# Lecture 17
# Coreference, Text Coherence, Discourse Structure and Conversational Implicatures

**CS 6320**

# Outline

- Discourse
- Coreference
- Text coherence
- Discourse relations
- Discourse structure
- Implicatures, Grice Maxims

# Discourse

- Discourse is a sequence of sentences.
- Context refers to the syntactic and semantic structure of preceding sentences. Context includes concepts from a text as well as those implied by the text.
- Context is an important concept in NLP as it plays a role in semantic disambiguation, discourse reference, inference, etc.

  Jack lost his wallet in the car.
  He looked for it for several hours.
- Here local context is defined by the first sentence, and its understanding solves the reference resolution problem in the second.

  Jack forgot his wallet.
  Sam did too.
- Here we face an ellipsis.

# Discourse

- How to determine local context? It is a difficult question. A good guess is to consider the preceding major clauses, rather then the entire sentence.
- **Discourse entity list:** is a list of objects mentioned in the last major clause that can be referred by a pronoun. It may also be enhanced to certain implied objects.
  - An indefinite NP normally introduces a new discourse entity.
  - A definite NP normally refers to an object previously mentioned in the discourse.
- **Reference:** is a linguistic process in which one word refers to one or more words in the discourse.

# Reference

- A simple taxonomy of reference:
  - **Endophor:** refers to an entity which appears in the discourse. It is further classified as:
    - *Anaphor*: refers to an entity which appeared earlier in the discourse. It is the most common reference:

      Tom bought a new car and he likes it very much.
    - *Cataphor*: refers to an entity which appears later in the discourse.

      When he entered the room, Tom found that the glass was broken.
  - **Exaphor**: refers to an entity in the real world not mentioned in the discourse.

    Pick that up. (pointing to an object)
- Types of anaphora:
  - Pronouns

    Tom bought a new car. He likes it.

    He and it are the referring expressions, i.e. pronouns, and Tom and a new car are the referents.

# Reference

- The referents have a high degree of salience in the discourse. Pronouns usually refer to entities that were introduced no further then one or two sentences back.
- **Indefinite Noun Phrases**

  I saw an Acura Integra today.

  Some Acura Integras were being unloaded at the local dealership today.
- **Definite Noun Phrases**

  Tom loves a sales girl at Broadway, but the girl does not like him.
- **Epithet NP**

  As Tom used his credit card too much, the poor guy bankrupted.
- **Surface count**

  Lynn has two boyfriends, Mark and Kevin.

  She likes the former better.

# Reference

- **One Anaphora**
  I saw no less than 6 Acura Integra today. Now I want one.
- **Inferrables**
  I almost bought an Acura today, but a door had a dent and the engine seemed noisy.
- **Generics**
  I saw no less than 6 Acura Integras today. They are the coolest cars.
- **Syntactic and Semantic Constraints on Coreference**
  John has three new Acuras. They are red. (number)
  You and I have Acuras. We love them. (person)
  John has an Acura. It is attractive. (gender)
  John bought himself a new Acura. (himself = John)
  John bought him a new Acura. (him John)
- **Selectional restrictions**
  John parked his Acura in the garage.
  He had driven it for hours.

# Reference

- Selectional restrictions are violated in the case of metaphor.

  John bought a new Acura. It drinks gasoline like you would not believe.

- **Semantic constraints:**

  John parked his Acura in the garage.

  It is incredibly messy, with old bike and car parts lying around everywhere.

- **Main Approaches to Anaphora Resolution (heuristics):**
  - *Recency*

    John has an Integra. Bill has a Legend.

    Mary likes to drive it.

  - *Grammatical role:* Treat entities in the subject position as more salient than those in object position, which in turn are more salient than those mentioned in subsequent positions.

    John went to the Acura dealership with Bill.

    He bought an Integra. (he = John)

# Reference

- *Repeated mention*

  John needed a car to get to his new job. He decided that he wanted something sporty. Bill went to the Acura dealership with him.

  He bought an Integra. (he = John)

- *Parallelism*

  Mary went with Sue to the Acura dealership.

  Sally went with her to the Mazda dealership. (her = Sue)

- *Verb semantics:* Certain verbs place a semantically oriented emphasis on one of their argument positions.

  John telephoned Bill. He lost the pamphlet on Acuras.

  John criticized Bill. He lost the pamphlet on Acuras.

# Pronoun Resolution Algorithm

- **Lappin and Leass Pronouns Resolution Algorithm**
  - The idea is to use a weighting scheme that integrates the effects of recency and syntactic preferences.
  - The algorithm computes a salience value as a sum of weights assigned by a set of salience factors.

| | |
|---|---|
| Sentence recency | 100 |
| Subject emphasis | 80 |
| Existential emphasis | 70 |
| Accusative (direct object) emphasis | 50 |
| Indirect object and oblique complement emphasis | 40 |
| Non-adverbial emphasis | 50 |
| Head noun emphasis | 80 |

  - subject > existential predicate nominal > object > indirect object > demarcated adverbial PP.

# Pronoun Resolution Algorithm

- Algorithm:
  1. Collect the potential referents.
  2. Remove referents that do not agree in number, gender
  3. Remove referents that do not pass intrasentence syntactic constraints.
  4. Compute the total salience value.
  5. Select referent with highest salience value.

