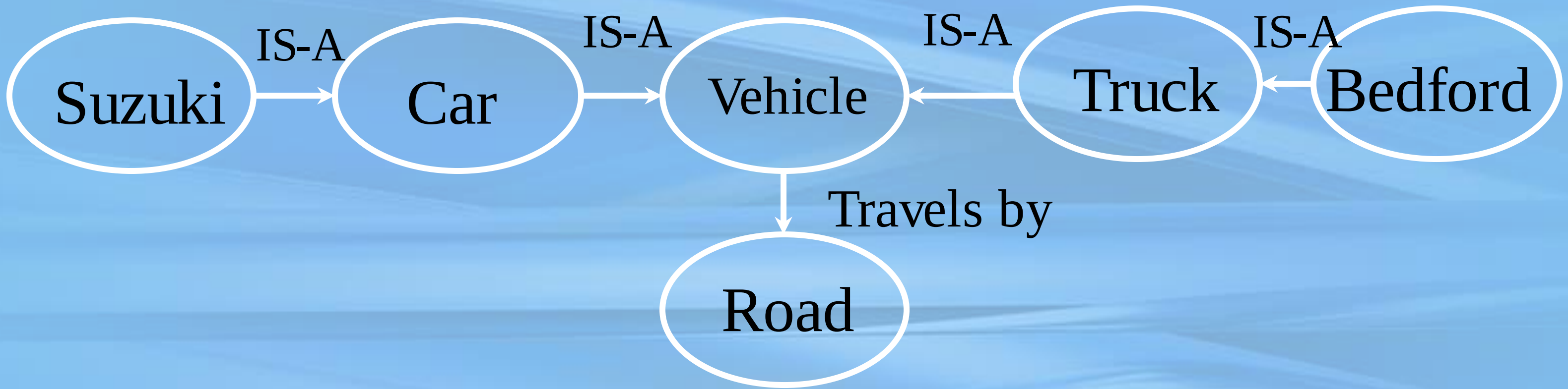
Semantic Networks

- Graphs, with nodes representing objects and arcs representing relationships between objects
- Various types of relationships may be defined.
  - IS-A (Inheritance relationship)
  - HAS (Ownership)

Semantic Network example



Network Operation: How to infer new information from semantic networks. We can ask nodes questions

- **Ask node vehicle: ‘How do you travel’**
  - **Looks at arc and replies: road**
- **Ask node Car X: ‘How do you travel’**
  - **Asks node Car (because of IS-A relationship)**
  - **Asks node Vehicle (IS-A relationship)**
  - **Node Vehicle Replies: road**

Problems with Semantic Networks

- **Computationally expensive at run-time**. In the worst case, we may need to traverse entire network and then discover that the requested info does not exist.
- They try to model human associative memory (store info using associations), but in the human brain the number of neurons and links are in the order of 10^{15}. Such numbers are computationally prohibitive in semantic networks.
- Are **logically inadequate**. Have **no analogues to quantifiers** (for all, for some, none).

Frames

- **“Frames are data structures for representing stereotypical knowledge of some concept or object” Durkin**
- Like a schema
- Extended to Classes and Objects
- e.g. for the object Student, the frame will look like this:

Frame Name: Student

Properties:

Age: 19

GPA: 4.0

Ranking: 1

Facets

- A feature of frames that allows us to put in **constraints**
- IF-NEEDED Facets
- IF-CHANGED Facets

Logic

- Logic representation techniques:
  - **Propositional Logic**
  - **Predicate Calculus**
- Algebra is a type of formal logic that deals with numbers, e.g. 2+4 = 6
- Similarly, **propositional logic and predicate calculus are forms of formal logic for dealing with propositions**.

Propositional Logic

- **Proposition**: Statement of a fact
- Assign a **Symbolic Variable** to represent a proposition. e.g.

  p = It is raining

  q = I carry an umbrella
- A declarative sentence may be classified as either True of False.
  - the proposition ‘A rectangle has four sides’ is true
  - the proposition ‘The world is a cube’ is false.
- A proposition is a sentence whose truth values may be determined. So, each variable has a truth value.

Compound Statements

- Different propositions may be logically related.
- We can form compound statements using logical connectives:
  - $\wedge$ AND (Conjunction)
  - $\vee$ OR (Disjunction)
  - ~ NOT (Negation)
  - $\Rightarrow$ If … then (Conditional)
  - $\Leftrightarrow$ If and only if (bi-conditional)

Compound statements

p = It is raining

q = I carry an umbrella

r = It is cloudy

- s = IF it is raining THEN carry an umbrella

  $p \Rightarrow q$

- t = IF it is raining OR it is cloudy, THEN carry an umbrella

  $(p \vee r) \Rightarrow q$

Truth Table of Binary Logical Connectives

p	q	$p \wedge q$	$p \vee q$	$p \Rightarrow q$	$p \Leftrightarrow q$
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

Limitations of Propositional Logic

- Can only represent knowledge as **complete sentences**, e.g. a = the ball's color is blue.
- Cannot analyze the **internal structure of the sentence**.
- **No quantifiers** e.g. For all, There exists
- Propositional logic provides **no framework for proving statements** such as:

  All humans are mortal

  All women are humans

  Therefore, all women are mortals
- This is a **limitation in its representational power**.

Predicate Calculus

- Extension of Propositional logic
- Allows structure of facts/sentences to be defined

  With predicate logic, we can say

  color(ball, blue)
- Provides a mechanism for proving statements
- Has greater representation power as we will see shortly

The Universal Quantifier

- Symbol $\forall$
- "for every" or "for all"
- Used in formulae to assign the same truth value to all variables in the domain
- e.g. Domain: numbers
  - $(\forall x)\ (x + x = 2x)$
  - In words: **for every** x (where x is a number), x + x = 2x is true
- e.g. Shapes
  - $(\forall x)\ (x = \text{square} \Rightarrow x = \text{polygon})$
  - In words: every square is a polygon.
  - For every x (where x is a shape), if x is a square, then x is a polygon (it implies that x is a p polygon).

Existential Quantifier

- Symbol: $\exists$
- Used in formulae to say that something is true for at least one value in the domain
- “there exists”, “ for some” “for at least one” “there is one”
- e.g.
  - $(\exists x)$ (person $(x) \wedge$ father (x,ahmed))
  - In words: there exists some person, x who is Ahmed’s father.

First Order Predicate Logic

- First Order Predicate logic is the simplest form.
- Uses symbols. These may be
  - **Constants**: Used to name specific objects or properties. e.g. Ali, Ayesha, blue, ball.
  - **Predicates**: A fact or proposition is divided into two parts
    - Predicate: the assertion of the proposition
    - Argument: the object of the proposition
    - e.g. Ali likes bananas becomes Likes (ali, bananas)
  - **Variables**: Used to represent general class of objects/properties. e.g. likes (X, Y). X and Y are variables that assume the values X=Ali and Y=bananas
  - **Formulae:** Use predicates and quantifiers

Predicate Logic Example

man(ahmed) father(ahmed, belal) brother(ahmed, chand) owns(belal, car) tall(belal) hates(ahmed, chand) family()	Predicates
$\forall$ Y ($\neg$sister(Y,ahmed)) $\forall$X,Y,Z(man(X) $\wedge$ man(Y) man(Z) $\wedge$ father(Z,Y) $\wedge$ father(Z,X) $\Rightarrow$ brother(X,Y))	Formulae
X, Y and Z	Variables
ahmed, belal, chand and car	Constants