Chapter 7: Semantics and Logical Form

7.1 Semantics and Logical Form

Precisely defining the notions of semantics and meaning is surprisingly difficult.

Example: - "*The fire means someone camped here last night.*"

The verb "*mean*" has not thing to do with language

- A word *"Amble" means to walk slowly*
- Consider the sentences*: I was at an airport recently and while I was walking toward my departure gate, a guard at the entrance asked :" Do you know what gate you are going to ?". I answer him "yes, I know". But the guard the asked "Which gate is it ?."*

The meaning we want is closer to the usage when defining a word.

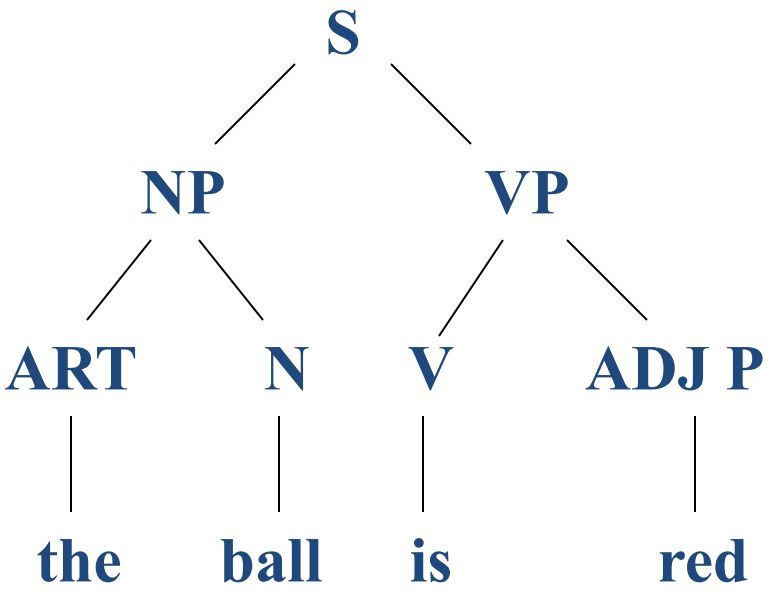
Chapter 7: Semantics and Logical Form

7.1 Semantics and Logical Form

From now on, we the term *meaning* in this context independent sense and we will use the term *usage* for context dependent aspect.

- **Logical form** –the interpretation of the context independent *meaning.*
- **Semantic interpretation-** The process of mapping a sentence to its *logical form.*
- **Context interpretation** – The process of mapping logical form to the *final knowledge representation* (KR) language.
- **Knowledge representation language** is First Order Predicate Calculus (FOPC).
- **The logical language** is the same as the final knowledge representation (FOPC)

Syntactic analysis



semantic interpretation

logical form

(RED 1 < THE b_1 BALL)

contextual interpretation

Final representation

Red (BO 73)

H 7.1 Logical form as an intermediate representation

Chapter 7: Semantics and Logical Form

7.1 Semantics and Logical Form

Logical form must allow to indexical terms, that is, the term are defined by context, such as pronouns, tense, quantifies.

For instance: *The red ball* are indexical *((RED 1 < THE b_1 BALL))*

Many aspects of language depend on the context as well

As the object referred to can only be identified with respect to a context and thus can not be uniquely determined at the logical form level. All of this could be treated as ambiguity at the logical form level.

- ***What is logical form's formal status ?***

Uses the notion of a ***situation***, which is a particular set of circumstances in the world.

Chapter 7: Semantics and Logical Form

7.1 Semantics and Logical Form

A situation can be a set of objects and their relations.

For instance: very simple situation might consist of two objects, a ball B0005 and a person P86 and include the relationship that the person owns the ball. To encode that situation as the set:

{ (BALL B0005), (PERSON P86), (OWNS P86 B0005)}

Logical form is a ***function*** which maps the discourse situation in which the utterance was made to a new discourse that result from the occurrence of the utterance.

