Lecture

Knowledge-based Systems

Part 3 – Knowledge Representation Levels

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Universität Duisburg-Essen

Recall…

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Offen im Denken

- **What is (artificial) intelligence?** The ability to acquire and apply knowledge and skills to achieve complex goals.

Recall…

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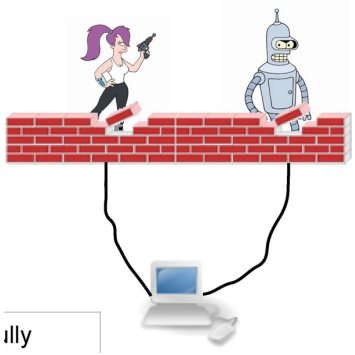
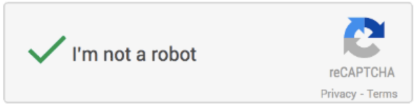
Offen im Denken

- **What is (artificial) intelligence?** The ability to acquire and apply knowledge and skills to achieve complex goals.
  - Turing Test



  - Captchas

CAPTCHA:
Completely Automated Public Turing test to tell Computers and Humans Apart



Recall…

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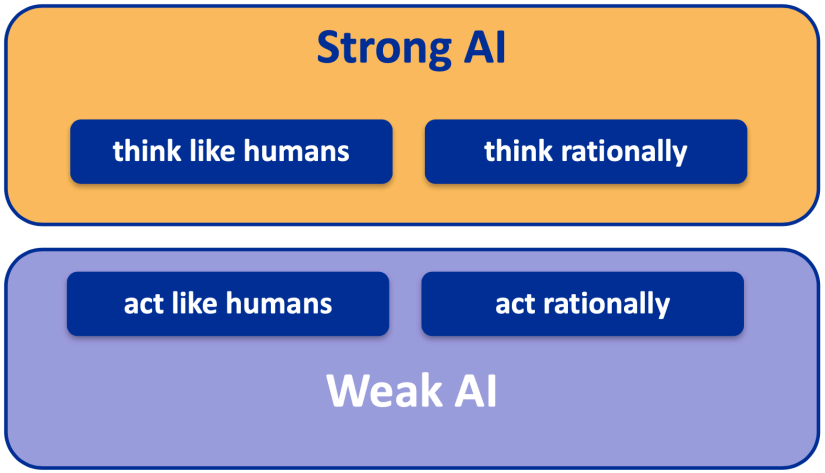
Offen im Denken

- **What is (artificial) intelligence?** The ability to acquire and apply knowledge and skills to achieve complex goals.
  - Turing Test
  - Captchas

- Strong AI vs weak AI

- Ethical concerns



Any other open questions?

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Recall…

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Offen im Denken

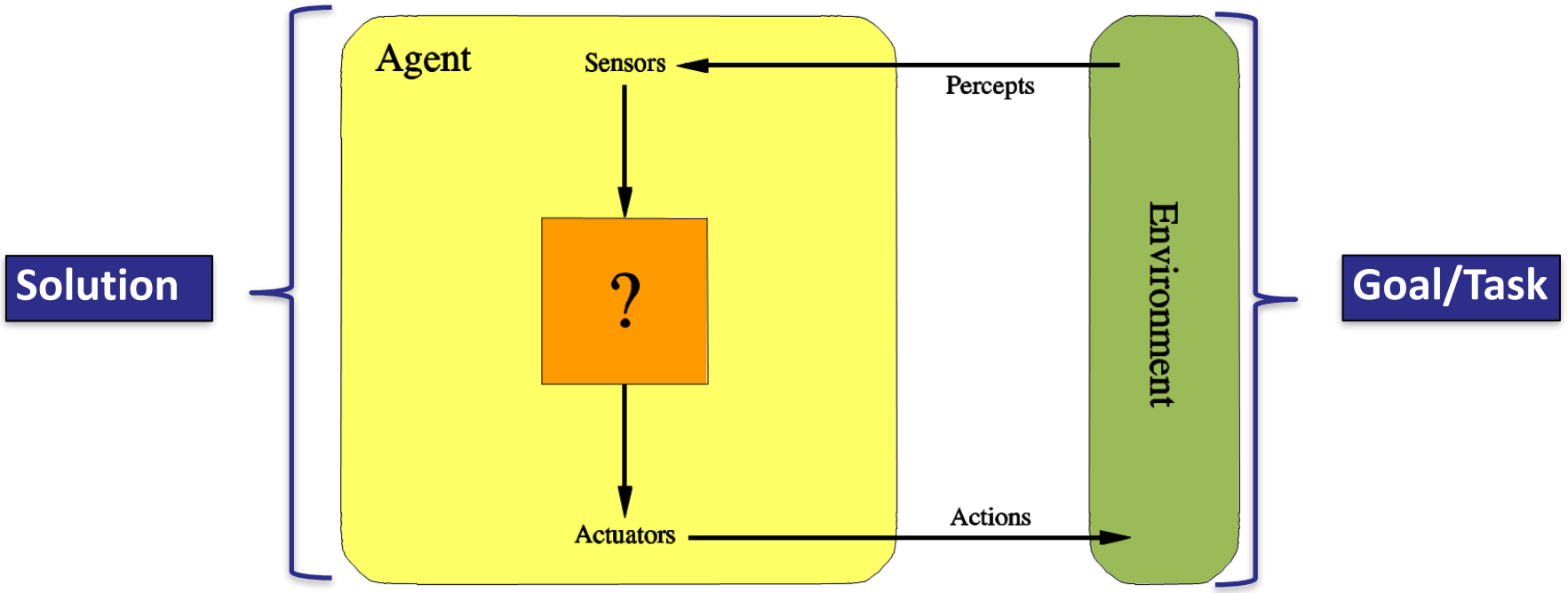
- **What is (artificial) intelligence?**