# Pronoun Resolution Algorithm

John saw a beautiful Acura Integra at the dealership. He showed it to Bob. He bought it.

| | Rec | Subj | Exist | Obj | Ind-Obj | Non-Adv | Head N | Total |
|---|---|---|---|---|---|---|---|---|
| John | 100 | 80 | | | | 50 | 80 | 310 |
| Integra | 100 | | | 50 | | 50 | 80 | 280 |
| dealership | 100 | | | | | 50 | 80 | 230 |

| Referent | Phrases | Value |
|---|---|---|
| John | { *John* } | 155 |
| Integra | { *a beautiful Acura Integra* } | 140 |
| dealership | { *the dealership* } | 115 |

| Referent | Phrases | Value |
|---|---|---|
| John | { *John*, $he_1$ } | 465 |
| Integra | { *a beautiful Acura Integra* } | 140 |
| dealership | { *the dealership* } | 115 |

# Pronoun Resolution Algorithm

| Referent | Phrases | Value |
|---|---|---|
| John | { *John*, $he_1$ } | 465 |
| Integra | { *a beautiful Acura Integra*, $it_1$ } | 420 |
| dealership | { *the dealership* } | 115 |

| Referent | Phrases | Value |
|---|---|---|
| John | { *John*, $he_1$ } | 465 |
| Integra | { *a beautiful Acura Integra*, $it_1$ } | 420 |
| Bob | { *Bob* } | 270 |
| dealership | { *the dealership* } | 115 |

| Referent | Phrases | Value |
|---|---|---|
| John | { *John*, $he_1$ } | 232.5 |
| Integra | { *a beautiful Acura Integra*, $it_1$ } | 210 |
| Bob | { *Bob* } | 135 |
| dealership | { *the dealership* } | 57.5 |

# Coreference

"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 of Megabucks Banking Corp since 1994, her, the 37-year-old, the Denver-based financial-services company's president, she*}
2. {*Megabucks Banking Corp, the Denver-based financial-services company, Megabucks*}
3. { *her pay* }
4. { *Lotsabucks* }

# Text Coherence

- A discourse is coherent when its sentences are logically related to each other.
- Coherence is important for reference, word sense disambiguation interpretation and other linguistic problems.
- On the other hand, coreference acts as a cohesive device – i.e. references tie up different parts of discourse.

  John hid Bill's car keys. He was drunk.

  *John hid Bill's car keys. He likes spinach.
- The first example is coherent. (why?), whereas the second is not.

# Coherence Relations

- $S_0$ and $S_1$ represent the meanings of two related sentences.
- **Result**: Infer that $S_0$ causes or could cause the state $S_1$or event asserted by .

  John bought an Acura. His father went ballistic.
- **Explanation**: Infer that $S_1$ causes or could cause the state or event asserted by $S_0$.

  John hid Bill's car keys. He was drunk.
- **Parallel:** Infer $P(a_1, a_2, \ldots)$ from the assertion of $S_0$ and $P(b_1, b_2, \ldots)$ from the assertion of $S_1$, where $a_i$ and $b_i$ are similar, for all i.

  John bought an Acura. Bill leased a BMW.
- **Elaboration:** Infer the same proposition P from the assertions of $S_0$ and $S_1$.

  John bought an Acura. He purchased a beautiful New Integra.

# Coherence Relations

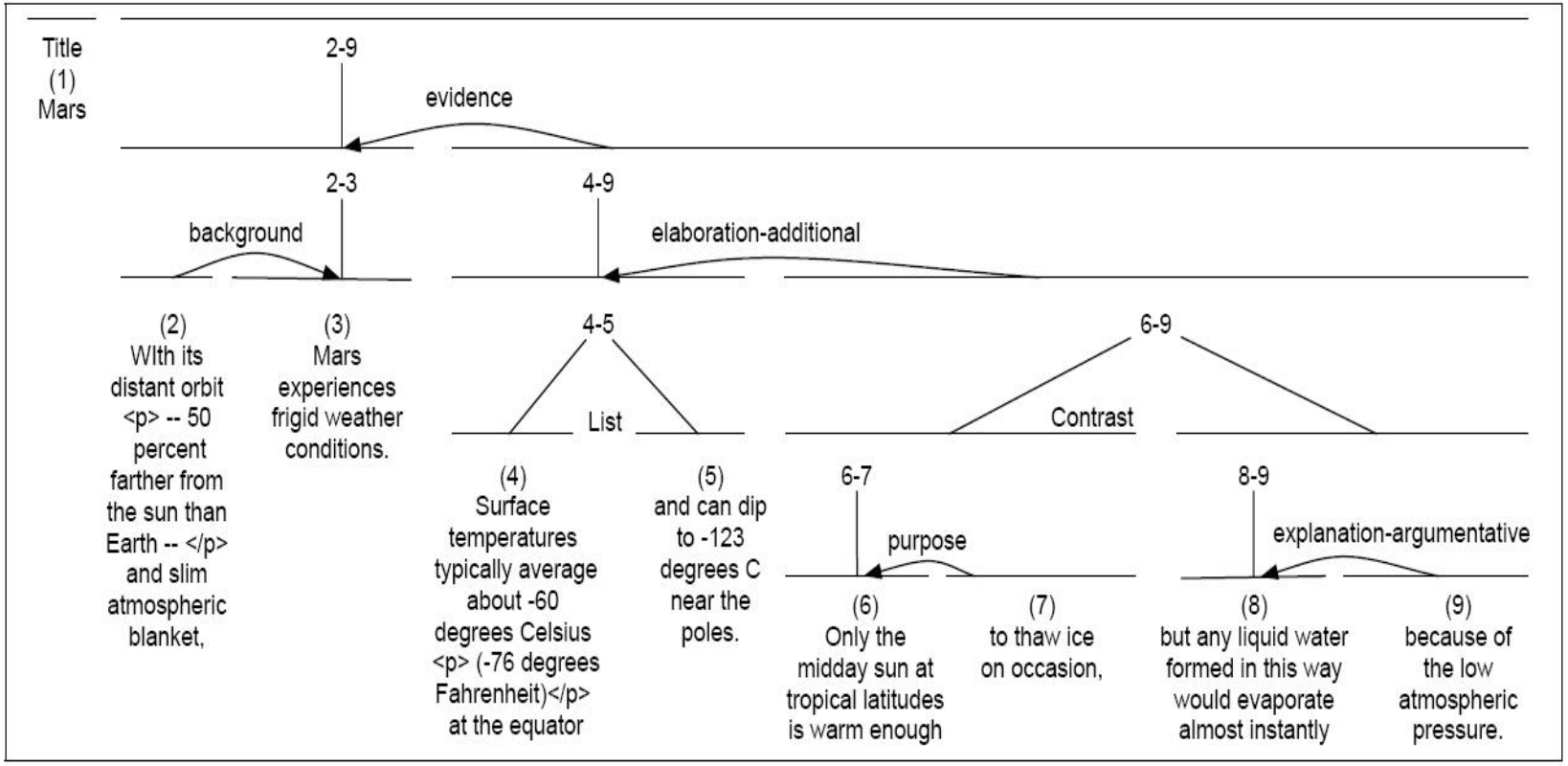
- **Occasion**: A change of state can be inferred from $S_0$, whose final state can be inferred from $S_1$, or vice-versa, a change of state can be inferred from $S_1$, whose initial state can be inferred from $S_0$.

