

Chapter 5. Ambiguity

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5.1 Ambiguity types in English:

5.1.1 lexical ambiguity:

5.1.1.1 Ambiguity in noun:

5.1.1.1.1 polysemy: one word with different meaning.

1) John is an unmarried man.

John holds a first university degree.

→ John is a bachelor

2) John is a medical doctor.

John is a doctor of philosophy.

→ John is a doctor.

3) He is looking for his drinking glasses.

He is looking for his reading glasses.

→ He is looking for his glasses.

4) Here is a small lamb.

Here is a small amount of lamb.

→ Here is a little lamb.

5.1.1.1.2 homonymy: different homonym words with different meaning.

1) He looked at the river bank..

He looked at the money bank.

→ He looked at the bank.

2) The period of sleep of the army was insufficient.

The remainder of the army was insufficient.

→ The rest of the army was insufficient.

5.1.1.1.3 The same form of singular noun and plural noun

1) I saw this sheep graze in the field.

I saw these sheep graze in the field.

→ I saw the sheep graze in the field.

2) They put the condemned person to death.

They put the condemned persons to death.

→ They put the condemned to death.

5.1.1.1.4 abbreviation ambiguity:

1) He is a news reporter from Australian Broadcasting Company.

He is a news reporter from American Broadcasting Company.

--. He is a news reporter from ABC.

2) In this book, he talks about the World Without War.

In this book, he talks about the World Wide Web.

→ In this book, he talks about WWW.

5.1.1.2 Ambiguity of pronoun

1) Nobody said he himself was wrong.

Nobody said the person in question was wrong.

→ Nobody said he was wrong.

2) He killed himself by shooting

He shot personally.

→ He shot himself.

3) Everyone was eating a large cake together.

Everyone was eating a large cake respectively.

→ Everyone was eating a large cake.

4) Every sailor loves his own girl.

Every sailor loves the same girl.

→ Every sailor loves a girl.

5.1.1.3 Ambiguity of verb:

1) I heard the child weeping.

I heard the child shouting.

→ I heard the child crying.

2) John is pulling a cart.

John is making a picture of a cart.

→ John is drawing a cart

3) They never saw the wood with their own eyes.

They never cut the wood with a saw.

→ They never saw the wood.

5.1.1.4 . Ambiguity of adjective

1) John is a mechanic with little money.

John is a mechanic who lacks competence.

→ John is a poor mechanic.

2) She is a student who is a Japanese.

She is a student who studies Japanese.

→ She is a Japanese student.

3) He tried to speed up the ship.

He tried to fasten the ship.

→ He tried to make the ship fast.

4) That was a clever idea.

That was a stupid idea.

→ That was a brilliant idea.

5) He is a salesman who is sweet.

He is a man who sells sweets (in this case, 'sweets' is a noun).

→ He is a sweet salesman.

5.1.1.5 Ambiguity of conjunctive

1) When it becomes cold, we do not go outside.

Because it became cold, we do not go outside.

→ As it became cold, we do not go outside.

2) When I was working at night in the library, I saw Mary often

Although I was working at night in the library, I saw Mary often.

- While I was working at night in the library, I saw Mary often..
- 3) From the time when I lost my glasses yesterday till now, I haven't been able to do any work.
 Because I lost my glasses yesterday, I haven't been able to do any work.
 → Since I lost my glasses yesterday, I haven't been able to do any work..

5.1.1.6 Ambiguity of preposition

- 1) The reminiscence written by my father was very interesting.
 The reminiscence about my father was very interesting.
 → The reminiscence of my father was very interesting.
- 2) John stays with Tom.
 John agrees with Tom.
 → John is with Tom.
- 3) John hits the man by means of the stick.
 John hits the man who carried the stick,
 → John hits the man with the stick.
- 4) The damage was brought about by the river.
 The damage was done beside the river.
 → The damage was done by the river.

5.1.2 POS ambiguity:

- 1) V?N: "V?N" means POS ambiguity between noun and verb.
- plan: Where do you plan to spend your vacation? (V)
 Have you made any plans for tomorrow night? (N)
- work: My daughter works in an office. (V)
 It is a gas works. (N)
 I read the works of Shakespears. (N)
- study: I study French. (V)
 We shall make a study of Shakespear's plays. (N)
- attack: The enemy could attack at night. (V)
 The city came under attack during the night. (N)
- face: The house faces the park. (V)
 She pulled a long face. (N)
- use: all the paper has been used. (V)
 A new machine for the kitchen with several different uses. (N)
- 2) AUX?N: AUX means auxiliary verb.
- may: May I help you? (AUX)
May Day is first day of May. (N)
- can: She can speak German. (AUX)
 He opened a can of beans. (N)
- will: It will rain tomorrow. (AUX)
 Free will makes us able to choose our way of life. (N)
- 3) N?ADJ:
- kind: I like that kind of book. (N)
 It was very kind of you to do it. (ADJ)
- standard: We work to a high standard of exactness. (N)

- It is one of the standard books on the subject. (ADJ)
- utmost: to do one's utmost . (N)
She worked with her utmost strength. (ADJ)
- 4) WH?PRON: PRON means pronoun.
which: Nobody wants to have a car which has been used for years. (WH)
Which do you like better, summer or winter? (PRON)
- 5) DET?N:
any: Any child would know that. (DET)
His gift was unknown to any except himself. (N) (any = anybody)
- 6) NUM?N: NUM mean number word.
one: It is one meter. (NUM)
Lent me that book -- the one with the red cover. (N)
- 7) PREP?CONJ:
for: They have bought some new chairs for the office. (PREP)
We must start early, for we have a long way to go. (CONJ)
than: He is taller than me. (PREP)
Nothing is more unpleasant than to find insects in your bath.
(CONJ)
- 8) PREP?ADV:
in: in the room. (PREP)
Open the bag and put the money in. (ADV)
down: He runs down the hill. (PREP)
It gets cold quickly when the sun goes down. (ADV)
on: a ring on my finger. (PREP)
If you walk on you shall come to the church. (ADV)
about: They walk about the street. (PREP)
I am about ready. (ADV)
- 9) ADV?CONJ:
so: Cut the apples up like so. (ADV)
I had a headache, so I went to bed. (CONJ)
- 10) PREP?V:
regard: She said nothing regarding your request. (PREP)
She regarded him curiously. (V)
- 11) PREP?TO: TO means 'to' in front of verb infinitive.
to: He wants to be fed. (TO)
He points to the moon. (PREP)
- 12) PRON?DET:
those: Those tree bear fruit. (DET)
Those are our happiest day. (PRON)
- 13) DET?ADV:
almost: A cry almost human was heard. (DET)
It is almost over. (ADV)
no: With no fire and no matches they could not light the candle. (DET)
He is no ordinary student. (ADV)

