Overview

• Some notes on the linguist’s stance
• Which aspects of semantics we’ll tackle
• Our formalization; Semantics Principles
• Building semantics of phrases
• Modification, coordination
• Structural ambiguity
Some of our statements are statements about how the model works:

“[prep] and [AGR 3sing] can’t be combined because AGR is not a feature of the type prep.”

Some of our statements are statements about how (we think) English or language in general works.

“The determiners *a* and *many* only occur with count nouns, the determiner *much* only occurs with mass nouns, and the determiner *the* occurs with either.”

Some are statements about how we code a particular linguistic fact within the model.

“All count nouns are [SPR < [COUNT +]>].”
The Linguist's Stance:
A Vista on the Set of Possible English Sentences

- ... as a background against which linguistic elements (words, phrases) have a distribution
- ... as an arena in which linguistic elements “behave” in certain ways
So far, our grammar has no semantic representations. We have, however, been relying on semantic intuitions in our argumentation, and discussing semantic contrasts where they line up (or don't) with syntactic ones.

Examples?

- structural ambiguity
- S/NP parallelism
- count/mass distinction
- complements vs. modifiers
Our Slice of a World of Meanings
Aspects of meaning we won’t account for

• Pragmatics
• Fine-grained lexical semantics:

The meaning of *life* is *life’s*, or, in our case,

\[
\begin{bmatrix}
\text{RELN} & \text{life} \\
\text{INST} & i
\end{bmatrix}
\]
Our Slice of a World of Meanings

“... the linguistic meaning of Chris saved Pat is a proposition that will be true just in case there is an actual situation that involves the saving of someone named Pat by someone named Chris.” (p. 140)
Our Slice of a World of Meanings

What we are accounting for is the compositionality of sentence meaning.

• How the pieces fit together
  
  Semantic arguments and indices

• How the meanings of the parts add up to the meaning of the whole.

  Appending RESTR lists up the tree
Semantics in Constraint-Based Grammar

• Constraints as (generalized) truth conditions
  • proposition: what must be the case for a proposition to be true
  • directive: what must happen for a directive to be fulfilled
  • question: the kind of situation the asker is asking about
  • reference: the kind of entity the speaker is referring to

• Syntax/semantics interface: Constraints on how syntactic arguments are related to semantic ones, and on how semantic information is compiled from different parts of the sentence.
Feature Geometry

\[
\begin{align*}
\text{SYN} & : \begin{bmatrix}
\text{HEAD} & \text{pos} \\
\text{VAL} & \begin{bmatrix}
\text{SPR} & \text{list(expression)} \\
\text{COMPS} & \text{list(expression)}
\end{bmatrix}
\end{bmatrix} \\
\text{SEM} & : \begin{bmatrix}
\text{MODE} & \{\text{prop, ques, dir, ref, none}\} \\
\text{INDEX} & \{i, j, k, \ldots s_1, s_2, \ldots\} \\
\text{RESTR} & \text{list(pred)}
\end{bmatrix}
\end{align*}
\]
How the Pieces Fit Together

⟨Dana ,

[W]word

 SYN

 [W]HEAD

 [W]AGR 3sing

 [W]SPR ⟨⟩

 [W]COMPS ⟨⟩

 [W]noun

 [W]VAL

 VAL

 [W]INDEX

 [W]MODE

 [W]INDEX i

 [W]MODE ref

 [W]RESTR

 [W]RELN name

 [W]NAME Dana

 [W]NAMED i

⟩
How the Pieces Fit Together

\[ \langle \text{slept,} \rangle \]

\[
\begin{array}{c}
\text{word} \\
\text{SYN} \\
\text{VAL} \\
\text{SEM} \\
\end{array}
\]

\[
\begin{array}{c}
\text{HEAD} \\
\text{SPR} \\
\text{INDEX} \\
\text{MODE} \\
\text{RESTR} \\
\end{array}
\]

\[
\begin{array}{c}
\text{verb} \\
\langle \text{NP} j \rangle \\
\text{prop} \\
\text{RELN} \text{ sleep} \\
\text{SIT} \\
\text{SLEEPER} \text{ j} \\
\end{array}
\]

\[
\begin{array}{c}
\langle \text{COMPS} \langle \rangle \rangle \\
\langle \text{SPR} \rangle \\
\langle \text{NP} J \rangle \\
\langle \text{RELN} \text{ sleep} \rangle \\
\langle \text{SIT} \text{ s_1} \rangle , \ldots \\
\end{array}
\]
The Pieces Together

[SEM [INDEX i]]

INP [SEM [INDEX i]]

S

VP

[SYN [VAL [SPR (1)]]]

SEM

RESTR

[RELN sleep

SIT s₁,

SLEEPER i]

Dana slept
A More Detailed View of the Same Tree
To Fill in Semantics for the S-node

We need the Semantics Principles

- The Semantic Inheritance Principle:

  In any headed phrase, the mother's MODE and INDEX are identical to those of the head daughter.

