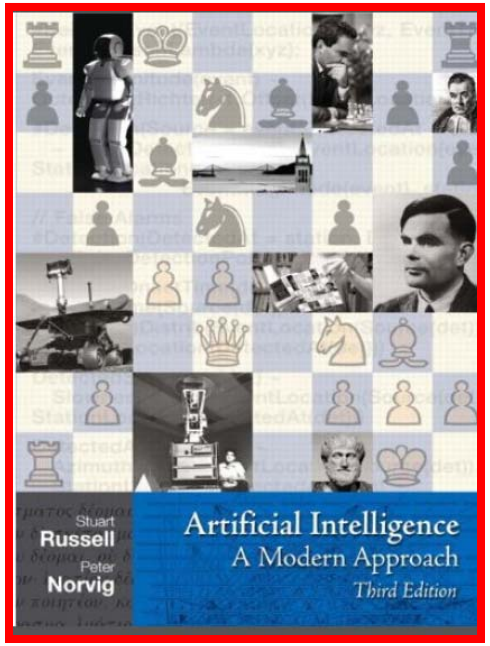


(CHAPTER-12)
KNOWLEDGE REPRESENTATION

Yanmei Zheng

Some General Representations

1. **Logical Representations**
2. **Production Rules**
3. **Semantic Networks**
   - **Conceptual graphs, frames, scripts**
4. ***Description Logics*** **(not covered in this course)**

Non-Logical Representations?

Non-Logical Representations?

1. Production rules
2. Semantic networks
    - Conceptual graphs
    - Frames
    - Scripts

Production Rules

Production Rules

- Rule set of <condition,action> pairs
  - ✓ "if condition then action"
- Match-resolve-act cycle
  - ✓ Match: Agent checks if each rule's condition holds
  - ✓ Resolve:
    - Multiple production rules may fire at once (conflict set)
    - Agent must choose rule from set (conflict resolution)
  - ✓ Act: If so, rule "fires" and the action is carried out

Rules

If Animal has hair
And Animal produces milk
Then animal is a mammal

IF	animal has feather,
THEN	animal is bird.

IF	animal flies,
AND	animal lays eggs,
THEN	animal is bird.

IF the interest-rate out look is down,

THEN do not buy money-market funds..

Rules-of-Thumb

- An apple a day keeps the doctor away .
- A stitch in time saves nine .

Fuzzy Rules

IF you're old,

THEN you have owned several homes .

IF you have owned several homes THEN you have had numerous headaches .

IF the interest-rate out look is up and the risk you can accept is low,

THEN buy a conservative money-market fund .

IF the interest-rate out look is up and the risk you can accept is high,

THEN buy aggressive money-market fund .

Rules with certainty factors

IF the patient is sneezing,

AND has a runny nose,

AND has watery eyes,

THEN the patient has cold, CF=0.5 .

Production Rules Example

- IF (at bus stop AND bus arrives)
  THEN action(get on the bus)

- IF (on bus AND not paid AND have oyster card)
  THEN action(pay with oyster) AND add(paid)

- IF (on bus AND paid AND empty seat)
  THEN sit down

Inference Engine

- **The inference engine** is a generic control mechanism for navigating through and manipulating knowledge and **deduce results** in an organized manner

- It applies a specific task take data and drive conclusions
- The inference engine is the part of the system that chooses which facts and rules to apply when trying to solve the user's query

Inference Engine

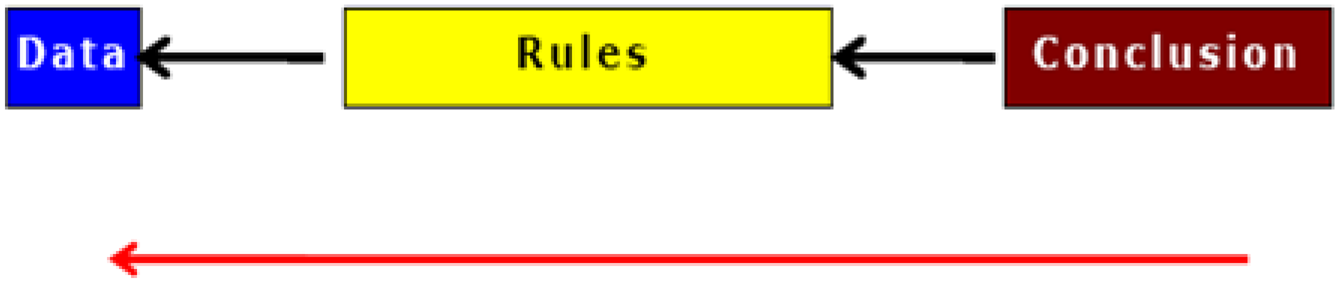
- The **forward chaining** , **backward chaining** and **tree search** are some of the techniques used for drawing inferences from the knowledge base

Inferences from rules

1. Goal driven = **backward chaining**
2. Data driven= **forward chaining**

➢ Goal driven or backward chaining

An inference technique which uses IF-THEN rules to repetitively break a goal into smaller sub-goals which are easier to prove



Example : KB contains Rule set :

Rule 1: if A and C   Then F
Rule 2: if A and E   Then G
Rule 3: if B   Then E
Rule 4: if G   Then D

Problem: prove
If A and B true   Then D is true

Example : KB contains Rule set :

Rule 1: if A and C Then F
Rule 2: if A and E Then G
Rule 3: if B then E
Rule 4: if G then D

Problem: prove
If A and B true
Then D is true

- **Solution :**

(i)
- Start with goal ie **D** is true
- go backward/up till a rule "fires" is found.

First iteration :

(ii)
- **Rule 4** fires :
- new sub goal to prove **G** is true
- go backward

(iii)
- **Rule 2** "fires"; conclusion: **A** is true
- new sub goal to prove **E** is true
- go backward;

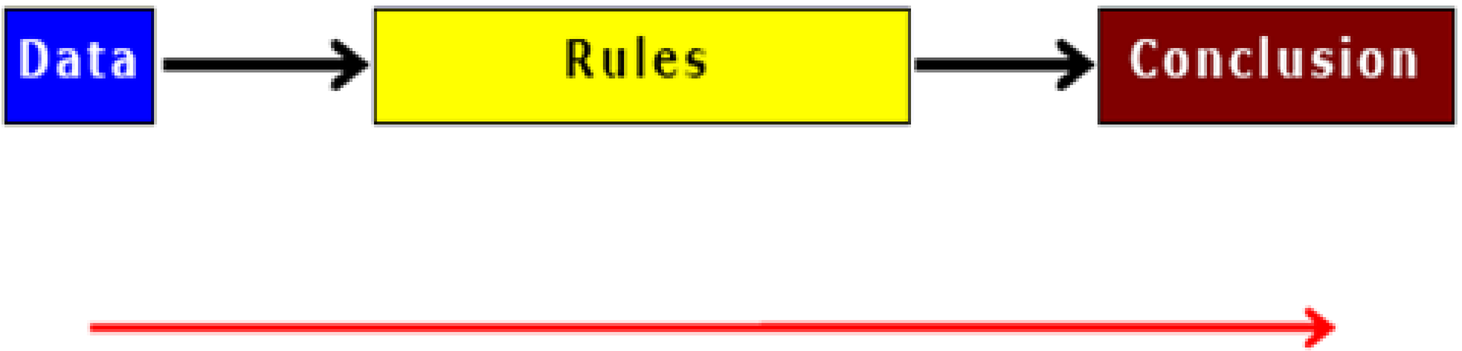
(iv)
- no other rule fires; end of first iteration.
- new sub goal found at (iii);
- go for second iteration