Chapter 7: Semantics and Logical Form

7.1 Semantics and Logical Form

Example: old utterance: { (BALL B0005), (PERSON P86), (OWNS P86 B0005)}+ **new fact** (B0005 has the property RED) -> new utterance {{ (BALL B0005), (PERSON P86), (OWNS P86 B0005), (RED B0005)}.

Figure 8.2 shows this view of the interpretation process where the logical form as a function between situations.

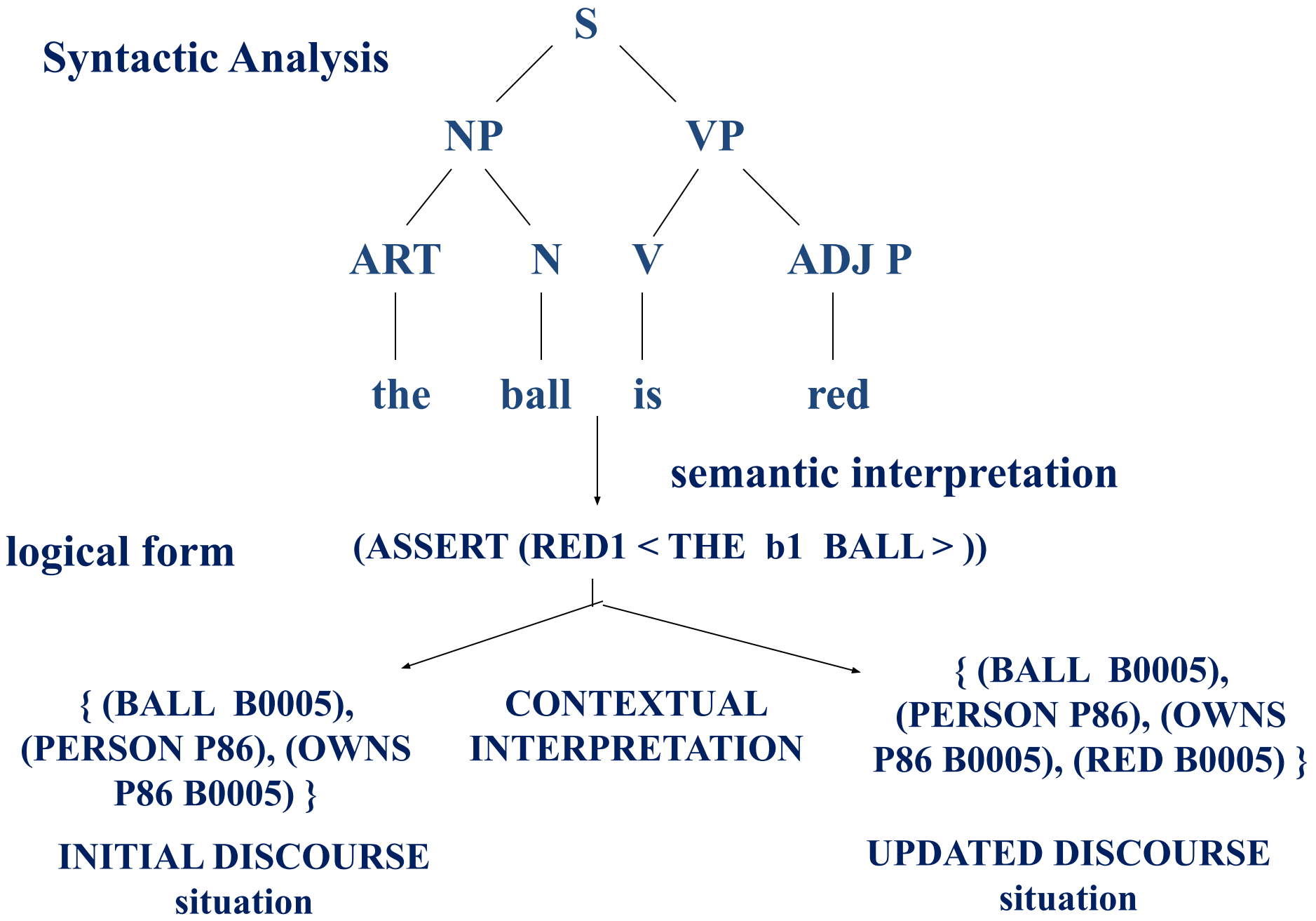


Figure 7.2 : logical form as a function

Chapter 7: Semantics and Logical Form

7.2 Word Senses and Ambiguity

To develop a theory of semantics and semantic interpretation, we need to develop a structural model, just as we did for syntax.

