COMP474/6741
Individuals and Relations
Ontologies

Pools: Chap 12 and 13

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web Technologies
- Main Components of an Ontology
- Challenges of building ontologies

Individuals and Relations

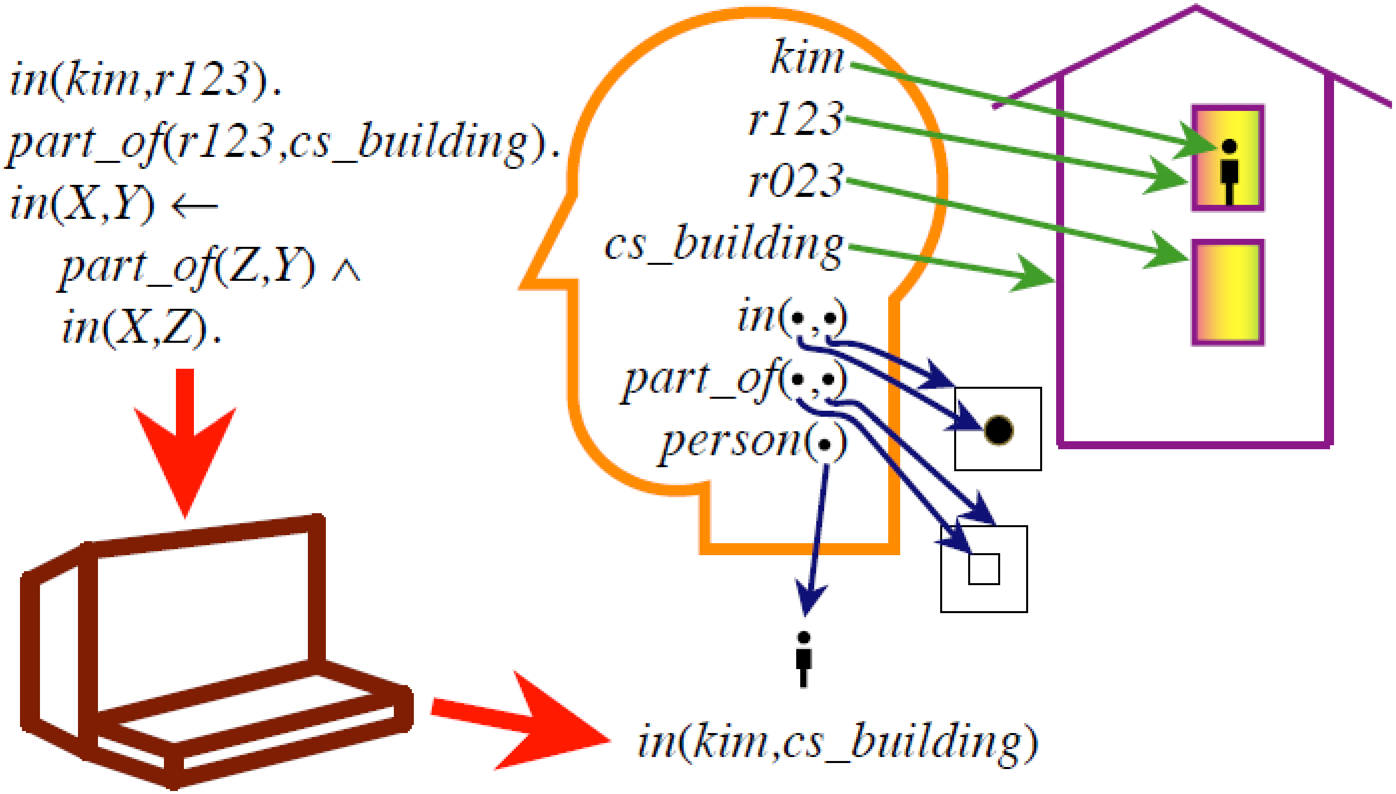
- It is useful to view the world as consisting of individuals (objects, things) and relations among individuals.
- Often features are made from relations among individuals and functions of individuals.
- Reasoning in terms of individuals and relationships can be simpler than reasoning in terms of features, if we can express general knowledge that covers all individuals.
- Sometimes we may know some individual exists, but not which one.
- Sometimes there are infinitely many individuals we want to refer to (e.g., set of all integers, or the set of all stacks of blocks).

