Logical form tutorial

`http://www-rohan.sdsu.edu/~gawron/semantics`

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Overview

Outline

Logical Form

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Goal:

- A few simple rules to help the beginner get the hang of translating into logic

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- Problems

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  - There are a LOT of things to cover

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    - There are a LOT of things to cover
    - The rules can't be complete.

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- A few simple rules to help the beginner get the hang of translating into logic
- Problems
  - There are a LOT of things to cover
  - The rules can't be complete.
  - Ambiguity of English

Outline

1. Introduction
2. **Background ideas**
   - General principles
   - Predicate Principles
3. Statement logic/predicates
4. Predicate logic
5. A recipe for English-to-Logic translation
6. Logical Form
7. Applying the recipe
8. Ambiguity
9. Embedded sentences

Outline

Principles

The logical form of an English sentence is a decomposition of the sentence into predicates and connectives. The predicates capture the concepts being expressed. The connectives caoture how the concepts are related.

1. Almost every noun, verb, and adjectives corresponds to a predicate.

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    1. Same arity (same number of arguments)
    2. Arguments are in a consistent order

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Noun, Adj, Prep

	Arity		Comments
Nouns	1-place	man(x)	except relational nouns (*husband*, *father*)
Adjectives	1-place	happy(x)	except relational adjectives (*fond+of*, *angry+at*)
Prepositions	2-place	from(x, Spain)	except sometimes part of verb meaning (*rely+on*), object of prep is arg2

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Connectives

(both) ... and	$\wedge$, &	$p \wedge q$ (Both) John and Bill awakened. Sue awakened (both) John and Bill.
(either) ... or	$\vee$	$p \vee q$ (Either) John or Bill awakened. Sue awakened John or Bill.
not	$\sim$	$\sim p$ John didnt sleep. It's not the case that John slept.
neither .. nor		Neither Sue nor Mary slept. Sue neither ran nor swam.
not ... nor		John didnt sleep (and) nor did Sue.
unless		John will win unless he withdraws.
because		Give up!

Connective Principle

Sentential Connective principle

To translate an English sentence using a sentential connective of statement logic, you must find a logically equivalent sentence in which two full sentences are conjoined.

John and Bill awakened.	John awakened and Bill awakened. p = John awakened ; q = Bill awakened p & q awaken(j) & awaken(b)
Sue awakened John and Bill.	Sue awakened John and Sue awakened Bill. p = Sue awakened John; q = Sue awakened Bill p & q awaken2(s,j) & awaken2(s,b)

Connective examples

Neither John nor Bill awakened.

John didn’t awaken and Bill didn’t awaken.

Q = awaken; p = John Q’ed ; q = Bill Q’ed

$\sim p \& \sim q$

$\sim (p \vee q)$

Truth table

J. Q’ed	B. Q’ed	Neither J. nor B. Q’ed	$\sim p \& \sim q$	$\sim (p \vee q)$
T	T	F	F	F
T	F	F	F	F
F	T	F	F	F
F	F	T	T	T

Verbs

	Arity		Comments
intransitive	1-place	walk(j)	*walk, faint, sleep, fall,* . . . Ignore tense.
transitive	2-place	hit(j,f) love(m,j)	*hit, kill, kick, eat,* . . . unpassivize passive sentences (*John was loved by Mary* → *Mary loved John*)
ditransitive	3-place	give(m, b, j)	*give, send, cost, charge,* . . .
Auxiliaries	syncategorematic		*be, do**, *have**, *may, might, can, could, should, shall, will, would*

*: *do* and *have* are ambiguous. They are also transitive verbs.

Arity issues

The arity of a predicate is the number of arguments it has.

a. John showed Mary the picture.
show(j, m, p)

b. John showed Mary.
show(j, m) NO NO! Ignore p. 36!

c. show2(j, m)

Predicate Principle

The arity of a linguistic predicate is the number of syntactic arguments it has.

