Knowledge Representation and Reasoning (KRR-2)

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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 (~)
- 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
- $\forall x \; \forall y \;\; ((E(x) \wedge P(y)) \rightarrow \sim GE((I(x), I(y)))$

Examples of Predicate Logic

- Can have several quantifiers, e.g.,
  - $\forall x \ \exists y$ (LOVES (x, y))
  - $\forall x$ (HANDSOME $(x) \Rightarrow \ \exists y$ (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(**tony**)*; AC*(**mike**)*; AC*(**john**)
  - Tony likes rain and snow:

    L(**tony, rain**)*; L*(**tony, 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) ^ ~ 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) $\Rightarrow$ ~ L (x, rain)] **^** $\forall x$ [~ L (x, snow) $\Rightarrow$ ~ S (x)]

– Mike dislikes whatever Tony likes, **and** likes whatever Tony dislikes.

$\forall x$ [L (tony, x) $\Rightarrow$ ~ L (mike, x)] **^** $\forall x$ [~ L (tony, x) $\Rightarrow$ L (mike, x)]

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

(There are some member of the AC who is mountain climber but not a skier)

$\exists x$ [AC (x) ^ C (x) ^ ~ S (x)]

Converting Statements to Predicate Logic

- Whoever can read is literate.

  $\forall x\ [\text{read}\ (x) \Rightarrow \text{lit}\ (x)]$

- Dolphins are not literate.

  $\forall x\ [\text{dolp}\ (x) \Rightarrow \sim \text{lit}\ (x)]$

- Flipper is an intelligent dolphin.

  Dolp (flip) ^ intell (flip)

- Who is intelligent but cannot read?

(Whoever that is intelligent but cannot read is the answer)

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

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 TALL(hasan) and TALL(belal) are true, we can say that $\forall x$ 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

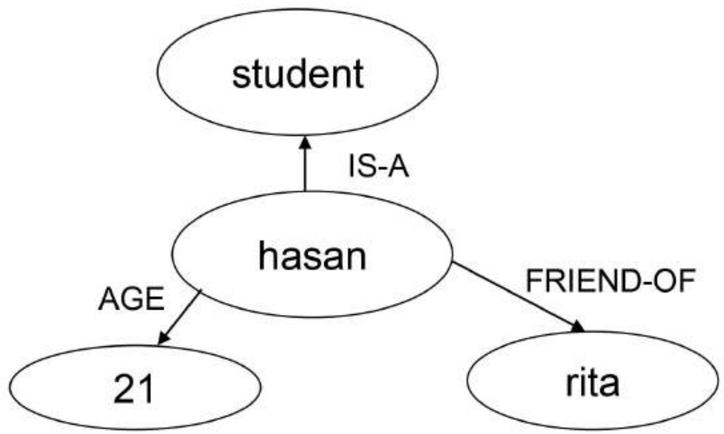
- Semantic net is a knowledge representation technique which is used to represent knowledge by some nodes and arcs where:

  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

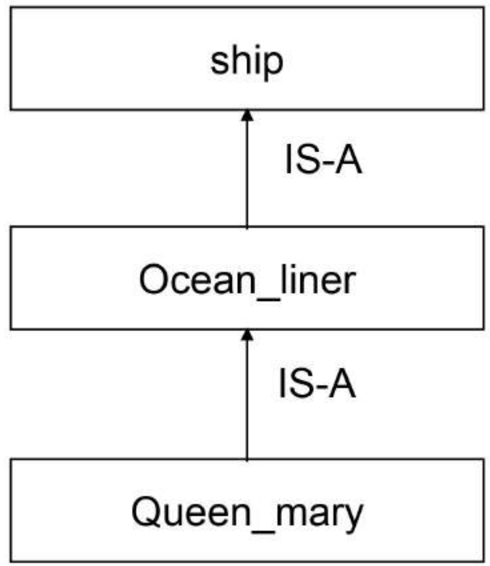


Semantic Net

- 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 …

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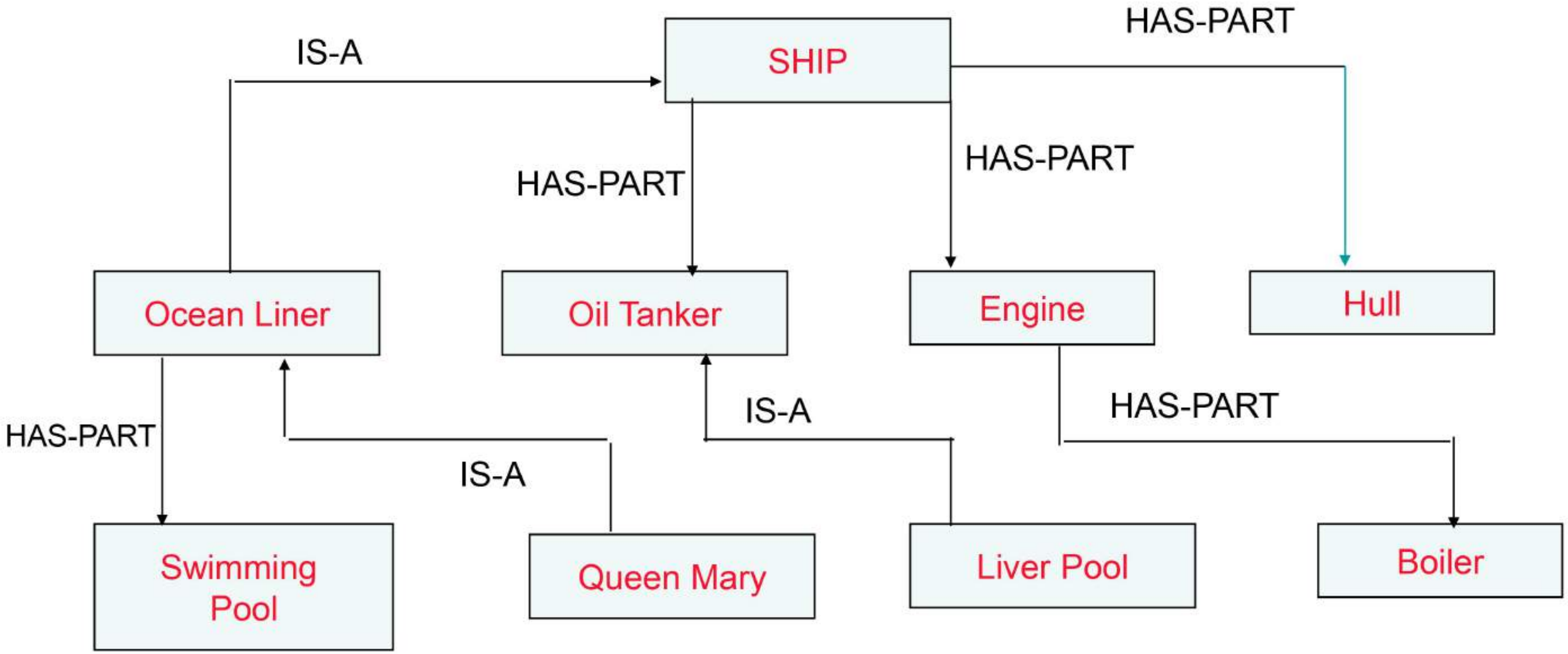
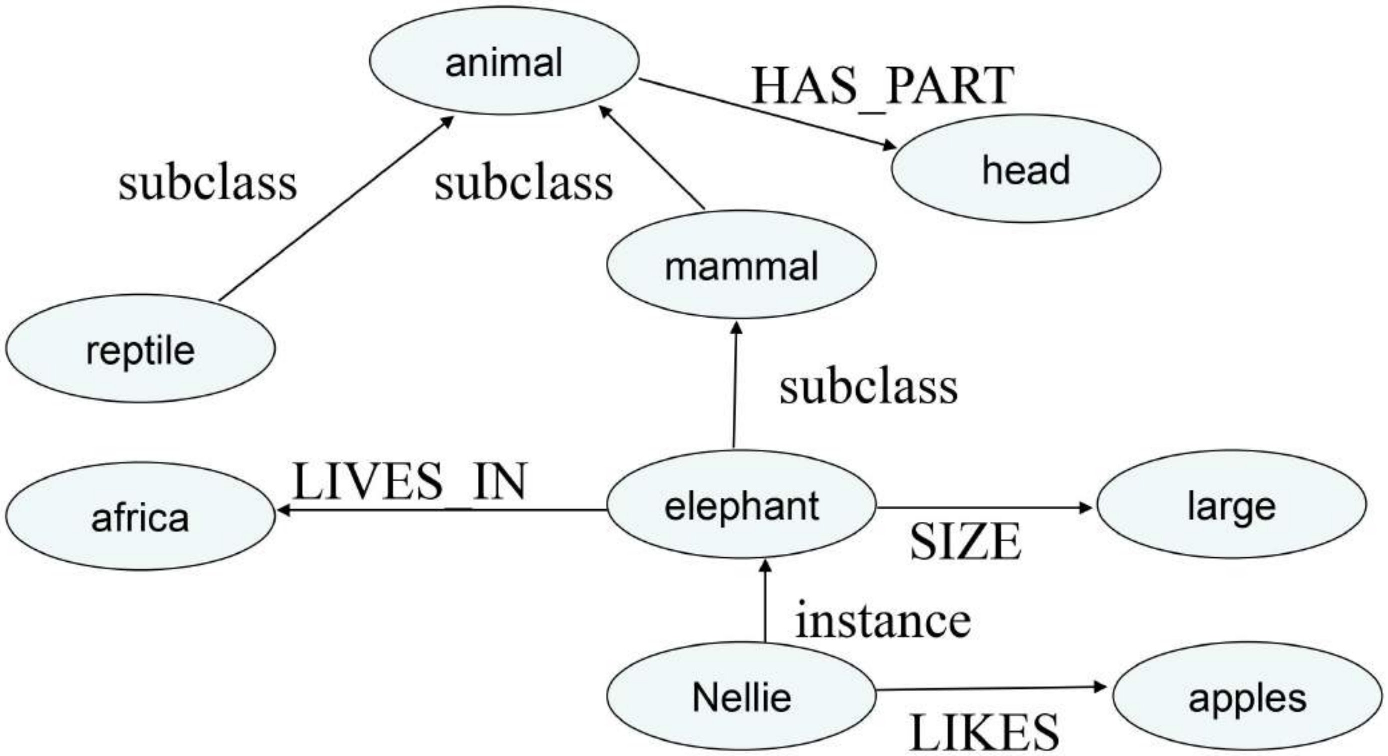