- The basic semantic unit could be word or morpheme, but every word has one or more senses.
- Different senses can be organized into a set of broad classes of objects by which we classify the world.
- Different classes are: *substance* (physical object), *quantity* (such as numbers), *quality, relation, place, time, position, state, action, affection, event, ideas, concept, and plans.*
- Two of the most influential classes such as **actions** and **events**
- ***Example:*** We lifted the box, ***it*** was hard work.

Chapter 7: Semantics and Logical Form

7.2 Word Senses and Ambiguity

- **Situation** may act like an abstraction of the world over some location and time.
- For example: *We laughed and sang at the football game*
  - actions are *laugh* and *sing* at the particular *time* and *location*.

The world can be semantically ambiguous if it maps to more than one a sense. For instance, word ***kid*** seems to be ambiguous between a *baby goat* and *human child; the horses* may be subdivided: mares, colts, trotters .

Example: *I have two kids and George has three*

Chapter 7: Semantics and Logical Form

7.2 Word Senses and Ambiguity

The ambiguity of verbs:

Example 1: ***I ran last year and George did too***

To distinguish between two senses we can index the verb *run:*

RUN1- exercise sense *RUN2- the political sense.*

Example 2: **I kissed Sue and George did too.**

Verb ***kiss*** is vague in that it does not specify where one is kissed. This is lexical ambiguity.

The syntactic ambiguity:

Example 3: ***Happy cats and dogs live on the farm***

(the dogs are happy or not ??)

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

- A primitive unit of meaning is called word sense.

- A language of meanings for more complex expressions resembles FOPC.

- Word senses will serve as atoms or constants of the representation.
  - Constants describe objects in the world including abstract objects such as event and situation, are called terms.
  - Constants describe relation and property, are called predicates.
  - Proposition is formed from a predicate followed by an appropriate number of terms to sever as its arguments.

Example: *Fido is a dog*: FIDO is a term, DOG is a predicate

proposition: (DOG1 FIDO1)

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

✔ unary predicate or properties, binary predicate, n-ary predicate

Example: *Sue loves Jack* would involve a binary predicate LOVE1 and would be written as: (LOVES1 SUE1 JACK1)

Different word classes in English corresponding to different types of constants in logical form:

+ proper names (Jack, Mary) have word senses as term;

+ common nouns (dog, horse)have word senses as unary predicate;

+ Verbs (run, love, put) have word senses as n-ary predicate, where n depends on how many terms the verb subcategorizes for.

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

Figure.7.3 : Two possible network representations of Sue loves Jack

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

A new class of constants called logical operator: NOT, AND (&), OR (V)

Example: **Sue does not love Jack**

(NOT (LOVES1 SUE1 JACK1))

The logical operators that combine two or more propositions to form a complex proposition. FOPC contains operators such as

V (OR – disjunction), & (AND – conjunction), ⊃ (implication)

Other forms - 16 functional binary operators in FOPC

When we apply 16 operators in natural language that situations are more complex than in FOPC.

Example: ***I went home and had a drink***

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

The general logical form*: (connective proposition proposition)*

Example: **Jack loves Sue or Jack loves Mary**

(OR (LOVES1 JACK1 SUE1) (LOVES1 JACK1 MARY1))

- One important construct is **quantifier.**
- In FOPC , there are only two quantifiers $\forall$ and $\exists$. English contains much large range of quantifies: all, some, most, many, a few, the, a,

Example: *"All dogs bark"; "Most people laugh"*

These quantifies are called **generalized quantifiers**

Scope of quantifies in natural language is more complex than FOPC

Example: "A man entered the room. He walked over the table"

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

The quantifiers are used in logical form of the general form

(quantifier variable: restriction-proposition body-proposition)

Example: "most dogs bark" □(MOST1 d1 : (DOG1 d1)(BARKS1d1))

This means that most of the objects d1 that satisfy (DOG1 d1) also satisfy (BARKS1 d1). Note that this has a very different meaning from the formula: (MOST1 d2 : (BARKS1 d2)(DOG1 d2)).