Second iteration :

(v)
- **Rule 3** fires :
- conclusion **B** is true (2nd input found)
- both inputs **A** and **B** ascertained
- Proved

➢ Data driven or Forward chaining

An inference technique which uses IF-THEN rules to deduce a problem solution from initial data



Example : KB contains Rule set :

Rule 1: if A and C Then F
Rule 2: if A and E Then G
Rule 3: if B then E
Rule 4: if G then D

Problem: prove
If A and B true
Then D is true

Example : KB contains Rule set :

Rule 1: if A and C Then F
Rule 2: if A and E Then G
Rule 3: if B then E
Rule 4: if G then D

Problem: prove
If A and B true
Then D is true

- **Solution** :

(i) ‡ Start with input given **A, B** is true and then
‡ start at **Rule 1** and go forward/down till a rule "fires" is found.

First iteration :

(ii) ‡ **Rule 3** fires : conclusion **E** is true
‡ new knowledge found

(iii) ‡ No other rule fires;
‡ end of first iteration.

(iv) ‡ Goal not found;
‡ new knowledge found at (ii);
‡ go for second iteration

Second iteration :

(v) ‡ **Rule 2** fires : conclusion **G** is true
‡ new knowledge found

(vi) ‡ **Rule 4** fires : conclusion **D** is true
‡ Goal found;
‡ Proved

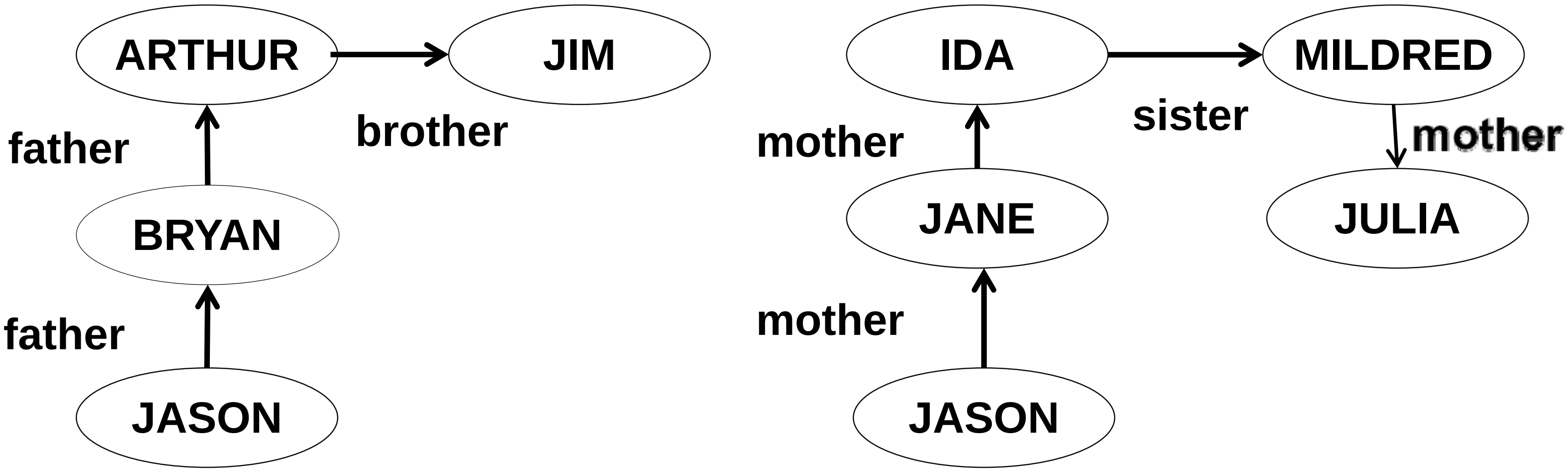
Advantages of Rules

- Rules are easy to understand
- Inference and explanation are easy to derive
- Modifications and maintenance are relatively easy
- Uncertainty is easily combined with rules
- Each rule is usually independent of all others

Semantic network

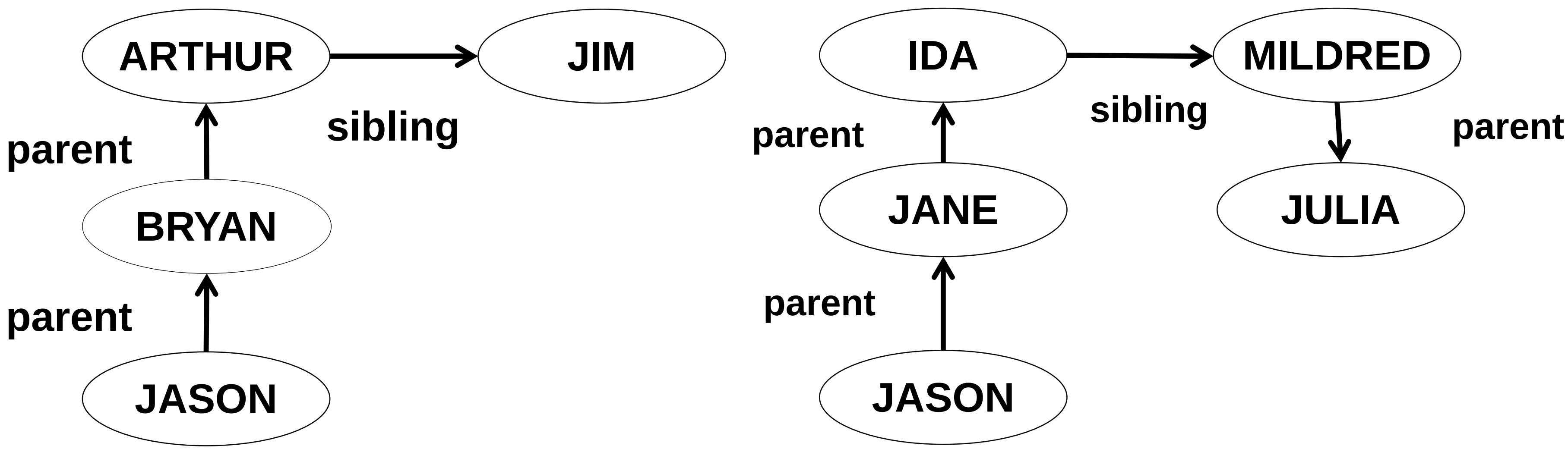
Graphical Representation

- Graphs easy to store in a computer
- To be of any use must impose a formalism



- ✓ Jason is 15, Bryan is 40, Arthur is 70, Jim is 74
- ✓ How old is Julia?

