Understanding sentences

“Every chef cooks a meal”
\[ \forall x [\text{chef}(x) \rightarrow \exists y [\text{meal}(y) \land \text{cooks}(y, x)]] \]
\[ \exists y [\text{meal}(y) \land \forall x [\text{chef}(x) \rightarrow \text{cooks}(y, x)]] \]

We translate sentences into (first-order) predicate logic.

Every (declarative) sentence corresponds to a proposition, which can be true or false.

Recap: CCG derivation with semantics

\[ \text{NP : John} \quad \text{sees} \quad \text{NP : Mary} \]
\[ \text{NP} \rightarrow \lambda x. \lambda y. \text{sees}(x, y) \]
\[ \text{NP} \rightarrow \lambda y. \text{sees}(\text{Mary}, y) \]
\[ \text{S} \rightarrow \text{sees}(\text{Mary}, \text{John}) \]
Verb semantics

Thematic roles

Verbs describe events or states (‘eventualities’):
- Tom broke the window with a rock.
- The window broke.
- The window was broken by Tom by a rock.

Thematic roles refer to participants of these events:
- **Agent** (who performed the action): Tom
- **Patient** (who was the action performed on): window
- **Tool/Instrument** (what was used to perform the action): rock

Thematic roles are different from grammatical roles (subject or object).

The inventory of thematic roles

It is difficult to give a formal definition of thematic roles that generalizes across all verbs.

Proposition Bank (PropBank):
- Arg0 = proto-agent
- Arg1 = proto-patient
- Arg2...: specific to each verb
- ArgM-TMP/LOC/...: temporal/locative/... modifiers

FrameNet:
Verbs fall into classes that define different kinds of frames (change-position-on-a-scale frame: rise, increase,...). Each frame has its own set of frame elements.

PropBank

agree.01
- Arg0: Agreer
- Arg1: Proposition
- Arg2: Other entity agreeing
  - [Arg0: The group] agreed [Arg1: it wouldn’t make an offer]
  - [Arg0: John] agrees with [Arg2: Mary]

fall.01
- Arg1: patient/thing falling
- Arg2: extent/amount fallen
- Arg3: start point
- Arg4: end point
  - [Arg1: Sales] fell [Arg4 to $251 million]
  - [Arg1: Junk bonds] fell [Arg2 by 5%]

Semantic role labeling: Recover the semantic roles of verbs (nowadays typically PropBank-style)
- Machine learning; trained on PropBank
- Syntactic parses provide useful information
Diathesis Alternations

Active/passive alternation:
- Tom *broke* the window with a rock. (active voice)
- The window *was broken* by Tom/by a rock. (passive voice)

Causative alternation:
- Tom *broke* the window. (‘causative’; active voice)
- The window *broke*. (‘anticausative’/‘inchoative’; active voice)

Dative alternation
- Tom *gave* the gift to Mary.
- Tom gave Mary the gift.

Locative alternation:
- Jessica *loaded* boxes into the wagon.
- Jessica loaded the wagon with boxes.

Verb classes

Verbs with similar meanings undergo the same syntactic alternations, and have the same set of thematic roles (Beth Levin, 1993)

VerbNet ([verbs.colorado.edu](http://verbs.colorado.edu); Kipper et al., 2008)
A large database of verbs, their thematic roles and their alternations

What is discourse?

On Monday, John went to Bevande. He wanted to buy lunch. But the cafe was closed. That made him angry, so the next day he went to Green Street instead.

‘Discourse’:
any linguistic unit that consists of multiple sentences

Speakers describe “some situation or state of the real or some hypothetical world” (Webber, 1983)

Speakers attempt to get the listener to construct a similar model of the situation.
What can go wrong in discourse?

**Discourse 1:**
John went to his favorite music store to buy a piano. It was a store John had frequented for many years. He was excited that he could finally buy a piano. It was closing just as John arrived.

**Discourse 2:**
John went to his favorite music store to buy a piano. He had frequented the store for many years. He was excited that he could finally buy a piano. He arrived just as the store was closing for the day.

Entity-based coherence

**Discourse 1:**
John went to his favorite music store to buy a piano. It was a store John had frequented for many years. He was excited that he could finally buy a piano. It was closing just as John arrived.

