Lecture 8a: Ontology & Semantic Networks

CSCI 360

Introduction to Artificial Intelligence

USC

Here is where we are…

Week	30000D	30282R	Topics	Chapters
1	1/7	1/8	Intelligent Agents	[Ch 1.1-1.4 and 2.1-2.4]
	1/9	1/10	Problem Solving and Search	[Ch 3.1-3.3]
2	1/14	1/15	Uninformed Search	[Ch 3.3-3.4]
	1/16	1/17	Heuristic Search (A*)	[Ch 3.5]
3	1/21	1/22	Heuristic Functions	[Ch 3.6]
	1/23	1/24	Local Search	[Ch 4.1-4.2]
	1/25		Project 1 Out	
4	1/28	1/29	Adversarial Search	[Ch 5.1-5.3]
	1/30	1/31	Knowledge Based Agents	[Ch 7.1-7.3]
5	2/4	2/5	Propositional Logic Inference	[Ch 7.4-7.5]
	2/6	2/7	First-Order Logic	[Ch 8.1-8.4]
	2/8		Project 1 Due	
	2/8		Homework 1 Out	
6	2/11	2/12	Rule-Based Systems	[Ch 9.3-9.4]
	2/13	2/14	Search-Based Planning	[Ch 10.1-10.3]
	2/15		Homework 1 Due	
7	2/18	2/19	SAT-Based Planning	[Ch 10.4]
	2/20	2/21	Knowledge Representation	[Ch 12.1, 12.2, 12.5]
8	2/25	2/26	Midterm Review	
	2/27	2/28	**Midterm Exam**	

Outline

- What is AI?
- Problem-solving agent
  - Uninformed (DFS), informed (A*), and local search
  - Adversarial search (minimax, alpha-beta pruning)
- **Knowledge-based agent**
  - Propositional Logic
  - First Order Logic (FOL)
  - Planning
    - Graph-based Planning, SAT-based Planning
  - **Knowledge Representation**
    - Ontology *[Ch 12.1, Ch 12.2]*
    - Semantic Networks *[Ch 12.5]*

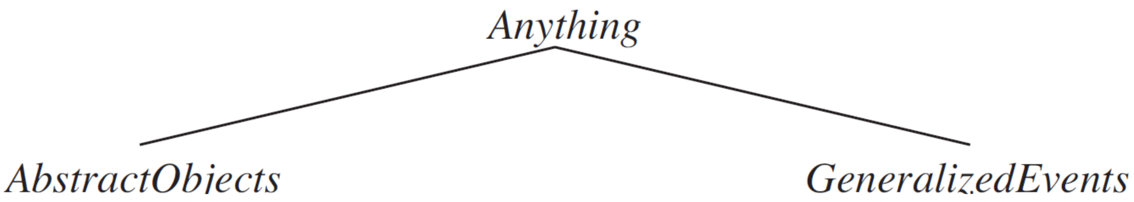
Knowledge-based agent: *What we have covered…*

- Syntax, semantics, and proof theory of ***propositional logic***
- Syntax, semantics, and proof theory of ***first-order logic***
- Implementation of ***agents*** that use these logics

- **Remaining question**: How to represent facts about the world?
  - Ontology
    - How to organize everything into a hierarchy of categories
  - Semantic networks
    - How to conduct efficient inference with the hierarchy of categories