  - The ability **to acquire and apply knowledge** and skills to **achieve complex goals.**

  - Knowledge-based agents can
    - accept new tasks in the form of **explicitly described goals**;
    - achieve **competence quickly by being told or learning new knowledge** about the environment;
    - **adapt to changes in the environment by updating the relevant knowledge.**

How to acquire knowledge?

AI Agent


Solution
Agent
Sensors
Percepts
?
Actuators
Actions
Environment
Goal/Task

Knowledge acquisition

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- **Procedural** approach
  - Encoding desired behaviors directly as program code

- **Declarative** approach
  - The agent designer declare the knowledge one by one until the agent knows how to operate in its environment

- **Learning** approach:
  - allowing an AI agent to learn for itself about the environment from a series of percepts

Knowledge acquisition

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Knowledge acquisition

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- **Declarative approach** to building an agent:
  - ***Tell*** it what it needs to know (or have it ***Learn*** the knowledge)
  - Then it can ***Ask*** itself what to do

- Where should we store the knowledge?

Knowledge base

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- Knowledge base = a set of **concepts** + their **relationships** in a **knowledge representation language**
- A single inference algorithm can answer any answerable question

- Agents can be viewed at the ***knowledge level***
  i.e., what they ***know***, regardless of how implemented
- The central component of a knowledge-based agent is its **knowledge base**, or **KB**.

Scope of knowledge in KB

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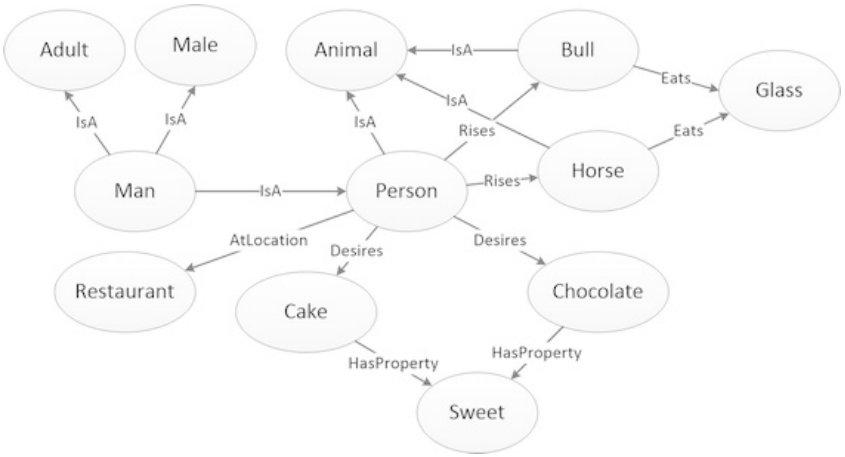
- Domain specific (useful for expert systems)
  - *As the **credit worthiness** decreases, the **interest rate** increases*
- Commonsense knowledge



How to represent knowledge?

Knowledge representation

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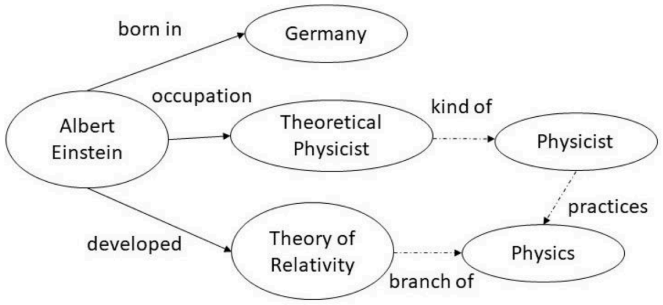
- **Descriptive**
  - ***Albert Einstein*** *was a German- born theoretical physicist who developed the theory of relativity.*
- **First order logics**
  - *isGerman(AlbertEinstein), isPhysicist(AlbertEinstein), …*
- **Graphs**