  John bought an Acura. He drove to the ballgame.

# Discourse tree

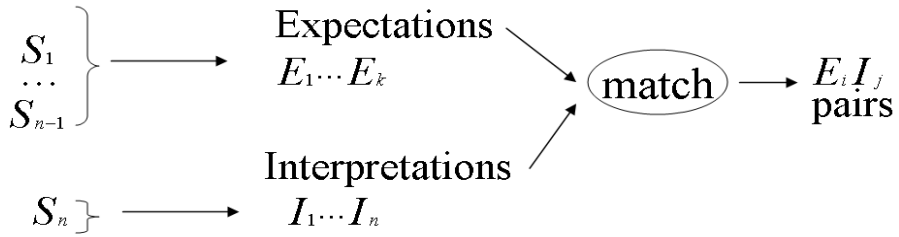
- With its distant orbit-50 percent farther from the sun than Earth-and slim atmospheric blanket, Mars experiences frigid weather conditions. Surface temperatures typically average about -60 degrees Celsius (-76 degrees Fahrenheit) at the equator and can dip to -123 degrees C near the poles. Only the midday sun at tropical latitudes is warm enough to thaw ice on occasion, but any liquid water formed in this way would evaporate almost instantly because of the low atmospheric pressure.

# Discourse Tree



# Approach to Coherence

- **Matching against Expectations:**
  - A technique to establish coherence is to match the interpretations of a sentence against the expectations generated by a previous sentence.
  - These expectations are inferences made when interpreting the sentence.




- **Methods for matching:**
  - **Attempt 1:** Prove an interpretation from an expectation. This usually fails.
  - **Attempt 2:** Prove an expectation from an interpretation. This is also weak.
  - **Attempt 3:** Unification – try to unify E with I.
- Coherence is AI-complete – i.e. it essentially requires all of the knowledge and the ability to utilize it – that humans have.

# Approach to Coherence

Expectations can be generated from causal relationships among actions.

- **Effect causality.** Every action has some effects.
  - Intended effects
  - Side effects
- **Precondition causality** – every action has a set of Conditions that typically must hold before action starts (or during action).

Relations between actions that generate expectations:

- **Enablement**. An action enables another if the effects of the first establish the preconditions for the second. (it may establish only some of the preconditions, the others are established by other actions).
- **Decomposition.** An action is a subpart (or substep) of another action if the first is one of a sequence of substeps that constitute the execution of the second action.

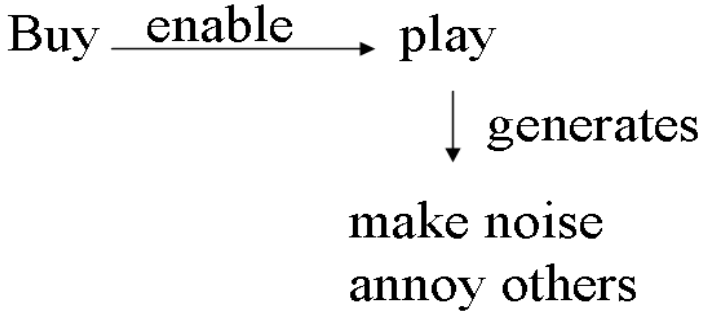
# Approach to Coherence

- **Generalization.** An action generates another if executing the first also executes the second one (turn a switch on, generates turning a light on).
- We need a KR system that captures these relations between actions. Then, it will be easy to generate expectations.

  Jack bought a stereo at the mall.
- All the effects of buy are implied. It is redundant to say:

  Jack bought a stereo at the mall. Now he owns it.
- More interesting is to derive expectations from actions that are enabled by the buying action.

  Jack bought a stereo at the mall. Now he can disturb his neighbors.



# Coherence Example

- Example:

  Prove coherence for:

  John hid Bill's car keys. He was drunk.

**Deduction**

$$\frac{a \Rightarrow b \quad a}{b}$$

*All Acuras are fast*

*John's car is an Acura.*

---

*John's car is fast.*

# Coherence Example

Prove coherence for:

John hid Bill's car keys. He was drunk.

