Semantics (Representing Meaning)

Allen’s Chapter 8
J&M’s Chapter 14
“Meaning” has different usages:

- A warm engine **means** that the car has been used (implication)
- “Amble” **means** to walk slowly (definition)

**Meaning**: context independent sense, versus

**Usage**: context dependent aspects
Semantic Interpretation

- **Logical Form**: context-independent representation of meaning

- **Semantic Interpretation**: mapping a sentence to its logical form

- **Contextual Interpretation**: mapping the logical form to the final representation
Figure 8.1  Logical form as an intermediate representation
Semantic Ambiguity

- Ambiguity is a serious obstacle

- A word is semantically ambiguous if it maps to more than one sense

- “Kid” is ambiguous between a baby goat and a human child

- “horse” is not ambiguous, though there are colts and mares
Test for semantic Ambiguity

• Certain syntactic constructs require identical class of objects

• *I have two kids and George has three*

• All senses involve some degree of vagueness

• *I ran last year and George did too*
Level of ambiguities

- The ambiguity might come from syntactic ambiguity
  
  Happy cats and dogs live on the farm

- the scope of quantifiers might be ambiguous
  
  Every boy loves a dog
  
  \[ \exists \, \text{d. } \text{Dog}(d) \land \forall \, \text{b. } \text{Boy}(b) \Rightarrow \text{Loves}(b, d) \]
  \[ \forall \, \text{b. } \text{Boy}(b) \land \exists \, \text{d. } \text{Dog}(d) \Rightarrow \text{Loves}(b, d) \]

- Quantifiers vary with respect to vagueness
  
  Many people saw the accident
The basic logical form language

- The primitive unit of meaning is the word sense
- Primitive senses are combined to form the meaning of more complex expressions
- Word senses serve as atoms or constants
- Events and situations: shown by terms
- Relations and properties: shown by predicates
Examples:

- *Fido is a dog* is represented as  
  \((\text{DOG1 FIDO1})\)

- *Sue does not love Jack*  
  \((\text{NOT (LOVE1 SUE1 JACK1)})\)

- *I went home and had a drink*  

- *A man entered the room. He walked over the table.*  
  \((\exists x \ P(x) \& \exists x \ Q(x))\)

- Need for generalized quantifiers: 
  All, some, more, many, a few, the, a , etc.
Common Quantifiers

<table>
<thead>
<tr>
<th>Quantifier</th>
<th>Use</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE</td>
<td>definite reference</td>
<td>the dog</td>
</tr>
<tr>
<td>A</td>
<td>indefinite reference</td>
<td>a dog</td>
</tr>
<tr>
<td>BARE</td>
<td>bare singular NP (mass term) or</td>
<td>water, food</td>
</tr>
<tr>
<td>BARE</td>
<td>bare plural NP (generics)</td>
<td>dogs</td>
</tr>
</tbody>
</table>

Figure 8.4  Some common quantifiers
Generalized quantifiers

All dogs bark and most people laughed
(quantifier variable : 
   restriction proposition body proposition)

The logical form of

• *Most dogs bark* :
  
  (MOST d1 : (DOG1 d1) (BARK1 d1))

• *Most barking things are doges* :
  
  (MOST d2 : (BARK1 d2) (DOG1 d2))
Generalized quantifiers (Cont.)

• **The dog barks:**
  \[(\text{THE } x : (\text{DOG}1 x) (\text{BARKS1} x))\]

• **The happy dog barks:**
  \[(\text{THE } x : (& (\text{DOG}1 x) (\text{HAPPY} x)) (\text{BARKS1} x))\]

• **The dogs bark:**
  \[(\text{THE } x : ((\text{PLUR DOG}1) x) (\text{BARKS1} x))\]
Modal Operators

- Modal operators: to show verbs such as believe and want

- Note terms within the scope of a modal operators

- Let’s assume Jack is known as John to some people,

\[
\text{If } (\text{JACK1} = \text{JOHN22}) \\
\text{Then } (\text{HAPPY1} \text{JACK1}) = (\text{HAPPY1} \text{JOHN22}), \\
\text{But } (\text{BELIEVE1} \text{SUE1} (\text{HAPPY1} \text{JACK1})) \text{ is not the same as} \\
(\text{BELIEVE1} \text{SUE1} (\text{HAPPY1} \text{JOHN22}))
\]

- This is called failure of substitutivity in modal contexts
Modal Operators (Cont.)