- 14) AUX?BE: BE means linking verb 'be'.
be: I am working now. (AUX)
The book is on the table. (BE, connecting verb)
- 15) V?ADJ:
correct: Please correct my spelling. (V)
It is very correct answer. (ADJ)
appropriate: The government appropriated a large sum of money for building hospitals. (V)
His bright clothes were not appropriate for a funeral. (ADJ)
alternate: Work alternated with sleep. (V)
He works on alternate days. (ADJ)
- 16) AUX?V:
have: he has gone to Beijing. (AUX)
This coat has no pocket. (V)
- 17) ADJ?ADV:
alive: He is very much alive. (ADJ)
He kept the memory alive. (ADV)
hard: hard duty. (ADJ)
The snow was hard frozen. (ADV)
- 18) PRON?ADV:
ourselves: We consider ourselves of no importance at all. (PRON)
We build the house ourselves. (ADV)
- 19) ADV?THERE: THERE means 'there' in 'there is'.
there: Put it there, not here. (ADV)
There is a pencil on the table. (THERE)
- 20) V?N?ADJ:
average: My mail averages 5 letters a day. (V)
On average we receive 5 letters each day. (N)
What is the average rainfall for July? (ADJ)
light: I light on the clue. (V)
The light travels faster than the plane. (N)
The box is light to carry. (ADJ)
express: She expressed her thanks. (V)
Send the letter by express. (N)
I come here with the express purpose of seeing you. (ADJ)
- 21) V?N?ADV:
back: She backed the horse. (V)
You must iron the backs of the shirts as well as the fronts. (N)
She turned her face back. (ADV)
- 22) ADJ?ADV?N:
enough: We have enough seats for everyone. (ADJ)
It is warm enough to swim. (ADV)
She doesn't have enough to do. (N)
- 23) DET?N?ADV:

more: Can I have more time to answer your questions? (DET)
 He liked the girl, and thought he'd like to see more of her. (N)
 His illness was more serious than the doctor first thought. (ADV)
 all: Please answer all questions on this list. (DET)
 That ugly little house was all the home that I ever had. (N)
 She was all worn out. (ADV)

24) ADJ?ADV?DET:

just: He is a very just man. (ADJ)
 He was sitting just here. (ADV)
 You have received a just punishment. (DET)

25) PREP?CONJ?ADV:

as: They all rose together as one man. (PREP)
 She doesn't run as fast as she used to. (CONJ)
 Paul runs fast, but I run as fast. (ADV)
 before: She stood before him. (PREP)
 We do want to buy something now before prices go up. (CONJ)
 He fell silent as before. (ADV)

26) THAT?DET?PRON: THAT means 'that' in 'that clause'.

that: There is no proof that she killed him. (THAT)
 This room is a lot warmer than that one. (DET)
 He kissed me and with that he left. (PRON)

27) BE?AUX?SS: SS means genitive 's'.

's: He's a student. (BE)
 It's raining hard, isn't it! (AUX)
 writer's ability. (SS)

28) ADJ?PREP?N:

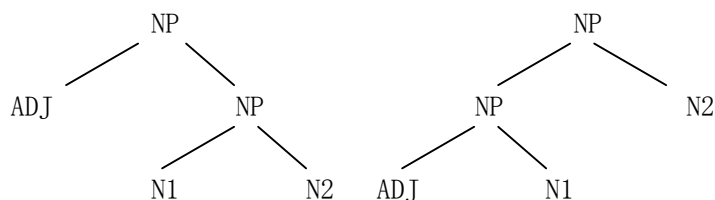
past: I have not been feeling very well for the past few days. (ADJ)
 The boy rushed past us. (PREP)
 Our country has a glorious past. (N)

29) PRON?BOTH?DET?ADV: BOTH means coordinate conjunctive (neither... nor ..., either ... or...)

neither: Books that are neither of them very interesting. (PRON)
Neither my father nor I were there. (BOTH)
Neither road out of town is very good, but this one is better than the other one. (DET)
 Just as I have not good eyes, so neither has my son, neither have my children. (ADV)

5.1.3 Structure ambiguity:

5.1.3.1 ADJ + N1 + N2



1) The salesman who sells old cars is busy.

The old salesman who sells cars is busy.

→ The old car salesman is busy.

2) He is a Department Head, who is from England.

He is Head of the English Department.

→ He is an English Department Head.

5.1.3.2 Ambiguity of 'and'

1) She looks care of old men and old women.

She looks care of women and old men.

→ She looks care of old men and women.

2) Mr. John is a scientist of great fame and a professor of great fame.

Mr. John is a professor of great fame and a scientist.

→ Mr. John is a scientist and a professor of great fame.

3) Someone tells me he's cheating, and I can't do anything about it.

Someone tells me that he's cheating and that I can't do anything about it.

→ Someone tells me he's cheating and I can't do anything about it.

4) John will go, or Dick and Tom will go.

John or Dick will go, and Tom will go.

→ John or Dick and Tom will go.

5.1.3.3 PP attachment ambiguity

1) They made a report about the ship.

On the ship, they made a report.

→ They made a report on the ship.

2) They made a decision concerning the boat.

On the boat, they made a decision.

→ They made a decision on the boat.

3) He drove the car which was near the post office.

Near the post office, he drove the car.

→ He drove the car near the post office.

4) They are walking around the lake which is situated in the park.

In the park, they are walking around the lake.

→ They are walking around the lake in the park.

5) He shot at the man who was with a gun.

With a gun, he shot at the man.

→ He shot at the man with a gun.

6) The policeman arrested the thief who was in the room.

In the room, the policeman arrested the thief.

→ The policeman arrested the thief in the room.

5.1.3.4 Ambiguity of 'Somebody is + V-ing + N'

<u>Somebody</u>	<u>is</u>	<u>V-ing</u>	<u>N</u>	<u>Somebody</u>	<u>is</u>	<u>V-ing</u>	<u>N</u>
NP	BE	NP		NP	VP		NP

1) They are receiving women as guest.

They are amusing women.

→ They are entertaining women.

- 2) They are flying the planes.
They are the flying planes.
→ They are flying planes.
- 3) They are roses which are growing.
They are cultivating roses.
→ They are growing roses.
- 4) They are having apples.
They are apples for eating.
→ They are eating apples.

5.1.3.5 Ambiguity of 'somebody has + V-ed + N'

<u>Somebody</u>	<u>has</u>	<u>V-ed</u>	<u>N</u>		<u>Somebody</u>	<u>has</u>	<u>V-ed</u>	<u>N</u>
NP	HAVE	NP			NP	VP	NP	NP

- 1) He has already discarded boots.
He has a pair of discarded boots.
→ He has discarded boots.
- 2) They have used cars as a transportation tool.
They have a few used cars.
→ They have used cars.

5.1.3.6 Ambiguity of infinitive verb

- 1) He wants an assistant who can finish the experiment.
To finish the experiment, he wants an assistant.
→ He wants an assistant to finish the experiment.
- 2) The students will discuss their plan about a dance party that they are to hold.
In order to hold a dance party, the students will discuss their plan.
→ The students will discuss their plan to hold a dance party.

5.1.3.7 Ambiguity of 'Something is not to do'

<u>Something</u>	<u>is</u>	<u>not</u>	<u>to</u>	<u>do</u>		<u>Something</u>	<u>is</u>	<u>not</u>	<u>to</u>	<u>do</u>
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- 1) His object isn't to eat.
Not to eat is his object.
→ His object is not to eat.

5.1.3.8 ambiguity of 'something is ready to do'

- 1) The chicken is ready to eat some food.
The chicken is ready to be eaten.
→ The chicken is ready to eat.
- 2) The horse itself is ready to ride on the track (on the way).
The horse is ready for someone to ride.
→ The horse is ready to ride.

5.1.3.9 ambiguity of 'V-ing'

- 1) John likes to question scientist.
John likes scientist who often asks questions.
→ John likes questioning scientist.
- 2) The way of the hunter shot was terrible.
That the hunter was shot was terrible.
→ The shooting of the hunter was terrible.

5.1.3.10 ambiguity of double-objects

- 1) Mary gave picture to her baby.
Mary gave baby picture to her.
→ Mary gave her baby picture.
- 2) Mary taught manners to her child.
Mary taught child manners to her.
→ Mary taught her child manners.