- The Semantic Compositionality Principle:
Semantic Inheritance Illustrated
To Fill in Semantics for the S-node

We need the Semantics Principles

• The Semantic Inheritance Principle:

In any headed phrase, the mother's MODE and INDEX are identical to those of the head daughter.

• The Semantic Compositionality Principle:

In any well-formed phrase structure, the mother's RESTR value is the sum of the RESTR values of the daughter.
Semantic Compositionality Illustrated

\[ S \]

\[
\begin{align*}
\text{SEM} & \quad \text{INDEX } s_1 \\
\text{MODE} & \quad \text{prop} \\
\text{RESTR} & \quad \left\langle \begin{array}{l}
\text{RELN } \text{name} \\
\text{NAME } \text{Dana} \\
\text{NAMED } i
\end{array} \right\rangle,
\begin{array}{l}
\text{RELN } \text{sleep} \\
\text{SIT } s_1 \\
\text{SLEEPER } i
\end{array}, \ldots
\end{align*}
\]

\[ \text{NP} \]

\[
\begin{align*}
\text{SEM} & \quad \text{INDEX } i \\
\text{RESTR} & \quad \left\langle \begin{array}{l}
\text{RELN } \text{name} \\
\text{NAME } \text{Dana} \\
\text{NAMED } i
\end{array} \right\rangle
\end{align*}
\]

\[ \text{VP} \]

\[
\begin{align*}
\text{SYN} & \quad \text{VAL} [ \text{SPR } \langle 1 \rangle ] \\
\text{SEM} & \quad \text{RESTR} \left\langle \begin{array}{l}
\text{RELN } \text{sleep} \\
\text{SIT } s_1 \\
\text{SLEEPER } i
\end{array} \right\rangle, \ldots
\end{align*}
\]
What Identifies Indices?

S

1. [NP_i the cat]

2. [VP[SPR \langle 1 \rangle] slept]

   3. [SPR \langle 1 \rangle]

   4. [RESTR [RELN sleep SIT s3 SLEEPER_i]]

5. [PP on the mat]
Summary: Words ...

• contribute predications
• ‘expose’ one index in those predications, for use by words or phrases
• relate syntactic arguments to semantic arguments

```
<slept,
[HEAD  verb
[SPR  \( \langle \text{NP}_j \rangle \)]
[COMPS \( \langle \rangle \)]

[INDEX  \( s_1 \)]
[MODE  \( \text{prop} \)]

[RESTR  \( \langle \text{RELN}  \text{sleep}  s_1, \ldots \rangle \)]
[\( \text{SIT}  s_1 \)]
[\( \text{SLEEPER}  j \)]
```
Summary: Grammar Rules ...

• identify feature structures (including the INDEX value) across daughters

HeadSpecifierRule

\[
\begin{align*}
\left[ \text{phrase} \right] & \quad \Rightarrow \quad H \left[ \text{word} \right] \\
\text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right] & \quad \Rightarrow \quad H \left[ \text{SYN} \left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right] \right]
\end{align*}
\]

HeadComplementRule

\[
\begin{align*}
\left[ \text{phrase} \right] & \quad \Rightarrow \quad H \left[ \text{word} \right] \\
\text{SYN} \left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right] & \quad \Rightarrow \quad H \left[ \text{SYN} \left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right] \right]
\end{align*}
\]

HeadModifierRule

\[
\begin{align*}
\left[ \text{phrase} \right] & \quad \Rightarrow \quad H \left[ \text{word} \right] \\
\text{SYN} \left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right] & \quad \Rightarrow \quad H \left[ \text{SYN} \left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right] \right]
\end{align*}
\]
Summary: Grammar Rules ...

- identify feature structures (including the INDEX value) across daughters
- license trees which are subject to the semantic principles
  - SIP ‘passes up’ MODE and INDEX from head daughter
Summary: Grammar Rules ...