**Discourse 2:**
John went to his favorite music store to buy a piano. He had frequented the store for many years. He was excited that he could finally buy a piano. He arrived just as the store was closing for the day.

How we refer to entities influences how coherent a discourse is (Centering theory)

Centering Theory

Grosz, Joshi, Weinstein (1986, 1995)

A linguistic theory of entity-based coherence and salience

It predicts which entities are salient at any point during a discourse. It also predicts whether a discourse is entity-coherent, based on its referring expressions.

Centering is about local (within a discourse segment) coherence and salience

Centering theory itself is not a computational model or an algorithm: many of its assumptions are not precise enough to be implemented directly. (Poesio et al. 2004)

But many algorithms have been developed based on specific instantiations of the assumptions that Centering theory makes. The textbook presents a centering-based pronoun-resolution algorithm

What else can go wrong?

**Discourse 1:**
John hid Bill’s car keys. He was drunk.

**Discourse 2:**
John hid Bill’s car keys. He likes spinach.
Coherence relations

Discourse 1:
John hid Bill’s car keys. He was drunk.

Discourse 2:
John hid Bill’s car keys. He likes spinach.

Discourse 1 is more coherent than Discourse 2 because “He(=Bill) was drunk” provides an explanation for “John hid Bill’s car keys.”

What kind of relations between two consecutive utterances (=sentences, clauses, paragraphs,...) make a discourse coherent?

Rhetorical Structure Theory; also lots of recent work on discourse parsing (Penn Discourse Treebank)

Example: The Result relation

The reader can infer that the state/event described in S0 causes (or: could cause) the state/event asserted in S1:

S0: The Tin Woodman was caught in the rain.
S1: His joints rusted.

This can be rephrased as:
“S0. As a result, S1”

Example: The Explanation relation

The reader can infer that the state/event in S1 provides an explanation (reason) for the state/event in S0:

S0: John hid Bill’s car keys.
S1: He was drunk.

This can be rephrased as:
“S0 because S1”

Rhetorical Structure Theory (RST)

RST (Mann & Thompson, 1987) describes coherence relations between utterances.

It defines a set of rhetorical relations: Evidence, Elaboration, Attribution, Contrast, List,...
Different variants of RST assume different sets of relations.

Most relations hold between a nucleus (N) and a satellite (S). Some relations (e.g. List) have multiple nuclei (and no satellite).

Every relation imposes certain constraints on its arguments (N,S), that describe the goals and beliefs of the reader R and writer W, and the effect of the utterance on the reader.
Discourse structure is hierarchical

How can we understand discourse?

On Monday, John went to Bevande. He wanted to buy lunch. But the cafe was closed. That made him angry, so the next day he went to Green Street instead.

Understanding discourse requires (among other things):

1) doing coreference resolution: ‘the cafe’ and ‘Bevande’ refer to the same entity. He and John refer to the same person. That refers to ‘the cafe was closed’.

2) identifying discourse (‘coherence’) relations: ‘He wanted to buy lunch’ is the reason for ‘John went to Bevande’.

Discourse models should capture...

Physical entities: John, Bevande, lunch

Events: On Monday, John went to Bevande involve entities, take place at a point in time

States: It was closed. involve entities and hold for a period of time

Temporal relations: afterwards between events and states

Rhetorical (‘discourse’) relations: ... so ... instead between events and states
How do we refer to entities?

**Referring expressions** (‘this book’, ‘it’) refer to some entity (e.g. a book), which is called the **referent**.

**Co-reference**: two referring expressions that refer to the same entity **co-refer** (are co-referent).

*I saw a movie last night. I think you should see it too!*

The referent is **evoked** in its first mention, and **accessed** in any subsequent mention.

**Indefinite NPs**

- **no determiner**:  
  *I like walnuts.*

- **the indefinite determiner**:  
  *She sent her a beautiful goose*

- **numerals**:  
  *I saw three geese.*

- **indefinite quantifiers**:  
  *I ate some walnuts.*

- **(indefinite) this**:  
  *I saw this beautiful Ford Falcon today*

Indefinites usually **introduce a new discourse entity**. They can refer to a specific entity or not:  
*I’m going to buy a computer today.*
Definite NPs

- the definite article (`the book`),
- demonstrative articles (`this/that book, these/those books`),
- possessives (`my/John's book`)
Definite NPs can also consist of
- personal pronouns (`I, he`)
- demonstrative pronouns (`this, that, these, those`)
- universal quantifiers (`all, every`)
- (unmodified) proper nouns (`John Smith, Mary, Urbana`)

Definite NPs refer to an identifiable entity
(previously mentioned or not)

Information status

Every entity can be classified along two dimensions:

**Hearer-new vs. hearer-old**

Speaker assumes entity is (un)known to the hearer
- Hearer-old: I will call Sandra Thompson.
- Hearer-new: I will call a colleague in California (=Sandra Thompson)

**Special case of hearer-old: hearer-inferrable**

I went to the student union. The food court was really crowded.