1. If it's obligatory, it's an argument.
2. If the same verb shows up with different sets of arguments, use different predicates.
3. Location, Time, and Manner are usually not arguments:

a.	Time	John painted the room *yesterday*. paint(j,r)
b.	Location	John wrote his essay *in the study*, write(j,e)
c.	Manner	John hid the letter *carefully*. hide(j,l)

Predicate Principle examples

John painted the kitchen	paint(j, k)
John painted in the kitchen.	paint2(j)
Da Vinci painted the Mona Lisa	
John gave the book to Mary.	give(j,b,m)
John gave Mary the book.	give(j,b,m)
WRONG!	give(j,m,b)
Mary was given the book by John.	give(j,b,m)
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Complex Predicates

Sometimes a predicate will be expressed by more than one word.

a. John *signed up for* the class.
sign-up-for(j,c)
b. John *blacked out* in the study.
black-out(j,e)
c. John *called up* Sue
John *called* Sue *up*. call-up(j,s)

Frequently such complex predicates are combinations of verbs and prepositions. It's convenient to use both the verb and preposition in naming such predicates, because it often helps make the meaning clear, and keeps different meanings distinct (*call-up* vs *call-on*)

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Connectives: Quantifiers, negation, and sentential

Universals ($\forall$), Existentials ($\exists$), and negation $\sim$ correspond to appropriate English words, and each quantifier goes with its appropriate sentential connective:

every, all, any	$\forall$	$\forall$	$\rightarrow$	$\forall x\, \text{dog}(x) \rightarrow \text{bark}(x)$
some, a, a certain	$\exists$	$\exists$	&	$\exists x\, \text{dog}(x)\ \&\ \text{bark}(x)$
not, n't	$\sim$			
no	$\sim\exists$	$\sim\exists$	&	$\sim\exists x\, \text{dog}(x)\ \&\ \text{bark}(x)$

Ambiguity

(1) a. Every prize was won by some high school kid.

Ambiguity

(2) a. Every prize was won by some high school kid.

b. For every prize, x, there was some high school kid, y, such that y won x.

b. $\forall x[\text{prize}(x) \rightarrow \exists y[\text{high-school-kid}(y)\ \&\ \text{win}(y, x)]\,]$

Ambiguity

(3) a. Every prize was won by some high school kid.

b. For every prize, x, there was some high school kid, y, such that y won x.

c. Some particular high school kid y won every prize, x.

b. $\forall x[\text{prize}(x) \rightarrow \exists y[\text{high-school-kid}(y)\ \&\ \text{win}(y, x)]\,]$

c. $\exists y[\text{high-school-kid}(y)\ \&\ \forall x[\text{prize}(x) \rightarrow \text{win}(y, x)]\,]$

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(4) a. Every prize was won by some high school kid.

b. For every prize, x, there was some high school kid, y, such that y won x.

c. Some particular high school kid y won every prize, x.

b. $\forall x[\text{prize}(x) \rightarrow \exists y[\text{high-school-kid}(y)\ \&\ \text{win}(y, x)]\,]$
c. $\exists y[\text{high-school-kid}(y)\ \&\ \forall x[\text{prize}(x) \rightarrow \text{win}(y, x)]\,]$

The two translations share all the same predicates, and even the arguments of the predicates are the same. All that differs is the way the predications are **connected**.

Noun phrases

Translate each Noun phrase (NP) in isolation.

Some examples of noun phrase translations

a kid$_x$

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a high school kid$_x$	$\exists\, x\ \mathrm{high\text{-}school}(x)\ \&\ \mathrm{kid}(x)$	Wrong!

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a kid$_x$ from Spain	$\exists\, x$ kid(x) & from(x, S)	
a tall kid$_x$ from Spain	$\exists\, x$ tall(x) & kid(x) & from(x, S)	
a high school kid$_x$	$\exists\, x$ high-school(x) & kid(x)	Wrong!
a high school kid$_x$	$\exists\, x$ high-school-kid(x)	Right!
a man$_x$ I like	$\exists\, x$ man(x) & like(I)	

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a high school kid$_x$	$\exists\, x\ \mathrm{high\text{-}school\text{-}kid}(x)$	Right!
a man$_x$ I like	$\exists\, x\ \mathrm{man}(x)\ \&\ \mathrm{like}(\mathrm{I})$	
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	$\exists\, x\ \text{man}(x)\ \&\ \text{like}(\text{I}, x)$	Right!