5.1.3.11 ambiguity of 'V + her + do'

- 1) I heard that she cried to help.
I heard her loud cry for help.
→ I heard her cry for help.
- 2) I saw the wonder she had done.
I saw her feel greatly surprised.
→ I saw her wonder.
- 3) I saw her remain awake.
I saw the watch belonged to her.
→ I saw her watch.
- 4) I saw her lower her head.
I saw the duck which belonged to her.
→ I saw her duck.

5.1.3.12 Ambiguity of 'V + somebody + V-ing'

- 1) I saw that a boy was swimming in the river.
I saw a boy who was swimming in the river.
I saw a boy while I was swimming in the river.
→ I saw a boy swimming in the river.
- 2) I noticed that the man was smoking in the corridor.
I noticed the man who was smoking in the corridor.
I noticed the man while smoking in the corridor.
→ I noticed the man smoking in the corridor.

5.1.3.13 Ambiguity of 'V + somebody + V-ed'

- 1) She found that a boy was hidden behind the door.
She found a boy who was hidden behind the door.
→ She found a boy hidden behind the door.

5.1.3.14 Ambiguity of 'V + somebody + who clause'

- 1) I asked the professor, who would give the lecture.
I ask the professor. This professor would give the lecture.
→ I asked the professor who would give the lecture.
- 2) John asked the lady, who was sitting on the stairs.
John asked the lady. She was sitting on the stairs.
→ John asked the lady who was sitting on the stairs.

5.1.3.15 Ambiguity of 'V + somebody + when clause'

- 1) Tell me at what time you are free.
When you are free, tell me.
→ Tell me when you are free.

5.1.3.17 Ambiguity of 'V + somebody + if clause'

- 1) Tell me whether you have time or not.

If you have time, Tell me.

→ Tell me if you have time.

5.1.3.18 Ambiguity of 'V + if clause'

- 1) Let me know whether you're coming or not.

If you're coming, let me know.

→ Let me know if you're coming.

5.1.3.19 Ambiguity of modifier

- 1) It is a pretty skirt for a little girl

It is a fairly (=pretty) little skirt for a girl.

It is an attractive (=pretty) little skirt for a girl

It is a skirt for a fairly little girl.

It is a skirt for an attractive little girl.

→ It is a pretty little girl's skirt.

- 2) Do you happen to know the gentleman next to the lady who is reading a book?

Do you happen to know the gentleman who is reading a book, next to the lady?

→ Do you happen to know the gentleman next to the lady reading a book.

- 3) I recommended John to Tom. The former was approachable.

I recommended John to Tom. The latter was approachable.

→ I recommended John to Tom who was approachable.

- 4) I like the books on the shelves. I bought the shelves yesterday.

I like the books on the shelves. I bought the books yesterday.

→ I like the books on the shelves I bought yesterday.

- 5) There is a theatre located near the business district. The theatre is crowded every night.

There is a theatre near the business district. The business district is crowded every night.

→ There is a theatre near the business district which is crowded every night.

- 6) The secretary granted my request namely that I might see the president.

The secretary granted my request so that I might see the president.

→ The secretary granted my request that I might see the president.

5.1.3.20 Ambiguity of adverbial

- 1) When you are free, tell him.

Tell him at what time you are free.

→ Tell him when you are free.

- 2) If you have time, tell me.

Tell me whether you have time or not.

→ Tell me if you have time.

- 3) She knew that, before I met you, you had begun to study NLP.

Before I met you, she knew that you had begun to study NLP.

→ She knew that you had begun to study NLP before I met you.

5.1.4 Garden Path Sentence

The 'garden path sentence' is the sentence where people get stuck (fixed in place,

not moving) and have to retrace their steps in analyzing this sentence. For example, in the sentence 'the horse raced past the barn fell'. When we just read 'the horse raced past the barn' ('barn' is a farm building for corps and food for animals), we believe that the 'raced' is its predicate, so the structure of this sentence must be as follows:

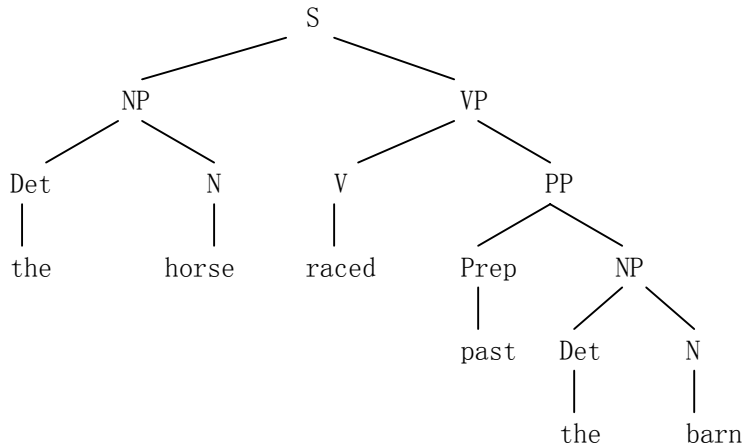


Fig. 2

However, when we further read next 'the', we have to retrace the steps to again analyze this sentence. The structure of this sentence is as follows:

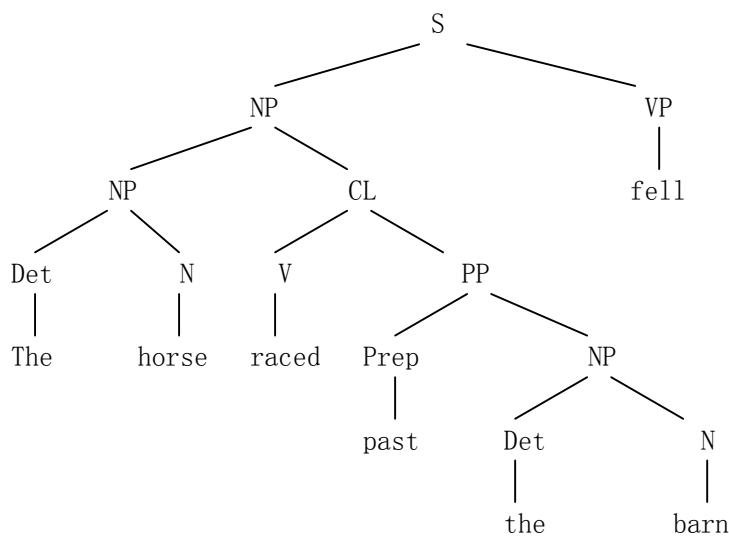


Fig. 3

The parsing of garden path sentence will be more difficult than other sentence.

Homework 3 for CS579

For the ambiguous sentence, if we paraphrase it, the sense of sentence will be clear. For example, for the ambiguous sentence "He shot at the man with a gun", we may paraphrase it as following two sentences:

"He shot at the man who was with a gun"

"With a gun, he shot at the man"

Please paraphrase following sentences:

- 1) This is a handsome man's shirt.
- 2) John told his father that he had been talking too much.
- 3) She is a Japanese student.
- 4) She has a French silk underwear.
- 5) We need more highly trained scientist.
- 6) The medicine the doctor prescribed immediately cured the infection.
- 7) John failed entirely to comprehend it.
- 8) John and Jane are married.
- 9) The old men and women went into the room.
- 10) You can dance and watch TV as you like.
- 11) The rich man wanted the money more than his wife.
- 12) I believe in Tom more than John.
- 13) She became a nurse like her sister.
- 14) I observed John in the garden
- 15) He kept the car in the garage.
- 16) They discussed the birds in the park.
- 17) We were surprised that he could telephone his son in Alaska.
- 18) She saw the old man with glasses.
- 19) I saw the young man with a telescope.
- 20) John saw the man with a camera.
- 21) The woman decorated the young girl with the flowers.
- 22) He was hit by the car on the corner.
- 23) They are pleasing friends.
- 24) They are amusing their guests.
- 25) They are visiting scholars
- 26) They are lecturing doctors.
- 27) They are growing tomatoes.
- 28) They are flying planes.
- 29) They are sinking ships.
- 30) They are running machines.
- 31) They have classified information.
- 32) They have finished papers.
- 33) The refugees have discarded clothes.
- 34) The window was broken.
- 35) The house is painted.
- 36) The shooting of the hunter occurred at down.
- 37) Mary showed her baby pictures.
- 38) He gave her dog biscuits.
- 39) I saw him going home.
- 40) I saw the girl crossing the street.
- 41) We have found him a good assistant.
- 42) They called Jane a waitress.
- 43) I saw John in the bus.
- 44) He found the cat up a tree.

