



Knowledge Representation and Reasoning (KRR)

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Knowledge Representation

- Propositional Logic
- **Predicate Logic (chapter 8)**
- Semantic Networks
- Frames
- Fuzzy Logic



Predicate Logic

❑ Basic Concepts

- Logical expressions are built out of components:
 - Objects (Constants)
 - Variables
 - Functions
 - The above three are called ***Terms***
- Predicates
- Connectives
- Quantifiers

Predicate Logic

□ Objects:

- Symbols that denote specific things or individuals:

- JOHN
- MARY
- BASKETBALL
- TRIANGLE
- Quantifiers

□ Variables:

- Unspecific references to objects

- x
- y
- z

Predicate Logic

□ Functions:

- An argument to a function is either an object or a variable
 - Starting with a lowercase letter
- The value of a function is either an object or a variable

$$\exp(0) = 1$$

next-day(THURSDAY) = FRIDAY

brother(JOHN) = JIM

Predicate Logic

❑ Predicates (or functions returning True/False):

- Functions which denote attributes of objects or relationships between individuals

- Starting with a uppercase letter

Loves(JOHN, MARY)

Man(SOCRATES)

Sunny(THURDAY)

Predicate Logic

□ Logical Connectives:

- AND (\wedge)
- OR (\vee)
- NOT (\sim)
- IMPLIES (\rightarrow)

Predicate Logic

□ Quantifiers:

- Logical operators which assert the scope of a predicate
 - \forall For All (universal quantifier)
 - \exists There Exists (existential quantifier)

Predicate Logic

- In predicate logic the basic unit is a **predicate/argument** structure called an atomic sentence:
 - LIKES (azad, chocolate)
 - TALL (habib)
- Arguments can be any of:
 - constant symbol, such as ‘azad’
 - variable symbol, such as x
 - function expression, e.g., FATHER_OF (hasan)
- So we can have:
 - LIKES (X, chocolate)
 - FRIENDS (FATHER_OF (rita), FATHER_OF (choiti))

Syntax of Predicate Logic

- These atomic sentences can be combined using logic connectives
 - LIKES (rita, hasan) \wedge TALL (hasan)
 - BASKET_BALL_PLAYER (hasan) \Rightarrow TALL (hasan)
- Sentences can also be formed using quantifiers
 - $\forall x$ LOVELY (x) Everything is lovely.
 - $\exists x$ LOVELY (x) Something is lovely.
 - $\forall x$ IN (x, garden) \Rightarrow LOVELY (x) Everything in the garden is lovely.

Predicate Logic: Examples

- All employees earning TK. 30,000 or more per year pay taxes.
- $\forall x ((E(x) \wedge GE(I(x), 30000)) \rightarrow T(x))$
- Some employees are sick today
- $\exists y ((E(y) \rightarrow S(y))$
- No employee earns more than the president
- $\forall x \forall y ((E(x) \wedge P(y)) \rightarrow \neg GE(I(x), I(y)))$

Examples of Predicate Logic

- Can have several quantifiers, e.g.,
 - $\forall x \exists y (\text{LOVES}(x, y))$
 - $\forall x (\text{HANDSOME}(x) \Rightarrow \exists y (\text{LOVES}(y, x)))$
- So we can represent things like:
 - All men are mortal.
 - No one likes hartal.
 - Everyone taking AI will pass their exams.
 - Every race has a winner.
 - Sajjad likes everyone who is tall.
 - Rita doesn't like anyone who prefers arguments.
 - There is something small and slimy on the table.



Examples of Predicate Logic

- Tony, Mike, and John are members of the Alpine Club.
- Every member of the Alpine Club who is not a skier is a mountain climber.
- Mountain climbers do not like rain, and anyone who does not like snow is not a skier.
- Mike dislikes whatever Tony likes, and likes whatever Tony dislikes.
- Tony likes rain and snow.
- Is there a member of the Alpine Club who is a mountain climber but not a skier?

Converting Statements to Predicate Logic

- **Individuals:** Constants (0-ary Functions)

- tony, mike, john
 - rain, snow

- **Types:** Unary Predicates

- $AC(x)$: x belongs to Alpine Club.
 - $S(x)$: x is a skier.
 - $C(x)$: x is a mountain climber.

- **Relationships:** Binary Predicates

- $L(x; y)$: x likes y .

