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    - If not already defined, what can it be defined in terms of?

Knowledge Sharing

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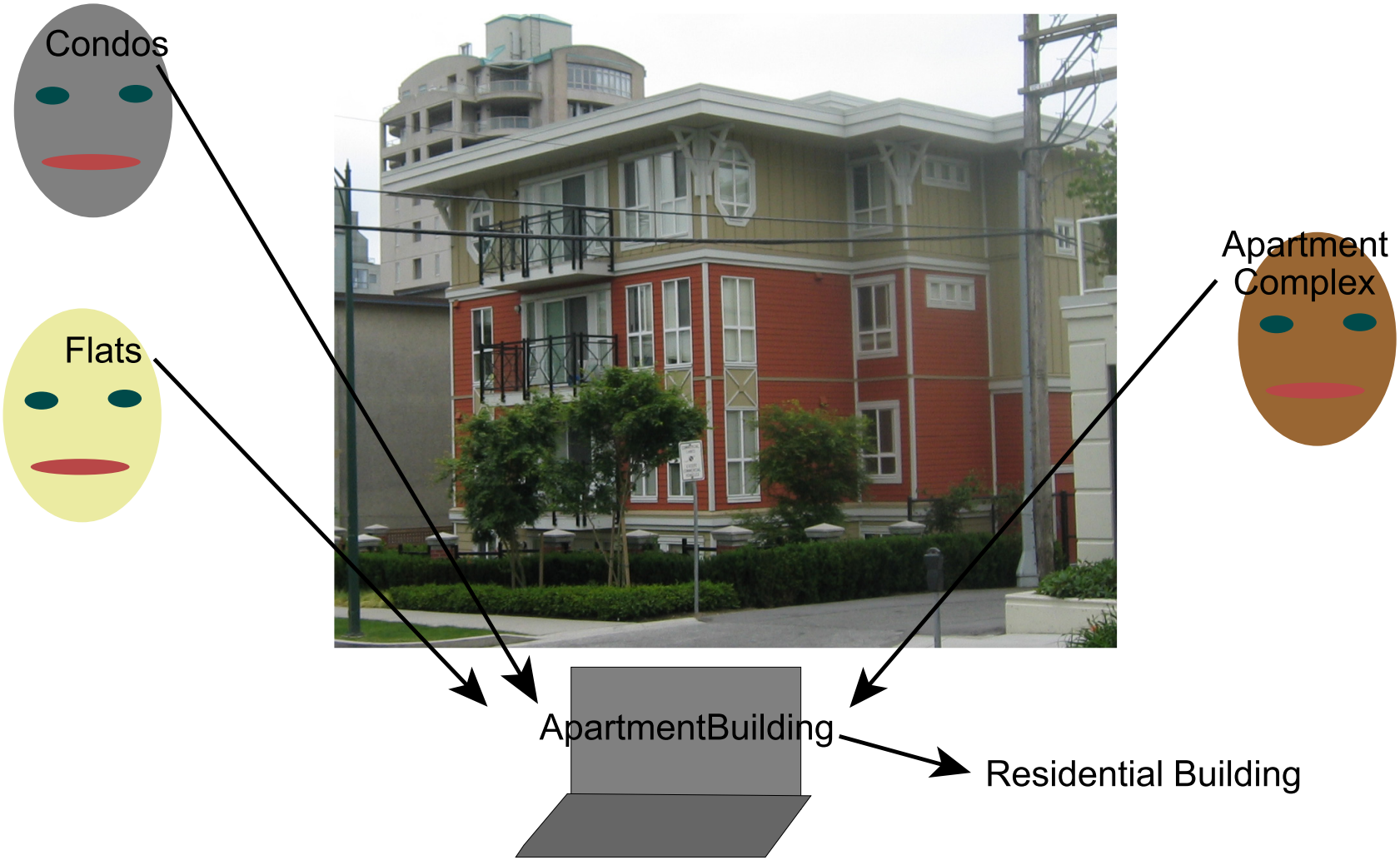
- If more than one person is building a knowledge base, they must be able to share the conceptualization.
  $\longrightarrow$ challenge: inter-operability of separately designed knowledge bases.
- An ontology is a specification of a conceptualization.
  An ontology specifies the meanings of the symbols in an information system.

Mapping from a conceptualization to a symbol



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  - Separately developed ontologies can have mappings between them published.

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- 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.

Semantic Web Technologies Revisited

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- Lots of alternative syntaxes: XML, Turtle, N-Triples, Json ...
- OWL the Web Ontology Language, defines some primitive properties that can be used to define terminology. (Uses multiple alternative syntaxes).