- **Embeddings**

Knowledge representation

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- **Descriptive**
- **First order logics (FOL)**
- **Graphs**

Symbolic AI

- **Embeddings**

Connectionist (non-symbolic) AI

Levels of representation

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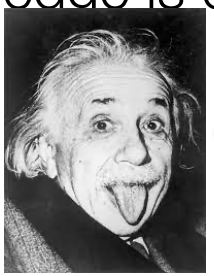
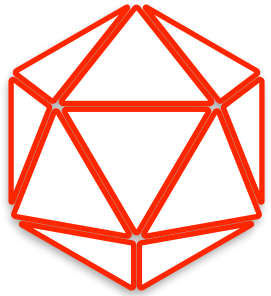
- **Symbolic**: Knowledge is encoded by symbols that refer to the knowledge.

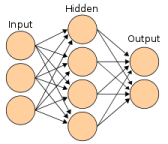




Albert Einstein

developing the theory of relativity, but he also made important contributions to the development of the theory of quantum mechanics.

- **connectionist**: Knowledge is embedded in parameters of a model.



Symbolic Knowledge Resources

Symbolic Knowledge Representation

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- symbolic artificial intelligence, also known as "classical AI,"
- Symbols are things we use to represent other things
- Symbols can represent
  - things (cat, car, airplane, etc.)
  - people (teacher, police, salesperson).
  - abstract concepts (bank transaction)
  - things that don't physically exist (web page, blog post, etc.).
  - actions (running)
  - states (inactive).

Descriptive KBs

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- Wikipedia
  - https://pypi.org/project/wikipedia/
- Project Gutenberg
  - https://www.gutenberg.org
- Dictionary
  - https://pypi.org/project/PyDictionary/

Dictionary

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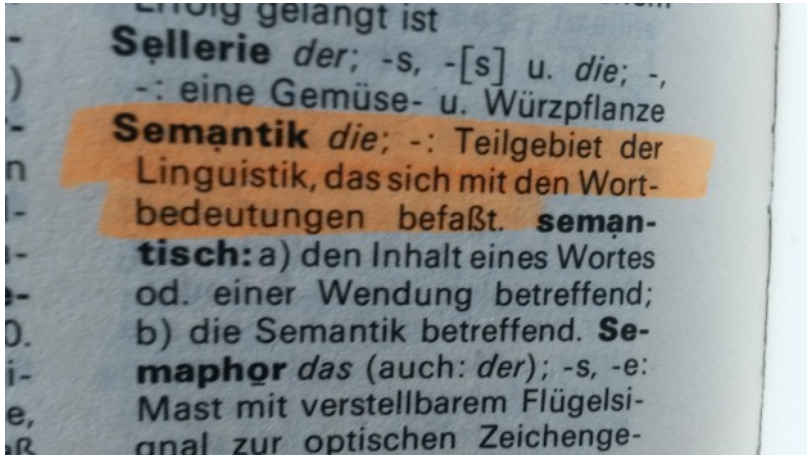
- In dictionaries, the **meaning (sense)** of a **word** is expressed in its gloss.
- **Glosses** = definitions of the meaning of a lexeme
  - leave (Verb): *go and leave behind, either intentionally or by neglect or forgetfulness*
  - leave (Verb): *act or be so as to become in a specified state*



Dictionary

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- In dictionaries, the meaning (sense) of a word is expressed in its gloss.
- Glosses = definitions of the meaning of a lexeme
- Many glosses are of the form genus-differentia (Aristotle)
  - **Genus – the broader category**
  - **Differentia – the distinguishing characteristics**

*An **X** `is-a` **Y**, and it differs from other hyponyms of Y by having properties A, B, and C, while D or E are not so important*

Dictionary

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- (Some) dictionaries contain **example sentences**.

- Usage-based approach: The meaning (sense) of a lexeme is expressed in its use.