Semantic Networks



- Because the syntax is the same
  - ✓ We can guess that Julia's age is similar to Bryan's
- Formalism imposes restricted syntax

Semantic network{12.5.1}

- Common sense: important, huge amount
- R.Quillian1968
- Underlying concepts：
  - ✓ Node: objects, states, properties,…
  - ✓ Line: relation
- The significant flag is semantics.

Semantic network{12.5.1}

- **Organizing & reasoning with categories**
  - ✓ **The *semantic networks* approach**
  - ✓ **Conveniently represents**
    - **Objects and categories of objects**
    - **Plus some relations among them**
  - ✓ **Was originally proposed (early 20th century)**
    - **As an alternative to conventional logic**
  - ✓ **Semantic network approach**
    - **Turns out, when fully analyzed is actually a form of logic with an alternative notation, syntax**

Semantic network{12.5.1}

Semantic networks

- ✓ Visualize the knowledge base as a graph
  - Nodes (bubbles) are categories & individual objects
  - Links are Subset & MemberOf relations
- ✓ This type of representation
  - Allows very efficient algorithms, for category membership inference
  - Just follow links upward

Semantic Networks

- Graphical representation (a graph)
  - ✓ Links indicate subset, member, relation, ...
- Equivalent to logical statements (usually FOL)
  - ✓ Easier to understand than FOL?
- Example: natural language understanding
  - ✓ Sentences with same meaning have same graphs
  - ✓ e.g. Conceptual Dependency Theory (Schank)