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

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- Without the determining equality, we can't count! Joe's mother was in the room. Sam's cousin was there. Chris's football coach was there. How many people were in the room?
- Using OWL:

  $(i_1, \text{'owl:SameIndividual'}, i_2)$

  $(i_1, \text{'owl:DifferentIndividuals'}, i_3)$

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

Example Concepts in an Ontology

The following are some of the concepts in an ontology for documents.
`http://www.cs.umd.edu/projects/plus/DAML/onts/docmnt1.0.daml`

homepage	correspondence	publication
letter	periodical	article
book	email	magazine
journal	document	communication
workshopPaper	journalPaper	discussion
newspaper	PersonalHomepage	speech

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- 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:

  rdfs:subPropertyOf(*livesIn*, *enclosure*)

  rdfs:subPropertyOf(*principalResidence*, *livesIn*)

Clicker Question

Suppose we are given the following triple as true:

```
years_eligibility 'rdfs:domain' student.
sam  years_eligibility  3).
```

Which is the following can we infer

A Sam is a student

B Sam could a student (but maybe isn't)

C All students have value 3 for `years_eligibility`

D We can infer nothing about whether Sam is a student

Clicker Question

Suppose we are given the following triples as true:

```
years_eligibility  'rdfs:domain'  student.
years_eligibility 'rdfs:domain' athlete.
sam years_eligibility 3.
```

Which is the following is true

A Sam is both a student and an athlete.

B Sam could be either student or an athlete.

C We can infer nothing about whether Sam is an athlete or a student

D There are no student athletes.

E The facts are inconsistent, and couldn't possible all be true

Clicker Question

RDF-schema provides a vocabulary for classes and properties. RDF-schema has a syntax for *domain* and *range* of a property. schema.org does not use `rdfs:domain` and `rdfs:range`. Why?

A The scheme.org designers didn't know about it even though they used other terminology from RDF-schema

B The scheme.org designers didn't care about domains and ranges because they just wanted to define a vocabulary.

C schema.org does not define anything, and so does not need domain and ranges

D The scheme.org designers did not want the meaning associated with RDF-schema's domain and range.

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- 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.

  owl:minCardinality(*principalResidence*, 1)

  owl:maxCardinality(*principalResidence*, 1)

Property and Class Restrictions

- We can define complex descriptions of classes in terms of restrictions of other classes and properties.
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owl:subClassOf(homeOwner,person)

owl:subClassOf(*homeOwner*,
owl:ObjectSomeValuesFrom(*owns*, *house*))

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- 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.

Example: Apartment Building

An apartment building is a residential building with more than two units and they are rented.

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```
Declaration(ObjectProperty(:numberOfunits))
FunctionalObjectProperty(:numberOfunits)
ObjectPropertyDomain(:numberOfunits :ResidentialBuilding)
ObjectPropertyRange(:numberOfunits
                    ObjectOneOf(:two :one :moreThanTwo))

Declaration(Class(:ApartmentBuilding))
EquivalentClasses(:ApartmentBuilding
    ObjectIntersectionOf(
        :ResidentialBuilding
        ObjectHasValue(:numberOfunits :moreThanTwo)
        ObjectHasValue(:ownership :rental)))
```

Example: hotel ontology

Define the following:

- Room
- BathRoom
- StandardRoom - what is rented as a room in a hotel
- Suite
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- Suite
- RoomOnly
- Hotel
- HasForRent
- AllSuitesHotel
- NoSuitesHotel
- HasSuitesHotel

Top-Level Ontology

A top-level ontology

- provides a definition of *everything* at a very abstract level.
- provides a useful categorization on which to base other ontologies.
- facilitates the integration of domain ontologies.

At the top is entity. OWL calls the top of the hierarchy thing. Essentially, everything is an entity.

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  E.g., 17, set of all mammals on Earth, an email, a course

Continuants vs Occurrents

- A continuant exists in an instance of time and maintains its identity through time.
  Examples: person, a finger, a country, a smile, the smell of a flower, an email, Newtonian mechanics
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Alternative: a four-dimensional or perdurant view where objects exist in the space-time.

- A person is a trajectory though space and time
- At any time, a person is a snapshot of the four-dimensional trajectory.

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  For example, the end of a lecture, the first goal in the 2022 FIFA World Cup final.

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- *Reusable* – the data uses rich metadata, including provenance, and an appropriate open license, so that the community can use the data.

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