Ontology

- Ontology = a hierarchy of categories



Ontology

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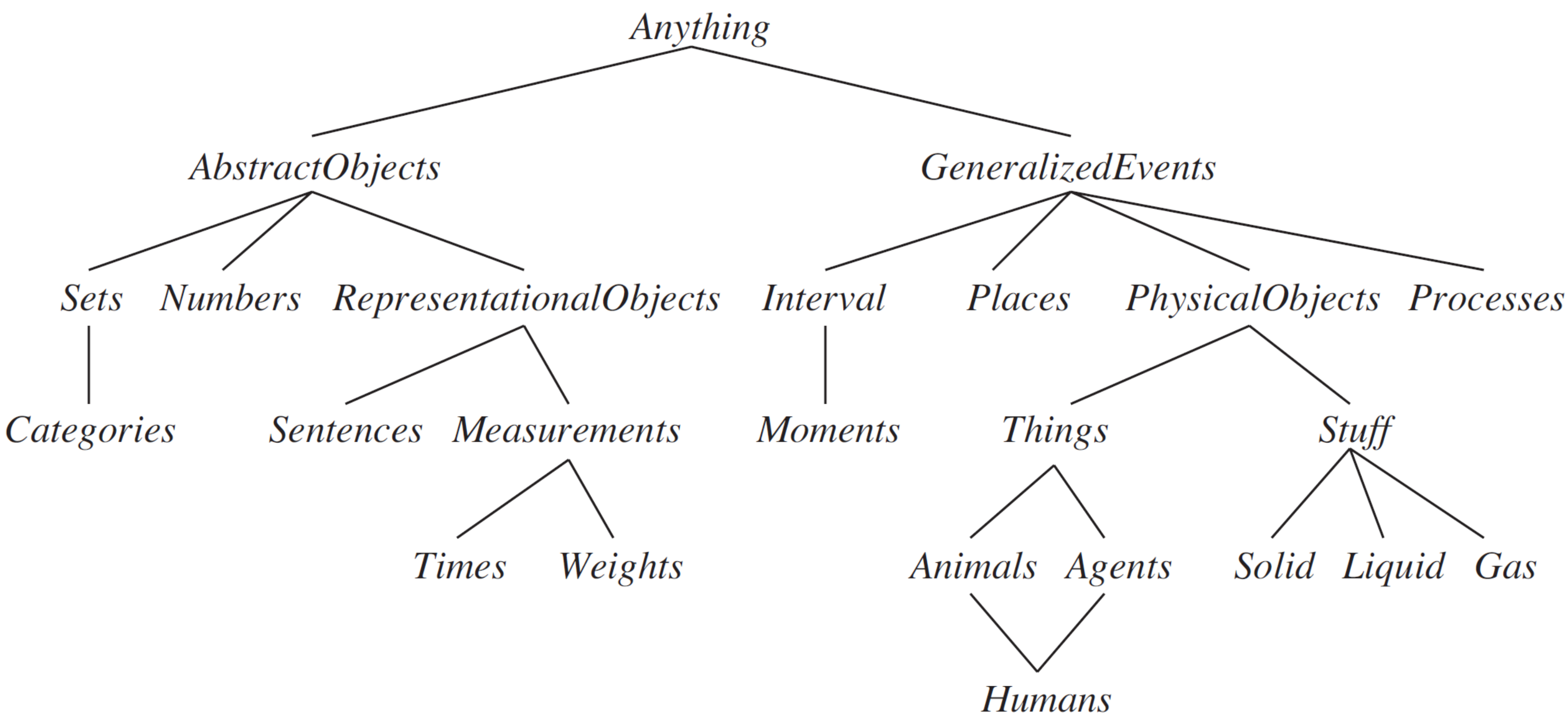


Categories and Objects

- What is the different?
  - “*Basketball*” is a category
  - “*BB9*”, which is a particular basketball, is an object

- Two ways of representing categories in first-order logic
  - Predicate: *Basketball(b)*
  - Convert to object, “*Basketballs*”, and then: *Member(b,Basketballs)*

Facts about categories

- An object is a member of a category

  $BB_9 \in Basketballs$

- A category is a subset of another category

  $Basketballs \subset Balls$

- All members of a category have some properties

  $(x \in Basketballs) \Rightarrow Spherical(x)$

- Properties may be used to recognize members of a category

  $Orange(x) \wedge Round(x) \wedge Diameter(x) = 9.5'' \wedge x \in Balls \Rightarrow x \in Basketballs$