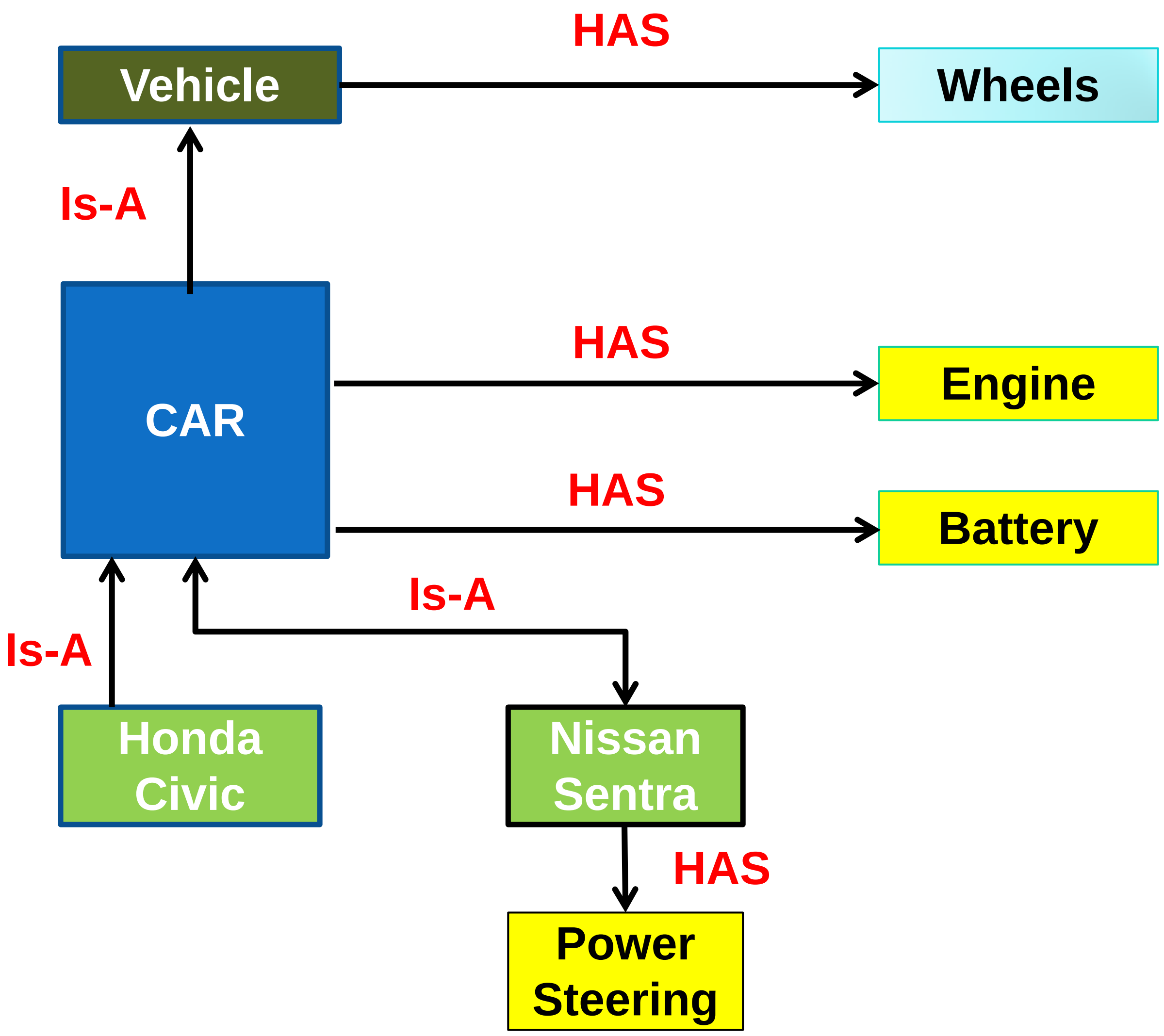
Semantic Networks

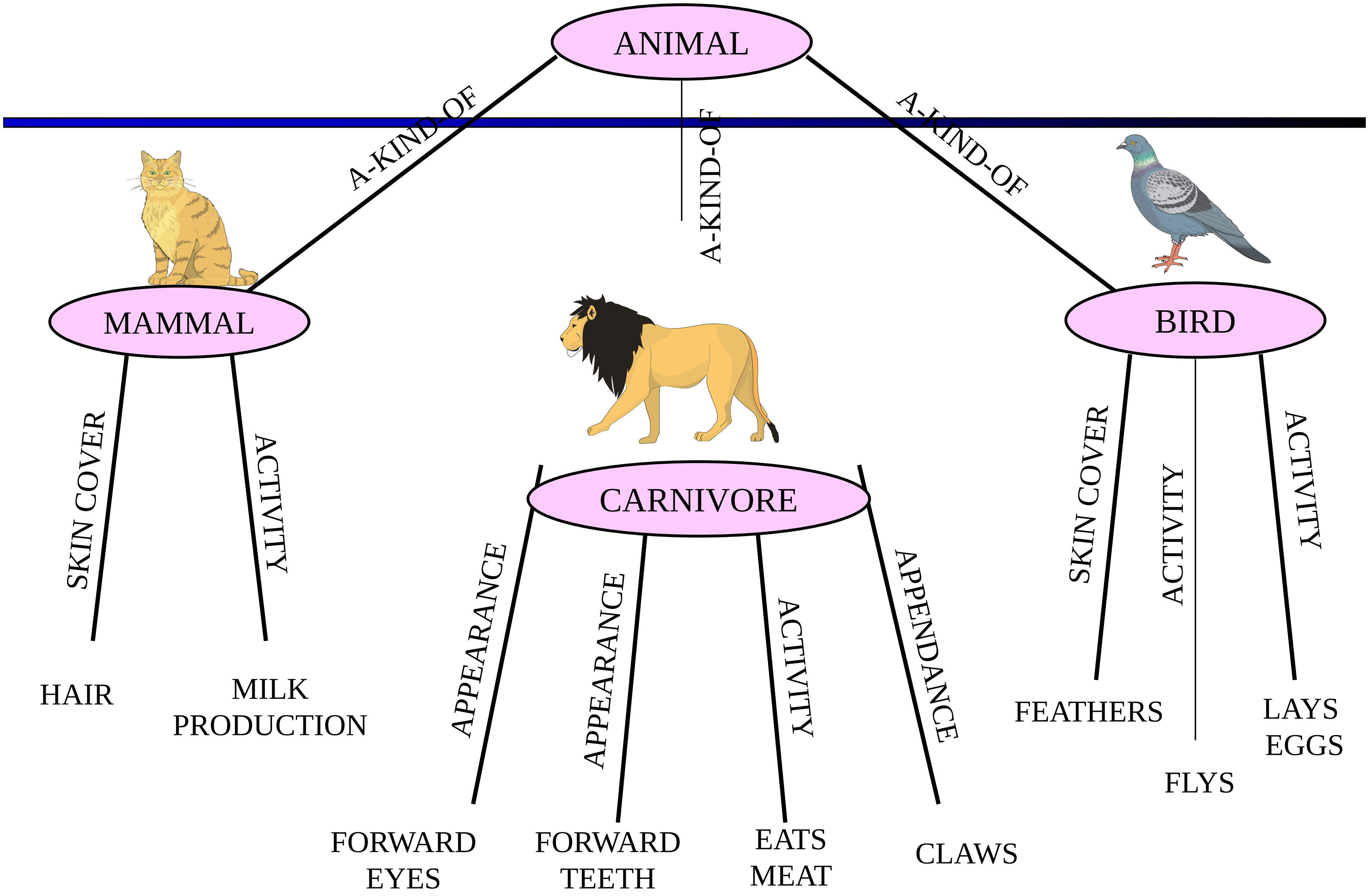
In this scheme , knowledge is represented in terms of objects and relationships between objects

The objects are denoted as nodes of a graph. The relationship between two objects are denoted as a link between the corresponding two nodes

The most common form of semantic network uses the link between nodes to represent IS-A and HAS relationships between objects

Example of semantic network





A Semantic network for animal kingdom

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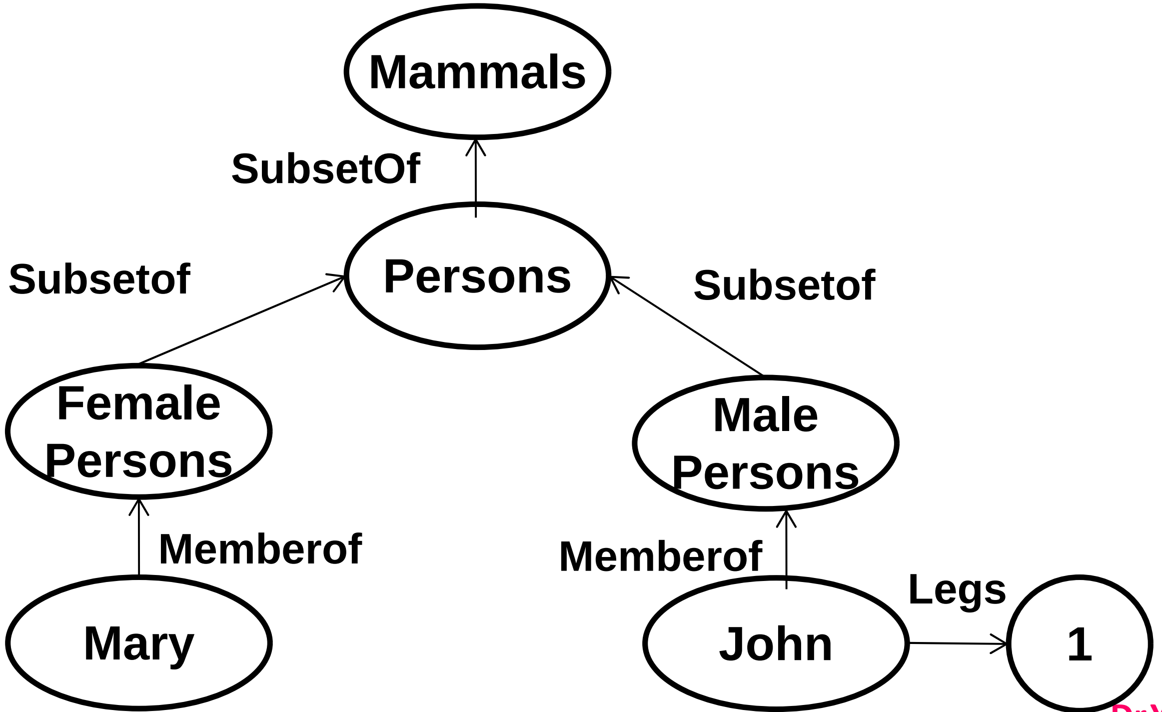
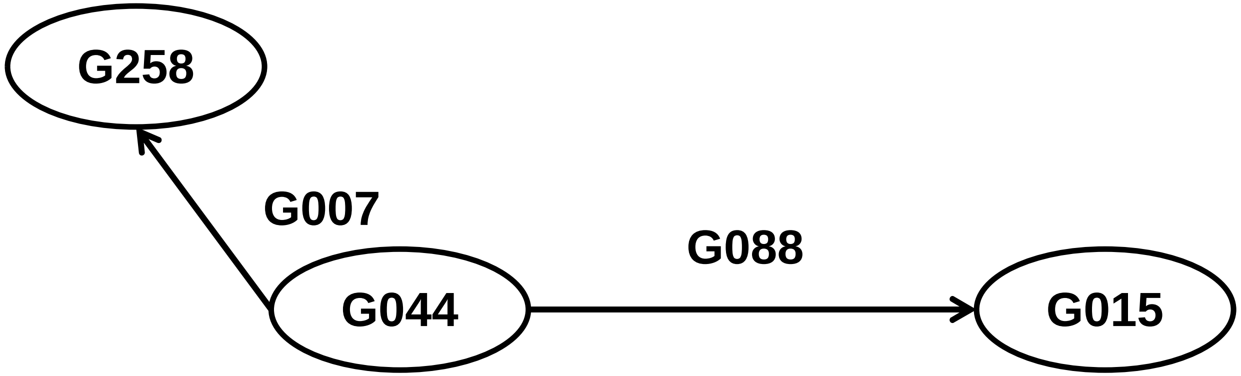
Semantic Networks

- Inheritance reasoning in semantic nets
  - ✓ Follow MemberOf & SubsetOf links
    - up the hierarchy
  - ✓ Stop at the category with a property link
    - to infer the property for an individual