- leave (Verb): *She left a mess when she moved out.*
- leave (Verb): *The president's remarks left us speechless.*

First Order Logics (FOL)

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- **Predicate Logic:** Represent knowledge by assertions that can be evaluated as true or false in a database

- $S(x)$ -> *x is a student.*
- $L(x)$ -> *x is lazy.*
- $\exists x\ (S(x)\ \&\ \neg\ L(x))$ -> *Some students are not lazy.*

FOL

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- Predicate Logic: Represent knowledge by assertions that can be evaluated as true or false in a database
- $S(x)$ -> *x is a student.*
- $L(x)$ -> *x is lazy.*
- $\exists x\,(S(x) \,\&\, \neg\, L(x))$ -> *Some students are not lazy.*

- **Predicates vs functions:**
  - *y is the father of x.*
  - Predicate: $Father(x,y)$
  - Function: $Father(x) = y$

Taxonomy as an example of knowledge graphs

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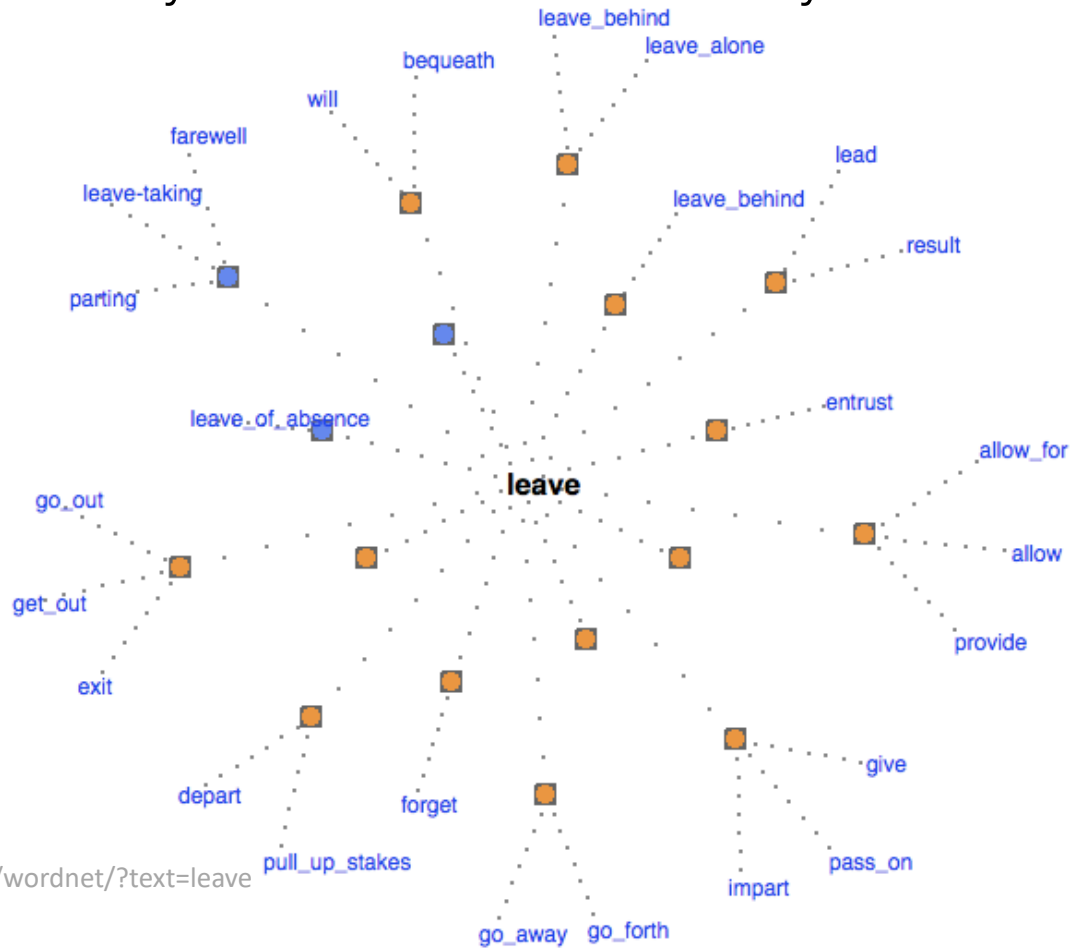
- Represent symbols by their relations to other symbols



Source: http://kylescholz.com/projects/wordnet/?text=leave
GUI is based on WordNet.

Taxonomy: Antonymy

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- important for organizing the meaning of adjectives and adverbs
  - DRY `is-antonym-of` WET

Taxonomy: Typical relations

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- Hypernymy / Hyponymy
- Holonymy / Meronymy
- Instance-of
- Antonymy

Taxonomy: Hypernymy / Hyponymy

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- Also known as `IS–A` relation
  - APPLE `IS–A` FRUIT
- Transitive relation
  - FRUIT `IS–A` NATURAL-OBJECT
  - APPLE `IS–A` NATURAL-OBJECT

Taxonomy: Holonymy / Meronymy

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- also called `IS-PART-OF` relation
  - TAIL `IS-PART-OF` DOG

- Transitivity is limited:
  - MUSICIAN `IS-PART-OF` ORCHESTRA
  - ARM `IS-PART-OF` MUSICIAN
  - can we induce that
    - ARM `IS-PART-OF` ORCHESTRA