- A category, as a whole, may have some properties

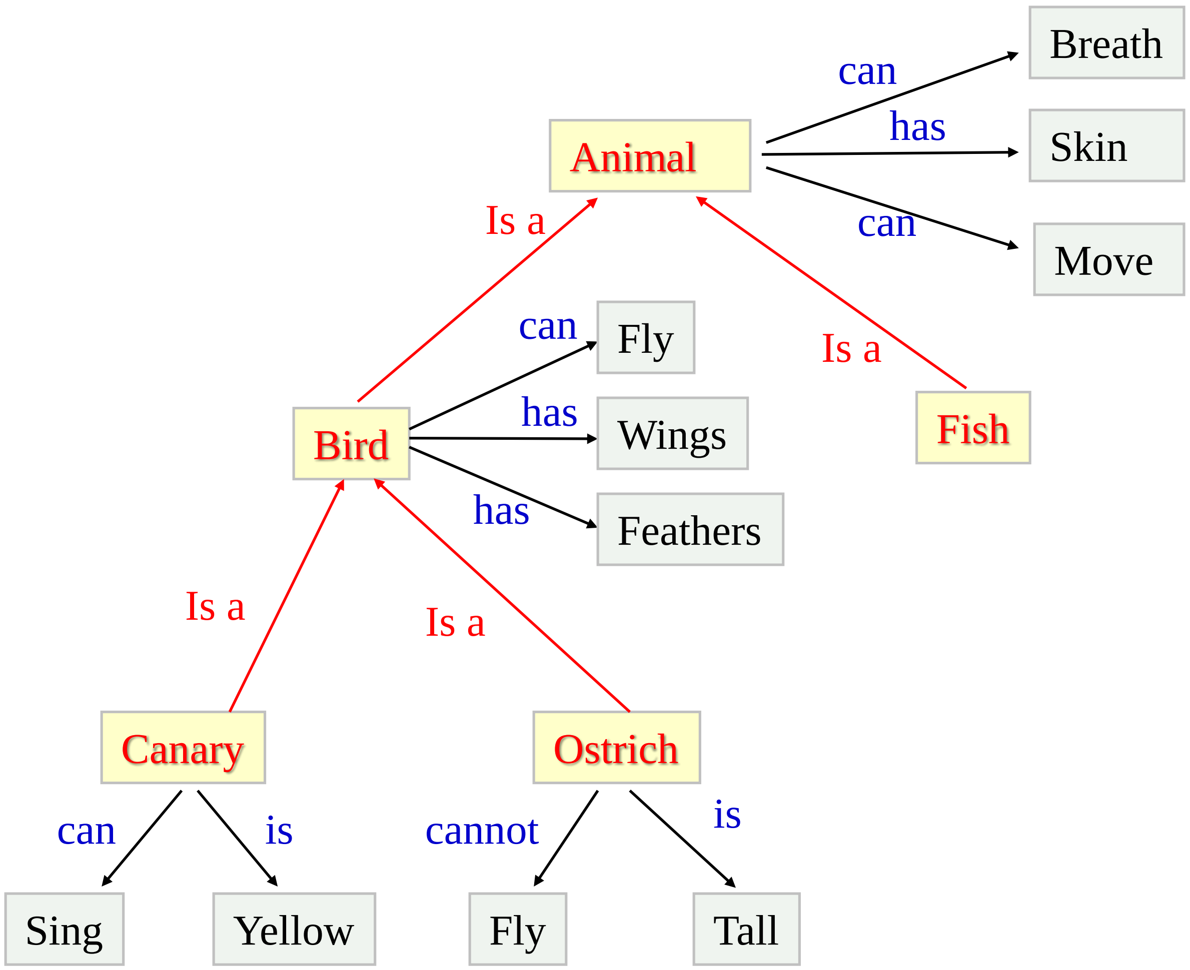
  $Dogs \in DomesticatedSpecies$

Inheritance

- Categories help organize the (KB) through inheritance
  - All instances of the category "**Food**" are *edible*
  - "**Fruit**" is a subclass of "**Food**"
  - "**Apple**" is a subclass of "**Fruit**"
  - All instances of the category "**Apple**" are *edible*
- Property of "*edibility*" is inherited via "**subclass**" relation

Subclass relations organize categories into a taxonomy, which makes it easy to reason about inheritance

Taxonomy Representation



Example: Taxonomic Knowledge

- **Subclass** relations organize categories into a **taxonomy**, which makes it easy to reason about **inheritance**

- Example:
  - “All **office machines** get their energy from **wall outlets**.”
  - “All **printers** are **office machines**.”
  - “All **laser printers** are **printers**.”
  - “**Hobbes** is a **laser printer**.”