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning

- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web Technologies
- Main Components of an Ontology
- Challenges of building ontologies

Role of Semantics in Automated Reasoning



Features of Automated Reasoning

- Users can have meanings for symbols in their head.
- The computer doesn't need to know these meanings to derive logical consequence.
- Users can interpret any answers according to their meaning.

Decision-theoretic Planning

- flat or modular or hierarchical
- explicit states or features or individuals and relations
- static or finite stage or indefinite stage or infinite stage
- fully observable or partially observable
- deterministic or stochastic dynamics
- goals or complex preferences
- single agent or multiple agents
- knowledge is given or knowledge is learned
- perfect rationality or bounded rationality

Semantics: General Idea

A semantics specifies the meaning of sentences in the language.
An interpretation specifies:

- what objects (individuals) are in the world
- the correspondence between symbols in the computer and objects & relations in world
  - constants denote individuals
  - predicate symbols denote relations

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics 

- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web
- Main Components of an Ontology
- Challenges of building ontologies

Formal Semantics

An interpretation is a triple $I = \langle D, \phi, \pi \rangle$, where

- D, the domain, is a nonempty set. Elements of D are individuals.
- ϕ is a mapping that assigns to each constant an element of D. Constant c denotes individual $\phi(c)$.
- π is a mapping that assigns to each n-ary predicate symbol a relation: a function from D^n into $\{TRUE, FALSE\}$.

Important points to note

- The domain D can contain real objects. (e.g., a person, a room, a course). D can't necessarily be stored in a computer.
- $\pi(p)$ specifies whether the relation denoted by the n-ary predicate symbol p is true or false for each n-tuple of individuals.
- If predicate symbol p has no arguments, then $\pi(p)$ is either *TRUE* or *FALSE*.

Computer's view of semantics

- The computer doesn't have access to the intended interpretation.
- All it knows is the knowledge base.
- The computer can determine if a formula is a logical consequence of KB.
- If $KB \models g$ then g must be true in the intended interpretation.
- If $KB \not\models g$ then there is a model of KB in which g is false. This could be the intended interpretation.

Ontologies and Knowledge-based Systems

- Is there a flexible way to represent relations?
- How can knowledge bases be made to inter-operate semantically?

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web
- Main Components of an Ontology
- Challenges of building ontologies

Choosing Individuals and Relations

How to represent: "Pen #7 is red."

- *red*(pen_7). It's easy to ask "What's red?"
  Can't ask "what is the color of pen_7?"
- *color*(pen_7, *red*). It's easy to ask "What's red?"
  It's easy to ask "What is the color of pen_7?"
  Can't ask "What property of pen_7 has value *red*?"
- *prop*(pen_7, *color*, *red*). It's easy to ask all these questions.

prop(*Individual*, *Property*, *Value*) is the only relation needed:
called individual-property-value representation
or triple representation

relation

Universality of prop

To represent "a is a parcel"

- *prop*(*a*, *type*, *parcel*), where *type* is a special property
- *prop*(*a*, *parcel*, *true*), where *parcel* is a Boolean property

Reification

- To represent $scheduled(cs422, 2, 1030, cc208)$. "section 2 of course $cs422$ is scheduled at 10:30 in room $cc208$."
- Let $b123$ name the booking:

$$prop(b123, course, cs422).$$
$$prop(b123, section, 2).$$
$$prop(b123, time, 1030).$$
$$prop(b123, room, cc208).$$

- We have reified the booking.
- Reify means: to make into an individual.
- What if we want to add the year?