Converting Statements to Predicate Logic

- Basic Facts:

- Tony, Mike, and John belong to the Alpine Club:

- $AC(\text{tony}); AC(\text{mike}); AC(\text{john})$

- Tony likes rain and snow:

- $L(\text{tony}, \text{rain}); L(\text{tony}, \text{snow})$

Converting Statements to Predicate Logic

- **Complex Facts:**

- Every member of the Alpine Club who is not a skier is a mountain climber.

$$\forall x [AC(x) \wedge \sim S(x) \Rightarrow C(x)]$$

- Mountain climbers do not like rain, and anyone who does not like snow is not a skier

$$\forall x [C(x) \Rightarrow \sim L(x, \text{rain})] \wedge \forall x [\sim L(x, \text{snow}) \Rightarrow \sim S(x)]$$

- Mike dislikes whatever Tony likes, and likes whatever Tony dislikes.

$$\forall x [L(\text{tony}, x) \Rightarrow \sim L(\text{mike}, x)] \wedge \forall x [\sim L(\text{tony}, x) \Rightarrow L(\text{mike}, x)]$$

- Is there a member of the Alpine Club who is a mountain climber but not a skier?

$$\exists x [AC(x) \wedge C(x) \wedge \sim S(x)]$$

Converting Statements to Predicate Logic

- Whoever can read is literate.

$$\forall x [read(x) \Rightarrow lit(x)]$$

- Dolphins are not literate.

$$\forall x [dolph(x) \Rightarrow \sim lit(x)]$$

- Flipper is an intelligent dolphin.

$$Dolph(flip) \wedge intell(flip)$$

- Who is intelligent but cannot read? (Whoever that is intelligent but cannot read is the answer)

$$\forall x [(intell(x) \wedge \sim read(x)) \Rightarrow answer(x)]$$

Semantics of Predicate Logic

- There is a precise meaning to expressions in predicate logic.
- Like in propositional logic, it is all about determining whether something is true or false.
- $\forall x P(x)$ means that $P(x)$ must be true for every object x in the *domain of interest*.
- $\exists x P(x)$ means that $P(x)$ must be true for at least one object x in the *domain of interest*.
- So if we have a domain of interest consisting of just two people, Hasan and Belal, and we know that $\text{TALL}(\text{hasan})$ and $\text{TALL}(\text{belal})$ are true, we can say that $\forall x \text{TALL}(x)$ is true.

Problem of FOPL

- It is difficult to represent the following using predicate logic:
 - Time
 - Beliefs and
 - Uncertainty

Knowledge Representation

- Propositional Logic
- Predicate Logic
- **Semantic Networks (chapter-12)**
- Frames
- Fuzzy Logic



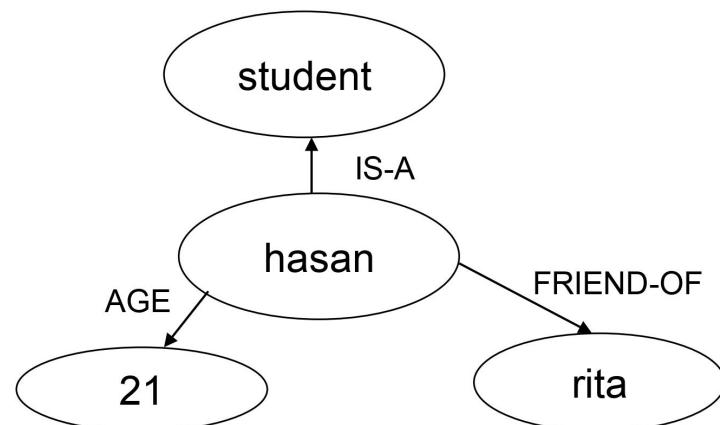
Semantic Network

- Semantic net is a knowledge representation technique which is used to represent knowledge by **some nodes** and **arcs** where:
 - i) Nodes → represent **concepts/objects** and
 - ii) Arcs → represent **relationship**

Semantic Net

- An long existing notion: there are different pieces of knowledge of world, and they are all linked together through certain semantics.
- Knowledge is expressed **as a collection of concepts, represented by nodes** (shown as boxes in the diagram), **connected together by relationships, represented by arcs** (shown as arrows in the diagram).
- Certain arcs - particularly **IS-A** arcs - allow **inheritance** of properties.