45) Write and tell me if you can come.

5.2 Disambiguation

5.2.1 Word sense Disambiguation

Word disambiguation involves selecting the most appropriate sense of a word.

There are several approaches for word sense disambiguation.

5.2.1.1 Selectional Restriction Approach

The general idea of selectional restriction is that lexical items indicate the broad semantic categories they can combine with, and any modifiers or complements that do not belong to these semantic categories cannot combine with them.

E.g.

The crane flew over plain. (Sense of crane = bird)

The builder operated the crane (sense of crane = machine)

The lexical entry of the verb 'fly' can specify in this lexical entry that its subject must be a bird. This restriction would immediately disallow the 'machine' sense of 'crane' in the first sentence, leaving only the correct sense (bird).

Similarly, the verb 'operate' can indicate a restriction stating that its direct object must be a machine. This would select correct sense of 'crane' in the second sentence.

A popular approach is to use nodes from a semantic hierarchy as the restriction on the constituent. Each node in the hierarchy represents a semantic type, and a restriction is violated if the semantic type of the combining constituent is not compatible with the restriction.

For example, assume the following semantic hierarchy:

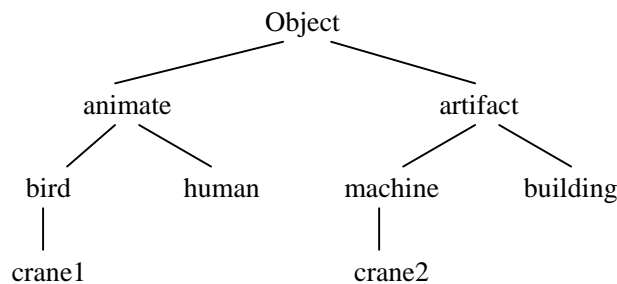


Fig. 1

The lexical entries can be defined as following:

crane (type: crane1)

crane (type: crane2)

builder (type: human)

operate (subj: human, obj: machine)

fly (subj: bird)

Wilks (1975) proposed the preference semantics. According to preference semantics, in the disambiguation, the interpretations are preferred rather than being completely rejected. When the words combine, a process of preference satisfaction is invoked for the different possible interpretation of the sentence. The interpretation that violates the fewest preferences is the selected interpretation.

E.g. In sentence

The policeman interrogated the crook

The word 'crook' is ambiguous between the two senses: a bad person and a shepherd's staff. In determining the favoured sense for this sentence, the verb 'interrogate' appears in the lexicon as preferring a human subject and object:

Interrogate (subject: human, object: human)

While processing this sentence, one interpretation, with 'crook' as human, would satisfy one more preference than with the interpretation as inanimate object. The correct sense of 'crook' for the context would thus be selected.

5.2.1.2 Frames and Semantic Distance Approach

Frame can be represented by the graph connected by predicates 'isa', 'has_part', 'made_of' and other relevant details about the concept, entity or event being represented.

Following is a frame system:

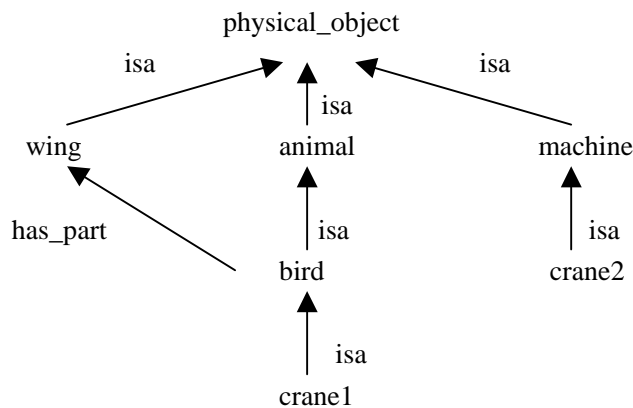


Fig. 2 a simple frame system

The information in the frame can frequently be used to decide which of two or more possible senses of word is the most appropriate in a given sentence. The general assumption is that the preferred sense of a word is that which is semantically closest to the sense of the words it combines with.

Given that frame can be modeled as graphs, it is possible to apply graph theoretic notions in order to define semantic distance

One common measure is the smallest weighted distance between the nodes corresponding to the frames in question. The distance can be calculated using standard shortest path algorithms, where the weight on an edge is treated as its distance.

Consider the following three frames for 'wing', 'bird' and the two senses of 'crane'.

```
[instance_of: wing,
 isa: physical_object]
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```
[instance_of: bird,
 isa: animal,
 has_part: wing]
```

```
[instance_of: crane1,
 isa: bird]
```

```
[instance_of: crane2,
```

isa: machine]

These frames can be visualized as Fig. 2. We assume that the various links have the following weights:

$$\text{isa} = 0.1 \quad \text{isa}^{-1} = 0.95 \quad \text{has_part} = 0.3 \quad \text{has_part}^{-1} = 0.8$$

An arc such as has_part^{-1} indicates the inverse relation (in the opposite arrow) of has_part , namely part_of . Thus traversing the link on the opposite direction can have a different cost.

The semantic distance $D(a,b)$ between nodes a and b is given by

$$D(a,b) = \min (d(a,b), d(b,a))$$

Where $d(x,y)$ is the graph distance between nodes x and y .

Consider disambiguating 'crane' in the 'crane's wing' assuming that the analysis step produces two representations, summarized as follows:

Genitive (wing, crane1)

Genitive (wing, crane2)

From Fig.2 and the weights of each arc, it is easy to verify that:

$$d(\text{wing}, \text{crane1}) = 0.8 + 0.95 = 1.75$$

$$d(\text{wing}, \text{crane2}) = 0.1 + 0.95 + 0.95 = 2.0$$

$$d(\text{crane1}, \text{wing}) = 0.1 + 0.3 = 0.4$$

$$d(\text{crane2}, \text{wing}) = 0.1 + 0.1 + 0.95 = 1.15$$

This gives $D(\text{wing}, \text{crane1}) = \min (d(\text{wing}, \text{crane1}), d(\text{crane1}, \text{wing}))$
 $= \min (1.75, 0.4) = 0.4$

$$D(\text{wing}, \text{crane2}) = \min (d(\text{wing}, \text{crane2}), d(\text{crane2}, \text{wing}))$$
$$= \min (2.0, 1.15) = 1.15$$

Therefore, the bird sense of crane is selected as required.

In addition to semantic distance, a frame hierarchy can also be used in constrain relaxation, a process analogous to semantic preferences, which is used when a selectional restriction (a constraint) is violated because of metaphorical or other figurative use. It is a frequent situation with verb arguments, as in following example:

The company agreed the proposal.

