13: Coreference, Text Coherence and Discourse Structure

CS 6320

Outline

- Discourse
- Coreference
- Text coherence
- Discourse relations
- Discourse structure

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

  As Tom used his credit card to 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_1or 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

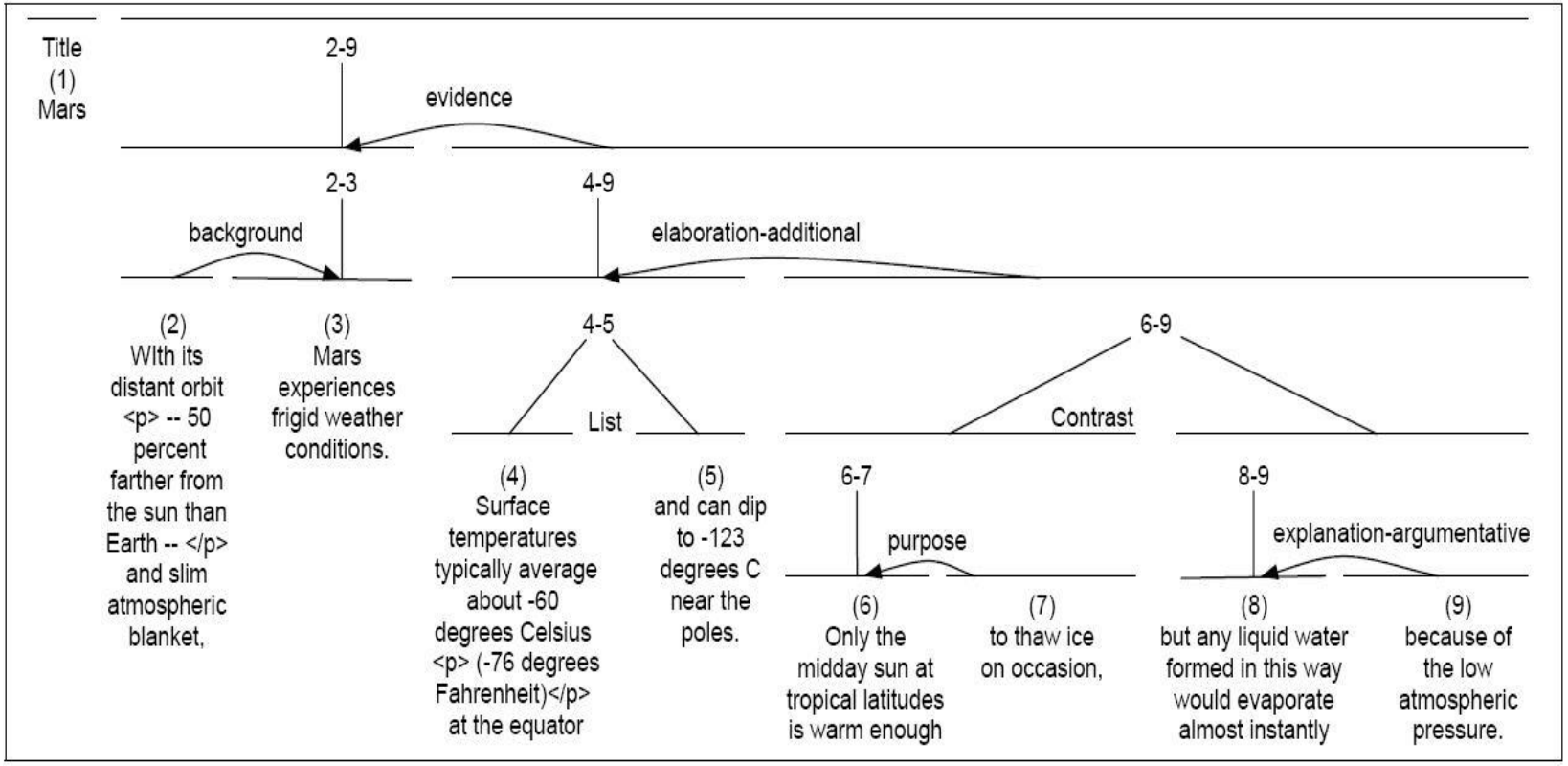
- **Occasion**: A change of state can be inferred from S_0, whose final state can be inferred from S_1, or vice-versa, a change of state can be inferred from S_1, whose initial state can be inferred from S_0.