- **Basic Components:**
 - Nodes
 - Represent concepts
 - Arcs
 - Represent relations
 - Labels for nodes and arcs

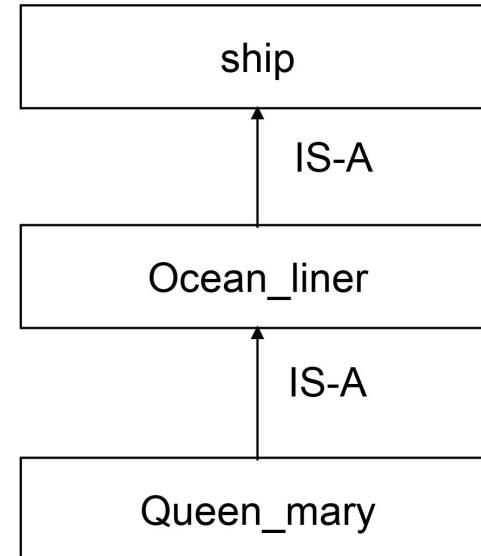


Semantic Net

- Common arcs used for representing hierarchies include *IS-A* and *has-part*.
 - Example:

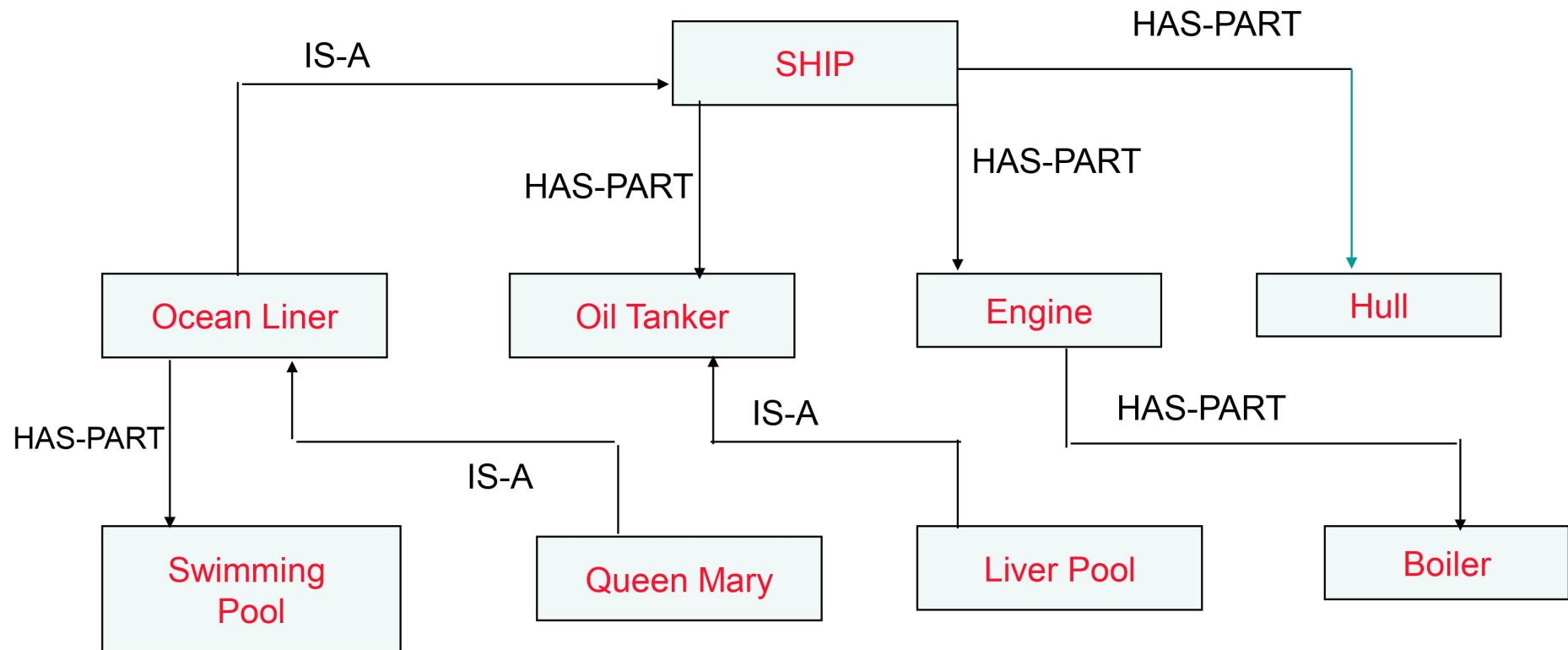
The Queen Mary is an ocean liner.