If 'agree' expects a 'human' subject, and 'company' is a 'social object', the restriction will be violated. To relax the constrain, the semantic between the expected complement and the actual complement can be computed, and if it below a certain threshold the proposed analysis is accepted.

5.2.1.3. Most Frequency Approach

The simplest statistical technique for word sense disambiguation is to determine the most frequent sense of a word from a corpus of disambiguated words and use this sense as the default sense.

This can be done with a sense tagged corpus. For example,

Pupils/STUDENT from/SOURCE a school/INTITUTION in north/POSITION Beijing/CITY met/COME_TOGETHER with/PARTICIPANT a film/SHOW star/ENTERTAINER.

Note that several words in this sentence have other meanings: a 'pupil' is also a part of the eye, a

'school' is also a group of fish (a large group of one kind of fish or certain other sea animals swimming together), a film is also a piece of cellulose (cellulose is the material from which the cell walls of plants are made, use in making paper), and a 'star' is also a celestial body.

In a large collection of sense tagged text, it is possible to determine the most frequent sense of a word for a particular corpus and use this as the default sense for the word. For example, assume that in a particular corpus, there are 1000 occurrences of pupil/STUDENT, but only 50 of pupil/BODY_PART. Then 'pupil' would always be tagged as STUDENT under this scheme for any new, untagged text.

Generally speaking, this simple approach yields around 70% accurate tagging for general English text. Exactly speaking, this approach yields 67.5% accurate tagging for close text, 64.8% for open text.

5.2.1.4 Application of word definition in dictionary

The word definition in dictionary is a useful knowledge source for word sense disambiguation. In the definition of word A and word B, if some words are same, then the sense of A and B will be similar, we can select the right sense for these two words.

For example, word 'pen' is a polysemy, its sense can be "an instrument for writing or drawing with ink", or "a small piece of land enclosed by a fence used for keeping domestic animals in". If there are word 'pen' and 'sheep' in a text, and the definition of 'sheep' is "a type of grass-eating domestic animal that is farmed for its wool and its meat.". Compare two definitions, we found that 'domestic' and 'animal' are consisted in two definitions, then we can judge that the sense of 'pen' in this text must be "enclosure for keeping domestic animal"..

The definition of functional word in dictionary can also be used to disambiguate the functional ambiguity of functional word.

For example, the function of preposition 'with' can used to express "instrument" or "part-of". It is functional ambiguity of preposition 'with'.

In sentence "I ate a fish with a fork", the definition of word 'fork' is "an instrument for eating food", 'instrument' in this definition is same as 'instrument' of function of 'with', so we can judge that the sense of 'with' in this sentence must be 'instrument'.

In sentence "I ate a fish with bones", the definition of word 'bone' is "the hard part of the body", "part of" is same as "part-of" of function of 'with', so we can judge that the sense of 'with' in this sentence must be 'part-of'.

5.2.1.5 Co-occurrence Words Retrieval Approach

P. Hanks found, the co-occurrence words of the word 'bank' in the text can divided to two groups (group A and group B):

Group A: money, notes, loan, account, investment, clerk, official, robbery, vault, working, in a, First national, of England.

Group B: river, swim, lake, boat, east, west, south, on top of.

When co-occurrence words belong to group A, the sense of 'bank' is "a place in which money is kept and paid out on demand". When co-occurrence words belong to group B, the sense of 'bank' is "land along the side of river, lake".

5.2.1.6 POS-based approach:

The sense of word is related with its part of speech (POS). We can select the sense based on POS of word.

For example, if POS of 'book' is noun, its sense will be "a collection of sheets of paper fastened together as a thing to be read, or to be written. If POS of 'book' is verb, its sense will be "to arrange in advance to have something".

5.2.2 POS disambiguation

5.2.2.1 V?N Disambiguation

---- 'in' + {V?N} + 'of' → {N}

In the rule expression, LHS is condition, RHS is conclusion.

For example, "plan" of "in plan(N) of" can be judged as N.

We can also propose other rules as follows:

---- DET {N?V} → {N}

"this plan(N) "

---- NUM + {N?V} → {N}

"three works(N) "

---- PREP + {N?V} → {N}

"before study(N) "

---- DET {N?V} AUX → {N}

"that work(N) should"

---- {N?V} + ADJ + 'for' → {N}

"plan(N) important for"

---- DET + {N?V} + AUX → {N}

"the work(N) should"

---- DET + {N?V} + V → {N}

"the work(N) finished"

---- DET + {N?V} + 'to' + V → {N}

"the work(N) to finish"

---- DET + {N?V} + 'of' → {N}

"the plan(N) of"

---- N + , + {N?V} + 'and' + N → {N}

"draft , plan(N) and manuscript"

---- N + 'and' + {N?V} + 'and' → {N}

"draft and plan(N) and"

---- {N?V} + 'why' + (N or PRON) + 'V' → {V}

"or" is the selective conjunction.

E.g. "wonder(V) why they come here" (Here, 'they' is PRON)

"wonder(V) why students come here" (Here, 'students' is N)

---- (DET or PRON) + {N?V} → {N}

"her face(N) ", "the face(N) "

---- DET + ADJ + {N?V} → {N}

"the good work(N) "

---- PREP + {N?V} → {N}

“ ‘regardless of’ reward (N)”, Here, “regardless of” is regarded as PREP.

---- AUX + ‘not’ + {N?V} --> {V}
 “can not work(V)”

---- AUX + {N?V} --> {V}
 “shall work(V)”,

---- N + WH + {N?V} + N + PREP --> {V}
 “student who studies(V) English in the classroom”

---- ‘please’ + {N?V} --> {V}
 “please work(V)”

---- BE + {N?V} + by --> {V}
 “is attacked(V) by”

---- N + ADV + {N?V} --> {V}
 “must slowly work(V)”

---- N + {N?V} +ADV --> {V}
 “John works(V) slowly”

---- WH + AUX + N + {N?V} + PUNC --> {V}
 “How should John work(V)?”

---- (N or PRON) + {N?V} + DET + N --> {V}
 “we use(V) our ingenuity”

5.2.2.2 AUX?N Disambiguation:

---- {AUX?N} + (N or PRON) + V --> {AUX}
 “May(AUX) I help you”

---- {AUX?N} + ‘not’ + V --> {AUX}
 “can(AUX) not have”

---- ‘as’ + (N or PRON) + {AUX?N} --> {AUX}
 “as you can(AUX)”,

---- (DET or ADJ) + {AUX?N} + BE --> {N}
 “the can(N) was”,
 “red can(N) broken”,

---- N + {AUX?N} + BE --> {AUX}
 “John can(N) be”

---- PRON + {AUX?N} --> {AUX}
 “I can(AUX)”

5.2.2.3 N?ADJ Disambiguation:

---- DET + {N?ADJ} + (‘of’ or ‘for’ or ‘to’) --> {N}
 “the kind(N) of rose”,
 “a medium(N) for amusing”

---- ADV + {N?ADJ} + (‘of’ or ‘for’ or ‘to’) --> {ADJ}
 “very kind(ADJ) of you”,
 “very kind(ADJ) for”,
 “very kind(ADJ) to”