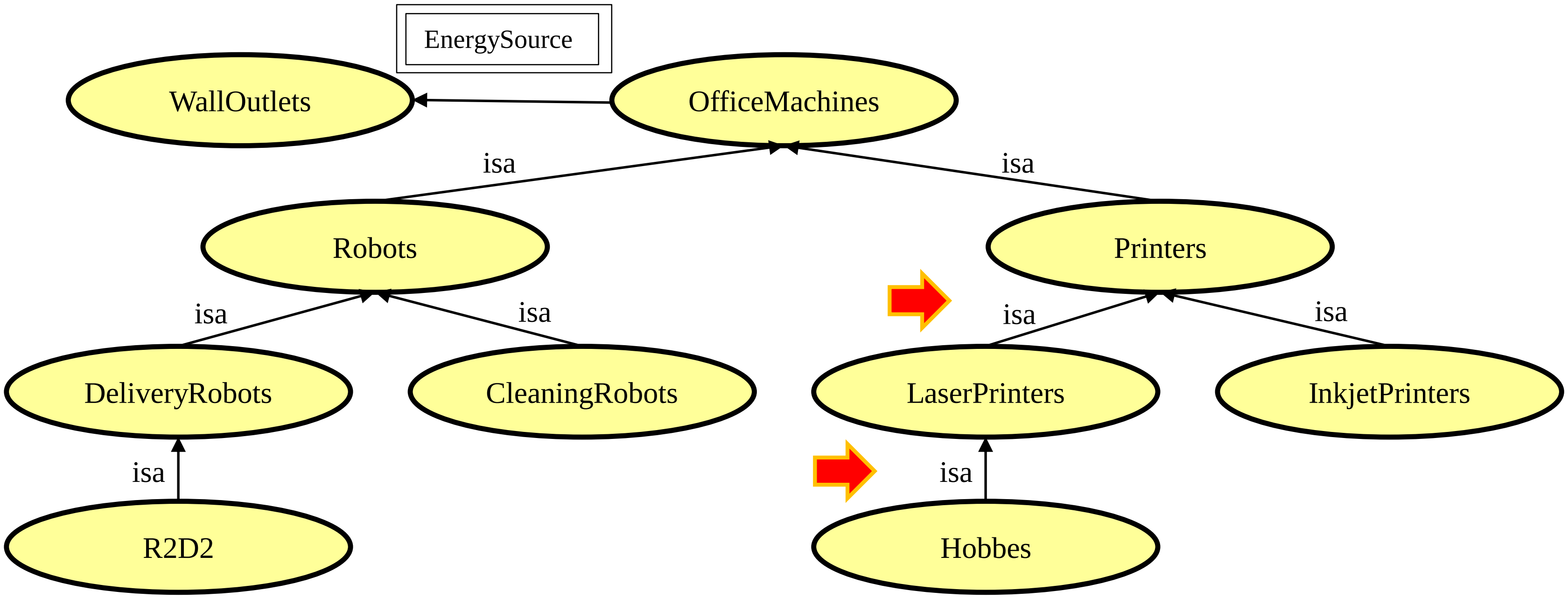
Example: Taxonomic Knowledge

- Knowledge base (KB) in first-order logic
  - $\forall x$ IsOfficeMachine(x) $\Rightarrow$ EnergySource(x, WallOutlets)
  - $\forall x$ IsPrinter(x) $\Rightarrow$ IsOfficeMachine(x)
  - $\forall x$ IsLaserPrinter(x) $\Rightarrow$ IsPrinter(x)
  - IsLaserPrinter(Hobbes)

- We can use **resolution** to show that KB entails
  - EnergySource(Hobbes, WallOutlets)

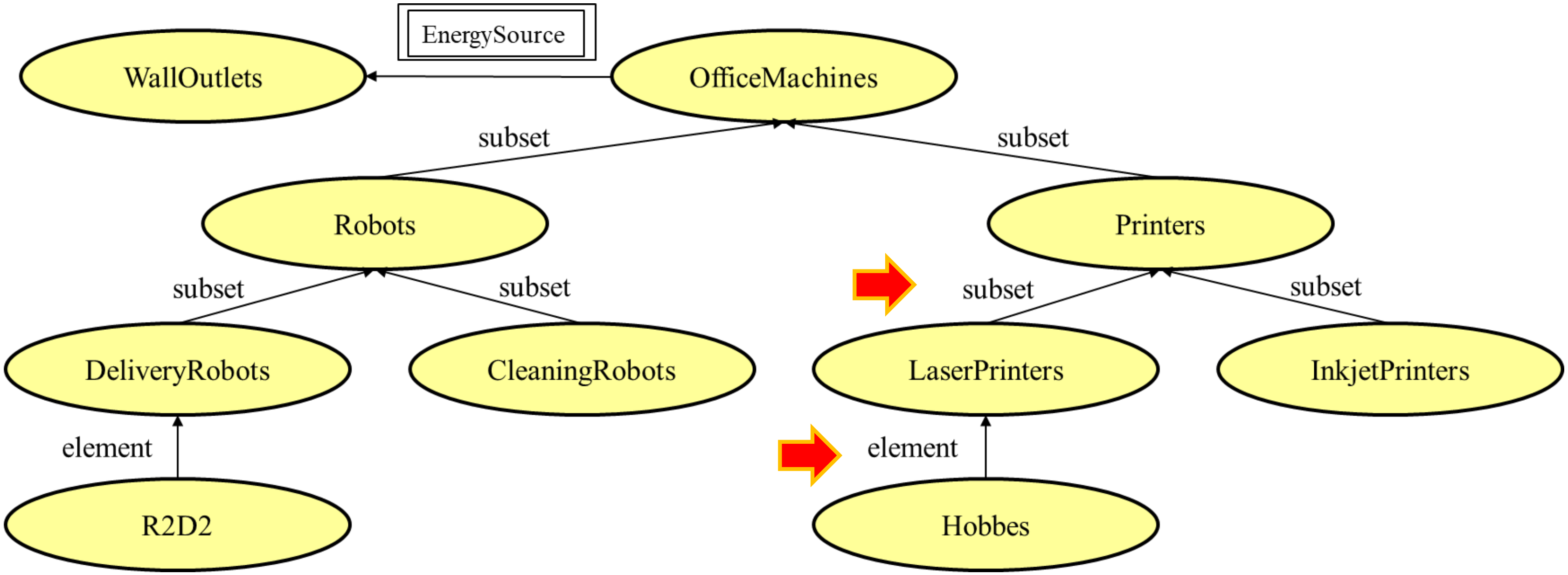
- But "first-order logic" is difficult to understand by non-experts and "resolution" is often slow
  - Any alternative?