The important quantifiers are ***the, a:***

Example: *"The dog barks"* □ (THE x : (DOG1 x) (BARKS x))

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

Quantifier	Use	Example
THE	definite reference	the dog
A	indefinite reference	a dog
BARE	bare singular NP (mass term)	water, food
BARE	Or bare plural NP (generic)	dogs

Figure 7.4: Some common quantifiers

The predicate operator PLUR:

Example: dogs □ (PLUR DOG1), so predicate DOG would be an argument of new predicate PLUR

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

Example: the dogs bark □

(THE x : ((PLUR DOG1) x) (BARK1 x))

Plural noun phrases introduce the possibility of a new form of ambiguity, this is called **distributive reading, collective reading**

Example: (1) *The dogs bark*

There is a specific set of dogs and each one of them barks-distributive reading

(2) *The dogs met at the corner*

It makes no sense to say that each individual dog met; rather the meeting is true of the entire set of dogs- collective reading

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

Example: *3) Two men bought a stereo*

There are two meanings: the sentence can mean that two men each bought a stereo (distributive reading) or two men bought a stereo together (collective reading).

Modal operators

Modal operators look similar to logical operators but have some important differences, specifically, terms within the scope.

We assume that Jack is also known as John to some people then Jack1 = John2

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

if (HAPPY JOHN2) is true, then (HAPPY JACK1) is true

Then so, if (OR (HAPPY JOHN2) (SAD JOHN2)) is true, then (OR (HAPPY JACK1) (SAD JACK1)) is true too.

The same propositions within the scope of modal such as BELIEVE1, however are not interchangeable.

Example: if Sue believes that jack is happy, that is:

(BELIEVE SUE1 (HAPPY JACK1))

Then is does not necessarily follow that Sue believes John is happy, that is: (BELIEVE SUE1 (HAPPY JOHN2))

Because, Sue might not know that JACK1 and JOHN2 are the same person.

Chapter 7: Semantics and Logical Form

- **7.3 The basic logical form language**

Tense- modal Operators: PAST, PRES, FUT

Example:

(1) John sees Fido □ (PRES (SEES1 JOHN1 FIDO1))

(2) John saw Fido □ (PAST (SEES1 JOHN1 FIDO1))

(3) John will see Fido □ (FUT (SEES1 JOHN1 FIDO1))

The three sentences are true.

If John was a president, but now was not, so we can not conclude that now, John sees Fido that means the president sees Fido too.

Chapter 7: Semantics and Logical Form

7.3 The basic logical form language

Example:

If (PAST (SEES1 JOHN1 FIDO1)) is true

then (PAST (SEES1 PRESIDENT1 FIDO1)) is true.

If (PRES (SEES1 JOHN1 FIDO1)) is true

then (PRES (SEES1 PRESIDENT1 FIDO1)) is **not true**

Chapter 7: Semantics and Logical Form

7.4 Encoding Ambiguity in the Logical Form

Ambiguity encoding is as separate level of representation from the logical form, and it is often referred to as **quasi-logical form.**

Often words have different senses that have identical structural constrains.

Only way to encode these would be to build a separate logical form for each possible combination of senses for words in the sentence.

Example: *"Sue watched the ball"*

The noun ball has at least two senses: BALL1 and BALL2. BALL1 is object used in game; BALL2 is the social event involving dancing. So the logical form of *"Sue watched the ball" is that:*

Chapter 7: Semantics and Logical Form

7.4 Encoding Ambiguity in the Logical Form

(THE b1: ({ BALL1 BALL2 } b1) (PAST (WATCH1 SUE1 b1)))

This abbreviates two possible logical forms:

1) (THE b1: (BALL1 b1) (PAST (WATCH1 SUE1 b1)))

2) (THE b1: (BALL2 b1) (PAST (WATCH1 SUE1 b1)))

Most complex forms of ambiguity in logical forms arises from the relative scoping of quantifies and operators.