Semantic network?{12.5.1}

a



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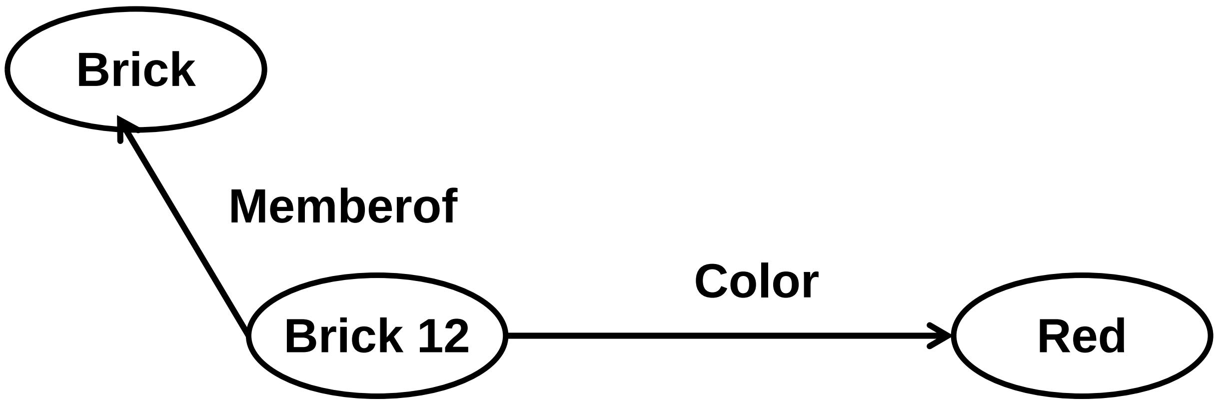

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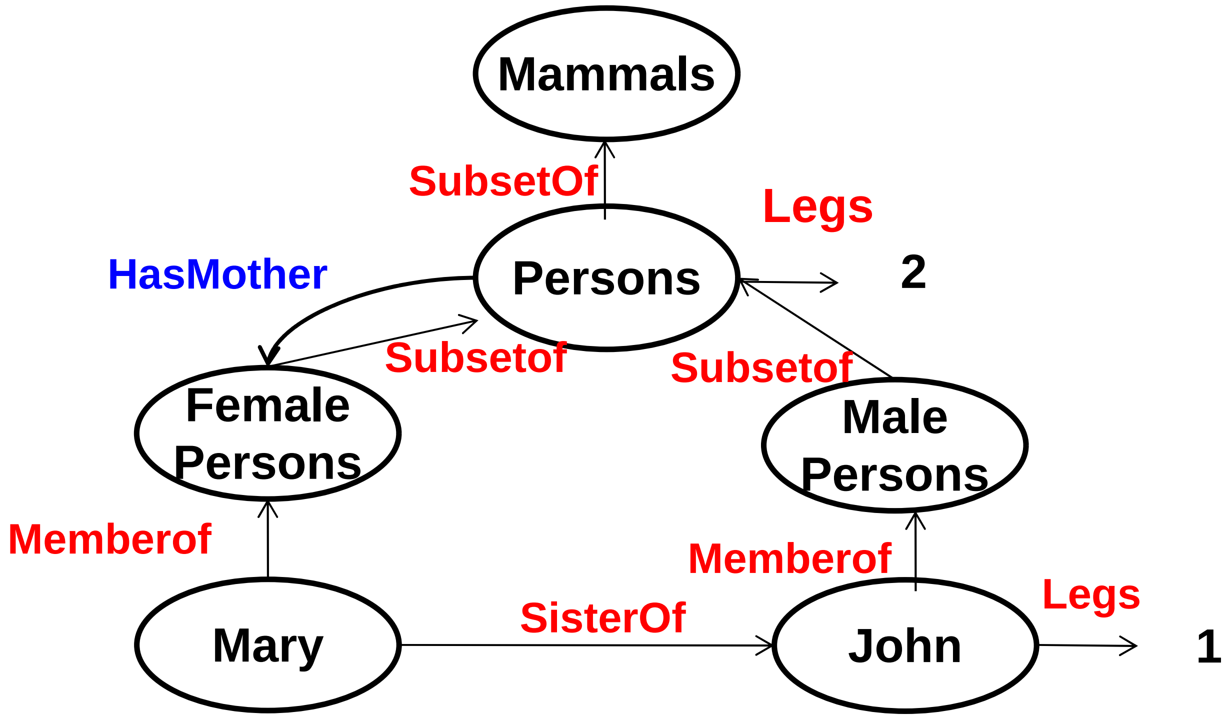
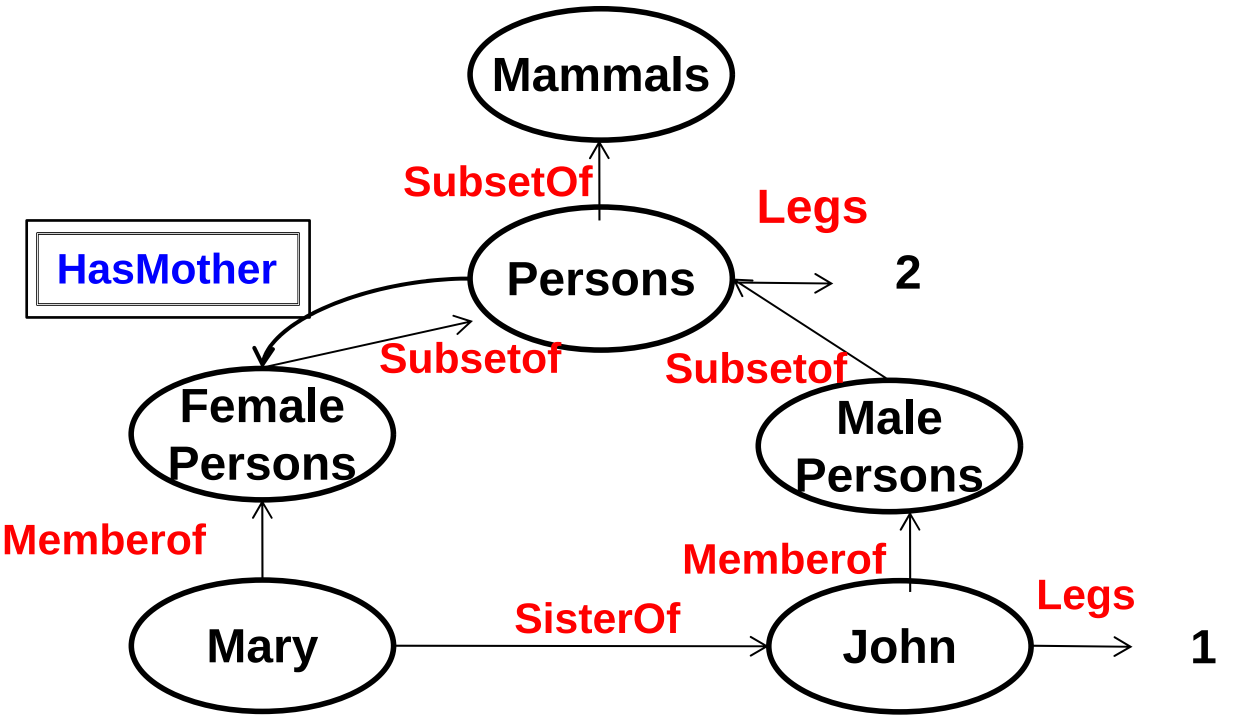
Semantic Networks