  John bought an Acura. He drove to the ballgame.

Discourse tree

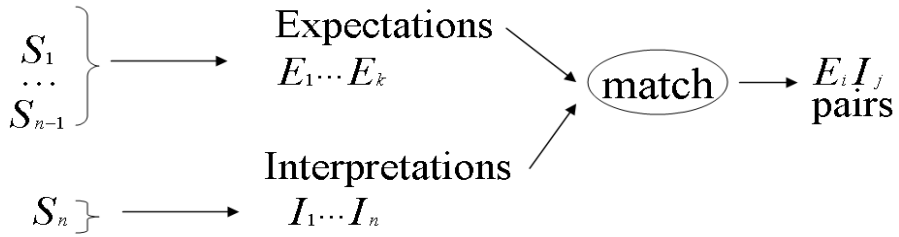
- With its distant orbit-50 percent farther from the sun than Earth-and slim atmospheric blanket, Mars experiences frigid weather conditions. Surface temperatures typically average about -60 degrees Celsius (-76 degrees Fahrenheit) at the equator and can dip to -123 degrees C near the poles. Only the 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.

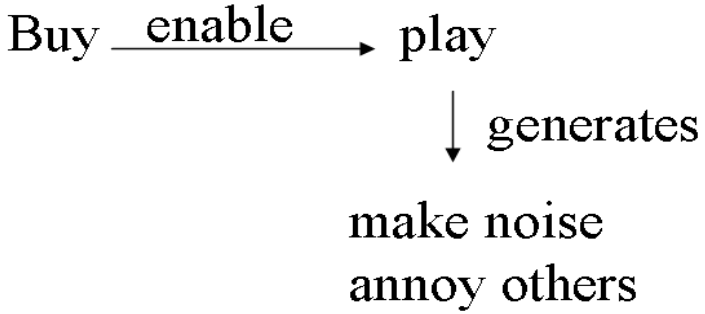
Approach to Coherence

- **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

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

$$\frac{\textit{All Acuras are fast} \quad \textit{John's car is an Acura.}}{\textit{John's car is fast.}}$$

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.

$$explanation(e_1, e_2)$$
$$cause(e_2, e_1)$$
$$cause(e_2, e_3) \wedge cause(e_3, e_1)$$
$$cause(e_2, e_4) \wedge cause(e_4, e_3)$$