Example: Every boy loves a dog □

(LOVES1 < EVERY b1 (BOY1 b1) > < A d1 (DOG1 d1 >)

"<" and " > " indicate the scoping abbreviation

Chapter 7: Semantics and Logical Form

7.4 Encoding Ambiguity in the Logical Form

This abbreviates an ambiguity between logical form:

(EVERY b1: (BOY1 b1) (A d1: (DOG1 d1) (LOVES1 b1 d1)))

(A d1: (DOG d1) (EVERY b1: (BOY b1) (LOVES1 b1 d1)))

Example: *"Every boy didn't run"* is ambiguous between the reading in which some boys didn't run and some did, that is,

(NOT (EVERY b1 : (BOY1 b1) (RUN1 b1))

and the reading where no boys ran, that is,

(EVERY b1 : (BOY1 b1) (NOT (RUN1 b1)))

These two reading are captured by the single logical form

(< NOT RUN1 > < EVERY b1 BOY1 >)

Chapter 7: Semantics and Logical Form

7.4 Encoding Ambiguity in the Logical Form

✔Two important structures of meaning, that are name (NAME) and pronoun (PRO)

(NAME < variable > < name >)

(PRO < variable > < proposition >)

Example: *(1) "John ran"* □

(< PAST RUN1>(NAME J1 "John"))

(2) "Every man liked him"□

< PAST LIKE1 >< EVERY m1 MAN1> (PRO m2 (HE2 m2)))

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

So far, verbs have mapped to appropriate senses acting as predicate, that can hold all the different forms but loses some generalities.

Example: *(i) John broke the window with the hammer*

(ii) The hammer broke the window

(iii) The window broke

All these sentences describer the same type of event but in varying detail.

We would need three different senses of *break*: BREAK1, BREAK2 and BREAK3.

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

Thus, these sentences have three logical forms, that are,

(i') (< PAST BREAK1 > (NAME J1 "John") < THE w1 WINDOW1 >
< THE h1 HAMMER1 >)

(ii') (< PAST BREAK2 > < THE h1 HAMMER1 >
< THE w1 WINDOW1 >)

(iii') (< PAST BREAK3 > < THE w1 WINDOW1 >)

The event is introduced into the ontology, and treating the meaning the sentence "*John broke it* " along the following lines,

(∃ e1 : (BREAK e1 (NAME J1 "John") (PRO i1 IT1)))

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

e1 is an event that John broke the window.

The meaning of the sentence *John broke it with the hammer* would be that,

(∃ e1 : (& (BREAK e1 (NAME J1 "John") (PRO I1 IT1))
(INSTR e1 < THE h1 HAMMER1 >)))

The advantage is that additional modifiers, as *with the hammer* or *on Saturday*…can be incrementally added to the basic representation by adding more predications involving the event.

Abstract semantic relationships that can hold between a **verb and its arguments,** these often called thematic roles or case roles.

The intuition is that *John, the hammer* and *the window* play the same semantic roles in each of these sentences.

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

Let' go back to the sentences:

- *John broke the window with the hammer*
- *The hammer broke the window*

John is an actor (agent role), the window is a object (theme role) and *the hammer* is an instrument (instrument role), that is used to make the action *break*.

The new notation for logical form:

(1) **(∃ e: (& (Event -p e) (Relation1 e obj1) … (Relation$_n$ e obj$_n$)))**

The abbreviated form (2) for an assertion of (1):

(2) **(Event –p e [Relation1 obj1] … [Relation$_n$ obj$_n$])**

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

From (2), three thematic roles such as agent role, theme role, and instrument role are mentioned, the meaning of

"John broke the window with the hammer" would be

(∃ e (& (BREAK e (AGENT e (NAME J1 "John")) (THEME e <THE w1WINDOW>) (INSTR e1 <THE h1 HAMMER1 >)))

We have sentence *Mary was unhappy,* then its meaning would be:

(< PAST UNHAPPY > (NAME J1 "MARY"))

If we will extend this sentence such as:

Chapter 7: Semantics and Logical Form

7.5 Verbs and states in Logical Form

Mary was unhappy in the meeting , then its meaning would be:

(< PAST UNHAPPY > < [THEME (NAME J1 “MARY”)]
[IN – LOC < THE m1 MEETING >])

Thus, we can develop a logical form appropriate for a extended sentence.