- The representation allows other relations
  - ✓ to be captured in additional arcs



Semantic Networks

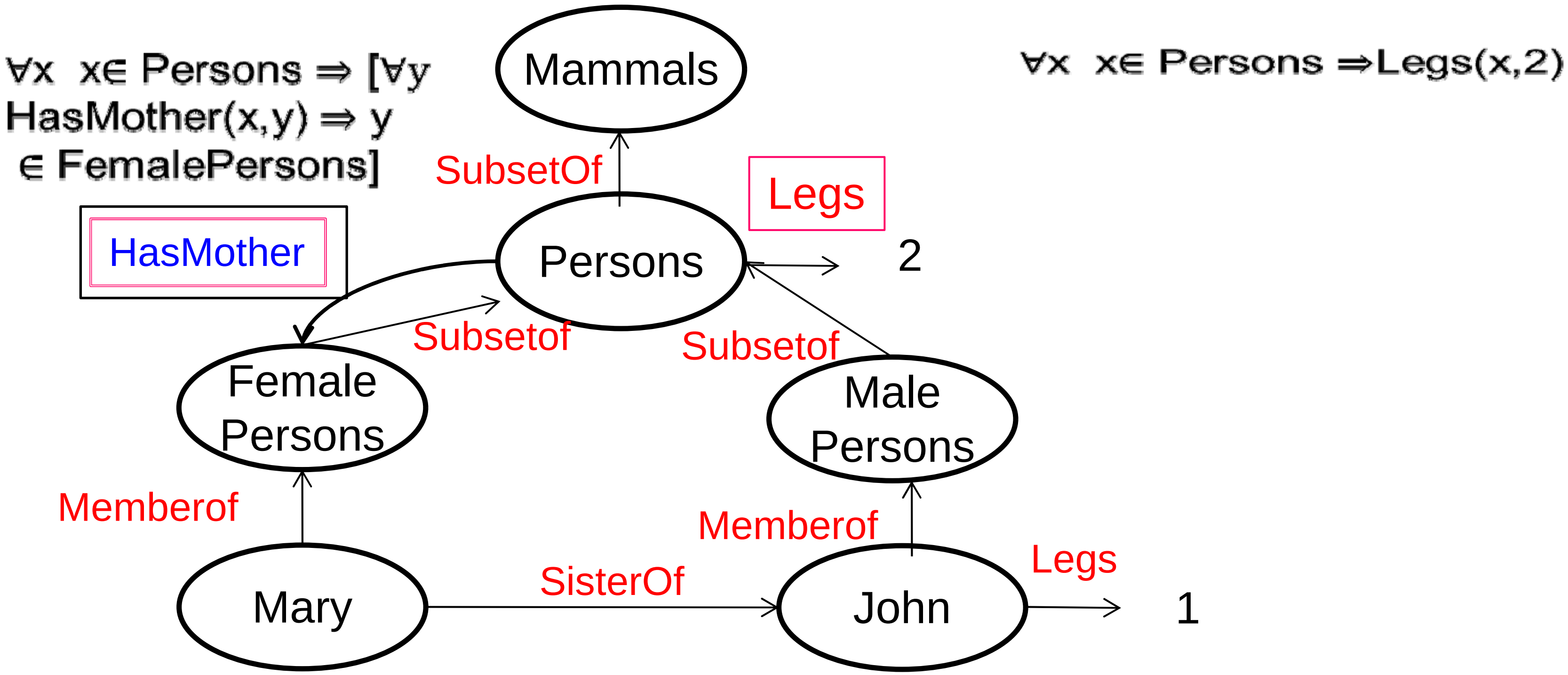
- Inheritance reasoning in semantic nets
  - ✓ An example: the HasMother relation
    - Applies between individuals, not categories
    - This is indicated by the double box special notation



Semantic Networks

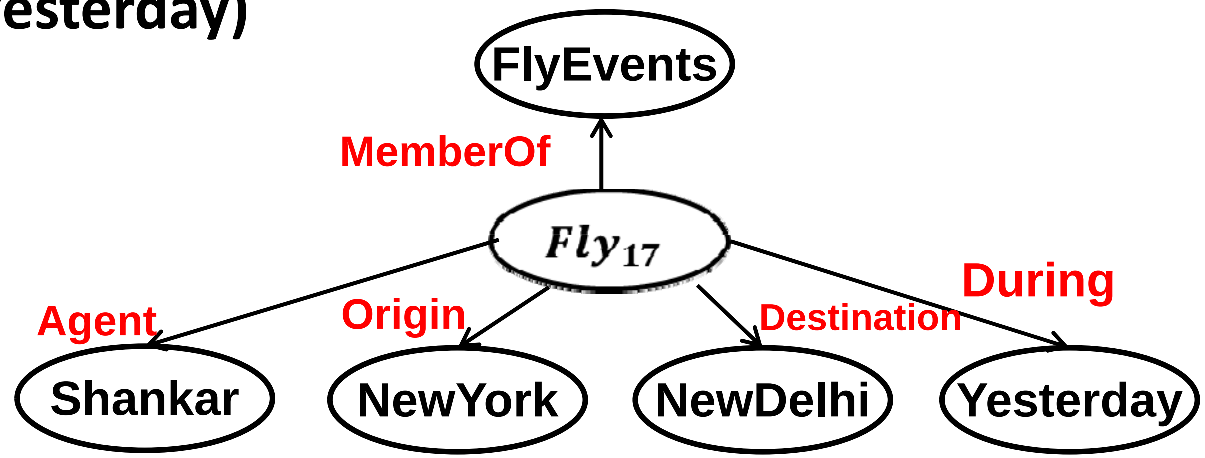
- Inheritance reasoning in semantic nets
  - ✓ Multiple MemberOf, SubsetOf links are possible
    - But multiple inheritance may produce conflicting values
  - ✓ Properties of every member of a category
    - Are indicated by the single box notation
  - ✓ Standard links represent binary relations

Semantic Networks



Semantic Networks

- Inheritance reasoning in semantic nets
  - ✓ Standard links represent *binary* relations
    - n-ary relations can be represented
    - Example: Fly (Shankar, NewYork, NewDelhi, Yesterday)
    - Process for representing n-ary relations involves
      - Reifying the proposition as an event in an appropriate event category so Fly (Shankar, NewYork, NewDelhi, Yesterday)