Important principle

NP modifiers

A	kid$_x$		from Spain
$\exists\, x$	kid(x)	&	from(, s)

Important principle

NP modifiers

A	kid$_x$		from Spain
$\exists x$	kid(x)	&	from(x, s)
			$\uparrow$

The NP variable always occurs in the translations of its modifiers.

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Procedure: Simple version

Initial sentence

Some young woman arrived.

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2. Remove Quantified NPs

Moved out	Sentence
	x arrived.

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1. Find Quantified NPs

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2. Move each quantified NP out of the sentence, leaving the variable you chose behind. But keep it around for later!

2. Remove Quantified NPs

Moved out	Sentence
$\boxed{\text{Some young woman}_x}$	x arrived.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

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Moved out	Sentence
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4. Turn the sentence into logic, using predicate principles.

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4. Sentence → logic

Moved out	Sentence
$\boxed{\exists x \text{ woman}(x)\ \&\ \text{young}(x)}$	arrive(x).

Procedure concluded

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Procedure concluded

5. Add each NP translation back *one at a time*, using the right sentential connective:

5. Move NP's back

Moved out	Sentence
	$\exists\, x$ woman(x) & young(x) & arrive(x)

Summary

Find Qtfd NPs

1. $\boxed{\text{Some young woman}_x}$ arrived.
2.
3.
4.
5.

Summary

Remove Qtfd NPs

1. $\boxed{\text{Some young woman}_x}$ arrived.
2. x arrived.
3.
4.
5.

Summary

Remove Qtfd NPs

1. $\boxed{\text{Some young woman}_x}$ arrived.
2. $\boxed{\text{Some young woman}_x}$ x arrived.
3.
4.
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Summary

NPs → logic

1.		$\boxed{\text{Some young woman}_x}$ arrived.
2.	$\boxed{\text{Some young woman}_x}$	x arrived.
3.	$\exists x\ \text{young}(x)\ \&\ \text{woman}(x)$	x arrived.
4.		
5.		

Summary

S → logic

1.		$\boxed{\text{Some young woman}_x}$ arrived.
2.	$\boxed{\text{Some young woman}_x}$	x arrived.
3.	$\exists x$ young(x) & woman(x)	x arrived.
4.	$\exists x$ young(x) & woman(x)	arrive(x)
5.		

Summary

Move NPs back

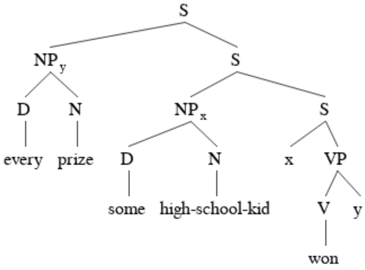
1.		$\boxed{\text{Some young woman}_x}$ arrived.
2.	$\boxed{\text{Some young woman}_x}$	x arrived.
3.	$\exists x$ young(x) & woman(x)	x arrived.
4.	$\exists x$ young(x) & woman(x)	arrive(x)
5.		$\exists x$ young(x) & woman(x) & arrive(x)

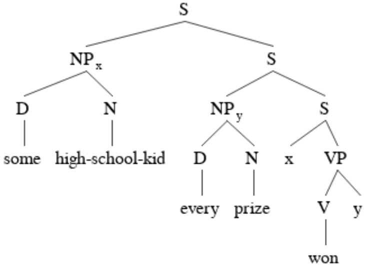
Outline

Non ambiguous sentences?