Discourse-new vs. discourse-old:

Speaker introduces new entity into the discourse, or refers to an entity that has been previously introduced.
- Discourse-old: I will call her/Sandra now.
- Discourse-new: I will call my friend Sandra now.

Coreference resolution

Victoria Chen, Chief Financial Officer of Megabucks Banking Corp since 2004, saw her pay jump 20%, to $1.3 million, as the 37-year-old also became the Denver-based financial services company’s president. It has been ten years since she came to Megabucks from rival Lotsabucks.

Coreference chains:
1. `{Victoria Chen, Chief Financial Officer...since 2004, her, the 37-year-old, the Denver-based financial services company’s president}
2. `{Megabucks Banking Corp, Denver-based financial services company, Megabucks}
3. `{her pay}
4. `{rival Lotsabucks`

Coref as binary classification

Represent each NP-NP pair (+context) as a feature vector.

Training:
Learn a binary classifier to decide whether NP_i is a possible antecedent of NP_j

Decoding (running the system on new text):
- Pass through the text from beginning to end
- For each NP_i:
  - Go through NP_{i-1}...NP_1 to find best antecedent NP_j
  - Corefer NP_i with NP_j
  - If the classifier can’t identify an antecedent for NP_i, it’s a new entity.
Features for Coref resolution

- Do the two NPs have the same head noun? (e.g. company)
- Do they contain the same modifier? (e.g. Denver-based)?
- Does the gender and number of the NPs match?
- Does one NP contain an alias (acronym) of the other? (United States = USA, Chief Executive Office = CEO)
- Is one NP a hypernym/synonym of the other?
- Are both NPs named entities of the same type? [CEO] = PERSON, Victoria Chen = PERSON

Evaluation: B-cubed F-score

The test data consists of $D$ documents $d$ with $N$ total mentions $m$ (mention boundaries are given as input).
- In the gold standard, each mention $m$ belongs to a ‘true’ cluster of mentions (connected component) of size $t_m$
- In the system output, each mention $m$ belongs to a predicted cluster of mentions (connected component) of size $p_m$
- For each mention $m$, the intersection of the gold standard and system output clusters defines a common cluster of mentions of size $c_m$

\[
\text{Precision } P = \frac{1}{N} \sum_{d \in D} \sum_{m \in d} \frac{c_m}{p_m}
\]

\[
\text{Recall } R = \frac{1}{N} \sum_{d \in D} \sum_{m \in d} \frac{c_m}{t_m}
\]

\[
\text{F-measure } = \frac{2PR}{P + R}
\]

Special case: Pronoun resolution

Task: Find the antecedent of an anaphoric pronoun in context

1. John saw a beautiful Ford Falcon at the dealership.
2. He showed it to Bob.
3. He bought it.

he$_2$, it$_2$ = John, Ford Falcon, or dealership?
he$_3$, it$_3$ = John, Ford Falcon, dealership, or Bob?

Anaphoric pronouns

Anaphoric pronouns refer back to some previously introduced entity/discourse referent:

John showed Bob his car. He was impressed.
John showed Bob his car. This took five minutes.

The antecedent of an anaphor is the previous expression that refers to the same entity.

There are number/gender/person agreement constraints: girls can’t be the antecedent of he

Usually, we need some form of inference to identify the antecedents.
Salience/Focus

Only some recently mentioned entities can be referred to by pronouns:

John went to Bob’s party and parked next to a classic Ford Falcon.
He went inside and talked to Bob for more than an hour.
Bob told him that he recently got engaged.
He also said he bought it (???)/the Falcon yesterday.

Key insight (also captured in Centering Theory)
Capturing which entities are salient (in focus) reduces the amount of search (inference) necessary to interpret pronouns!