- identify feature structures (including the INDEX value) across daughters
- license trees which are subject to the semantic principles
  - SIP ‘passes up’ MODE and INDEX from head daughter
  - SCP: ‘gathers up’ predications (RESTR list) from all daughters
Reading Questions

• What's with the overly specific semantic role labels (LOVER, LOVED, etc)? Why not go with something more general, like AGENT, PATIENT, …or SUBJ, OBJ, …

• Thing #68

• What's up with ARG as a feature on a predication?

• How do we pick RELN values?
• I understand that verbs can be relations (love, walk), but I do not understand how a Proper noun (Kim) can be a relation (I understand that name is participating in the verb relation, but I do not understand why the value of RELN for Kim is name - unless it is supposed to express the role of Kim, but then wouldn't subject be more appropriate?)
Reading Questions

- Why use lists for RESTR if the order never matters?
- If today is modifying the verb, why do we not say that the verb's original index is 's' and then modified to 's1' once today and the verb merge together into a VP?
- What happens to the semantic index when an optional argument is not picked up?
Reading Questions

• How could this semantic representation be extended to handle quantifier scope ambiguities (involving other quantifiers and/or modal operators)?

• What are some of the "standard" techniques that computational natural language applications employ to resolve the precise scope of quantifiers? When would one want to do this as opposed to leaving scope unresolved where it was originally unspecified?
Reading Questions


• What does it mean for the value of a semantic feature to be an "identity" and not a "constraint"?
Other Aspects of Semantics

- Tense, Quantification (only touched on here)
- Modification
- Coordination
- Structural Ambiguity
Evolution of a Phrase Structure Rule

Ch. 2: \[ \text{NOM} \rightarrow \text{NOM PP} \]
\[ \text{VP} \rightarrow \text{VP PP} \]

Ch. 3:
\[ \begin{bmatrix}
\text{phrase} \\
\text{VAL} \\
\text{SPR}
\end{bmatrix}
\rightarrow
\begin{bmatrix}
\text{phrase} \\
\text{VAL} \\
\text{SPR}
\end{bmatrix}
\]

Ch. 4:
\[ [\text{phrase}] \rightarrow \begin{bmatrix}
\text{H}\begin{bmatrix}
\text{VAL} \\
\text{COMPS} \langle \rangle
\end{bmatrix}
\end{bmatrix}
\]

Ch. 5:
\[ [\text{phrase}] \rightarrow \begin{bmatrix}
\text{H}^{1}\begin{bmatrix}
\text{SYN}\begin{bmatrix}
\text{VAL} \\
\text{COMPS} \langle \rangle
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\]

Ch. 5 (abbreviated):
\[ [\text{phrase}] \rightarrow \begin{bmatrix}
\text{H}^{1}\begin{bmatrix}
\text{COMPS} \langle \rangle
\end{bmatrix}
\end{bmatrix}
\]
Evolution of Another Phrase Structure Rule

Ch. 2: \[ X \rightarrow X^+ \text{ CONJ } X \]

Ch. 3: \[ 1 \rightarrow 1^+ \begin{bmatrix} \text{word} \\
\text{HEAD} & \text{conj} \end{bmatrix} 1 \]

Ch. 4: \[ \begin{bmatrix} \text{VAL} [1] \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL} [1]^+ \text{ word} \\
\text{HEAD} & \text{conj} \end{bmatrix} \begin{bmatrix} \text{VAL} [1] \end{bmatrix} \]

Ch. 5: \[ \begin{bmatrix} \text{SYN} [\text{VAL} [0]] \\
\text{SEM} [\text{IND } s_0] \end{bmatrix} \rightarrow \]

\[ \begin{bmatrix} \text{SYN} [\text{VAL} [0]] \end{bmatrix} \ldots \begin{bmatrix} \text{SYN} [\text{VAL} [0]] \end{bmatrix} \begin{bmatrix} \text{SYN} [\text{HEAD conj}] \\
\text{SEM} [\text{IND } s_0] \end{bmatrix} \begin{bmatrix} \text{SEM} [\text{IND } s_{n-1}] \end{bmatrix} \begin{bmatrix} \text{SEM} \text{ RESTR } \langle \text{ARGS } \langle s_1 \ldots s_n \rangle \rangle \end{bmatrix} \begin{bmatrix} \text{SYN} [\text{VAL} [0]] \\
\text{SEM} [\text{IND } s_n] \end{bmatrix} \]