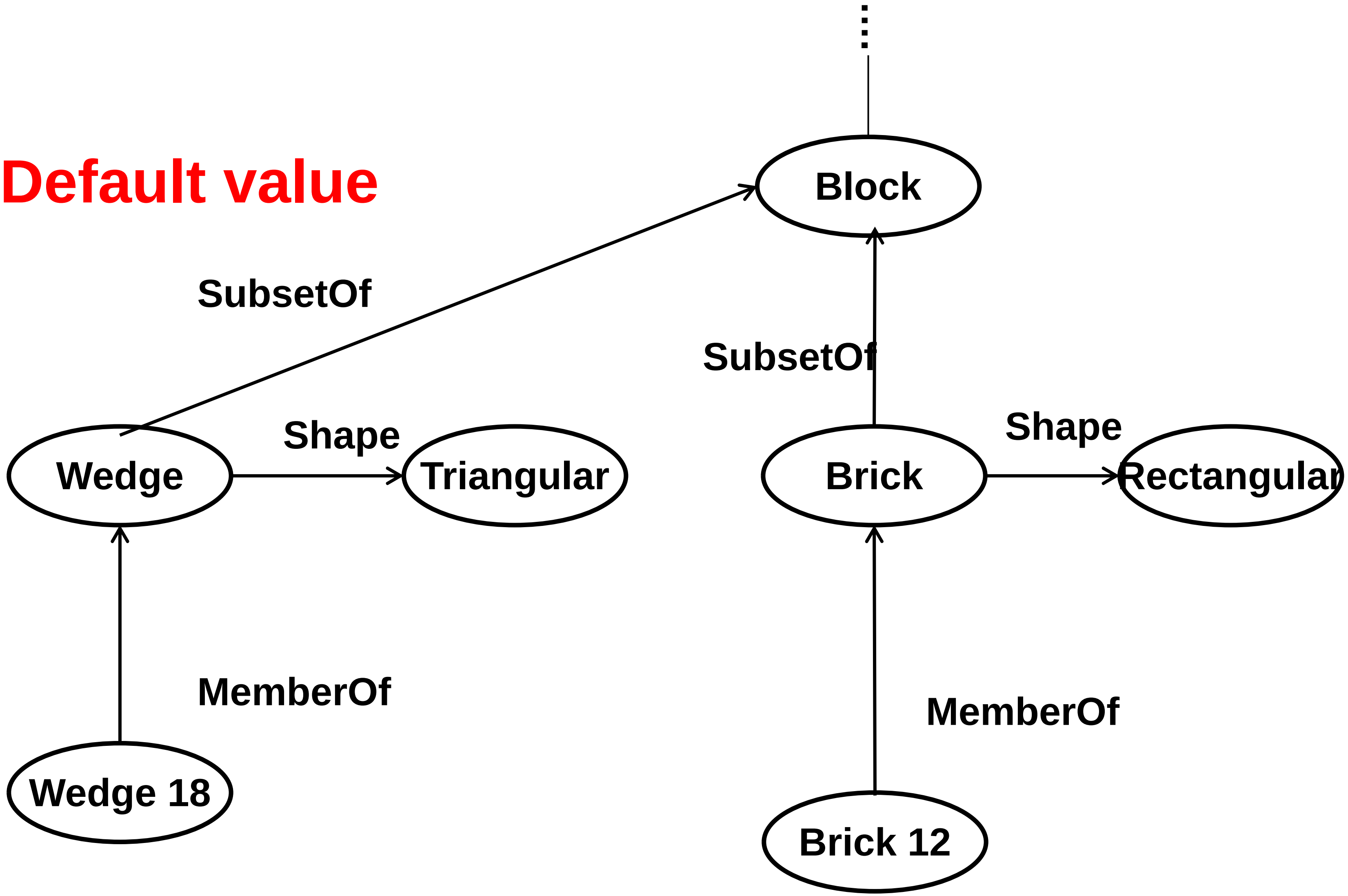


Examples{12.5.1}

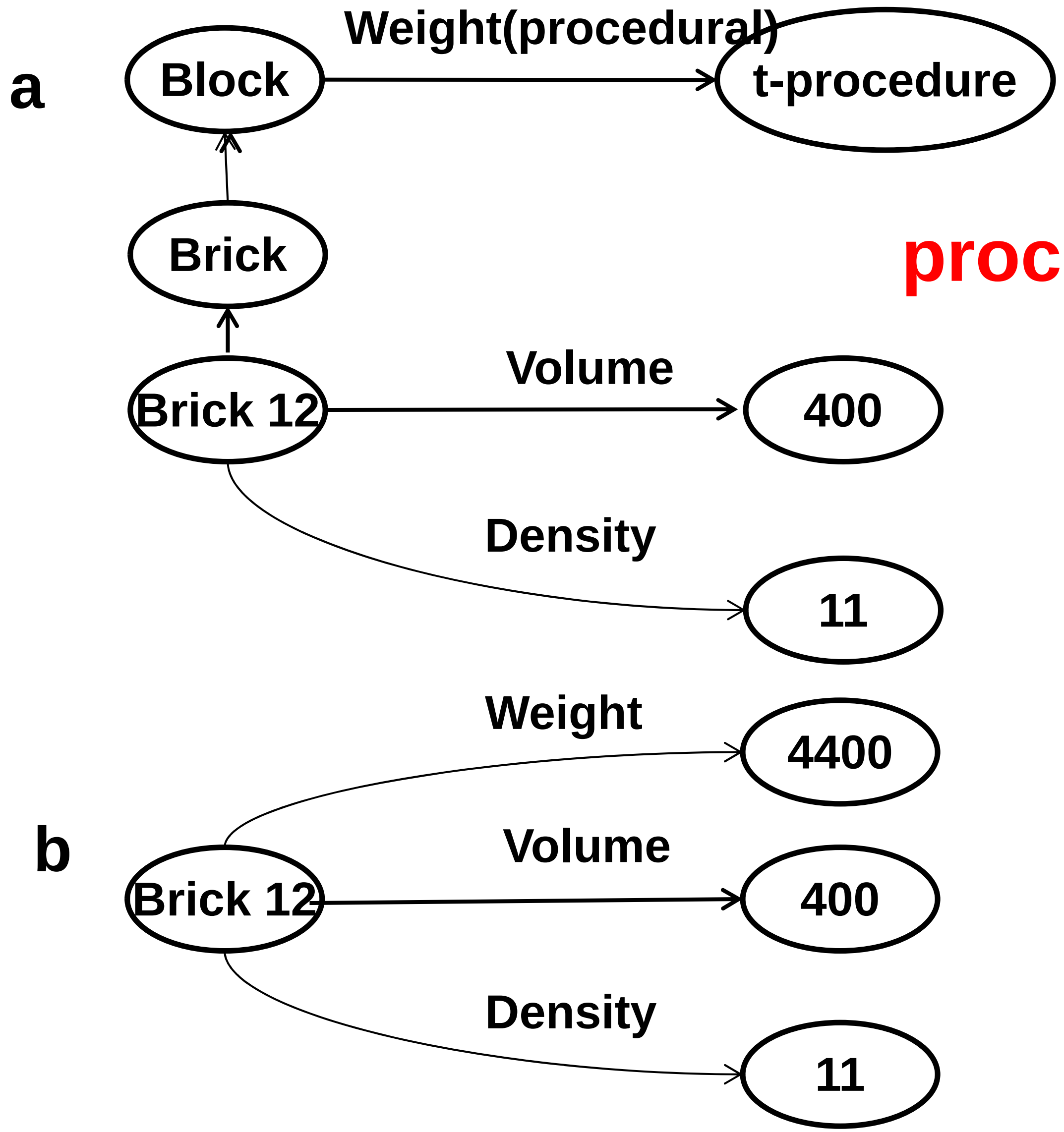
- Sweedy is a swallow, a swallow is a bird. Sweedy has a nest N1 which is an instantiation of nest.
- object-centered semantic relation: MemberOf、SubsetOf、properties、partof

