AI

Artificial Intelligence

Other Logics (from 3.6.3)

Lambda Expressions

- Example
  - $inc(x) = \lambda x\ x+1$
  - then $inc(4) = (\lambda x\ x+1)(4) = 5$
- Example
  - $add(x,y) = \lambda x,\lambda y(x+y)$
  - then $add(3,4) = (\lambda x,\lambda y(x+y))(3)(4)= (\lambda y\ 3+y)(4) = 3+4 = 7$
- Useful for semantic parsing (see later)

Modal operators

- Beliefs
- Knowledge
- Assertions
- Issues:
  If you are interested in baseball, the Red Sox are playing tonight.

Representing Time

- Example
  - Martin went from the kitchen to the yard
  - ISA(e,Going) ^ Goer(e,Martin) ^ Origin (e,kitchen) ^ Target (e,yard)
- Issues
  - no tense information: past? present? future?
  - PresidentOf (“USA”, “Donald Trump”)
  - PresidentOf (“USA”, Harry Truman”)
- Fluents
  - A predicate that is true at a given time: T(f,t)

Temporal Logic

Setup: all formulas interpreted at a current time.

$$\mathcal{I}(f, w, t) = 1 \text{ if } f \text{ is true in } w \text{ at time } t$$

$$\mathcal{I}(\mathbf{P} f, w, t) = 1 \text{ if exists } s < t \text{ such that } \mathcal{I}(f, w, s) = 1$$

The following operators change the current time and quantify over it:

$\mathbf{P}\, f$: f held at some point in the past
$\mathbf{F}\, f$: f will hold at some point in the future
$\mathbf{H}\, f$: f held at every point in the past
$\mathbf{G}\, f$: f will hold at every point in the future

Every student will at some point never be a student again.

$$\forall x.\text{Student}(x) \rightarrow \mathbf{FG}\neg\text{Student}(x)$$

Slide from Percy Liang

Representing Time

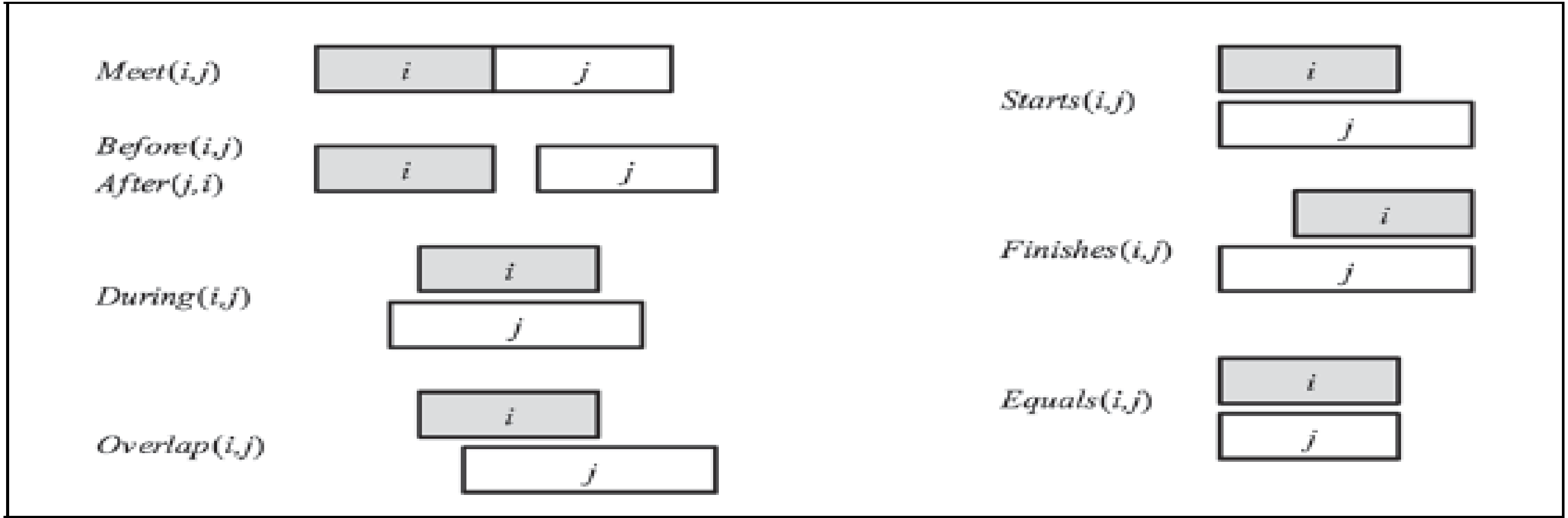
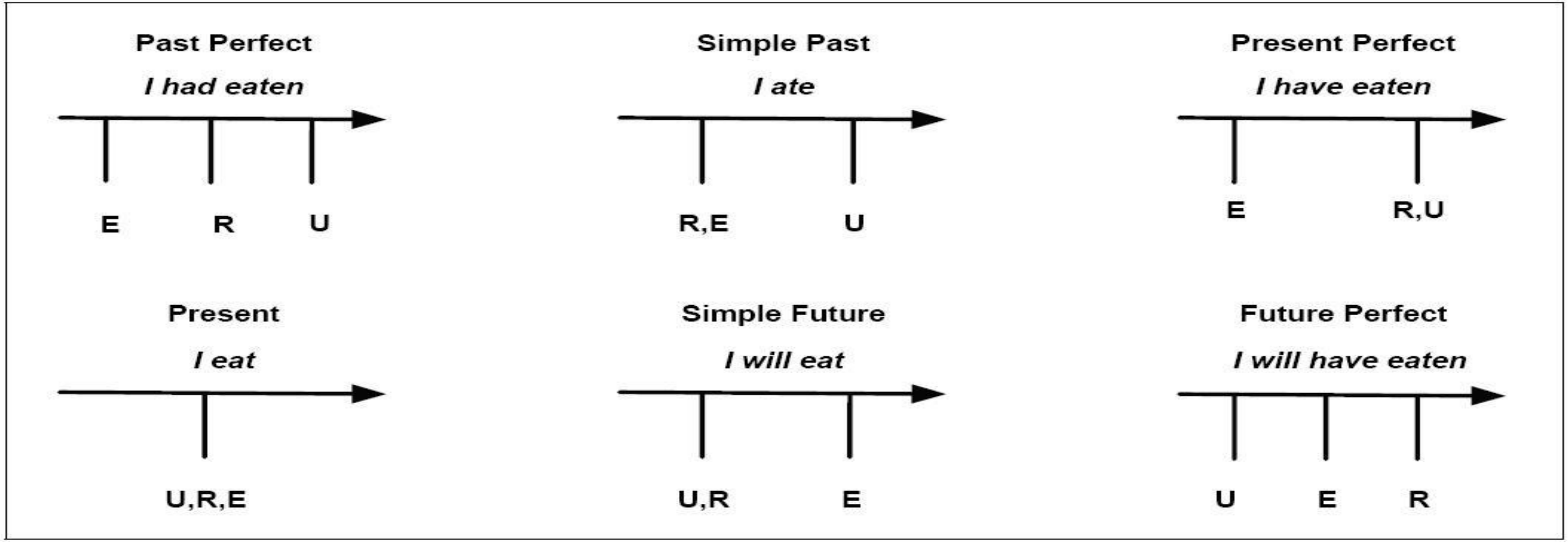