Ch. 5 (abbreviated): \[ \begin{bmatrix} \text{VAL} [0] \\
\text{IND } s_0 \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL} [0] \end{bmatrix} \ldots \begin{bmatrix} \text{VAL} [0] \end{bmatrix} \begin{bmatrix} \text{HEAD conj} \\
\text{IND } s_0 \end{bmatrix} \begin{bmatrix} \text{IND } s_{n-1} \end{bmatrix} \begin{bmatrix} \text{RESTR } \langle \text{ARGS } \langle s_1 \ldots s_n \rangle \rangle \end{bmatrix} \begin{bmatrix} \text{VAL} [0] \\
\text{IND } s_n \end{bmatrix} \]
Combining Constraints and Coordination

Coordination Rule

\[
\begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_0
\end{bmatrix} \rightarrow \begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_1
\end{bmatrix} \cdots \begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_{n-1}
\end{bmatrix} \begin{bmatrix}
\text{HEAD} & \mathit{conj} \\
\text{IND} & s_0 \\
\text{RESTR} & \langle [\text{ARGS} \langle s_1 \ldots s_n \rangle] \rangle
\end{bmatrix} \begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_n
\end{bmatrix}
\]

Lexical Entry for a Conjunction

\[
\langle \text{and} , \\
\text{SEM}
\rangle \begin{bmatrix}
\text{SYN} \\
\text{HEAD} & \mathit{conj} \\
\text{INDEX} & s \\
\text{MODE} & \mathit{none} \\
\text{RESTR} & \langle [\text{RELN} \langle \text{and} \rangle] \rangle
\end{bmatrix}
\]
Combining Constraints and Coordination

Lexical Entry for *and*

\[
\begin{array}{c}
\text{SYN} \\
\text{SEM} \\
\text{INDEX} \\
\text{MODE} \\
\text{RESTR}
\end{array}
\begin{array}{c}
[\text{HEAD} \ \text{conj}] \\
[\text{RELN} \ \text{and}] \\
[\text{SIT} \ s] \\
\text{none} \\
\text{and}
\end{array}
\]

Coordination Rule

\[
\begin{align*}
[\text{VAL} \ [0] \ \text{IND} \ s_0] & \rightarrow [\text{VAL} \ [0] \ \text{IND} \ s_1] \cdots [\text{VAL} \ [0] \ \text{IND} \ s_{n-1}] \\
[\text{HEAD} \ \text{conj} \ \text{IND} \ s_0] & \rightarrow [\text{RESTR} \ {\langle \text{ARGS} \ s_1 \ldots s_n \rangle}] \\
[\text{VAL} \ [0] \ \text{IND} \ s_n]
\end{align*}
\]
Structural Ambiguity, Tree I

S

IND \( s_0 \)

CONJ

IND \( s_0 \)

S

IND \( s_1 \)

NP

Pat

VP

sings

and

IND \( s_2 \)

NP

Lee

VP

dances

MOD \( \langle \bigcirc \rangle \)

ADV

frequently

RESTR

RELN name

NAME Pat

NAMED k

RELN name

NAME Lee

NAMED j

RELN sing

SIT \( s_1 \)

SINGER k

RELN dance

SIT \( s_2 \)

DANCER j

RELN and

SIT \( s_0 \)

ARGS \( \langle s_1, s_2 \rangle \)

RELN frequently

ARG \( s_0 \)
Structural Ambiguity, Tree II

[IND $s_0$]

[IND $s_1$]

[IND $s_2$]

NP

VP

Pat

sings

and

NP

VP

Lee

dances

[MOD $\langle \text{frequently} \rangle$]
Question About Structural Ambiguity

Why isn’t this a possible semantic representation for the string *Pat sings and Lee dances frequently*?
Semantic Compositionality

IND \( s_0 \)
MODE prop

\[
\begin{align*}
\text{RESTR} & \langle [RELN \ name \ NAME \ Pat \ NAMED k], [RELN \ sing \ SIT \ s_1], [RELN \ and \ SIT \ s_0], [ARGS \ \langle s_1, s_2 \rangle] \rangle \\
& \langle [RELN \ name \ NAME \ Lee \ NAMED j], [RELN \ dance \ SIT \ s_2], [RELN \ frequently \ ARG \ s_0] \rangle
\end{align*}
\]
Overview

• Some notes on the linguist’s stance
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• Next time: How the grammar works