Taxonomy: `Instance-of`

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- Hypernym relation for persons and locations
  - SEBASTIAN BACH `Instance-of` COMPOSER
  - SEBASTIAN BACH `Instance-of` ORGANIST
  - SEBASTIAN BACH `Instance-of` GERMAN

Some example Taxonomy

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Wordnet

- http://www.nltk.org/howto/wordnet.html

FrameNet

- http://www.nltk.org/howto/framenet.html

Cyc

- https://www.programmableweb.com/api/cyc

BabelNet

- https://babelnet.org/guide

WordNet

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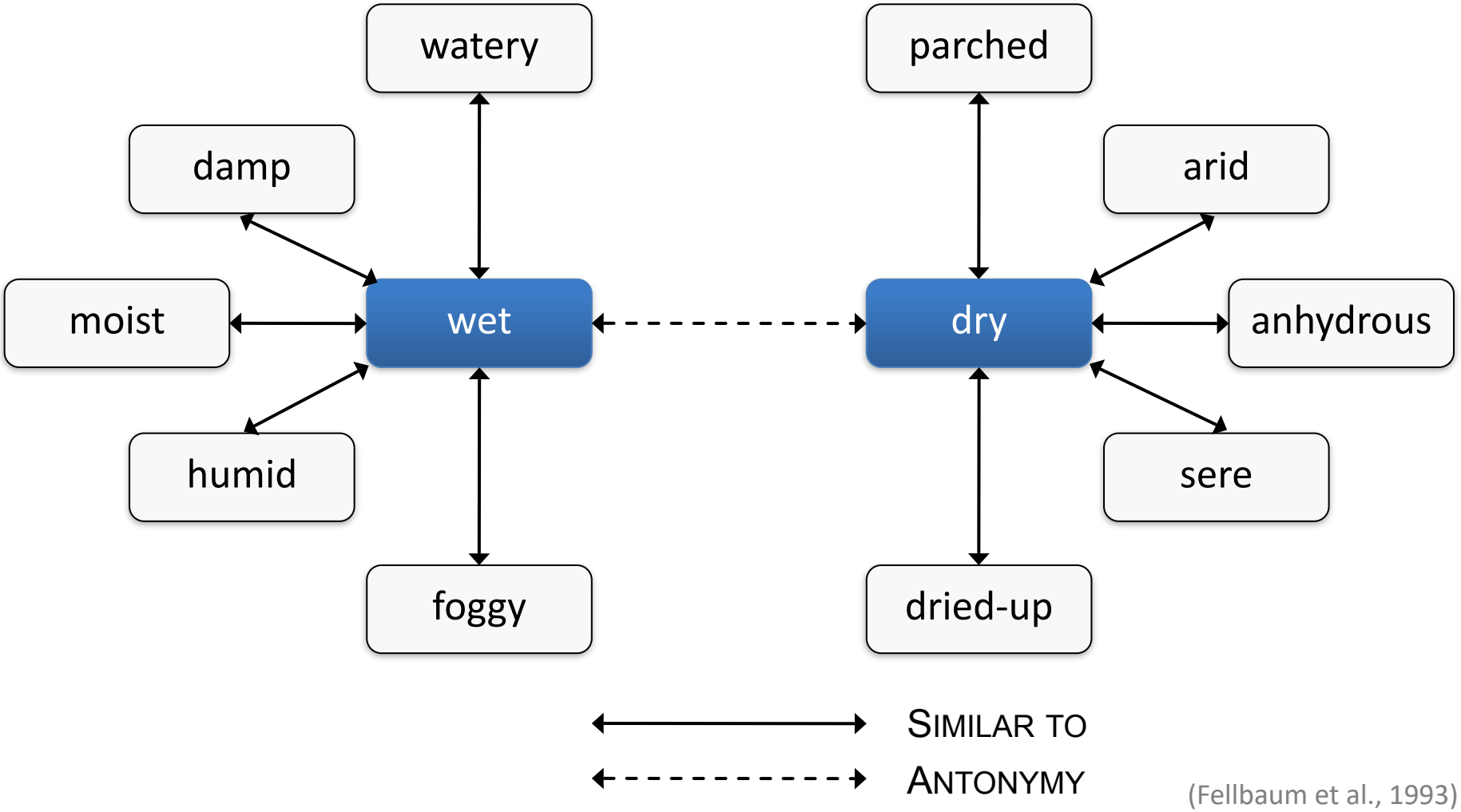
- Electronic lexical database for the English language
- Realized at Princeton University by George Miller's team
- Started in 1985
- Hundreds of scientists have used it
- Publicly available:
  - http://wordnet.princeton.edu/wordnet/

Standard Reference:

Fellbaum C. (Ed.): **WordNet, an Electronic Lexical Database (Language, Speech, and Communication)**, MIT Press, 1998.