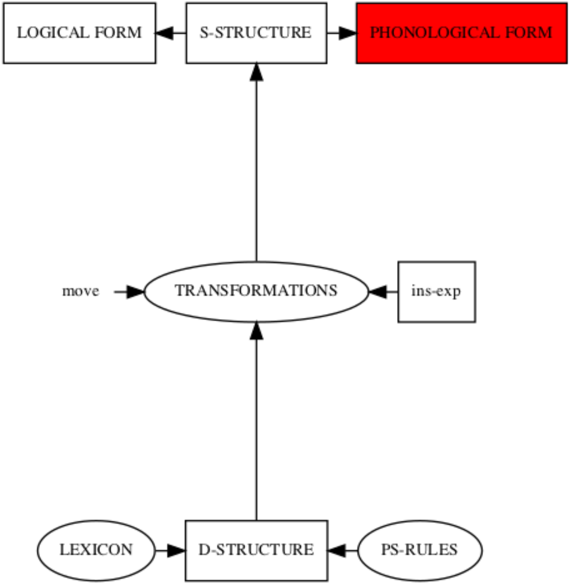
(5) a. Everyone in this room speaks two languages.
b. Two languages are spoken by everyone in this room.
c. It is certain that no one will leave.
d. No one is certain to leave.

What kind of ambiguity?





This is getting weird



LOGICAL FORM

S-STRUCTURE

PHONOLOGICAL FORM

move

TRANSFORMATIONS

ins-exp

LEXICON

D-STRUCTURE

PS-RULES

Outline

A different example

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2. Remove Quantified NPs

Moved out	Sentence
	Utopia welcomes x.

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1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

Utopia welcomes $\boxed{\text{every traveler}_x \text{ from Spain}}$.

2. Move each quantified NP out of the sentence, leaving the variable you chose behind. But keep it around for later!

2. Remove Quantified NPs

Moved out	Sentence
$\boxed{\text{every traveler from Spain}_x}$	Utopia welcomes x.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\forall\, x \text{ traveler}(x) \,\&\, \text{from}(x,\ \mathrm{S})}$	Utopia welcomes x.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\forall\, x \text{ traveler}(x) \,\&\, \text{from}(x,\ \textsc{s})}$	Utopia welcomes x.

4. Turn the sentence into logic, using predicate principles.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\forall\, x \text{ traveler}(x)\ \&\ \text{from}(x,\ \textsc{s})}$	Utopia welcomes x.

4. Turn the sentence into logic, using predicate principles.

4. Sentence → logic

Moved out	Sentence
$\boxed{\forall\, x \text{ traveler}(x)\ \&\ \text{from}(x,\ \textsc{s})}$	welcome(U, x).

Procedure concluded

5. Add each NP translation back *one at a time*, using the right sentential connective:

Procedure concluded

5. Add each NP translation back *one at a time*, using the right sentential connective:

5. Move NP's back

Moved out	Sentence
	$\forall\, x$ traveler(x) & from(x, S)→welcome(U, x)

Outline

Two qtfd NPs

(6) a. Every prize was won by some high school kid.

Two qtfd NPs

(7) a. Every prize was won by some high school kid.
    b. Some high school kid won every prize. (unpassivized form)

Step 0. Unpassivize.

Two qtfd NPs

(8) a. Every prize was won by some high school kid.
    b. Some high school kid won every prize. (unpassivized form)

Step 0. Unpassivize.

1. Find each quantified NP, and choose a variable for it.

Two qtfd NPs

(9) a. Every prize was won by some high school kid.

b. Some high school kid won every prize. (unpassivized form)

Step 0. Unpassivize.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

$\boxed{\text{Some high school kid}_x}$ won $\boxed{\text{every prize}_y}$.

Two qtfd NPs

(10) a. Every prize was won by some high school kid.
b. Some high school kid won every prize. (unpassivized form)

Step 0. Unpassivize.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

$\boxed{\text{Some high school kid}_x}$ won $\boxed{\text{every prize}_y}$.

2. Move each quantified NP out of the sentence, leaving the variable you chose behind.

Two qtfd NPs

(11) a. Every prize was won by some high school kid.
b. Some high school kid won every prize. (unpassivized form)

Step 0. Unpassivize.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

$\boxed{\text{Some high school kid}_x}$ won $\boxed{\text{every prize}_y}$.