---- DET + {N?ADJ} + PUNC|V|AUX|BE --> {N}
 “the red(N),”,

“the American(N) comes”
 ---- {N?ADJ} + {N?ADJ} --> {ADJ} + {N}
 “basic(ADJ) standard(N)”,
 ---- DET + {N?ADJ} + ADJ + N --> {ADJ}
 “the kind(ADJ) old man”
 ---- N + {N?ADJ} + (‘to’ or ‘for’) --> {ADJ}
 “professor kind(ADJ) to student”,
 ---- DET + {N?ADJ} + ‘one’ --> {ADJ}
 “the red(ADJ) one”
 ---- ADJ + (‘and’ or ‘or’) + {N?ADJ} --> {ADJ}
 “nice and red(ADJ)”
 ---- DET + {N?ADJ} + N --> ADJ
 “the utmost(ADJ) care”

5.2.2.4 WH?PRON Disambiguation:
 ---- N + {WH?N} + BE --> {WH}
 “book which(WH) is”

5.2.2.5 DET?N Disambiguation:
 ---- {DET?N} + N --> {DET}
 “a(DET) student”
 ---- V + {DET?N} + PREP --> {N}
 “read many(N) at”
 ---- {DET?N} + ADJ + N --> {DET}
 “any(DET) other possibility”

5.2.2.6 NUM?N Disambiguation
 ---- {NMU?N} + N --> {NUM}
 “one(NUM) meter”
 ---- {NUM?N} + AUX --> {N}
 “one(N) cannot”

5.2.2.7 PREP?CONJ Disambiguation
 ---- {PREP?CONJ} ‘than’ + ‘that’ + WH --> {PREP}

When {PREP?CONJ} is ‘than’, use this rule.
 “than (PREP) that which”
 ---- {PREP?CONJ} + DET + N --> {PREP}
 “for(PREP) the independence”
 ---- {PREP?CONJ} ‘for’ + ‘sure’ --> {PREP}

When {PREP?CONJ} is for, use this rule.
 “for(PREP) sure”
 ---- {PREP?CONJ} + DET + N --> {PREP}
 “before(PREP) the night”,
 ---- {PREP?CONJ} + ADJ + N + \$END --> {PREP}

\$ENG is the end of sentence.
 “for(PREP) individual freedom.”
 ---- DET + ‘longing’ + {PREP?CONJ} ‘for’ --> {PREP}
 “the longing for(PREP)”

5.2.2.8 PREP?ADV Disambiguation

- {PREP?ADV} + (N or ADJ or DET) --> {PREP}
“in(PREP) Japan” ,
“in(PREP) the country” ,
- {PREP?ADV} ‘on’ + DET ‘a’ + ADJ --> {PREP}
“on(PREP) a dangerous”
- {PREP?ADV} ‘about’ + PRON (possessive case) --> {PREP}
“about(PREP) mine”
- {PREP?ADV} + DET + ADJ + N --> {PREP}
“in(PREP) this wonderful play”
- {PREP?CONJ} ‘down’ + V ‘go’ --> {ADV}
“down(ADV) go”

5.2.2.9 ADV?CONJ Disambiguation

- ‘seem’ + {ADV?CONJ} + ADJ --> {ADV}
“seem so(ADV) obvious”

5.2.2.10 PREP?V Disambiguation

- {PREP?V} ‘regarding’ + DET + N --> {PREP}
“regarding(PREP) the content”

5.2.2.11 PREP?TO Disambiguation

- ADJ + {PREP?TO} + V or BE or AUX --> {TO}
“able to(TO) read” ,
“able to(TO) be read” ,
“able to(TO) have”
- {PREP?TO} ‘to’ + PRON (accusative) --> {PREP}
“to(PREP) us”
- {PREP?TO} ‘to’ + V ‘love’ + N ‘labor’ --> {TO}
“to(TO) love labor”
- {PREP?TO} ‘to’ + V ‘do’ + N or DET or ADJ --> {TO}
“to(TO) do something”

5.2.2.12 PRON?DET Disambiguation

- {PRON?DET} + N --> {DET}
“those(DET) men”
- {PRON?DET} + BE --> {PRON}
“those(PRON) are”

5.2.2.13 DET?ADV Disambiguation

- BE + {DET?ADV} + V --> {ADV}
“She is almost(ADV) killed”
- {DET?ADV} + DET + N --> {DET}
“no(DET) other country” ,
- {DET?ADV} + N --> {DET}
“no(DET) thing”
- {DET?ADV} + ‘as’ + ADJ --> {ADV}
“almost (ADV) as wonderful”
- {DET?ADV} + DET + ADJ --> {DET}

“even(DET) the few event”

5.2.2.14 AUX?BE Disambiguation

---- ‘there’ + {AUX?BE} --> {BE}
“there is(BE)”
---- it + {AUX?BE} + ADJ --> {BE}
“it is(BE) better”
---- {AUX?BE} + V(ed) --> {AUX}
“be(AUX) done”
---- AUX + {AUX?BE} +ADJ --> {BE}
“must be(BE) red”
---- {AUX?BE} + ADV + ADJ --> {BE}
“be really able”
---- {AUX?BE} + ADV + ADV +ADJ --> {BE}
“be(BE) often more important”
---- ‘there’ + ‘have’ + ‘not’ + {AUX?BE} --> {BE}
“there have not be(BE)”

5.2.2.15 V?ADJ Disambiguation

---- DET + {ADJ?V} + N --> {ADJ}
“the correct(ADJ) plan”
---- ‘very’ or ‘rather’ + {ADJ?V} --> {ADJ}
“very correct(ADJ)”
---- AUX + {ADJ?V} --> {V}
“should correct”
---- ‘make’ + N + {ADJ?V} --> {ADJ}
“make draft appropriate(ADJ)”
---- {ADJ?V} + ADV --> {V}
“alternate(V) rapidly”
---- {ADJ?V} + ‘and’ + ADJ --> {ADJ}
“correct(ADJ) and concise”
---- ADJ + {ADJ?V} --> {ADJ}
“concise and correct(ADJ)”
---- {ADJ?V} + ‘and’ + V --> {V}
“correct(V) and revise”
---- V + ‘and’ + {ADJ?V} --> {V}
“revise and correct(V)”
---- ‘most’ + {ADJ?V} --> {ADJ}
“most correct(ADJ)”

5.2.2.16 AUX?V Disambiguation

---- {AUX?V} + V --> AUX
“have(AUX) done”
---- AUX + {AUX?V} + BE + V --> {AUX}
“would have(AUX) be regard”
---- {AUX?V} + not + V + and + V --> {AUX}
“have(AUX) not hope and dream”

- {AUX?V} + DET + N + V --> {AUX}
 “have(AUX) any writer shown”
- 5.2.2.17 ADJ?ADV Disambiguation
- BE + (ADJ?ADV) + ‘to’ --> {ADJ}
 “be alive(ADJ) to the dangers”
- {ADJ?ADV}&lex!=‘still’ + N --> {ADJ}
- In this rule, {ADJ?ADV} can not be ‘still’, “!=” means does not equal to.
 “hard(ADJ) duty”
- DET + {ADJ?ADV} + N --> {ADJ}
 “the hard(ADJ) person”
- AUX + {ADJ?ADV} + V --> {ADV}
 “The snow has hard(ADV) frozen”
- V + ADV + {ADJ?ADV} + PREP --> {ADV}
 “to work very hard(ADV) for the boss”
- BE + {ADJ?ADV} --> ADJ
 “be hard(ADJ)”
- V + {ADJ?ADV} + (‘.’ or ‘?’ or ‘!’) --> {ADV}
 “work hard(ADV).”
- 5.2.2.18 PRON?ADV Disambiguation
- PRON + V + N + {PRON?ADV} + PUNC --> {ADV}
 “we achieve happiness ourselves(ADV).”
- 5.2.2.19 ADV?THERE Disambiguation
- {ADV?THERE} + BE --> {THERE}
 “there(THERE) is”
- 5.2.2.20 V?N?ADJ Disambiguation
- {V?N?ADJ} + N + BE --> {ADJ}
 “average(ADJ) work is”
- {V?N?ADJ} + N + PREP --> {ADJ}
 “average(ADJ) rainfall for July”
- {V?N?ADJ} + V + ADJ + ‘than’ --> {N}
 “light(N) travels faster than”
- DET + {V?N?ADJ} + V --> {N}
 “the light(N) travels”
- ‘able to’ + {V?N?ADJ} + DET + N --> {V}
 “able to express(V) an idea”
- 5.2.2.21 V?N?ADV Disambiguation
- V + DET + N + {V?N?ADV} + PUNC --> {ADV}
 “She turned her face back (ADV).”
- V + DET + N + {V?N?ADV} + ‘when’ --> {ADV}
 “She turned her face back(ADV) when some body looks for her”
- 5.2.2.22 ADJ?ADV?N Disambiguation
- BE + {ADJ?ADV?N} + ‘to’ + (PRON or N) --> {ADJ}
 “be enough(ADJ) to me”
- ‘have’ + {ADJ?ADV?N} --> {ADJ}