Semantic Networks

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

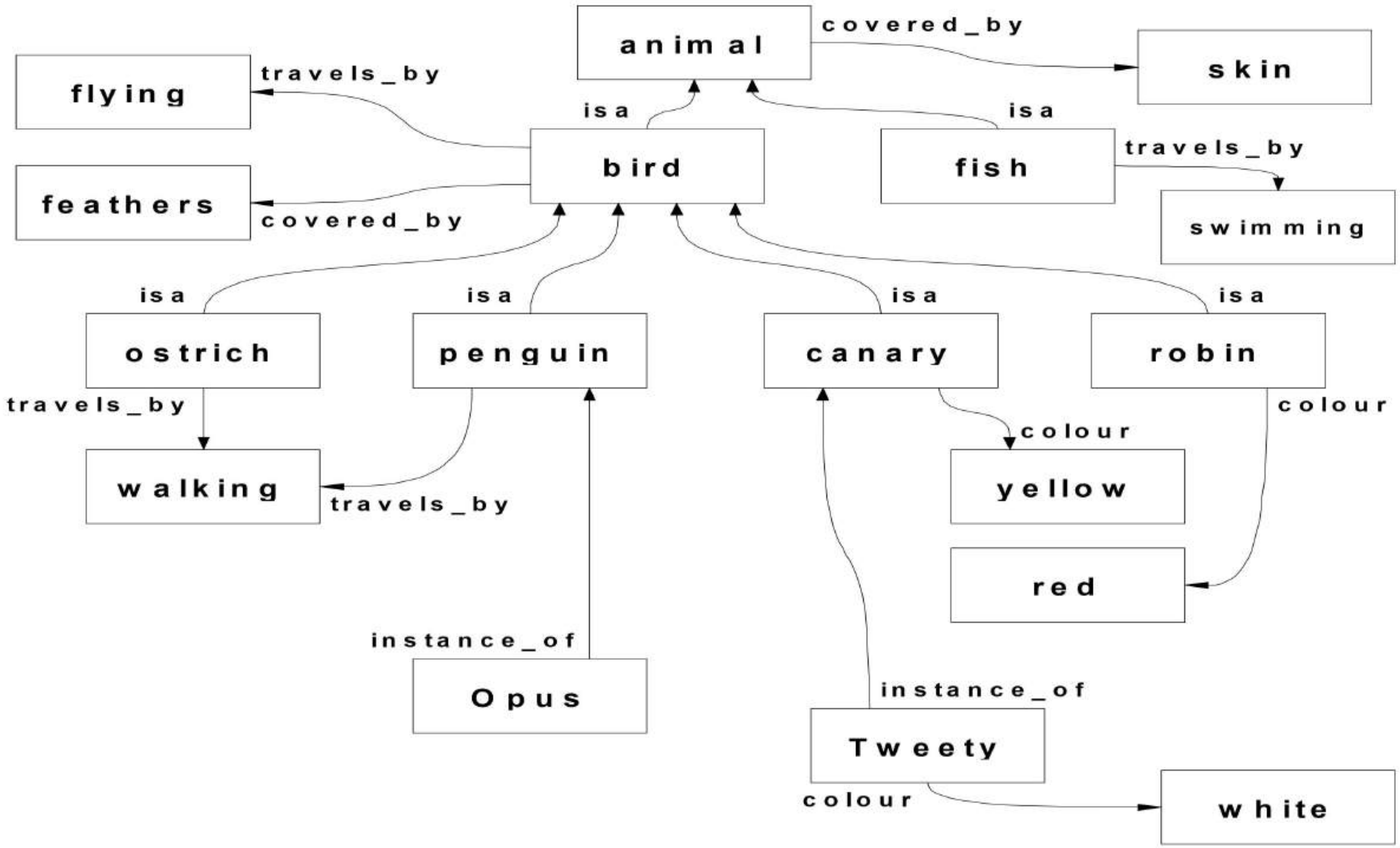


Semantic Net

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