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

We introduced the roles AGENT, THEME, INSTR, now we define these relations more precisely and introduce other thematic roles. A range of roles has to do with locations, or abstract locations.

Example	***Roles***
I threw the ball **to John** It fell **to the ground**	TO – LOC
I gave a book **to John**	TO – POSS
I caught the ball **from John** I walked **from here** to school yesterday	FROM – LOC
I borrowed a book **from John**	FROM – POSS
he box **contains a ball**	AT – LOC
John **owns a book**	AT – POSS
The bird flew **from** the lake **along** the river gorge	PATH – LOC

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

A range of roles has to do with time: AT-TIME, TO-TIME, FROM-TIME

Example	Roles
I saw the car at 3 o'clock	AT-TIME
I worked from one until three	FROM- TIME and TO- TIME

The roles apply to general state change as well as with temperature: AT – VALUE, FROM – VALUE.

Example	Roles
The temperature remain at zero	AT - VALUE
The temperature rose from zero	FROM – VALUE

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

BENEFICIARY role, which is filled by the animate, person for whom a certain event is performed, as in

*I rolled on the floor **for** Lucy*
*Find **me** the paper*
*I gave the book to Jack **for Susan***

Note: the last example demonstrates the need to distinguish the TO-POSS (that is *to Jack*) from the BENEFICIARY role.

INSTR role describes a tool, material, or force used to perform some event, as in: *Harry broke the glass with telescope*
The telescope broke the glass
I used some flour to make a cake
I made a cake with some flour

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

Example: *The sun dried the apples*

Jack used the sun to dry the apples

The AGENT and INSTR roles could be combined into more general role named CAUSAL-AGENT.

CO – AGENT role**,** when two actors at the same time make an action together.

Henry lifted the piano with Jack

CO – THEME role, when two objects are effected by an action.

(i) Jack paid $1 to man for the book
(ii) Jack bought the book from the man for $1

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

To handle this , we must add the role CO – THEME for second object in an exchange.

PRIMARY event and SECONDARY event

Example: *Jack paid $1 to man for the book.*

Jack: AGENT of both PRIMARY and SEONDARY event;

$1: THEME of PRIMARY event;

The man: TO-POSS of PRIMARY event and FROM-POSS of SECONDARY event;

The book: THEME of SECONDARY event.

The table of some possible roles in the Figure 8.5

Role and Subroles	Other Common Names	Definition
CAUSAL-AGENT		the object that caused the event
AGENT		intentional causation
INSTR		force/tool used in causing the event
THEME	PATIENT	the thing affected by the event
EXPERIENCER		the person involved in perception or a physical/psychological state
BENEFICIARY		the person for whom an act is done
AT		the state/value on some dimension
AT-LOC	LOCATION	current location
AT-POSS	POSSESSOR	current possessor
AT-VALUE		current value
AT-TIME		current time
TO		final value in a state change
TO-LOC	DESTINATION	final location
TO-POSS	RECIPIENT	final possessor
TO-VALUE		final value
FROM		original value in a state change
FROM-LOC	SOURCE	original location
FROM-POSS		original possessor
FROM-VALUE		original value
PATH		path over which something travels
CO-AGENT		secondary agent in an action
CO-THEME		secondary theme in an exchange

Figure 7.5: Some possible semantic roles

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

Inner role of the verbs

Example: (i) *John and I ran to the store*

(ii) I ran to the store and to the bank

Thus, AGENT and TO – LOC are inner roles of ***run.***

THEME is usually an inner role obliged of verb while AGENT might not obliged inner role (in the passive sentence)

Chapter 7: Semantics and Logical Form

7.6 Thematic roles

The table of inner roles

Example	Inner roles
Jack run	AGENT
Jack ran with a crutch	AGENT + INSTR
Jack ran with a crutch for Susan	AGENT+INSTR+BENEFICIARY
Jack destroyed the car	AGENT + THEME
Jack put the car through the wall	AGENT + THEME + PATH
Jack sold Henry the car	AGENT + TO - POSS + THEME