Need axioms:

$$\forall e_i, e_j \ \text{explanation}(e_i, e_j) \Rightarrow coherence(e_i, e_j)$$

$$\forall e_i, e_j \ cause(e_j, e_i) \Rightarrow \text{explanation}(e_i, e_j)$$

$$\forall x, y, e_i \ \ drunk(e_i, x) \Rightarrow$$
$$\exists e_j e_k \ \ diswant(e_j, y, e_k) \wedge drive(e_k, x) \wedge cause(e_i, e_j)$$

$$\forall x, y, e_j, e_k \ \ diswant(e_j, y, e_k) \wedge drive(e_k, x) \Rightarrow$$
$$\exists z, e_l e_m \ \ diswant(e_l, y, e_m) \wedge have(e_m, x, z) \wedge carkeys(z, x) \wedge$$
$$cause(e_j, e_l)$$

# Coherence example

$$\forall x, y, z, e_l, e_m \; diswant(e_l, y, e_m) \wedge have(e_m, x, z) \Rightarrow$$
$$\exists e_n \; hide(e_n, y, x, z) \wedge cause(e_l, e_n)$$

$$\forall e_i, e_j, e_k \; cause(e_i, e_j) \wedge cause(e_j, e_k) \Rightarrow$$
$$cause(e_i, e_k)$$

$$hide(e_1, John, Bill, ck) \wedge carkeys(ck, Bill)$$

$$drunk(e_2, he)$$

Hypothesize that relation is explanation.

$$\exp lanation(e_1, e_2)$$
$$cause(e_1, e_2)$$
$$cause(e_2, e_3) \wedge cause(e_3, e_1)$$
$$cause(e_2, e_4) \wedge cause(e_4, e_3)$$

# Coherence Example

- Hypothesize that John did not want Bill to have his car keys:

$$diswant(e_3, John, e_5) \wedge have(e_5, Bill, ck)$$

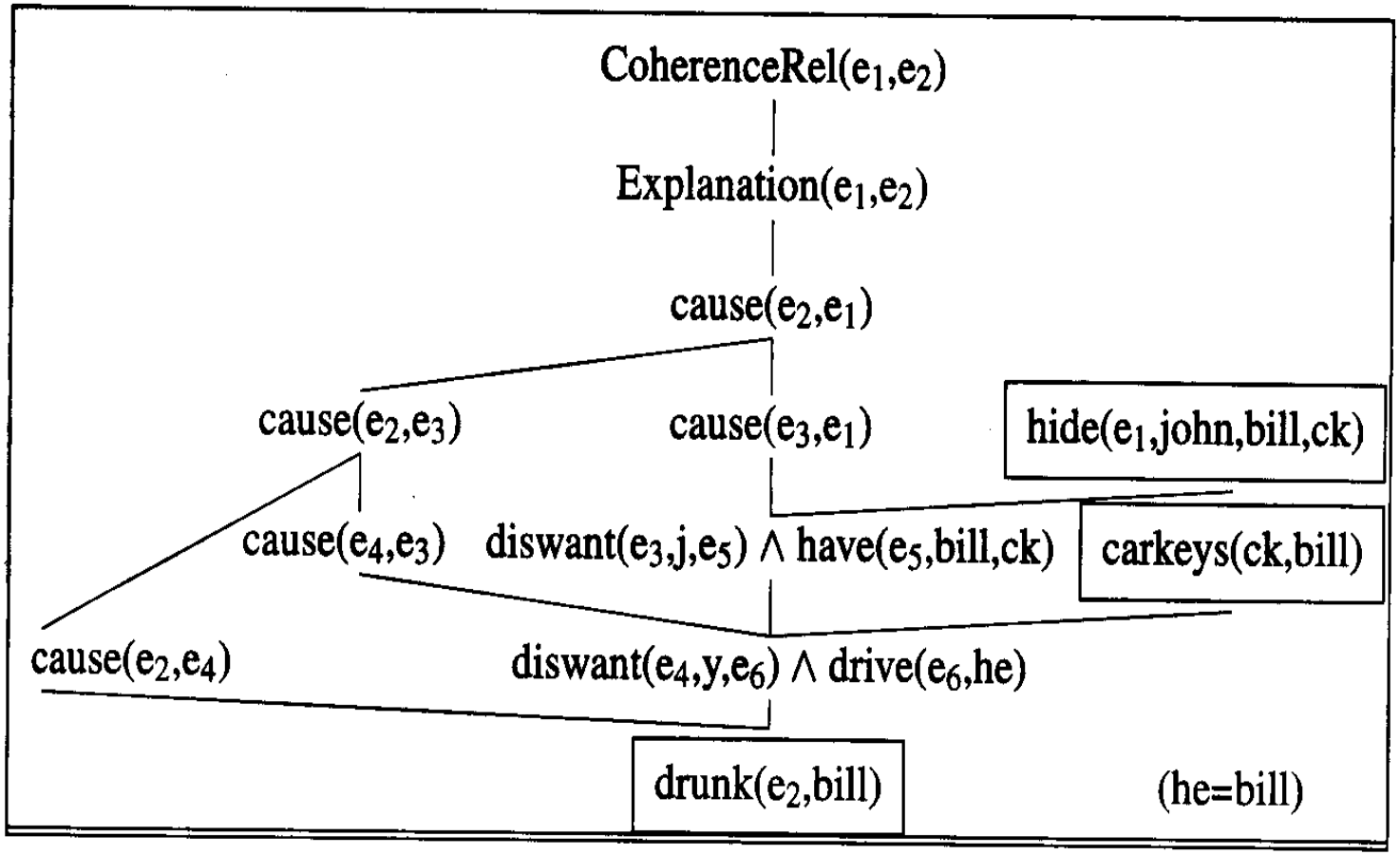
*John does not want Bill to drive*

$$diswant(e_4, John, e_6) \wedge drive(e_6, Bill)$$

*Bill was drunk.*

$$drunk(e_2, Bill)$$

# Coherence example

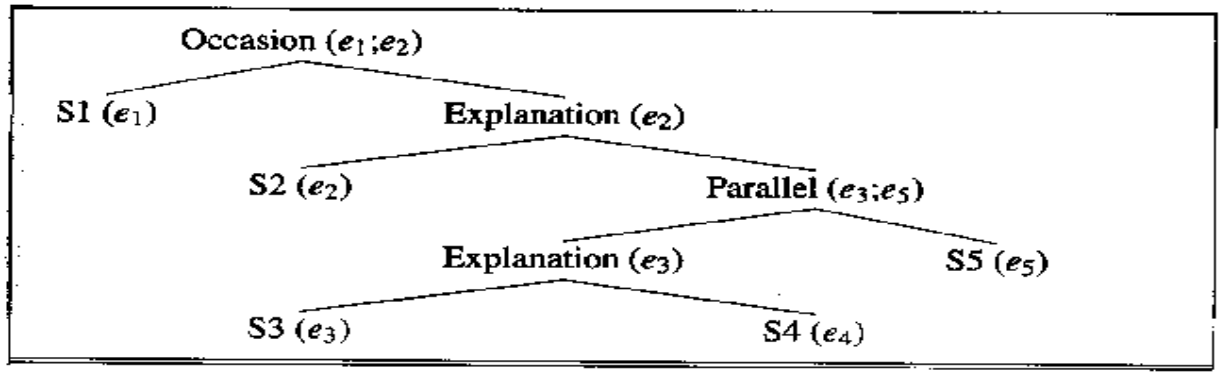


# Coherence Example

- **Generalizations:**
  - We would like the axioms to be as general as possible.
  - WordNet is a good source of world knowledge axioms.
  - For a particular domain, it may be supplemented by domain specific axioms

# Discourse Structure

- A discourse structure does not result from the coherence relations between all adjacent pairs of sentences. Discourse has an overall global structure.




**$S_1$** John went to the bank to deposit his paycheck.
**$S_2$** He then took a train to Bill's car dealership.
**$S_3$** He needed to buy a car.
**$S_4$** The company he works for isn't near any public transportation.
**$S_5$** He wanted to talk to Bill about their softball league.

# Discourse Structure

- Each node in the tree represents a discourse segment.
  - **Analysis:** Add axiom (a sentence is a discourse segment).

    $\forall w,e \;\; drunk(w,e) \Rightarrow segment(w,e)$
  - **Axiom:** Two smaller segments can be composed into a larger one if coherence relation can be established between the two.

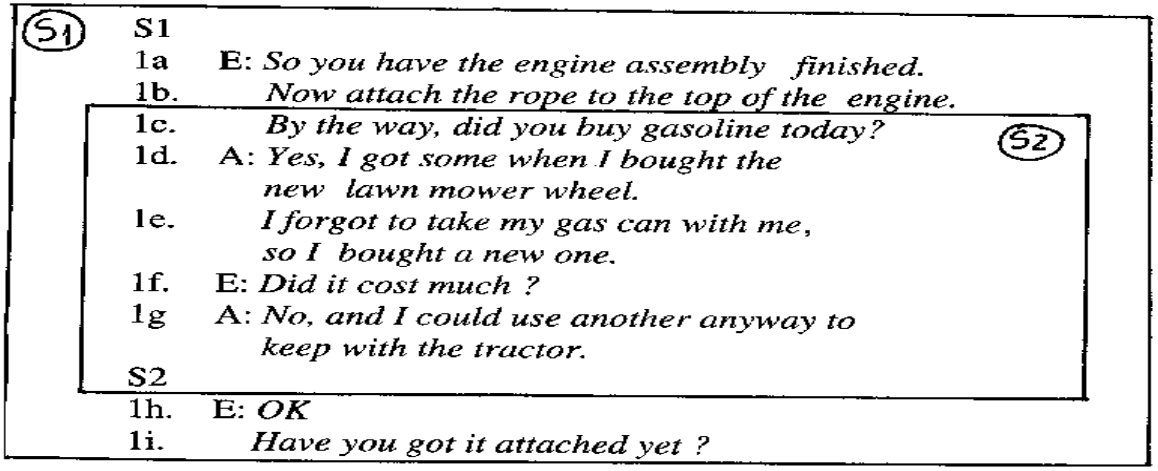
    $\forall w_1,w_2,e_1,e \;\; segment(w_1,e_1) \wedge segment(w_2,e_2) \wedge$

    $coherence\_rel(e_1,e_2,e) \Rightarrow segment(w_1,w_2,e)$
  - **Subordinating relations:** Explanation. pass only one argument
  - **Coordinating relations:** Parallel, Occasion pass both arguments.
  - To prove that a text is coherent, need to prove that

    $\exists e \;\; segment(w,e)$

# Discourse Structure

- A discourse model is introduced, and it is useful for reference resolution, coherence analysis and others.




- Discourse segments:
  - The model consists of breaking down a discourse into segments and establishing some relationships between the segments.
  - Each segment is a sequence of clauses that have local coherence.
  - Segmentation is not easy; nor is unique.

# Discourse Structure

- Properties of a segment:
  - A fixed time and location,
  - A fixed set of speakers and hearers,
  - A fixed set of assumptions is relevant.
- **Intentional view** (of a segment): all sentences in a segment contribute to a common discourse purpose.
- **Informational view** (of a segment): all sentences in a segment related to each other by some temporal, causal or rhetorical relations (i.e. an event or situation).