Every ocean liner is a ship



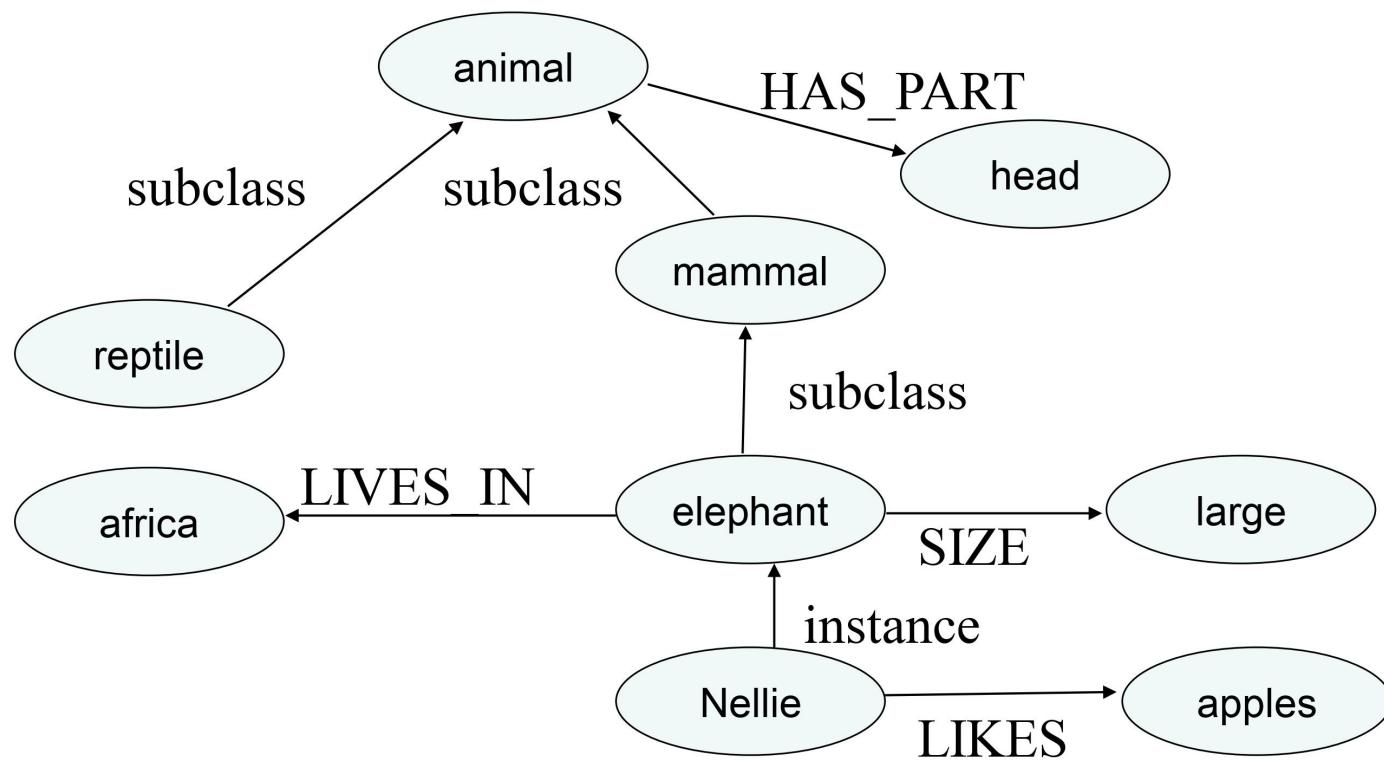
Semantic Net ...

- Common arcs used for representing hierarchies include *is-a* and *has-part*.