Jack *ran*.	AGENT only
Jack *ran* with a crutch.	AGENT + INSTR
Jack *ran* with a crutch for Susan.	AGENT + INSTR + BENEFICIARY
Jack *destroyed* the car.	AGENT + THEME
Jack *put* the car through the wall.	AGENT + THEME + PATH
Jack *sold* Henry the car.	AGENT + TO-POSS + THEME
Henry *pushed* the car from Jack's house to the junkyard.	AGENT + THEME + FROM-LOC + TO-LOC
Jack *is tall*.	THEME
Henry *believes* that Jack is tall.	EXPERIENCER + THEME
Susan *owns* a car.	AT-POSS + THEME
I *am* in the closet.	THEME + AT-LOC
The ice *melted*.	THEME
Jack *enjoyed* the play.	EXPERIENCER + THEME
The ball *rolled* down the hill to the water.	THEME + PATH + TO-LOC

Role	Realization
AGENT	as subject in active sentences preposition *by* in passive sentences
THEME	as object of transitive verbs as subject of nonaction verbs
INSTR	as subject in active sentences with no agent preposition *with*
EXPERIENCER	as animate subject in active sentences with no agent
BENEFICIARY	as indirect object with transitive verbs preposition *for*
AT-LOC	prepositions *in*, *on*, *beyond*, etc.
AT-POSS	possessive NP as subject of sentence if no agent
TO-LOC	prepositions *to*, *into*
TO-POSS	preposition *to*, indirect object with certain verbs
FROM-LOC	prepositions *from*, *out of*, etc.
FROM-POSS	preposition *from*

Figure 7.6: Common relalizations of the major roles

Chapter 7: Semantics and Logical Form

7.7 Speech Acts and Embedded Sentences

The logical form language is extend to capture the semantic distinctions of utterances.

Each of major sentence types has corresponding operator that takes the interpretation as an argument and produces what is called *surface speech act*, They are indicated by new operators as follows:

ASSERT –the proposition is being asserted

Y/N – QUERY – the proposition is being queried

COMMAND – the proposition describes an action to perform

WH – QUERY – the proposition describes an object to be identified

Chapter 7: Semantics and Logical Form

7.7 Speech Acts and Embedded Sentences

Example:

(1) The man ate a peach □ (ASSERT(<PAST EAT> e1
[AGENT<THE m1 MAN1>] [THEME < A p1 PEACH1 >]))

(2) Did the man ate a peach? □ (Y/N –QUERY(<PAST EAT> e1
[AGENT<THE m1 MAN1>] [THEME < A p1 PEACH1 >]))

(3) Eat the peach! □ (COMMAND (EAT e1
[THEME < THE p1 PEACH1 >]))

✔ For WH – question, such as ***What id the man ate*** ?, several additions need to be made to the logical form language that indicates what wh-term represents.

Chapter 7: Semantics and Logical Form

7.7 Speech Acts and Embedded Sentences

The noun phrase such as:

what would be represented <WH o1 ANYTHING >,

which man □ < WH m1 MAN1 >,

who □ < WH p1 PERSON >,

which man □ <WH m1 MAN>,

who □ <WH p1 PERSON>,

how many □ < HOW – MANY >,

how – much □ < HOW – MUCH

- ***Example:*** *Who is the leader of every group? is ambiguous* between asking for single person who leads every group and asking for the leader of each of the groups.