Semantic Networks



These two relations are of different types, right?

Semantic Networks



These two relations are of different types.
One is "subset" and the other is "element"

Semantic Networks

Link Type	Semantics
$A \xrightarrow{\text{Subset}} B$	$A \subset B$
$A \xrightarrow{\text{Member}} B$	$A \in B$
$A \xrightarrow{R} B$	$R(A,B)$
$A \xrightarrow{\boxed{R}} B$	$\forall x \; x \in A \Rightarrow R(x, B)$
$A \xrightarrow{\boxed{\boxed{R}}} B$	$\forall x \; x \in A \Rightarrow \exists y \; (y \in B \wedge R(x,y))$

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$\text{Cats} \xrightarrow{\text{subset}} \text{Mammals}$

$\text{Bill} \xrightarrow{\text{element}} \text{Cats}$

$\text{Bill} \xrightarrow{\text{Age}} 12$

$\text{Birds} \xrightarrow{\boxed{\text{Legs}}} 2$

$\text{Birds} \xrightarrow{\boxed{\boxed{\text{Parent}}}} \text{Birds}$

Properties of semantic networks

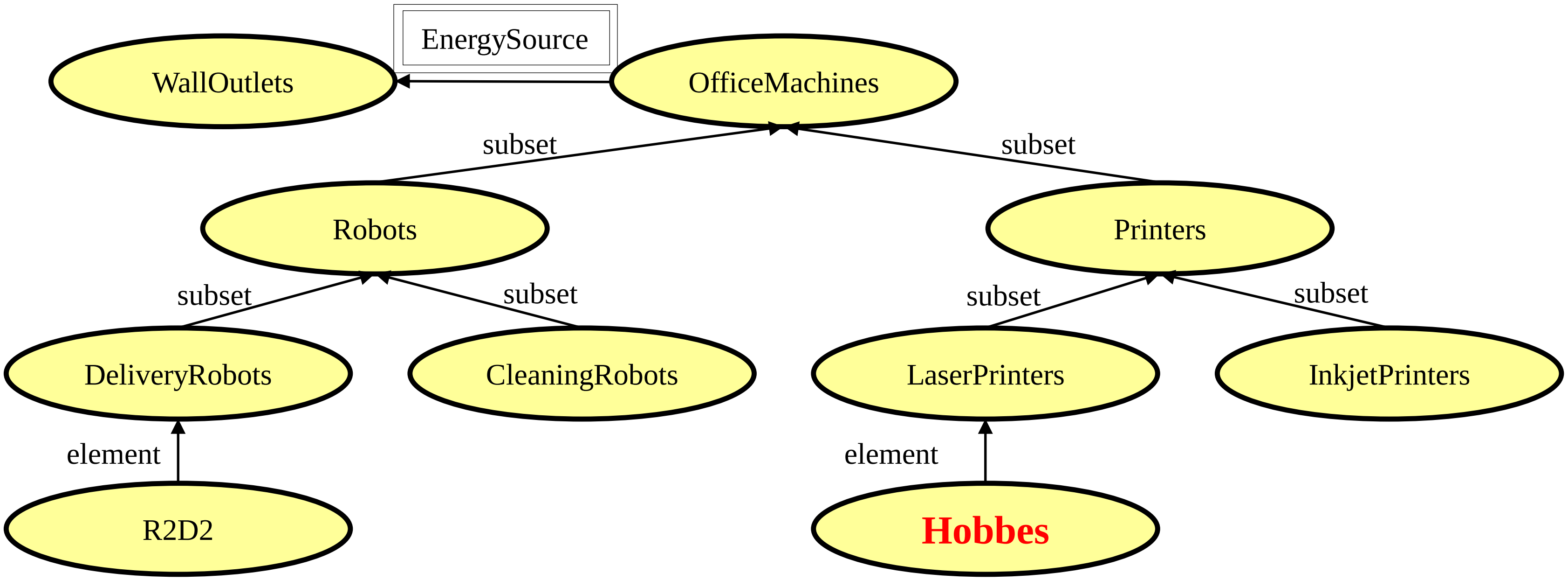
- Semantic networks versus first-order logic
  - KB is often easier to understand by humans, but semantics is often not as well defined
  - Reasoning is easier to implement and more efficient, but is also limited in capability
  - Sometimes is more expressive than first-order logic
    - Default reasoning
  - Sometimes is less expressive than first-order logic
    - Logical operators such as negation and disjunction