2a. *Jack shopped early in the day.*
2b. *He took his car*
2c. *and he bought a dozen of live lobsters.*
2d *When he got home,*
2e. *he spent the day preparing the feast.*

| Event Described | Informational Relation | Communicative Goal |
|---|---|---|
| E1: Jack goes to store | | Describe E1 as start of story |
| E2: Jack drives car | E2 part of E1 | Elaborate on E1 |
| E3: Jack buys lobsters | E2 before E3, E3 part of E1 | Elaborate on E1 |
| E4: Jack gets home | E4 provides temporal setting for E5 | Elaborate story after E1 |
| E5: Jack prepares for feast | E5 follows E4, E4 enables E5 | Elaborate story after E4 |

**Figure 16.1** Informational relations versus communicative goals

# Discourse Structure

- Example of segmentation:

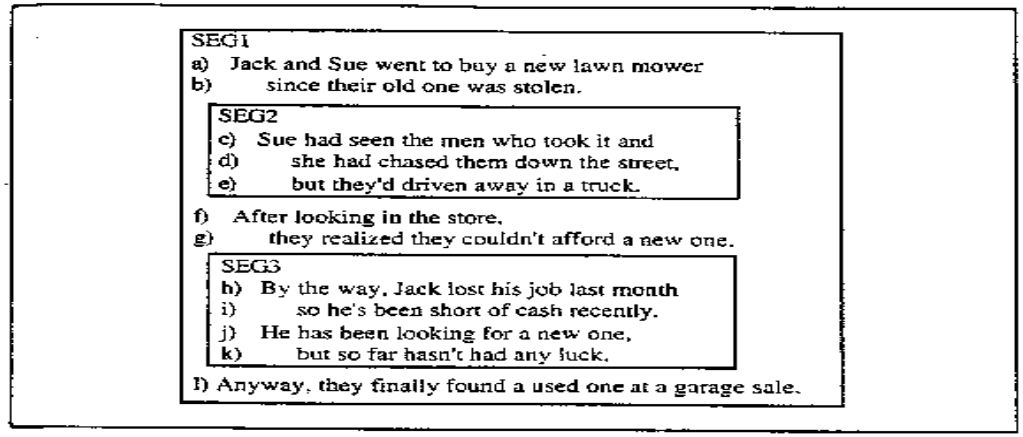



**Figure 16.2** The segment hierarchy represented by boxing

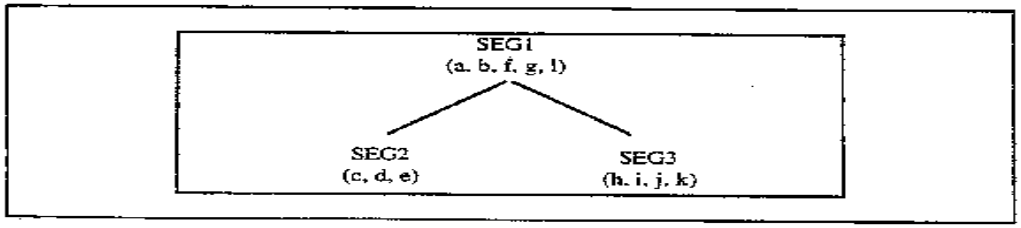
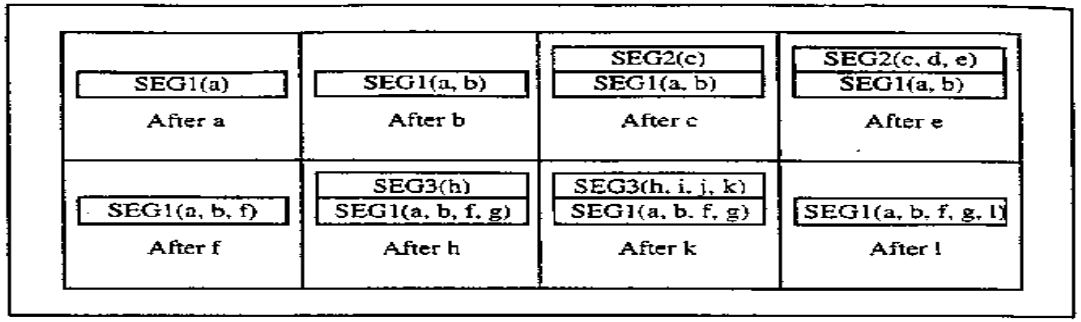



**Figure 16.3** The same segment hierarchy represented as a tree

- **Local discourse state** (for each segment):
  - Sentences in a segment,
  - Local context,
  - Coherence relations.
- **Attention stack:** consist of discourse states as discourse progresses.

# Discourse Structure




| Cue Phrases for Structure | Typical Use | Cue Phrases for Semantic Relations | Typical Use |
|---|---|---|---|
| anyway | end digression | and | continuation |
| by the way | start digression | because | causation/reason |
| bye | end dialogue | but | contrast |
| first | intro. subtopic (itemization) | furthermore | new subtopic |
| | | however | contrast |
| incidentally | start digression | meanwhile | new topic (at same time) |
| last | new subtopic (itemization) | so | conclusion |
| next | new subtopic (itemization) | then | causal/ temporal |
| | | therefore | summary |
| now | intro. subtopic | though | contrast |
| OK | close topic | | |

- Cue phrases: are words or expressions that provide clues for segment boundaries. They also signal the nature of relationship of the next clause to the preceding discourse.

# Discourse Structure

- Tense and Aspect:
  - Tense and aspect provide information about segment boundaries, and many help derive coherent relations.
  - Orient relation: between two events or states in the same segment.