2. Move each quantified NP out of the sentence, leaving the variable you chose behind.

2. Remove Quantified NPs

Moved out	Sentence
$\boxed{\text{Some high school kid}_x}$ $\boxed{\text{every prize}_y}$	x won y.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\exists x \text{ high-school-kid}(x)}$	x won y.
$\boxed{\forall y \text{ prize}(y)}$	

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\exists x$ high-school-kid(x)	x won y.
$\forall y$ prize(y)	

4. Turn the sentence into logic, using predicate principles.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\exists x$ high-school-kid(x)	x won y.
$\forall y$ prize(y)	

4. Turn the sentence into logic, using predicate principles.

4. Sentence → logic

Moved out	Sentence
$\exists x$ high-school-kid(x)	win$(x,\ y)$
$\forall y$ prize(y)	

Procedure concluded, rdg 1

5. Add each NP translation back *one at a time*, using the right sentential connective:

Procedure concluded, rdg 1

5. Add each NP translation back *one at a time*, using the right sentential connective:

5a. Move first NP back, using right connective (&).

Moved out	Sentence
$\boxed{\forall y \text{ prize}(y)}$	$\exists x$ high-school-kid(x) & win(x, y)

Procedure concluded, rdg 1

5. Add each NP translation back *one at a time*, using the right sentential connective:

5a. Move first NP back, using right connective (&).

Moved out	Sentence
$\boxed{\forall y \text{ prize}(y)}$	$\exists x$ high-school-kid(x) & win(x, y)

5b. Move second NP back, using right connective ($\rightarrow$).

Moved out	Sentence
	$\forall y$ prize$(y) \rightarrow (\exists x$ high-school-kid(x) & win$(x, y))$

Second reading

Hold on! We've only got ONE of the two readings!

(12) a. For every prize, *x*, there was some high school kid, *y*, such that *y* won *x*.

a. $\boxed{\forall x[\text{prize}(x) \rightarrow \exists y[\text{high-school-kid}(y) \ \& \ \text{win}(y,\, x)]\,]}$

b.

Second reading

Hold on! We've only got ONE of the two readings!

(13) a. For every prize, x, there was some high school kid, y, such that y won x.

b. Some particular high school kid, y, won every prize, x.

a. $\boxed{\forall x[\text{prize}(x) \rightarrow \exists y[\text{high-school-kid}(y) \mathbin{\&} \text{win}(y, x)]\,]}$

b. $\exists y[\text{high-school-kid}(y) \mathbin{\&} \forall x[\text{prize}(x) \rightarrow \text{win}(y, x)]\,]$

Procedure concluded, rdg 2

5. Add each NP translation back *one at a time*, using the right sentential connective:

Procedure concluded, rdg 2

5. Add each NP translation back *one at a time*, using the right sentential connective:

5a. Move second NP back, using right connective ($\rightarrow$).

Moved out	Sentence
$\boxed{\exists x\ \text{high-school-kid}(x)}$	$\forall y\ \text{prize}(y) \rightarrow \text{win}(x,\ y)$

Procedure concluded, rdg 2

5. Add each NP translation back *one at a time*, using the right sentential connective:

5a. Move second NP back, using right connective ($\rightarrow$).

Moved out	Sentence
$\boxed{\exists x \text{ high-school-kid}(x)}$	$\forall y \text{ prize}(y) \rightarrow \text{win}(x, y)$

5b. Move first NP back, using right connective (&).

Moved out	Sentence
	$\exists x \text{ high-school-kid}(x) \ \& \ (\forall y \text{ prize}(y) \rightarrow \text{win}(x, y))$

Consequences

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What we did

We were able to capture the ambiguity by allowing the quantified NPs to recombine with the main sentence translation in either order.

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A new kind of ambiguity

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We were able to capture the ambiguity by allowing the quantified NPs to recombine with the main sentence translation in either order.

A new kind of ambiguity

1. Not lexical ambiguity

Consequences

What we did

We were able to capture the ambiguity by allowing the quantified NPs to recombine with the main sentence translation in either order.

