NLP
Introduction to NLP

Knowledge Representation
Knowledge Representation

- Ontologies
- Categories and objects
- Events
- Times
- Beliefs
Knowledge Representation

- **Object**
  - Martin the cat

- **Categories**
  - Cat

- **Ontology**
  - Mammal includes Cat, Dog, Whale
  - Cat includes PersianCat, ManxCat

- **ISA relation**
  - ISA (Martin, Cat)

- **AKO relation**
  - AKO (PersianCat, Cat)

- **HASA relation**
  - HASA (Cat, Tail)
Semantics of FOL

- FOL sentences can be assigned a value of true or false.
  \[ \text{ISA}(\text{Milo},\text{Cat}) = \text{true} \]

- Milo is younger than Martin
  \[ <(\text{AgeOf}(\text{Milo}),\text{AgeOf}(\text{Martin})) = \text{true} \]
  \[ = (\text{AgeOf}(\text{Milo}),\text{AgeOf}(\text{Martin})) = \text{false} \]
Examples with Quantifiers

• All cats eat fish
  \( \forall x:ISA(x,\text{Cat}) \Rightarrow EatFish(x) \)
Representing Events

- Martin ate
- Martin ate in the morning
- Martin ate fish
- Martin ate fish in the morning
One Possible Representation

• FOL representations
  – Eating1(Martin)
  – Eating2(Martin,Morning)
  – Eating3(Martin,Fish)
  – Eating4(Martin,Fish,Morning)

• Meaning postulates
  – Eating4(x,y,z) \rightarrow Eating3(x,y)
  – Eating4(x,y,z) \rightarrow Eating2(x,z)
  – Eating4(x,y,z) \rightarrow Eating1(x)

Example from Jurafsky and Martin
Second Possible Representation

- **Eating4(x,y,z)**
  - With some arguments unspecified

- **Problems**
  - Too many commitments
  - Hard to combine Eating4(Martin,Fish,z) with Eating4(Martin,y,Morning)

Example from Jurafsky and Martin
Third Possible Representation

• Reification
  – $\exists e: \text{ISA}(e, \text{Eating}) \land \text{Eater}(e, \text{Martin}) \land \text{Eaten}(e, \text{Fish})$

Example from Jurafsky and Martin
Representing Time

• Example
  – Martin went from the kitchen to the yard
  – ISA(e,Going) ^ Goer(e,Martin) ^ Origin (e,kitchen) ^ Target (e,yard)

• Issue
  – no tense information: past? present? future?

• Fluents
  – A predicate that is true at a given time: T(f,t)
Representing Time

**Figure 12.2** Predicates on time intervals.

Example from Russell and Norvig
Representing Time

Example from Jurafsky and Martin
Representing time

- \( \exists i,e,w,t: \text{Isa}(w, \text{Arriving}) \land \text{Arriver}(w, \text{Speaker}) \land \text{Destination}(w, \text{NewYork}) \land \text{IntervalOf}(w, i) \land \text{EndPoint}(i, e) \land \text{Precedes}(e, \text{Now}) \)
- \( \exists i,e,w,t: \text{Isa}(w, \text{Arriving}) \land \text{Arriver}(w, \text{Speaker}) \land \text{Destination}(w, \text{NewYork}) \land \text{IntervalOf}(w, i) \land \text{MemberOf}(i, \text{Now}) \)
- \( \exists i,e,w,t: \text{Isa}(w, \text{Arriving}) \land \text{Arriver}(w, \text{Speaker}) \land \text{Destination}(w, \text{NewYork}) \land \text{IntervalOf}(w, i) \land \text{StartPoint}(i, s) \land \text{Precedes}(\text{Now}, s) \)

Example from Jurafsky and Martin
Representing time

- **We fly from San Francisco to Boston at 10.**
- **Flight 1390 will be at the gate an hour now.**
  - Use of tenses
- **Flight 1902 arrived late.**
- **Flight 1902 had arrived late.**
  - “similar” tenses
- **When Mary’s flight departed, I ate lunch**
- **When Mary’s flight departed, I had eaten lunch**
  - reference point

Example from Jurafsky and Martin
Aspect

• Stative
  – I know my departure gate

• Activity
  – John is flying
    (no particular end point)

• Accomplishment
  – Sally booked her flight
    (natural end point and result in a particular state)

• Achievement
  – She found her gate

• Figuring out statives:
  – I am needing the cheapest fare.
  – I am wanting to go today.
  – Need the cheapest fare!

Example from Jurafsky and Martin
Representing Beliefs

• Example
  – Milo believes that Martin ate fish

• One possible representation
  – $\exists e, b: \text{ISA}(e, \text{Eating}) \land \text{Eater}(e, \text{Martin}) \land \text{Eaten}(e, \text{Fish}) \land \text{ISA}(b, \text{Believing}) \land \text{Believer}(b, \text{Milo}) \land \text{Believed}(b, e)$

• However this implies (by dropping some of the terms) that “Martin ate fish” (without the Belief event)

• Modal logic
  – Possibility, Temporal Logic, Belief Logic
Representing Beliefs

• Want, believe, imagine, know – all introduce hypothetical worlds
• I believe that Mary ate British food.
• Reified example:
  – $\exists u,v: Isa(u, Believing) \land Isa(v, Eating) \land Believer(u, Speaker) \land BelievedProp(u, v) \land Eater(v, Mary) \land Eaten(v, BritishFood)$

  However this implies also:
  – $\exists u,v: Isa(v, Eating) \land Eater(v, Mary) \land Eaten(v, BritishFood)$

• Modal operators:
  – $Believing(Speaker, Eating(Mary, BritishFood))$ – not FOPC! – predicates in FOPC hold between objects, not between relations.
  – $Believes(Speaker, \exists v: ISA(v, Eating) \land Eater(v, Mary) \land Eaten(v, BritishFood))$
Modal operators

• Beliefs
• Knowledge
• Assertions
• Issues:

*If you are interested in baseball, the Red Sox are playing tonight.*
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