    Jack was at the store. **state**

    He bought some roses. **event**

    $S_1$ orients $E_2$ ( $E_2 \subseteq S_1$ )

    Jack had five dollars.

    He bought some roses.

    $S_1 < E_2$ (event precedes state)

    Jack has some roses.

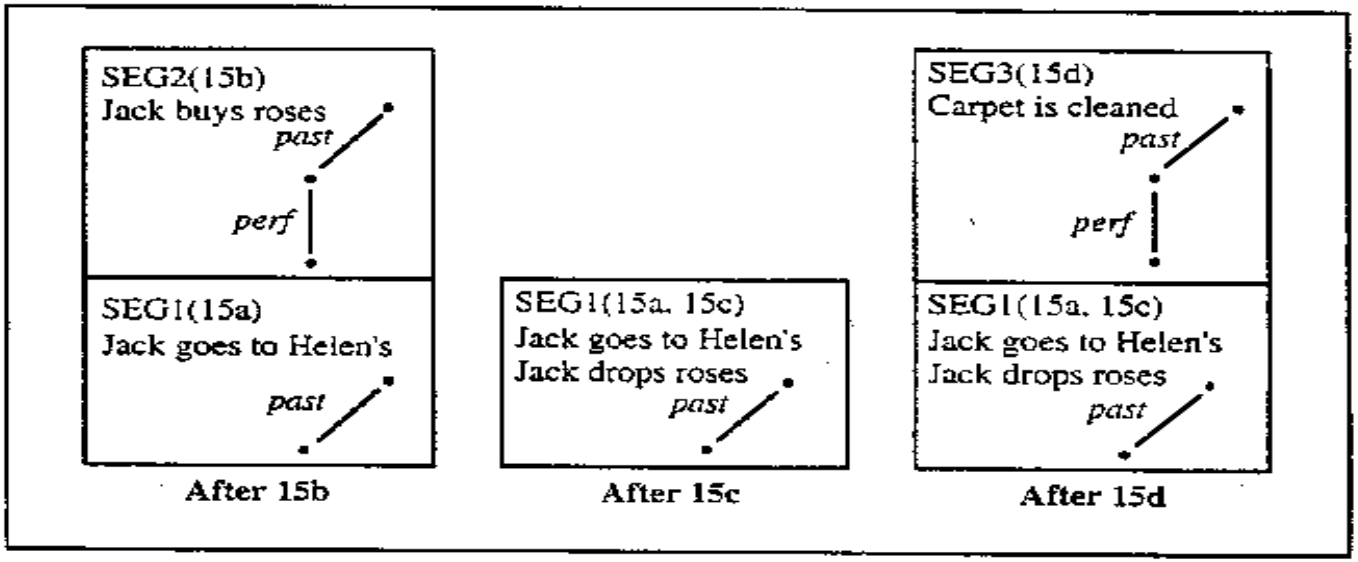
    He bought them at the store.

    $E_2 < S_1$ (event causes state)

# Discourse Structure

- Tense trees and their role in segment.

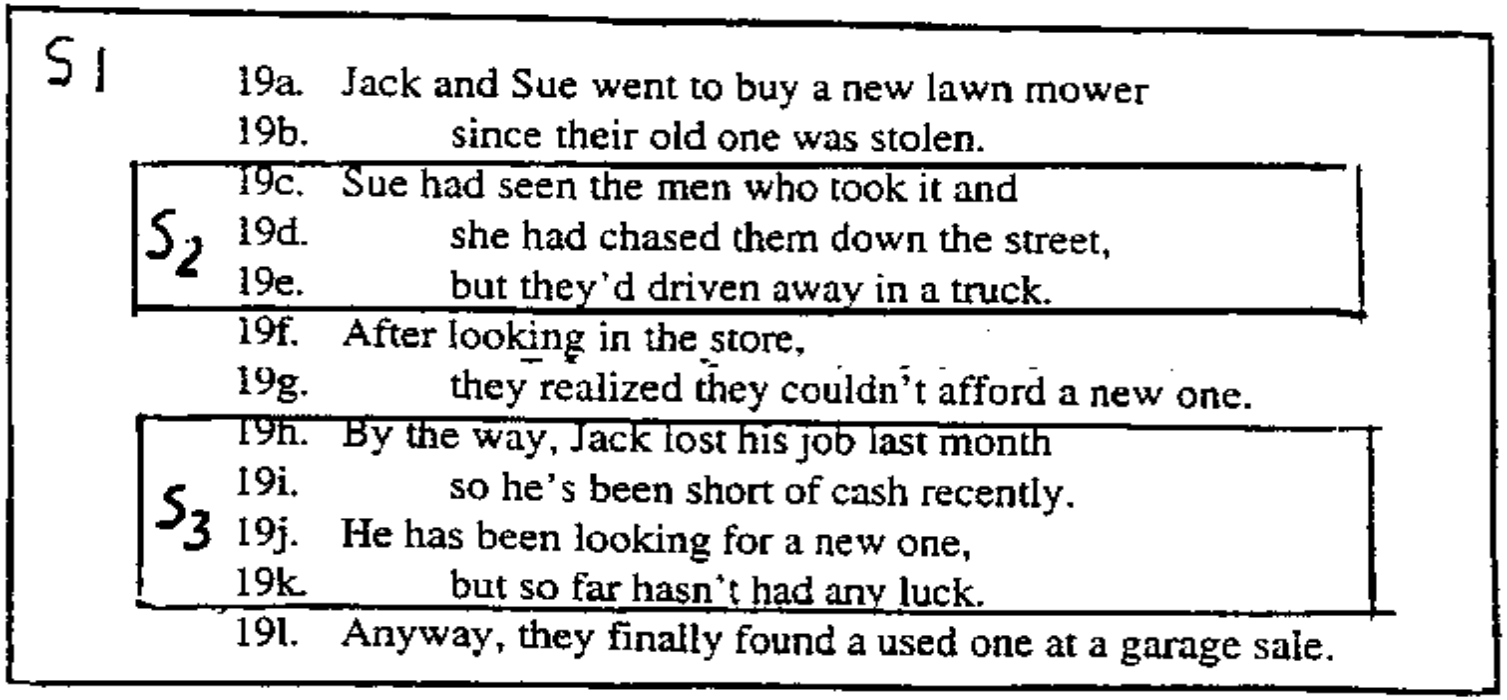
15a. Jack went to Helen's house. $S_1$
15b. He had bought some rouses. $S_2$
15c. He dropped them on the carpet
when he gave them to her.
15d. Helen had had the carpet cleaned,
so she was upset. $S_3$