- Modal (tense) operators: PAST, PRES, AND FUT
  (PRES (SEES1 JOHN1 FIDO1))
  (PAST (SEES1 JOHN1 FIDO1))
  (FUT (SEES1 JOHN1 FIDO1))

- If JOHN1 = PRESIDENT1 at now, it may not be
  (PAST (SEES1 PRESIDENT1 FIDO1))

- P and ~P can be both true in the past (at different times)
  (PAST (HAPPY1 JOHN1)) and
  (PAST (NOT (HAPPY1 JOHN1))) can be both true
Encoding ambiguity in the logical form

- A sentence may have multiple possible syntactical structures
- Each structure may have multiple logical forms
- Each word in the sentence may have multiple senses
- Simply generating all possible logical forms is not practical
- Certain ambiguities can be represented within the logical form (quasi logical form)
Encoding ambiguity in the logical form

- Anywhere an atomic sense is allowed, a set of possible atomic senses can be used
- The noun *ball* has at least two senses: *BALL1*, the object used in games, and *BALL2*, the social event
- *Sue watched the ball* is ambiguous

\[(\text{THE } b1 : \{\text{BALL1, BALL2} \} b1) \ (\text{PAST} \ \text{WATCH1} \ \text{SUE1} \ b1))\],

which abbreviates:

- \[(\text{THE } b1 : \{\text{BALL1} \} b1) \ (\text{PAST} \ \text{WATCH1} \ \text{SUE1} \ b1))\]
- \[(\text{THE } b1 : \{\text{BALL2} \} b1) \ (\text{PAST} \ \text{WATCH1} \ \text{SUE1} \ b1))\]
Ambiguity regarding scope of quantifiers

• **Every boy loves a dog**
  \[(\text{LOVES1} \ <\text{EVERY} \ b1 \ <\text{BOY1} \ b1> \ <\text{A} \ d1 \ <\text{DOG1} \ d1>\]
  which abbreviates an ambiguity between:
  - \((\text{EVERY} \ b1 : \ <\text{BOY1} \ b1> \ <\text{A} \ d1 : \ <\text{DOG1} \ d1> \ <\text{LOVES1} \ b1 \ d1>))\)
  - \((\text{A} \ d1 : \ <\text{DOG1} \ d1> \ <\text{EVERY} \ b1 : \ <\text{BOY1} \ b1> \ <\text{LOVES1} \ b1 \ d1>))\)

• A sentence with 4 quantifier would have 4! (24) possible ordering, and with 5 quantifier would have 5! (120) possible ordering
Ambiguity regarding scope of quantifiers

- All generalized quantifier, including THE, are subject to scoping

  At every hotel, the receptionist was friendly
Ambiguity regarding scope of quantifiers

- Operators such as **negation** and **tense** are also scope sensitive
- *Every boy didn’t run* is ambiguous between
  - \((\text{NOT (EVERY} \, b_1 : \text{(BOY} \, b_1 \, \text{) (RUN} \, b_1 \, \text{}))\)
  - \((\text{EVERY} \, b_1 : \text{(BOY} \, b_1 \, \text{) (NOT (RUN} \, b_1 \, \text{))})\)
- Quasi logical form of the sentence is:
  \((<\text{NOT RUN1}> <\text{EVERY} \, b_1 \, \text{BOY1}>))\)
Proper names and Pronouns

- Proper names must be interpreted in context
- Name *John* refers to different people in different situations
- *(NAME <variable> <name>)*, means that variable has the specified name
- *John ran* is represented as
  *(<PAST RUN1> (NAME j1 “John”))*
- Pronouns are indexical and need a special function, too.
- *(PRO <variable> <proposition>)*
- *Every man liked him*
Proper names and Pronouns

• Pronouns are indexical and need a special function, too.