Efficiency in inference

- Specialized reasoning procedure ("**pointer following**") makes reasoning about properties easy, using the **inheritance** of properties.

Semantic Networks

- What's the energy source of Hobbes?



Semantic Networks

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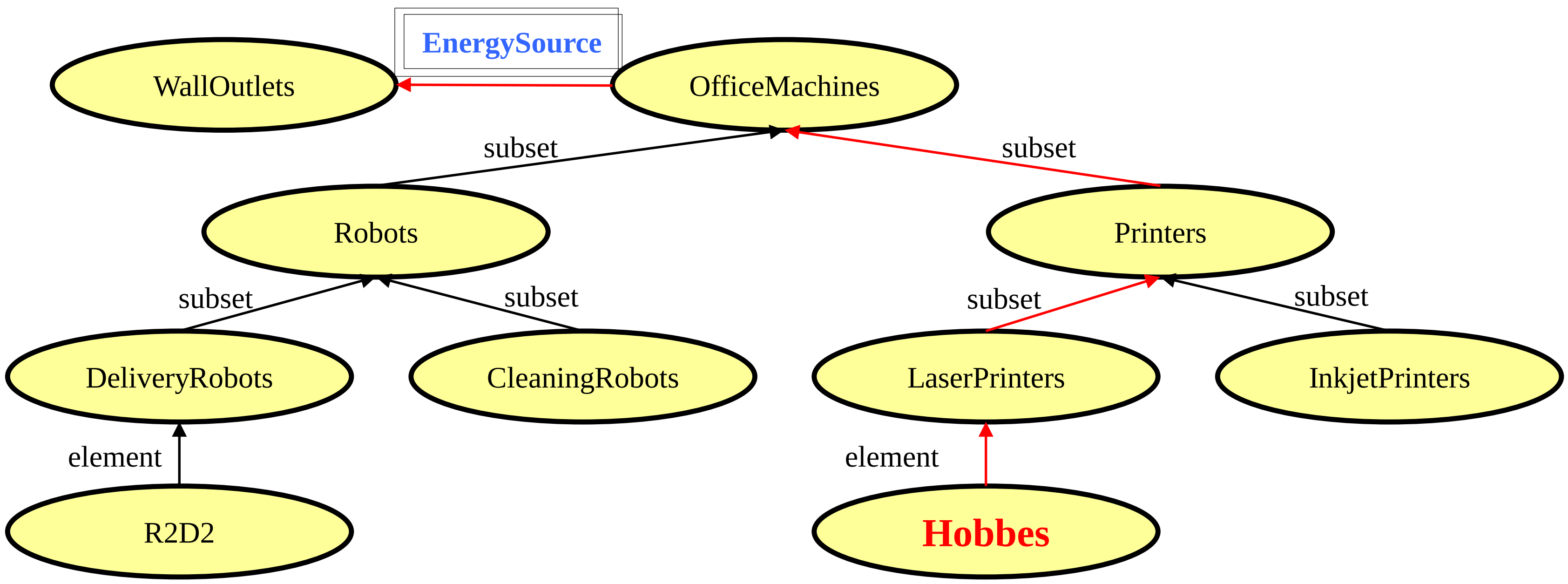

