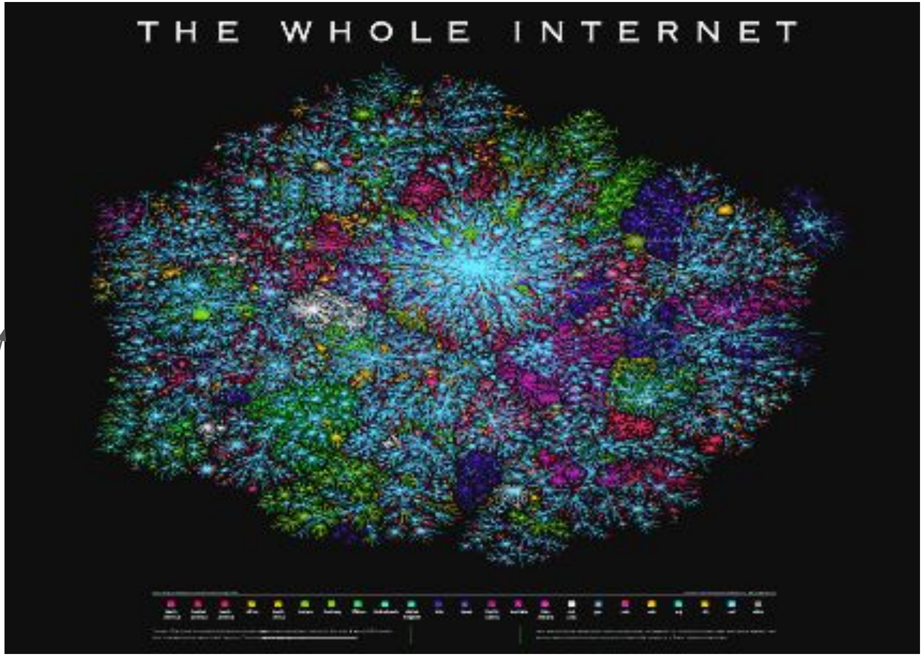
Detailed domain ontologies?

[Dbpedia.org](#) [Schema.org](#)

Semantic web browser?

[LodView](#) [Magpie](#)

OK, so what's the problem? THIS



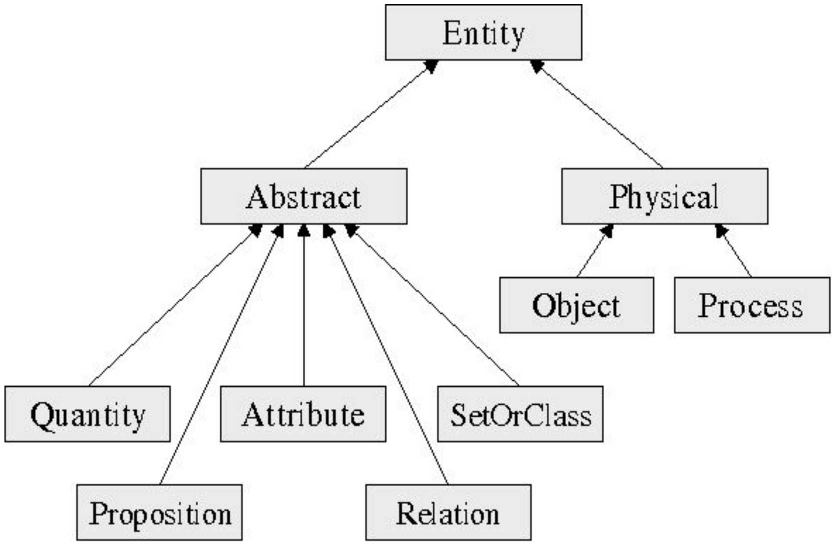

but also this

# Upper Merged Ontologies

SUMO (appoximately 25000 terms linked)

Dolce

Yago



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# Open book vs Closed book exam

Tests intelligence in applying knowledge

Test analytical ability (looking for knowledge, recognizing relevant knowledge)

Tests memory

The goal should never be the accumulation of knowledge. The right answer means nothing without the right question (42).