Semantic Networks

- Knowledge is represented as a network or *a graph*

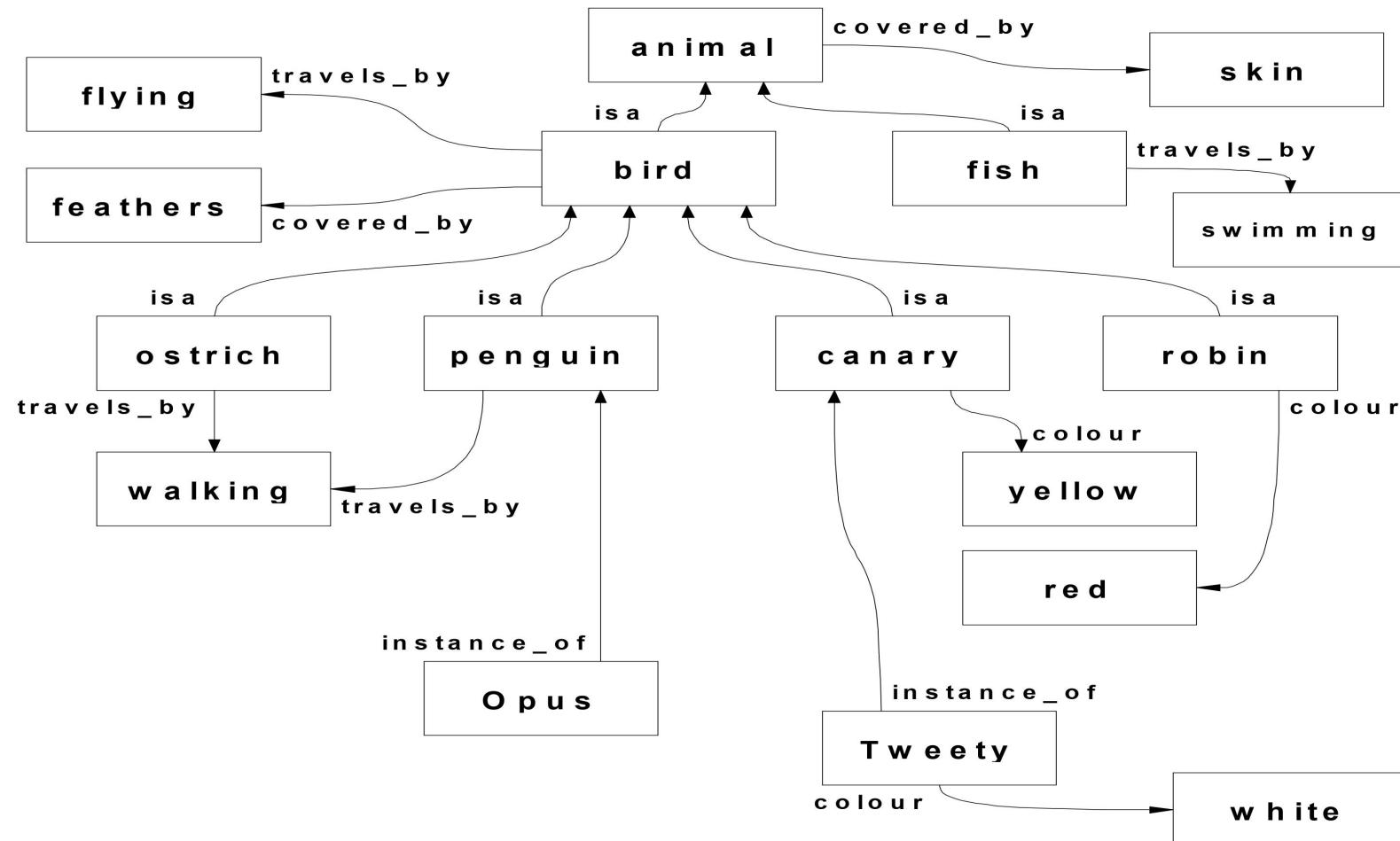


Semantic Net

An long existing notion:

There are different pieces of knowledge of world, and they are all linked together through certain semantics.

Semantic Net



Semantic Net

- Developments of the semantic nets idea:
 - psychological research into whether human memory really was organised in this way.
 - used in the knowledge bases in certain expert systems: e.g. PROSPECTOR.
 - special-purpose languages have been written to express knowledge in semantic nets.

Organization of Knowledge

- By traversing network we can find:
 - That Nellie has a head (by inheritance)
 - That certain concepts related in certain ways (e.g., apples and elephants).
- BUT: Meaning of semantic networks was not always well defined.
 - Are all Elephants big, or just typical elephants?
 - Do all Elephants live in the “same” Africa?
 - Do all animals have the same head?
- For machine processing these things must be defined.

Limitations/Problems

■ Lack of Semantics

- No formal semantic of the relations
 - E.g. Does “IS-A” mean subclass, member, etc?
- Possible multiple interpretations
- Restricted expressiveness
 - E.g. can not distinguish between instance and class

Advantages:

- Easy to follow hierarchy, easy to trace association, flexible

Disadvantages:

- Meaning attached to nodes might be ambiguous
- Exception handling is difficult
- Difficult to program

Semantic Nets ...

- **Problems with semantic nets**
- logical inadequacy - vagueness about what types and tokens really mean.
- heuristic inadequacy – finding a specific piece of information could be chronically inefficient.
- trying to establish negation is likely to lead to a combinatorial explosion.
- "spreading activation" search is very inefficient, because it is not knowledge-guided.

Acknowledgement

- AIMA = Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norving (3rd edition)
- UC Berkeley (Some slides were created by Dan Klein and Pieter Abbeel for CS188 Intro to AI at UC Berkeley)
- U of toronto
- Other online resources

Thank You