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Semantic Networks

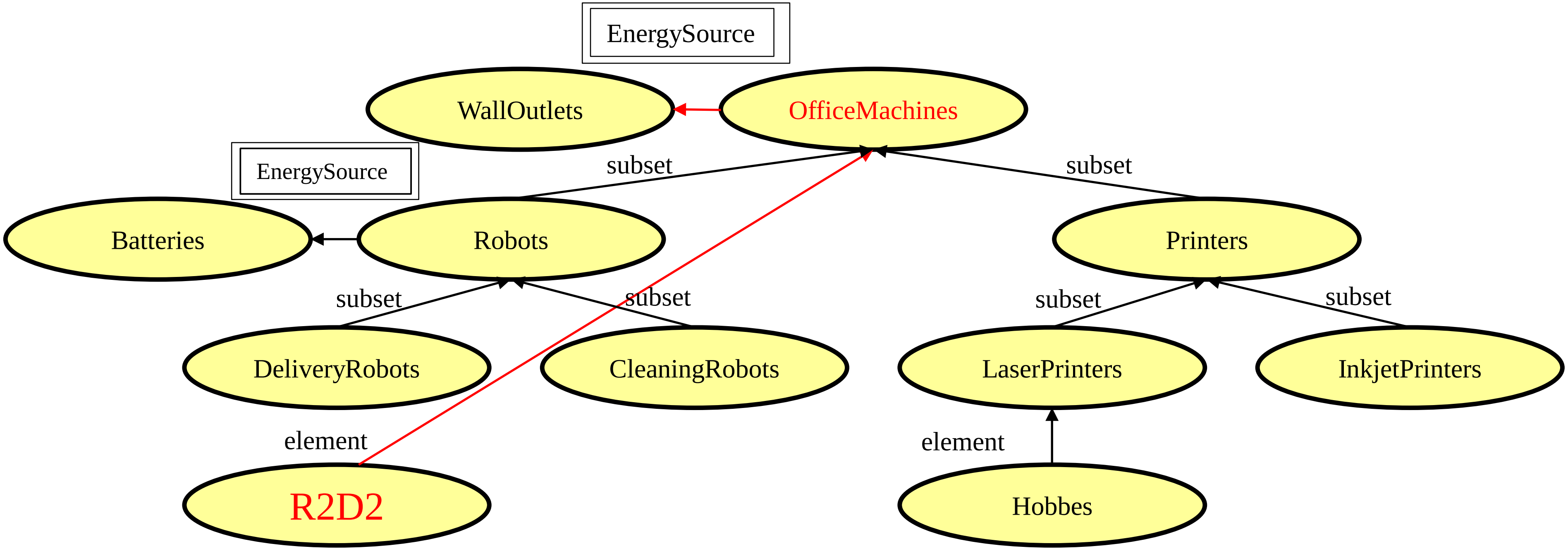
- "Yesterday, I looked out of the window and saw a bird."
  - Do you think that the bird I saw could (likely) fly?
  - Why do people jump to conclusions here? They reason with defaults.
- "Let me continue. It had a broken wing and sat on the ground."
  - If you thought that the bird could fly, you now need to revise your conclusion.
  - But First-order logic **doesn't allow revision**: KB ∧ KB' ⊨ S if KB ⊨ S.

IsBird(Tweety) ∧ BrokenWing(Tweety) ⊨ CanFly(Tweety) if IsBird(Tweety) ⊨ CanFly(Tweety)

- **Default reasoning** can be done with semantic networks.

Semantic Networks

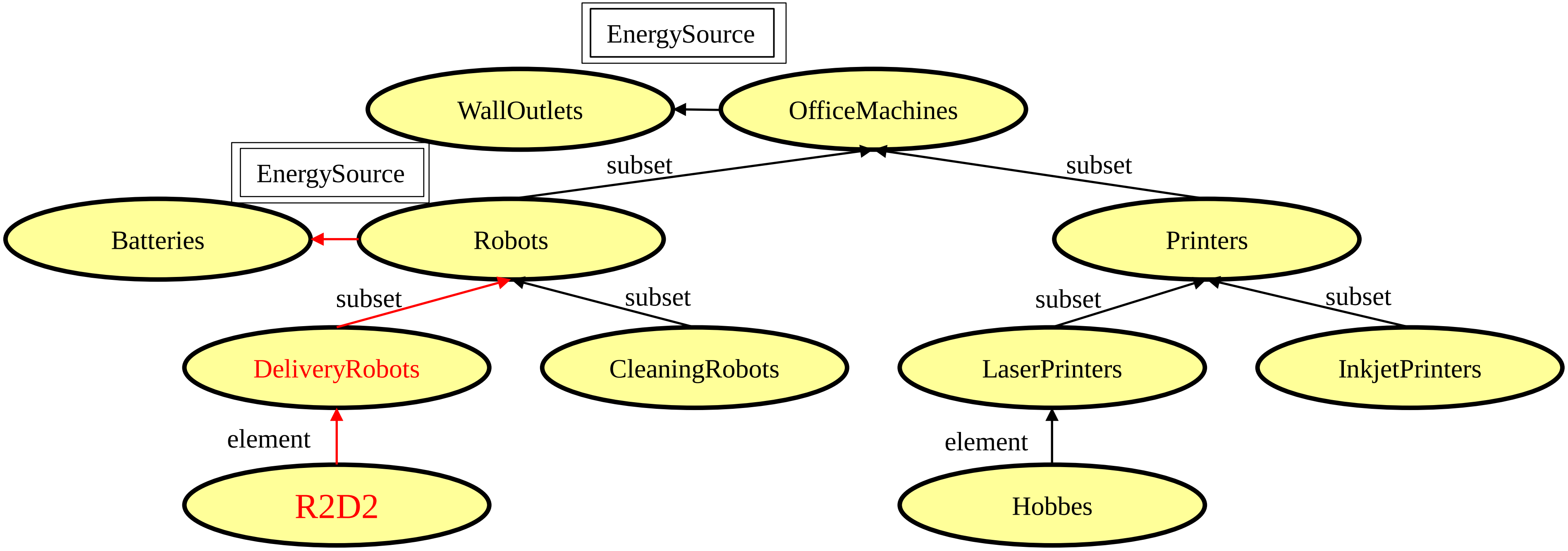
- "R2D2 is an office machine." → *it must use Walloutlets…*