Coherence Example

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

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

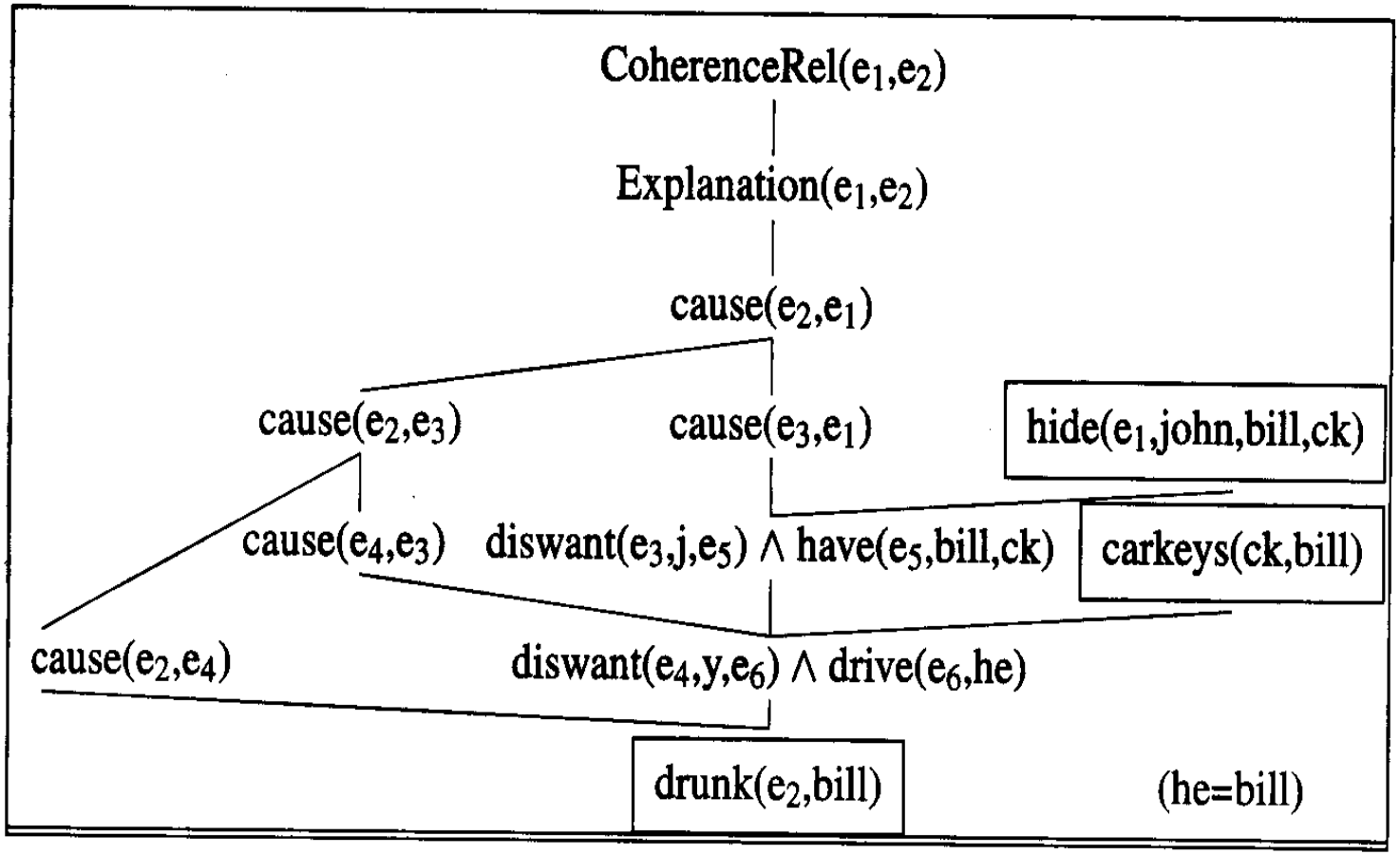
John does not want Bill to drive

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

Bill was drunk.

$$drunk(e_2, Bill)$$

Coherence example

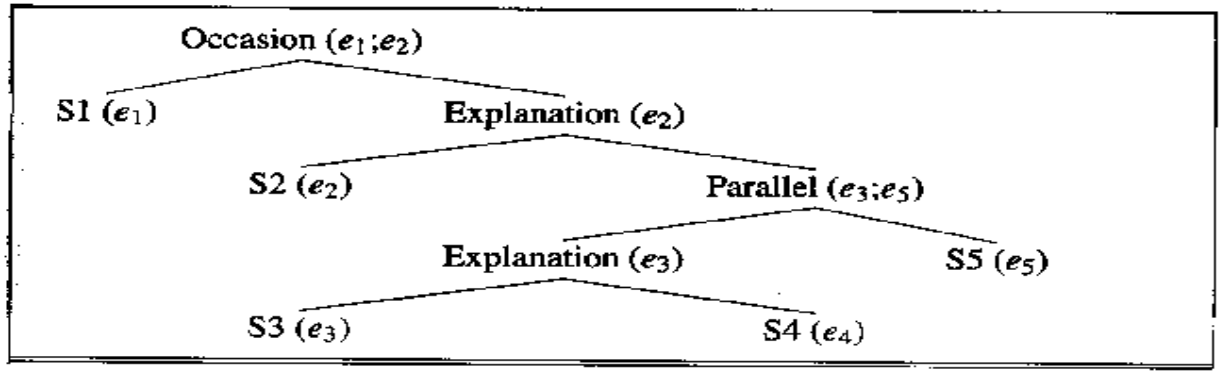


Coherence Example

- **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.