Chapter 7: Semantics and Logical Form

7.7 Speech Acts and Embedded Sentences

Example: the logical form for WH – question:

(i) *What did the man eat?* □(WH - QUERY(< PAST EAT > e1
[AGENT<THE m1 MAN1>][THEME<WH w1 PHYSOB>]))

The logical form for the complex assertive sentence:

(ii) The man ate a peach left □ (ASSERT(<PAST LEAVE> l1
[AGENT < THE m1 (& (MAN m1) (< PAST EAT > e2
[AGENT m1] [THEME < A p1 PEACH1 >])) >]))

UTTERANCE → (ASSERT *PROPOSITION*) |
(Y/N-QUERY *PROPOSITION*) |
(COMMAND *PROPOSITION*) |
(WH-QUERY *PROPOSITION*)

PROPOSITION → (*n-ARY-OPERATOR PROPOSITION*$_1$ ... *PROPOSITION*$_n$) |
(*QUANTIFIER VARIABLE : PROPOSITION PROPOSITION*) |
(*n-ARY-PREDICATE TERM*$_1$ ... *TERM*$_n$) |
(*EVENT-STATE-PRED VARIABLE* [*ROLE-NAME TERM*]$_1$ ...
[*ROLE-NAME TERM*]$_n$)

TERM → *VARIABLE* |
(NAME *VARIABLE NAME-STRING*) |
(PRO *VARIABLE PROPOSITION*)

1-ARY-OPERATOR → NOT | PAST | PERF | PROG | ...

2-ARY-OPERATOR → AND | BUT | IF-THEN | ...

QUANTIFIER → THE | SOME | WH | ∃ | ..

VARIABLE → b1 | man3 | ...

1-ARY-PREDICATE → *TYPE-PREDICATE* | HAPPY1 | RED1 | ...

TYPE-PREDICATE → *EVENT-STATE-PRED* | (PLUR *TYPE-PREDICATE*) | MAN1 | ...

EVENT-STATE-PRED → RUN1 | LOVE3 | GIVE1 | HAPPY | ...

2-ARY-PREDICATE → *ROLE-NAME* | ABOVE1 | ...

ROLE-NAME → AGENT | THEME | AT-LOC | INSTR | ...

NAME-STRING → "John" | "The New York Times" | ...

Figure 7.7 A formal definition of the syntax of the logical form language

$TERM \rightarrow \langle QUANTIFIER\ VARIABLE\ PROPOSITION \rangle$

$TERM \rightarrow \langle n\text{-}ARY\text{-}OPERATOR\ TERM_1 \ldots TERM_n \rangle$

$n\text{-}ARY\text{-}PREDICATE \rightarrow \langle m\text{-}ARY\text{-}OPERATOR\ n\text{-}ARY\text{-}PREDICATE_1 \ldots n\text{-}ARY\text{-}PREDICATE_m \rangle$

$n\text{-}ARY\text{-}OPERATOR \rightarrow \{n\text{-}ARY\text{-}OPERATOR_1 \ldots n\text{-}ARY\text{-}OPERATOR_m\}$

$QUANTIFIER \rightarrow \{QUANTIFIER_1 \ldots QUANTIFIER_m\}$

$n\text{-}ARY\text{-}PREDICATE \rightarrow \{n\text{-}ARY\text{-}PREDICATE_1 \ldots n\text{-}ARY\text{-}PREDICATE_m\}$

$TYPE\text{-}PREDICATE \rightarrow \{TYPE\text{-}PREDICATE_1 \ldots TYPE\text{-}PREDICATE_m\}$

$EVENT\text{-}STATE\text{-}PRED \rightarrow \{EVENT\text{-}STATE\text{-}PRED_1 \ldots EVENT\text{-}STATE\text{-}PRED_m\}$

$ROLE\text{-}NAME \rightarrow \{ROLE\text{-}NAME_1 \ldots ROLE\text{-}NAME_m\}$

Figure 7.8: Additional rules defining the quasi-logical form

EXERCISE of CHAPTER 7

1. State why each of the sentences are ambiguous or not. Specifically, state whether they are ambiguous because of their possible syntactic structures, their word senses, their semantic structures, or a combination of these factors. Give a paraphrase of each reading.

   a) *A man stopped at every truck stop.*

   b) Several people ate the pizza.

   c) We saw her duck.

2. Specify a quasi-logical form for the following sentences. If the sentence is ambiguous, mark sure you represent all the possibilities, either using ambiguous logical forms or listing several logical forms.

George ate a pizza at every road stop.

Several employees from every company bought a pizza.

We saw John in the park by the beach