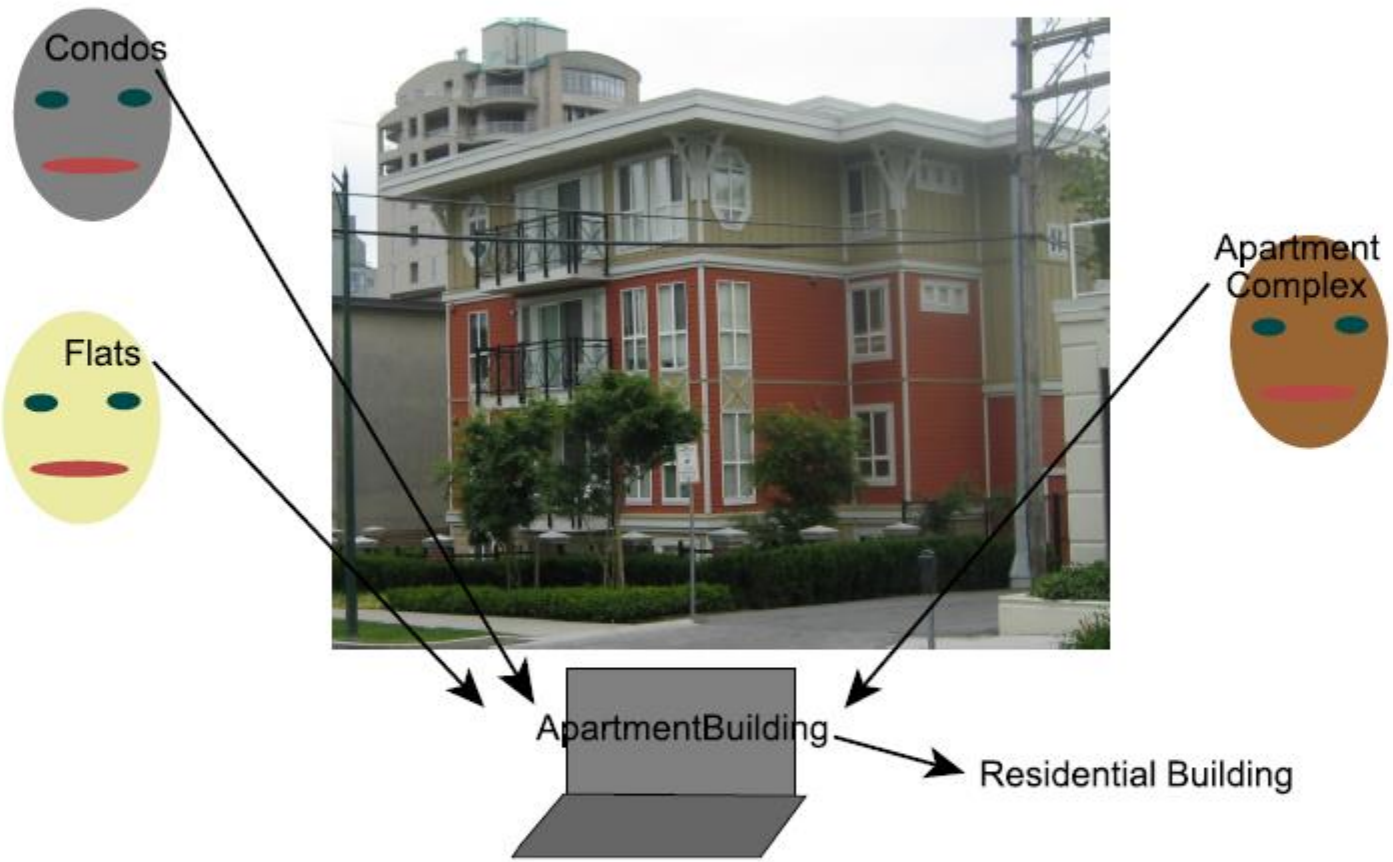
Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web Technologies
- Main Components of an Ontology
- Challenges of building ontologies

Knowledge Sharing

- A conceptualization is a map from the problem domain into the representation. A conceptualization specifies:
  - What sorts of individuals are being modeled
  - The vocabulary for specifying individuals, relations and properties
  - The meaning or intention of the vocabulary
- If more than one person is building a knowledge base, they must be able to share the conceptualization.
- An ontology is a specification of a conceptualization. An ontology specifies the meanings of the symbols in an information system.

Mapping from a conceptualization to a symbol



Semantic Web

- Ontologies are published on the web in machine readable form.
- Builders of knowledge bases or web sites adhere to and refer to a published ontology:
  - a symbol defined by an ontology means the same thing across web sites that obey the ontology.
  - if someone wants to refer to something not defined, they publish an ontology defining the terminology.
    Others adopt the terminology by referring to the new ontology.
    In this way, ontologies evolve.
  - Separately developed ontologies can have mappings between them published.