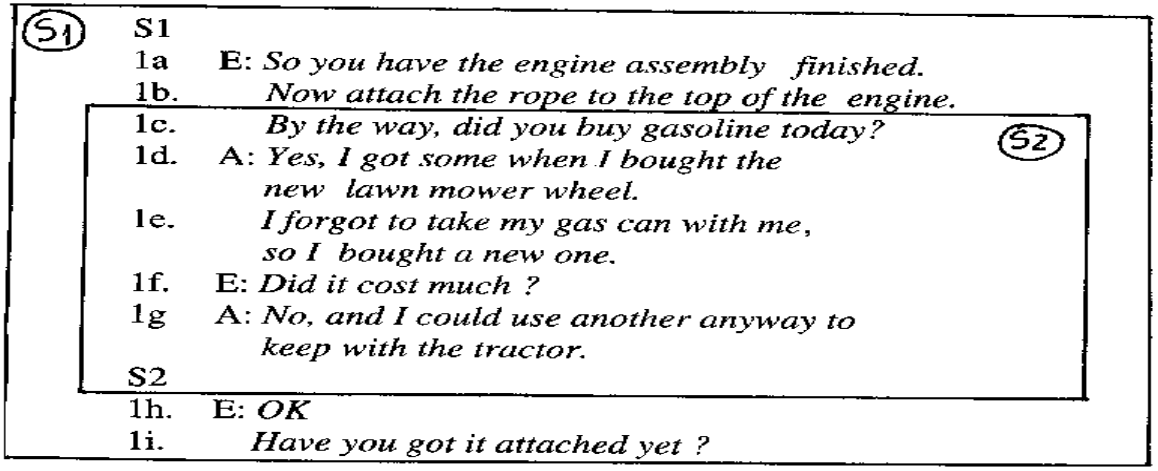
    $\forall w_1,w_2,e_1,e \;\; segment(w_1,e_1) \wedge segment(w_2,e_2) \wedge$

    $coherence\_rel(e_1,e_2,e) \Rightarrow segment(w_1,w_2,e)$
  - **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:

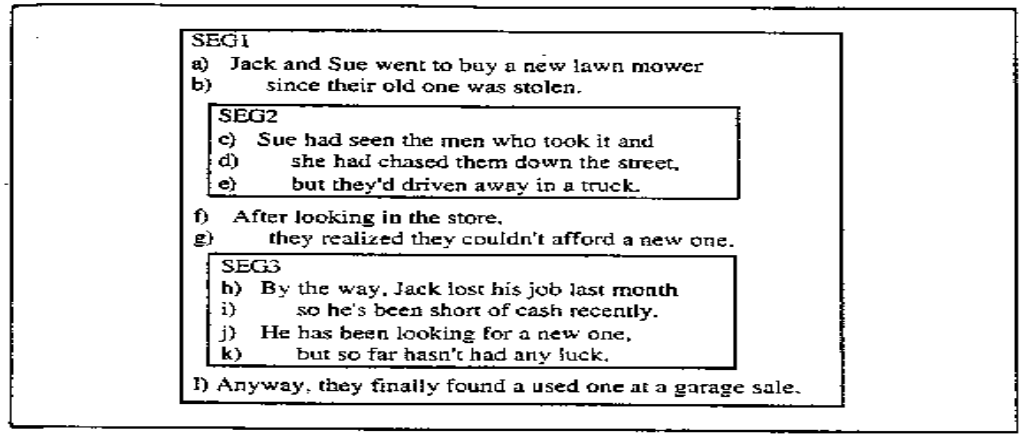


Figure 16.2 The segment hierarchy represented by boxing

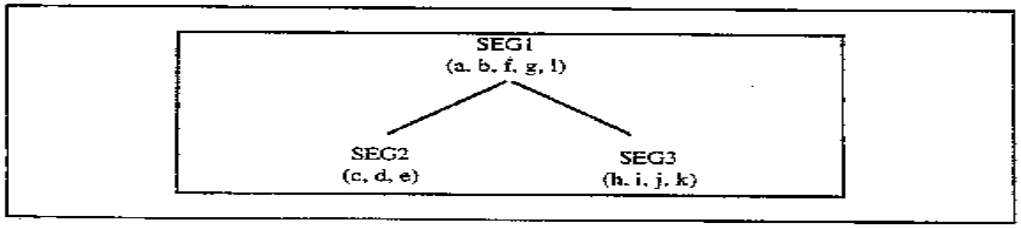
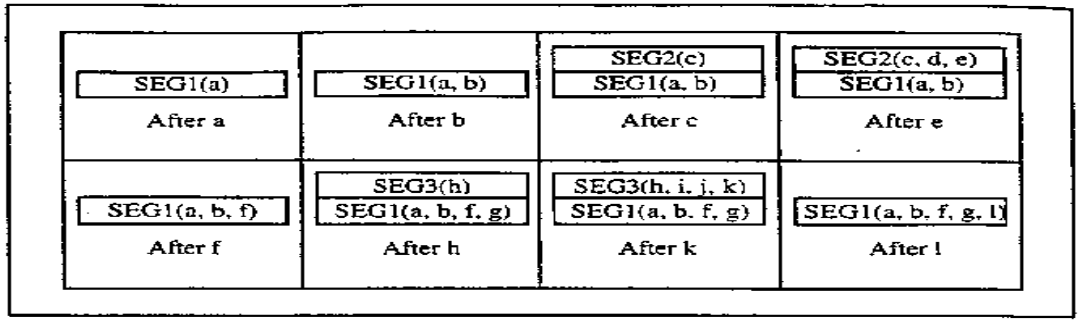


Figure 16.3 The same segment hierarchy represented as a tree

- **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.

    $S_1 < E_2$ (state precedes event)

    Jack has some roses.

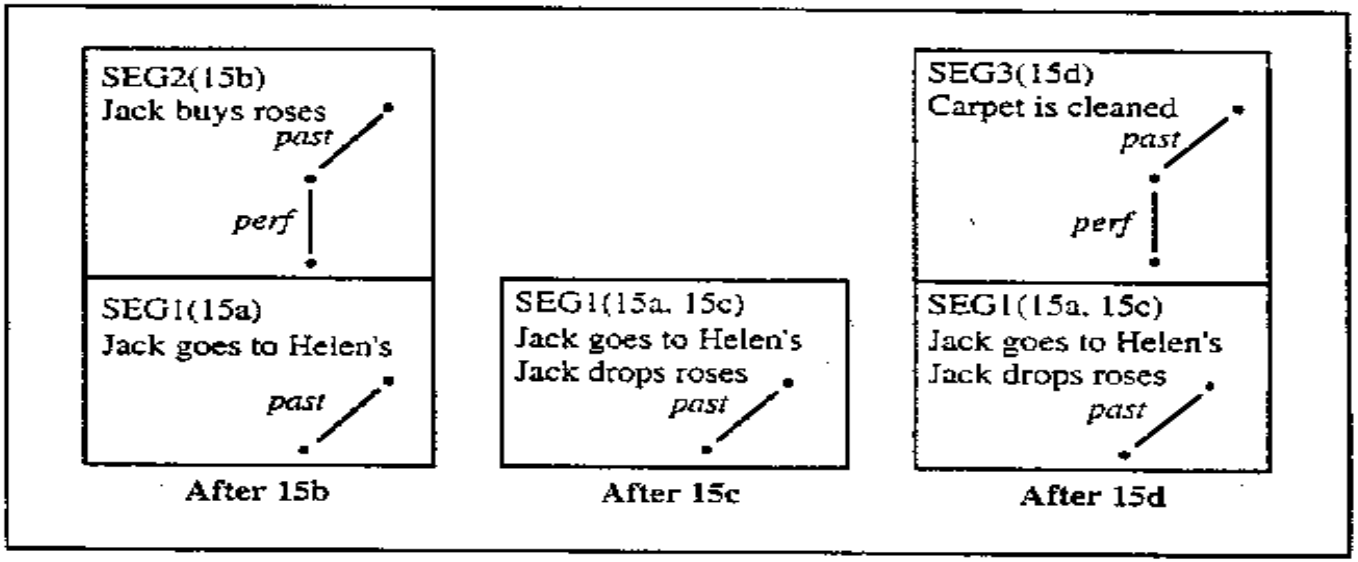
    He bought them at the store.

    $E_2 < S_1$ (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)