Semantic Networks

- “Let me continue. In fact, R2D2 is a delivery robot.”

→ *no problem. Then, it must use Batteries instead…*



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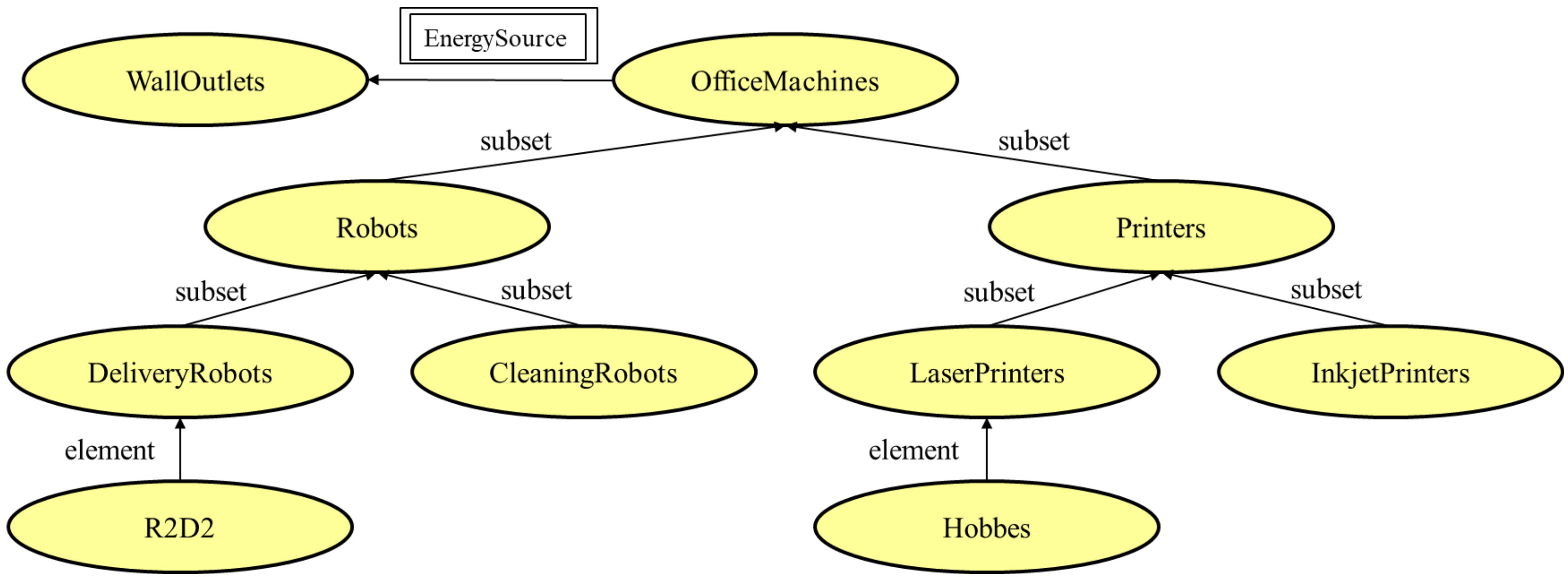
Problem: *Cannot handle "negation" and "disjunction"…*

- How would you depict "R2D2 is not a cleaning robot"?
- How would you depict "R2D2 is a delivery or cleaning robot"?

You can't!



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