“have enough(ADJ) money”

---- (!BE! or !AUX) + {ADJ?ADV?N} --> {ADV}

If in front of {ADJ?ADV?N} is not BE or AUX, {ADJ?ADV?N} will be {ADV}.

“warm enough(ADV)”,

---- ‘have’ + {ADJ?ADV?N} + ‘to’ + V --> {N}

“have enough(N) to do”

5.2.2.23 DET?N?ADV Disambiguation

---- {DET?N?ADV} + ADJ --> {ADV}

“more(ADV) important”

---- V + {DET?N?ADV} + (N or PRON) + AUX --> {N}

“learn all(N) I can about”

5.2.2.24 ADJ?ADV?DET Disambiguation

---- N + BE + {ADJ?ADV?DET} + PUCT --> {ADJ}

“view is just(ADJ).”

5.2.2.25 PREP?CONJ?ADV Disambiguation

---- \$START + {PREP?CONJ?ADV} + ADJ + N + ‘as’ (CONJ) --> {ADV}

\$START means the start of a sentence

“as(ADV) many vegetables as”

---- {PREP?CONJ?ADV} + (‘,‘ or ‘?’ or ‘!’) --> {ADV}

“Haven’t I seen you before(ADV) ?”

---- {PREP?CONJ?ADV} + (DET or N) --> !ADV

“!ADV” means “is not ADV”.

“before(!ADV) the table”,

“before(!ADV) table”

---- {PREP?CONJ?ADV} + NUM --> {PREP}

“before(PREP) 1997”

---- {PREP?CONJ?ADV} + PRON(accusative) --> {PREP}

“before(PREP) me”

---- {PREP?CONJ?ADV} + PRON (nominative) + (V or AUX or BE) --> {CONJ}

“before(CONJ) you go”,

“before(CONJ) you should go”,

“before(CONJ) I am a student”

---- (‘as’ or ‘so’) + ADJ + {PREP?CONJ?ADV} --> {CONJ}

“so cheap as(CONJ)”

---- {PREP?CONJ?ADV} ‘as’ + ADJ + ‘to’ --> ADV

“as(ADV) anxious to learn”

---- {PREP?CONJ?ADV} ‘as’ + PRON + BE + TO + V --> {CONJ}

“as(CONJ) you be to learn”

---- {PREP?CONJ?ADV} ‘as’ + BE + V --> {ADV}

“as(ADV) be shown”

---- ‘only’ + (PREP?CONJ?ADV) ‘as’ + (PRON or N) + V --> {CONJ}

“only as(CONJ) we use”

5.2.2.26 THAT?DET?PRON Disambiguation

---- (‘it’ or ‘this’) + (‘mean’ or ‘need’) + {THAT?DET?PRON} --> {THAT}

“it means that(THAT)”
 ---- ('it' or 'this') + BE + ADJ + {THAT?DET?PRON} --> {THAT}

“it is true that(THAT)”
 ---- (N or PRON) + ('believe' or 'think') + {THAT?DET?PRON} --> {THAT}

“I believe that(THAT)”
 ---- N + {THAT?DET?PRON} + V --> {THAT}

“the letter that(THAT) comes today”
 ---- {THAT?DET?PRON} + (BE or V or AUX) --> {PRON}

“that(PRON) is good”
 ---- {THAT?DET?PRON} + (N or ADJ) --> {DET}

“that(DET) man comes” ,
 “that(DET) nice girl comes”
 ---- {THAT?DET?PRON} + DET + N --> {THAT}

“that(THAT) the suggestion”
 ---- DET + N + {THAT?DET?PRON} + PRON --> {THAT}

“few event that(THAT) we”

5.2.2.27 BE?AUX?SS Disambiguation

---- 'for' + N + (BE?AUX?SS) + 'own' + N --> {SS}

“for labor's(SS) own sake”
 ---- DET + N + {BE?AUX?SS} + N --> {SS}

“the writer's(SS) ability”

5.2.2.28 ADJ?PREP?N Disambiguation

---- DET + {ADJ?PREP?N} + N --> {ADJ}

“the past(ADJ) event”

5.2.2.29 PRON?BOTH?DET?ADV Disambiguation

---- {PRON?BOTH?DET?ADV} + ADV + CONJ + ADV --> {BOTH}

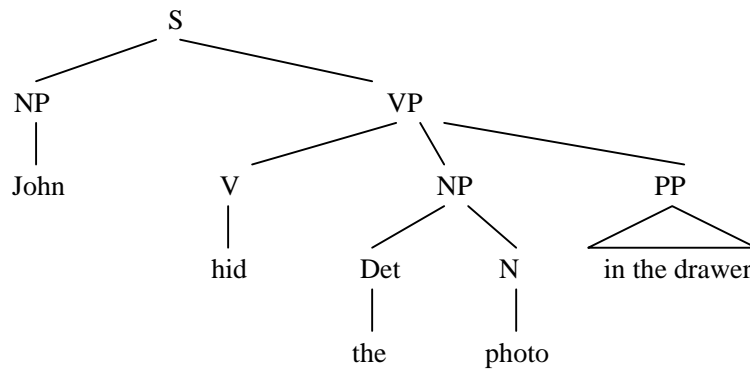
“neither(BOTH) before nor since the time”

5.2.3 Disambiguation of Syntactic Analysis

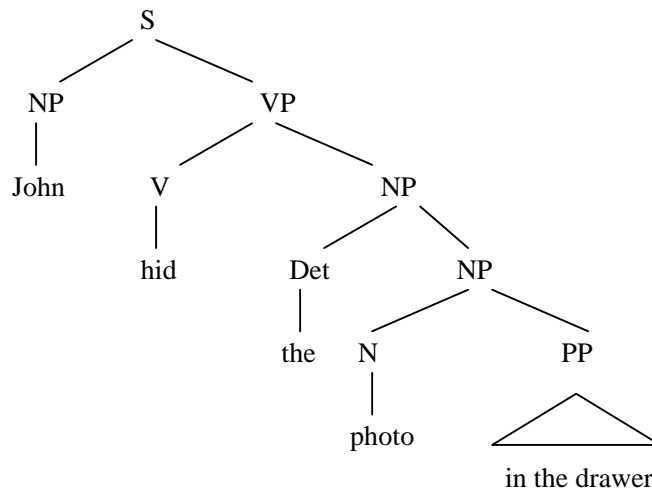
5.2.3.1 Minimal Attachment

In 1978, Frazier and Fodor proposed the principle of minimal attachment: Given two possible attachment sites of a node to an incomplete constituent, the simpler attachment will be preferred. A simpler attachment is one that has fewer nodes between the new node and the nascent constituent.