(following Bernardo Magnini)

Adjectives in WordNet – Satellite Approach



(Fellbaum et al., 1993)

Hypernymy / Hyponymy

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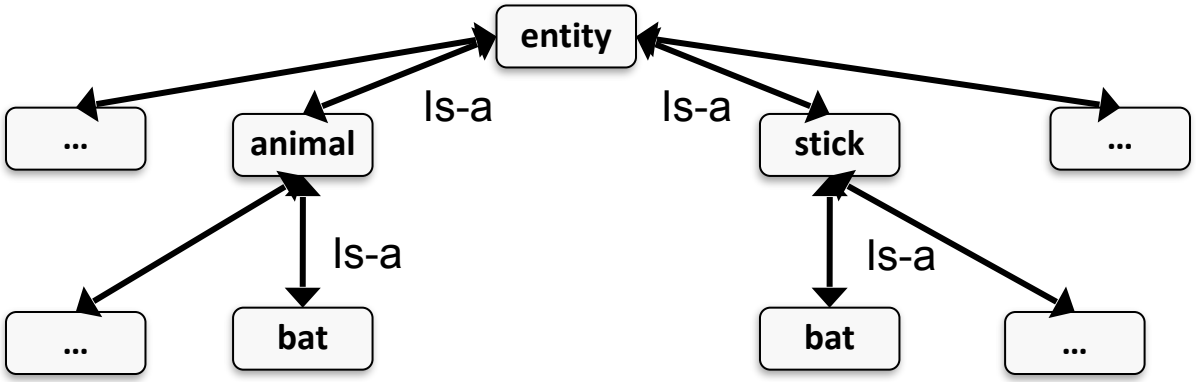
Relation between two synsets

- A **synset** is a **hyponym** (subordinate) of another **synset** if it is more specific, denoting a subclass of the other
- **Hypernymy** is the inverse relation of hyponymy
- **Programming analogy:** Object Hierarchy in **OO** programming

Examples

- *car / vehicle*
- *dog / animal*
- *mango / fruit*
- oak / tree



Hypernymy / Hyponymy

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Also called the `IS-A` relation

Test question:

- Is the sentence "An X `IS-A (kind of)` Y" acceptable?

Transitive

- TAXI `IS-A` CAR `IS-A` VEHICLE → TAXI `IS-A` VEHICLE

Multiple inheritance is rare in WordNet, but it happens

- e.g. person is both an organism and a causal agent
- WordNet taxonomy **is not a tree**, but a **graph**

Instance-of

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What about persons, locations?

- Is Johann Sebastian Bach a hyponym of composer?
- Or of organist?
- Or of German?

Concrete entities might have a lot of “roles”

WordNet has a special Instance-of relation for such cases

Holonymy / Meronymy

Relation between two synsets

- A synset is a meronym (part) of another synset if native speaker accept sentences such as
  - “An X is a part of Y.”
  - “A Y has an X (as a part).”