# Discourse Structure

In this example, tense changes help with the segmentation.

An example (revisited)



# Implicatures

# Levels of Text Understanding

- Explicit information

  Extract only the strict meaning of words and their semantic relationships

- Entailments

  Perform inferences and draw new conclusions not stated in the text

  Entailments are computed from sentence semantics and world knowledge.

- Conversational Implicatures

  Implicatures are computed not only from sentence stated and world knowledge (like entailments), but also from the context and speaker intentions.

# Levels of Text Understanding

- Twitter conversation
  - **A:** *Dinner's ready! prawns, grouper in some sauce, vegetables, rice and shark's fin melon soup! Still waiting for lotus root soup this week!*
  - **B:** *Eeeeeee lotus root?*
  - **A:** *so what you having for dinner?*

- Conversation meaning
  - Explicitly conveyed
    - Dinner is ready. The shark's fin and melon are ingredients of the soup. A is still waiting for lotus root soup this coming week. A is asking B what B is having for dinner.
  - Inferred logically
    - The sauce is part of a dish. The soup is a dish. Dish is part of dinner. One or more dishes are ready.
  - Implicitly conveyed based on common sense assumptions
    - A is excited and proud about having prepared a gourmet dinner. B dislikes lotus root and cannot believe A would choose to eat it. A has a poor opinion of B's gastronomic knowledge (B should not question A's choices in dinner dishes).

# Boundary between Entailments and Implicatures

A: Are you inviting Mike to the party?

B: No. I'm inviting nice people.

- Scenario 1. Without any context. B thinks Mike is not a nice person.
  This is an entailment, a presupposition.

- Scenario 2. With context. Suppose B had an argument with Mike, and A knows it was B's fault. Implicature by A: +> B is revengeful.

# Examples of Implicatures

Example 1

$S_1$:That car is cheap

Scenario 1: Owner is a wealthy person driving a rather inexpensive car compared to what he can afford, the car may not be cheap compared to other cars

Scenario 2: The car is cheap compared to other cars

Example 2

John: Do you want to play tennis this weekend?

Mary: I have to study.

Scenario 1: Mary is sincere, she is an underachiever student

Scenario 2: Mary does not want to see John, refusing him politely

# Examples of Implicatures

Example 3:

A: Has Bob got a girlfriend?

B: He's been playing a lot of tennis lately

Scenario 1: No, he does not have a girlfriend, evidenced by spending time plying tennis

Scenario 2: Yes, he has a girlfriend, spending time with her playing tennis, reinforced by

A: He always liked athletic girls.

# Gricean Theory

Grice developed a theory to *explain* and *predict* conversational implicatures

**Cooperative Principle**: Contribute what is required by the accepted purpose of the conversation

1. **Maxim of Quality**: Say only what you believe to be true and only what you have evidence for (justified)
2. **Maxim of Quantity**: Be as informative as required, no more no less
3. **Maxim of Relation**: Be relevant to the topic at hand
4. **Maxim of Manner**: Be perspicuous, avoid obscurity, ambiguity, be brief, be orderly

Note: These maxims are valid for cooperative activities in general, not only for conversations

# How are Implicatures Generated?

Three ways to generate conversational implicatures

A-type Observing the maxims

A. Do you work here?

B. The doctors' office is around the corner.

All maxims are respected.

B-type Violating a maxim (a clash between maxims, one is reinforced)

A. Where's UTD located?

B. Somewhere in the Dallas area.

B violates the Quantity maxim, but can't be more specific without violating the Quality maxim; +> does not know

C-type Flouting a maxim (intentionally violating a maxim)

A. Are you playing tennis this weekend?

B. You know I don't like tennis.

B is an avid tennis player; +> yes

# Are the Implicatures Calculable?

- Implicatures can be constructed based on the literal meaning of the utterance, plus context, plus the co-operative principle and the maxims
- H must be able to make this inference in order to preserve the assumption of co-operation

1. S has said p
2. There is no reason to think S is not observing the maxims, or at least the co-operative principle
3. In order for S to say that p and be indeed observing the maxims or the co-operative principle, S must think that q
4. S must know that it is mutual knowledge that q must be supposed if S is to be taken to be co-operating
5. S has done nothing to stop H from thinking that q
6. Therefore, S intends H to think that q, and in saying that p has implicated q

# How to Compute a Conversational Implicature

- A: What on earth has happened to the roast beef?
- B: The dog is looking very happy

  A +> The dog has eaten the roast beef

1. A assumes B is following the maxim of relevance
2. B's remark will not be relevant unless the dog has something in common with the roast beef
3. Both A and B know dogs like eat roast beef, and eating make a dog happy
4. A thinks B did not say anything else to prevent A to believe that the dog ate the roast beef.
5. A concludes that B believes the dog ate the roast beef.