For example, assume that the verb 'hide' is ambiguous between an NP and an NP PP complement pattern.. Minimal attachment prefers the top structure shown in Fig. 3 with 8 nodes, instead of the bottom structure with 9 nodes.



(8 nodes)



(9 nodes)

Fig. 3

This seem to accord with human preferences for this sentence, where the preferred interpretation is that of being hidden in the drawer, as opposed to the photo in the drawer being hidden somewhere else.

Minimal attachment is clearly dependent on the structure assigned to a sentence by the grammar rules. In particular, it relies on the rules having multiple daughters. This principle can not be applied to binary grammars such as categorical grammar and grammars in Chomsky Normal Form (as CYK approach).

5.2.3.2 Right Association

In 1973, Kimball proposed seven principle parsing, of which right association has been used for parsing selection. This principle states that constituent are attached to the current constituent (i.e. lowest in the parse tree) in preference to other constituents higher in the parse tree..

The preferred interpretation for the sentence in Fig. 4 where 'yesterday' modifies 'arrived' rather than 'thought'.

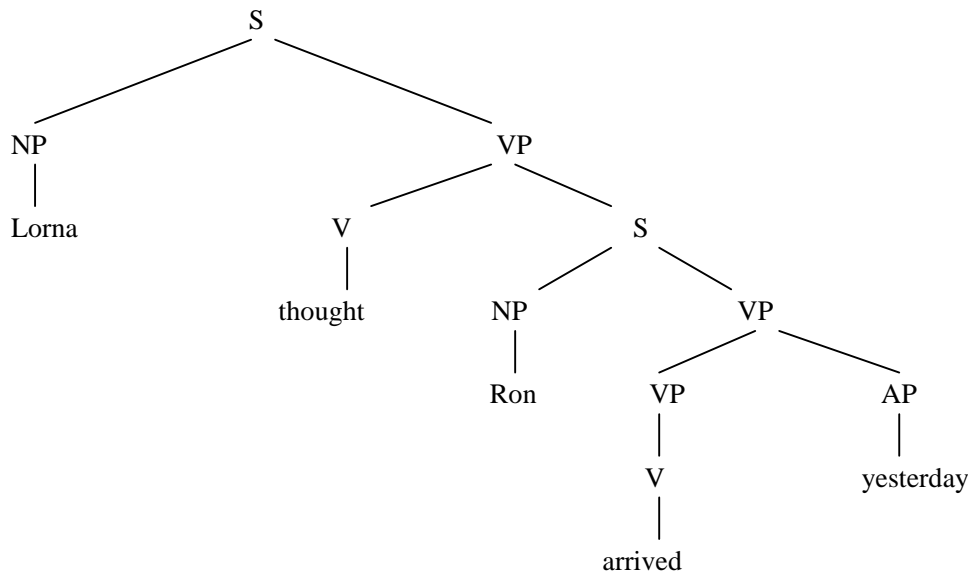


Fig. 4

However, if we use right association principle to analyze the sentence “John hid the photo in the drawer”, we shall get different conclusion from the conclusion of minimal attachment.

Therefore, these preferences are in fact heuristics rather than infallible predictors of structure and should be used in combination with other disambiguation methods.

5.2.3.3 Probabilistic Context-Free Grammars

As general and simple strategies for structure disambiguation, the above heuristics serve an useful purpose, but it is not clear how they can be improved without including further information regarding the grammar used, the lexical items found in the sentence, the way lexicon and grammar interact, and the frequency with which different phenomena occur and co-occur in real text.

Probabilistic context-free grammars (PCFG) has been developed as extensions of CFG that include this information in the form of probabilities for each rule.

In order to see how probabilities are assigned in a PCFG, consider the task of deriving a random sentence in a top-down manner, applying each rule expansion according to its probability.

- Initially the start symbol would be the only symbol to be rewritten, and would therefore have a probability 1 of being used in the current derivation.
- Expanding this symbol will involve selecting a rule with S as its LHS and some terminal and non-terminal symbols on the RHS. Since S has been chosen it is certain that it must be expanded. Hence the probability of all rules with S on their LHS must add to one. Imagine that there is only one such rule, $S \rightarrow NP VP$ with probability 1.
- After applying this expansion, the probability that a rule with NP on the LHS will be used is 1. This means that the probability of all rules with ‘NP’ on their LHSs must add up to 1.

A PCFG consists of a set of rules where the probabilities of rules with the same LHS add up to 1. These probabilities can be estimated from their frequency in a corpus of syntactically analyzed sentences. For example, assume that a rule R_i of the form $C \rightarrow D_1 \dots D_n$ is used r times in the corpus. That is, there are r sub-trees in the corpus of the following form

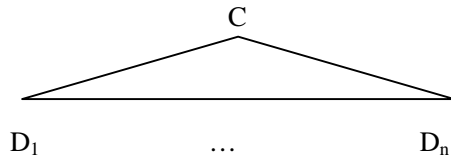


Fig. 5.

Then, if c rules with C as their LHS are used in the corpus, the estimate for the probability of R_i is r/c . Thus, if there are 90 occurrences of this rule $NP \rightarrow \text{Pron}$ and 200 NP rules altogether, then the probability for this rule is $90/200 = 0.45$.

Imaging there are three such rules, with probabilities as indicated below:

Rule	Probability	
$NP \rightarrow \text{Pron}$	0.45	
$NP \rightarrow \text{Det N1}$	0.35	(N1 is also another type NP, e.g. ADJ + N.)
$NP \rightarrow \text{N1}$	0.20	

Assume that the second rule ($NP \rightarrow \text{Det N1}$) is chosen, so the probability of this 'NP' will be 0.35. Then go to the rules with 'Det' on the LHS.

- 'Det' would then be a given and all rules with 'Det' on the LHS must have probabilities adding to 1. One of these rules (with probability 0.5) would be selected.
- All non-terminals can be thus expanded until there are no more non-terminals.
- The result would be a parse tree whose probability is given by the **product** of the probability of each rule applied.

Consider the following tree (Fig. 6):

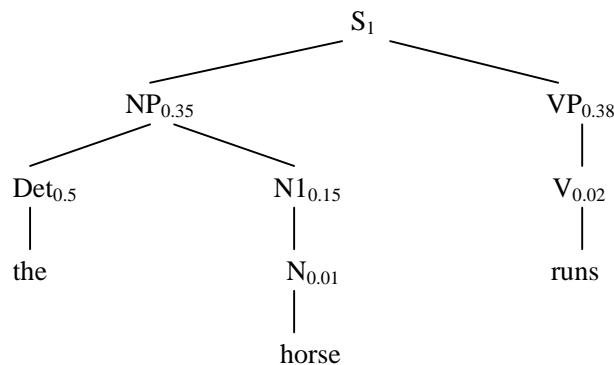


Fig. 6

Its probability is given by $1 \times 0.35 \times 0.5 \times 0.15 \times 0.01 \times 0.38 \times 0.02 = 1.99 \times 10^{-6}$

Note that lexical generation probabilities (e.g. $P(\text{the} | \text{Det}) = 0.5$, $P(\text{horse} | \text{N}) = 0.01$, $P(\text{runs} | \text{V}) = 0.02$) are involved in such a derivation.

Obviously, the PCFG must be based on the corpus linguistics. That is why the corpus linguistics became an important scientific field in NLP.