• (PRO <variable> <proposition>)

• Every man liked him
  (<PAST LIKE1> <EVERY m1 MAN1> (PRO m2 (HE1 m2))),
  where HE1 is the sense for he and him

• “He” is often written as (PRO m2 HE1)
Verbs and states in logical form

1. John broke the window with the hammer
2. The hammer broke the window
3. The window broke

- The verb “break” has verb senses of different arity
  1. (\(<\text{PAST BREAK1}\> \ (\text{NAME j1 "John"})
      \ <\text{THE w1 WINDOW1}> <\text{THE h1 HAMMER1}>\))
  2. (\(<\text{PAST BREAK2}\> <\text{THE h1 HAMMER1}>
      <\text{THE w1 WINDOW1}>\ ))
  3. (\(<\text{PAST BREAK3}\> <\text{THE w1 WINDOW1}>\))
Events in logical form

• Introducing events into logical forms:
  1. John broke it
     \((\exists e_1 : \text{BREAK1} e_1 (\text{NAME} j_1 "John") (\text{PRO} i_1 \text{IT1}))\)
  2. John broke it with the hammer
     \((\exists e_1 : (\& (\text{BREAK1} e_1 (\text{NAME} j_1 "John")
     \quad (\text{PRO} i_1 \text{IT1})) (\text{INSTR} e_1 <\text{THE} h_1 \text{HAMMER1}>))))\)

• Only one sense of verb break is needed
Case Grammars

- How are noun phrases related to verbs?
- Case Grammar claims: number of possible semantic relationships is small
- Sentences with different syntax but same meanings: identical case analyses
  - John broke the window with a hammer.
  - The hammer broke the window.
  - The window broke.
Case and Thematic roles

- There is only a limited set of abstract semantic relationships that can hold between a verb and its arguments.
- These are often called **thematic** or **case roles**.

  - *John broke the window* is represented as:
    
    $$(\exists e_1 : (\& (\text{BREAK}_1 e_1))$$
    
    $$(\text{AGENT } e_1 (\text{NAME } j_1 \text{ “John”}))$$
    
    $$(\text{THEME } e_1 <\text{THE } w_1 \text{ WINDOW}_1>)))$$

- General form:
  
  $$(\exists e : (\& (\text{Event-p } e) (\text{Relation}_1 e \text{ Obj}_1) ... (\text{Relation}_n e \text{ Obj}_n)))$$

- Abbreviated as:
  
  $$(\text{Event-p } e [\text{Relation}_1 \text{ Obj}_1] ... [\text{Relation}_n \text{ Obj}_n])$$
Case and Thematic roles

• The quasi-logical form of *John broke the window* is:

  (<PAST BREAK1> e1
   [AGENT (NAME j1 “John”)]
   [THEME <THE w1 WINDOW1>])
Speech Acts

- Different sentences have different purposes
- Each type of sentence indicates a different relation between the speaker and the receiver
- Each type is represented by an operator called a speech act

- (ASSERT (Proposition))
- (Y/N-QUERY (Proposition))
- (WH-QUERY (Proposition))
- (COMMAND (Proposition))
The man ate a peach

(ASSERT (<PAST EAT> e1
 [AGENT <THE m1 MAN1>]
 [THEME <A p1 PEACH>])))

Did the man eat a peach?

(Y/N-QUERY (<PAST EAT> e1
 [AGENT <THE m1 MAN1>]
 [THEME <A p1 PEACH>])))

Eat the peach

(COMMAND (EAT e1 [THEME <THE p1 PEACH>])))
Wh questions

• A new quantifier WH is needed to represent wh-terms
  – What: <WH p1 PHYSOBJ1>
  – Which man: <WH m1 MAN1>
  – Who: <WH p1 PERSON1>

• For how many and how much two more quantifiers HOW-MANY and HOW-MUCH are needed:

What did the man eat?

(WH-QUERY (<PAST EAT1> e1
  [AGENT <THE m1 MAN1>]
  [THEME <WH w1 PHYSOBJ1>])))
Embedded sentences

• Embedded sentences do not need any new notation

The man who ate a peach left

\[
\text{(ASSERT (<PAST LEAVE> e1}
\text{[AGENT <THE m1 (& (MAN1 m1)
\text{( <PAST EAT1> e2
\text{[AGENT m1]
\text{[THEME <A p1 PEACH1>))> >}])}
\text{)}})}
\]