Basis of semantic network{12.5.1}

Default value



Basis of semantic network{12.5.1}



procedural

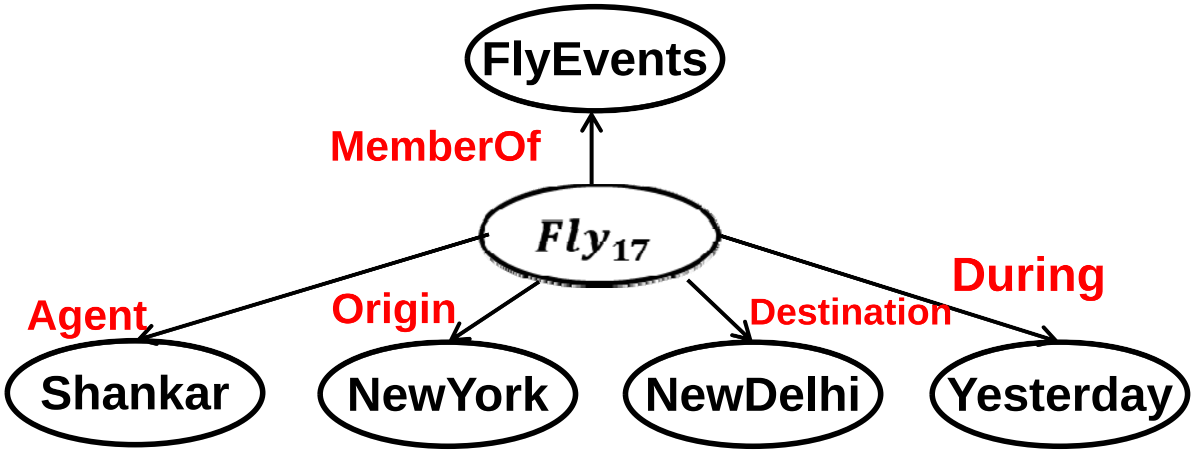
Semantic network & FOL {12.5.1}

MemberOf(LIMING,MAN) or MAN(LIMING)

(FOL)

FOL and Semantic Network {12.5.1}

- Fly (Shankar, NewYork, NewDelhi, Yesterday)



Semantic network & FOL {12.5.1}

$\boxed{\text{LIMING}} \xrightarrow{\text{MemberOf}} \boxed{\text{MAN}}$ （Semantic network）

$\boxed{\text{MemberOf(LIMING,MAN)orMAN(LIMING)}}$ （ FOL ）

Semantic Networks

- The semantic net advantages
  - ✓simplicity of inference
  - ✓ease of visualizing, even for large nets
  - ✓ease of representing default values for categories
  - ✓ ease of overriding defaults by more specific values
- ✓ but, awkward or impossible
  - ☹ to capture many of FOL's representational capabilities
  - ☹ negation, disjunction, existential quantification, ...
  - ☹ when extended to do so, it loses its attractive simplicity

Frames

Frames

- **In this technique, knowledge is decomposed into highly modular pieces called frames, which are generalized record structures**

- **Knowledge consist of concepts, situation, attributes of concepts , relationships between concepts , and procedure to handle relationships**

Frames

- Each concept may be represented as a separate frame
- The attributes, the relationships between concepts and the procedures are allotted to slots in a frame
- The contents of a slot may be of any data type –numbers, strings, functions or procedures and so on
- The frames may be linked to other frames, providing the same kind of inheritance as that provided by a semantic network

Frame Representations

- **Semantic networks where nodes have structure**
  - ✓ Frame with a number of slots (age, height, ...)
  - ✓ Each slot stores specific item of information
- **When agent faces a new situation**
  - ✓ Slots can be filled in (value may be another frame)
  - ✓ Filling in may trigger actions
  - ✓ May trigger retrieval of other frames
- **Inheritance of properties between frames**
  - ✓ Very similar to objects in OOP

Frames

- **Basic frame design**

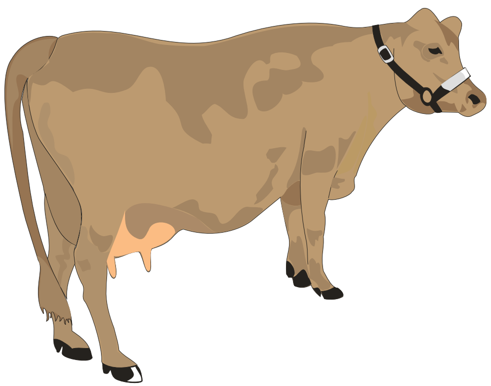
Frame Name:	*Object1*	
Class:	*Object2*	
Properties:	**Property1**	**Value1**
	Property2	**Value2**
	***	***
	***	***

Frame Representation of the “animal kingdom”

MAMMAL

A-KIND-OF	ANIMAL

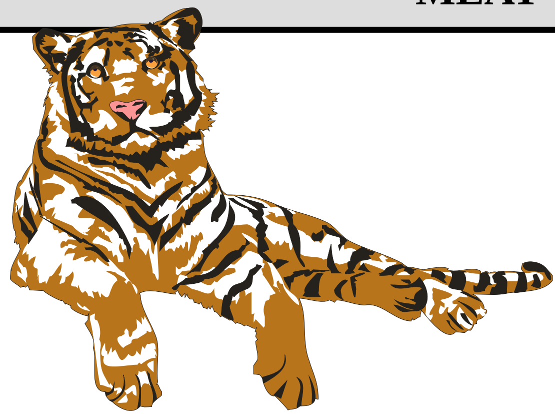
SKIN COVER	HAIR
ACTIVITY	PRODUCES MILK



CARNIVORE

A-KIND-OF	ANIMAL

APPEARANCE	FORWARD EYES POINTED TEETH
APPENDAGES	CLAWS
ACTIVITY	EATS MEAT



BIRD

A-KIND-OF	ANIMAL

SKIN COVER	FEATHER
ACTIVITY	FLY LAYS EGGS

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Chair frame

9 £99.99
INCLUDES FREE HOME DELIVERY
10 £139.99
INCLUDES FREE HOME DELIVERY
AVAILABLE AS A SUITE
11 £299.95
INCLUDES FREE HOME DELIVERY
SAVE £40
AS A 3 PIECE SUITE

Flexibility in Frames

- **Slots in a frame can contain**
  - ✓ Information for choosing a frame in a situation
  - ✓ Relationships between this and other frames
  - ✓ Procedures to carry out after various slots filled
  - ✓ Default information to use where input is missing
  - ✓ Blank slots: left blank unless required for a task
  - ✓ Other frames, which gives a hierarchy

Description logics

- **Are designed to describe defintions and properties about categories**
  - **A formalization of semantic networks**
- **Principal inference task is**
  - ***Subsumption*: checking if one category is the subset of another by comparing their definitions**
  - ***Classification*: checking whether an object belongs to a category.**
  - **Consistency: whether the category membership criteria are logically satisfiable.**

Thank you

End of Chapter 12