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web Technologies

- Main Components of an Ontology
- Challenges of building ontologies

Semantic Web Technologies

- XML the Extensible Markup Language provides generic syntax.
  $\langle tag \ldots / \rangle$ or
  $\langle tag \ldots \rangle \ldots \langle / tag \rangle$.
- URI a Uniform Resource Identifier is a name of an individual (resource). This name can be shared. Often in the form of a URL to ensure uniqueness.
- RDF the Resource Description Framework is a language of triples
- OWL the Web Ontology Language, defines some primitive properties that can be used to define terminology. (Doesn't define a syntax).

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
  - Conceptualization
  - Ontology
- Semantic web Technologies
- Main Components of an Ontology
- Challenges of building ontologies

Main Components of an Ontology

- Individuals the things / objects in the world (not usually specified as part of the ontology)
- Classes sets of individuals
- Properties between individuals and their values

Individuals

- Individuals are things in the world that can be named. (Concrete, abstract, concepts, reified).
- Unique names assumption (UNA): different names refer to different individuals.
- The UNA is not an assumption we can universally make: "The Queen", "Elizabeth Windsor", etc.
- Without the determining equality, we can't count!
- In OWL we can specify:

$$i_1 \;\; \textit{SameIndividual} \;\; i_2.$$

$$i_1 \;\; \textit{DifferentIndividuals} \;\; i_3.$$

Classes

- A class is a set of individuals. E.g., house, building, officeBuilding
- One class can be a subclass of another

  house subClassOf building.

  officeBuilding subClassOf building.
- The most general class is *Thing*.
- Classes can be declared to be the same or to be disjoint:

  house EquivalentClasses singleFamilyDwelling.

  house DisjointClasses officeBuilding.
- Different classes are not necessarily disjoint.
  E.g., a building can be both a commercial building and a residential building.

Properties

- A property is between an individual and a value.
- A property has a domain and a range.

  livesIn domain person.

  livesIn range placeOfResidence.
- An *ObjectProperty* is a property whose range is an individual.
- A *DatatypeProperty* is one whose range isn't an individual, e.g., is a number or string.
- There can also be property hierarchies:

  livesIn subPropertyOf enclosure.

  principalResidence subPropertyOf livesIn.

Properties (Cont.)

- One property can be inverse of another

  livesIn InverseObjectProperties hasResident.
- Properties can be declared to be transitive, symmetric, functional, or inverse-functional. (Which of these are only applicable to object properties?)
- We can also state the minimum and maximal cardinality of a property.

  principalResidence minCardinality 1.

  principalResidence maxCardinality 1.

Property and Class Restrictions

- We can define complex descriptions of classes in terms of restrictions of other classes and properties.
  E.g., A homeowner is a person who owns a house.

$$homeOwner \subseteq person \cap \{x : \exists h \in house \text{ such that } x \text{ owns } h\}$$

Challenges of building ontologies

- They can be huge: finding the appropriate terminology for a concept may be difficult.
- How one divides the world can depend on the application. Different ontologies describe the world in different ways.
- People can fundamentally disagree about an appropriate structure.
- Different knowledge bases can use different ontologies.
- To allow KBs based on different ontologies to inter-operate, there must be mapping between ontologies.
- It has to be in user's interests to use an ontology.
- The computer doesn't understand the meaning of the symbols. The formalism can constrain the meaning, but can't define it.

Knowledge Sharing

- One ontology typically imports and builds on other ontologies.
- OWL provides facilities for version control.
- Tools for mapping one ontology to another allow inter-operation of different knowledge bases.
- The semantic web promises to allow two pieces of information to be combined if
  - they both adhere to an ontology
  - these are the same ontology or there is a mapping between them.

Today

- Individuals and Relations
- Role of Semantics in Automated Reasoning
- Formal Semantics
- Choosing Individuals and Relations to represent knowledge
- Knowledge Sharing
    - Conceptualization
    - Ontology
- Semantic web Technologies
- Main Components of an Ontology
- Challenges of building ontologies