Holonymy is the inverse relation of meronymy

Examples

- car / door
- dog / tail
- mango / kernel
- oak / leaf

Holonymy / Meronymy

Transitivity is limited

- orchestra / musician
- musician / arm
- ? orchestra / arm

Nouns in WordNet – Taxonomy

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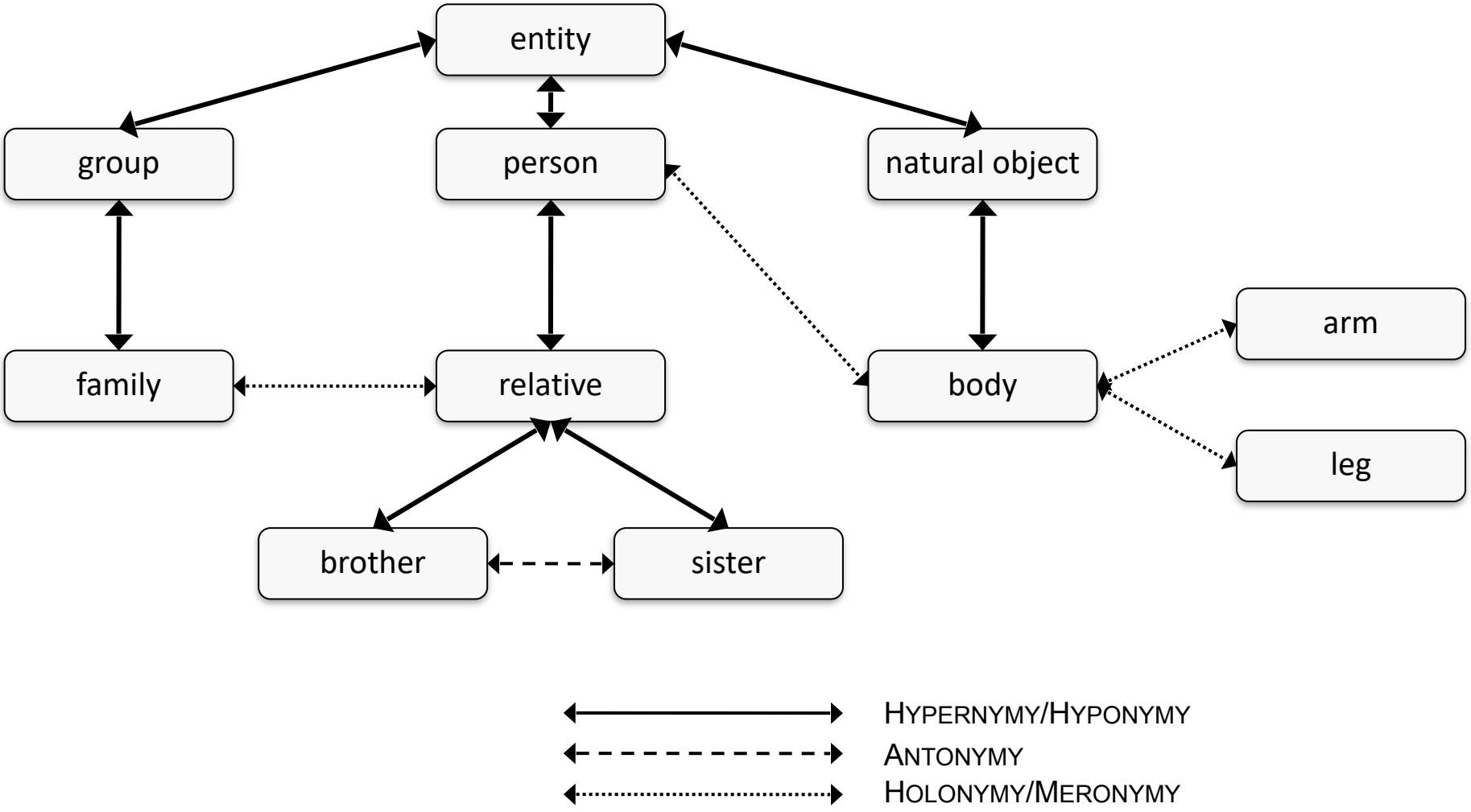

Troponymy

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Semantic relation between verb synsets

Informal

- *"Hyponymy for verbs"*

Formal

- a verb expressing a specific manner
- elaboration of another verb

Examples

- move / walk
- walk / stroll

Test Question:

"X is to Y in some manner"

"Y is a particular way to X"

→ "to stroll is a particular way to walk."

Entailment

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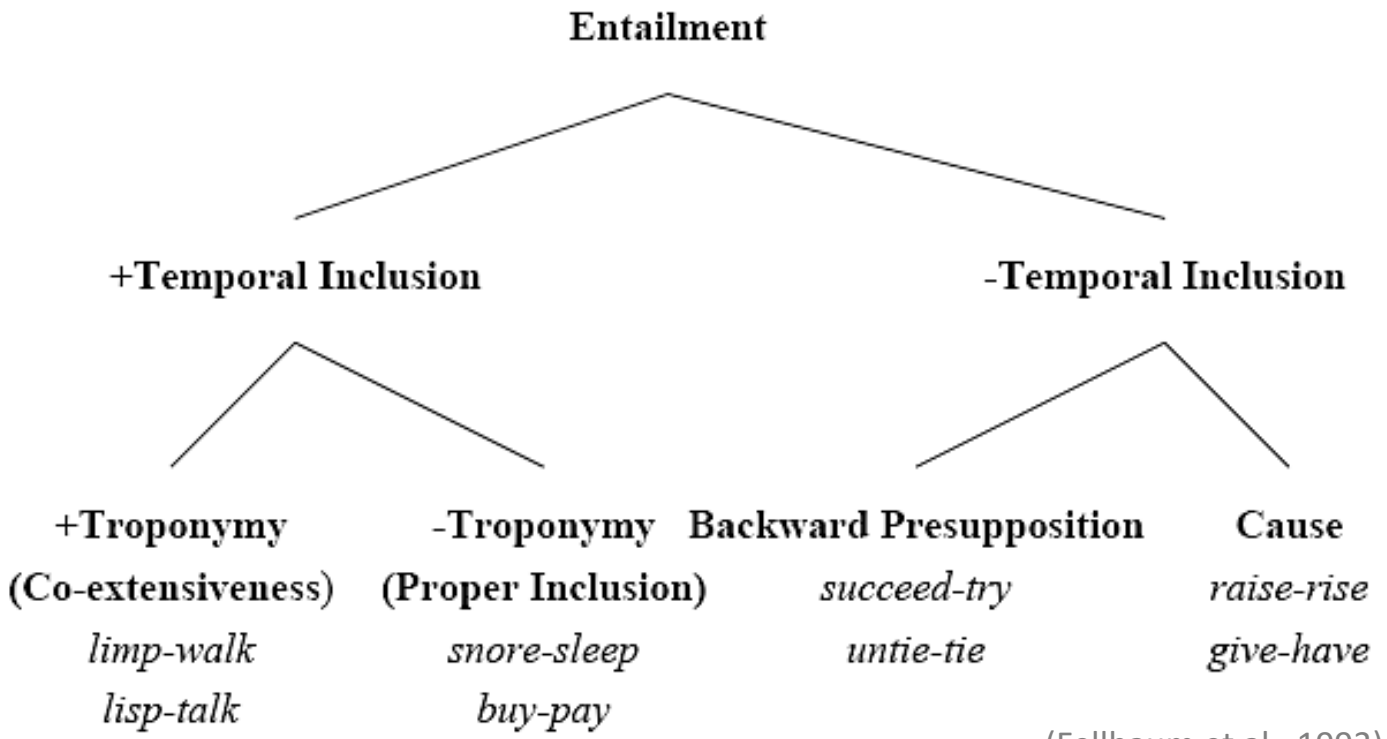
Semantic relation between verb synsets