Figure 12.2 Predicates on time intervals.

Example from Russell and Norvig

Representing Time



Example from Jurafsky and Martin

Representing time

- ∃ *i,e,w,t: Isa(w,Arriving)* ∧ *Arriver(w,Speaker)* ∧ *Destination(w,NewYork)* ∧ *IntervalOf(w,i)* ∧ *EndPoint(i,e)* ∧ *Precedes (e,Now)*
- ∃ *i,e,w,t: Isa(w,Arriving)* ∧ *Arriver(w,Speaker)* ∧ *Destination(w,NewYork)* ∧ *IntervalOf(w,i)* ∧ *MemberOf(i,Now)*
- ∃ *i,e,w,t: Isa(w,Arriving)* ∧ *Arriver(w,Speaker)* ∧ *Destination(w,NewYork)* ∧ *IntervalOf(w,i)* ∧ *StartPoint(i,s)* ∧ *Precedes (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: ISA(e,Eating) $\wedge$ Eater(e,Martin) $\wedge$ Eaten(e,Fish) $\wedge$ ISA(b,Believing) $\wedge$ Believer(b,Milo) $\wedge$ 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:
  - *∃ u,v: Isa(u,Believing) ∧ Isa(v,Eating) ∧ Believer (u,Speaker) ∧ BelievedProp(u,v) ∧ Eater(v,Mary) ∧ Eaten(v,BritishFood)*

  However this implies also*:*
  - *∃ u,v: Isa(v,Eating) ∧ Eater(v,Mary) ∧ Eaten(v,BritishFood)*
- Modal operators:
  - *Believing(Speaker,Eating(Mary,BritishFood))* - not FOPC! – predicates in FOPC hold between objects, not between relations.
  - *Believes(Speaker, ∃ v: ISA(v,Eating) ∧ Eater(v,Mary) ∧ Eaten(v,BritishFood))*

Markov Logic

- Distribution over models
- Example:

Table 1. Example of a first-order knowledge base and MLN. $\mathtt{Fr}()$ is short for $\mathtt{Friends}()$, $\mathtt{Sm}()$ for $\mathtt{Smokes}()$, and $\mathtt{Ca}()$ for $\mathtt{Cancer}()$.

First-Order Logic	Clausal Form	Weight
"Friends of friends are friends." $\forall x \forall y \forall z\, \mathtt{Fr}(x,y) \wedge \mathtt{Fr}(y,z) \Rightarrow \mathtt{Fr}(x,z)$	$\neg \mathtt{Fr}(x,y) \vee \neg \mathtt{Fr}(y,z) \vee \mathtt{Fr}(x,z)$	0.7
"Friendless people smoke." $\forall x\, (\neg(\exists y\, \mathtt{Fr}(x,y)) \Rightarrow \mathtt{Sm}(x))$	$\mathtt{Fr}(x,g(x)) \vee \mathtt{Sm}(x)$	2.3
"Smoking causes cancer." $\forall x\, \mathtt{Sm}(x) \Rightarrow \mathtt{Ca}(x)$	$\neg \mathtt{Sm}(x) \vee \mathtt{Ca}(x)$	1.5
"If two people are friends, then either both smoke or neither does." $\forall x \forall y\, \mathtt{Fr}(x,y) \Rightarrow (\mathtt{Sm}(x) \Leftrightarrow \mathtt{Sm}(y))$	$\neg \mathtt{Fr}(x,y) \vee \mathtt{Sm}(x) \vee \neg \mathtt{Sm}(y)$, $\neg \mathtt{Fr}(x,y) \vee \neg \mathtt{Sm}(x) \vee \mathtt{Sm}(y)$	1.1 1.1

[Domingos et al]

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