- A verb X *entails Y if X cannot be done* unless Y is or has been done

Example

- snore / sleep



(Fellbaum et al., 1993)

Problems

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- Which facts are relevant for a given domain?
- Which changes are relevant for a given situation?

- How to represent similar concepts?
- How to learn new concepts from interaction with the world?
  - How to connect a perception to a symbol?

- How do we know what a symbol means?
  - grounding problem

Limitations of symbolic representation

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Similarity between symbols needs to be explicitly modeled:

- red, pink, rose, ruby, burgundy, magenta

Similarity of symbol names is usually irrelevant

- blau/grau
- rot/orange

Modeling unseen instances

- Color?
- New predicate required?

Summary

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- How to acquire knowledge?
  - Procedural approach, **declarative approach**, Learning approach
- How to represent knowledge?
  - **Symbolic** vs connectionist representations
- Symbolic representation
  - Dictionary
  - Taxonomy
    - WordNet

Practice …

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- Make groups of 2 or 3 students
- Select a knowledge base:
  - **WordNet** (https://www.nltk.org/howto/wordnet.html)
  - **Wikidata** (https://www.wikidata.org/wiki/Wikidata:Main_Page)
  - **Wikipedia** (https://pypi.org/project/wikipedia/)
  - **ConceptNet** (https://conceptnet.io, https://github.com/ldtoolkit/conceptnet-lite)
  - **FrameNet** (http://www.nltk.org/howto/framenet.html)
  - **BabelNet** (https://babelnet.org/guide, https://pypi.org/project/py-babelnet/)
  - **ATOMIC** (https://homes.cs.washington.edu/~msap/atomic/)
  - **DBPedia** (https://www.dbpedia.org/about/)

Practice …

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- Search for concepts in the KB
- Output the available information
- How to compute similarity between two concepts?
- Take screen shots from your notebook
- In Overleaf, write a paragraph about what you have done and use the images as results

Practice …

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- Write another paragraph about the KB you selected. How do you assess the KB from the following aspects:
  - **Access:** Is it easy to query a specific fact from the selected KB?
  - **Consistency:** Is the output of a query consistent when
    - You insert a query in different languages (for KB that are multilingual)? (**Multilinguality**)
    - You insert a paraphrase of a query? (**Paraphrasing**)
    - You insert a query and its negation? e.g. (Birds can fly vs Birds cannot fly) (**Commonsense**)
  - **Edibility**
    - Can you update a fact in the KB?
    - Does your update affect other facts in the KB?
    - Does the KB check if your update is consistent with other facts? Can you add inconsistency in the KB?
  - **Reasoning**
    - Logical reasoning?
    - Mathematical reasoning?
    - Commonsense reasoning?
  - **Explainability & Interpretability**
    - **Explainability**: Is the KB's output explainable in a post-hoc setting?
    - **Interpretability:** Is it possible to inspect the inner working of the KB to understand the reasoning behind its output?

Readings

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Mandatory

- Gärdenfors, Chapter 1:
  - 1.3: Quality Dimensions, p. 6-7
  - 1.4: Phenomenal and Scientific Interpretation of Dimensions, 8-9
  - 1.8: Integral and Separable Dimensions, p. 24-26

- Miller et al (1993): Introduction to WordNet: An On-line Lexical Database, p.5-10, Starting with:
  How are word meanings represented in WordNet?

Optional

- Rest of Chapter 1