A new kind of ambiguity

1. Not lexical ambiguity
2. Not syntactic ambiguity.

Consequences

What we did

We were able to capture the ambiguity by allowing the quantified NPs to recombine with the main sentence translation in either order.

A new kind of ambiguity

1. Not lexical ambiguity
2. Not syntactic ambiguity.
3. What is it?

Summary

Separating NP meanings from sentences

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- Unpassivize the sentence, if necessary.

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- Unpassivize the sentence, if necessary.
- Find all Qtfd NPs and choose variable for each.

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- Unpassivize the sentence, if necessary.
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- Remove Qtfd NPs, leaving behind their variables.

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- Unpassivize the sentence, if necessary.
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- Remove Qtfd NPs, leaving behind their variables.
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- Unpassivize the sentence, if necessary.
- Find all Qtfd NPs and choose variable for each.
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- Translate each NP into logic.
- Translate the main S into logic.

Summary

Separating NP meanings from sentences

- Unpassivize the sentence, if necessary.
- Find all Qtfd NPs and choose variable for each.
- Remove Qtfd NPs, leaving behind their variables.
- Translate each NP into logic.
- Translate the main S into logic.
- Move the NPs back. Putting the NPs back in different orders will capture different readings.

Outline

Relative clause

Replace pronouns with their antecedents.

(14) a. Maxine sent every letter John had written to her to Ruth.

Relative clause

Replace pronouns with their antecedents.

(15) a. Maxine sent every letter John had written to her to Ruth.

b. Maxine sent every letter John had written to Maxine to Ruth.

Relative clause

Replace pronouns with their antecedents.

(16) a. Maxine sent every letter John had written to her to Ruth.

b. Maxine sent every letter John had written to Maxine to Ruth.

1. Find each quantified NP, and choose a variable for it.

Relative clause

Replace pronouns with their antecedents.

(17) a. Maxine sent every letter John had written to her to Ruth.

b. Maxine sent every letter John had written to Maxine to Ruth.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

Maxine sent $\boxed{\text{every letter}_x \text{ John had written to Maxine}}$ to Ruth.

Relative clause

Replace pronouns with their antecedents.

(18) a. Maxine sent every letter John had written to her to Ruth.

b. Maxine sent every letter John had written to Maxine to Ruth.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

Maxine sent $\boxed{\text{every letter}_x \text{ John had written to Maxine}}$ to Ruth.

2. Move each quantified NP out of the sentence, leaving the variable you chose behind.

Relative clause

Replace pronouns with their antecedents.

(19) a. Maxine sent every letter John had written to her to Ruth.

b. Maxine sent every letter John had written to Maxine to Ruth.

1. Find each quantified NP, and choose a variable for it.

1. Find Quantified NPs

Maxine sent $\boxed{\text{every letter}_x \text{ John had written to Maxine}}$ to Ruth.

2. Move each quantified NP out of the sentence, leaving the variable you chose behind.

2. Remove Quantified NPs

Moved out	Sentence
$\boxed{\text{every letter }_x \text{ John had written to Maxine}}$	Maxine sent x to Ruth.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\forall\, x\ \text{letter}(x)\ \&\ \text{write}(\textsc{j},\ x,\ \textsc{m})}$	Maxine sent x to Ruth.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\boxed{\forall\, x\ \text{letter}(x)\ \&\ \text{write}(\textsc{j},\ x,\ \textsc{m})}$	Maxine sent x to Ruth.

4. Turn the sentence into logic, using predicate principles.

Continuing procedure

3. Translate each quantified NP into logic, replacing the head noun with a 1-place predicate whose argument is the NP variable:

3. NPs → logic

Moved out	Sentence
$\forall x$ letter(x) & write(J, x, M)	Maxine sent x to Ruth.

4. Turn the sentence into logic, using predicate principles.

4. Sentence → logic

Moved out	Sentence
$\forall x$ letter(x) & write(J, x, M)	send(M, x, R).

Procedure concluded

5. Add each NP translation back *one at a time*, using the right sentential connective:

Procedure concluded

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5. Move NP's back

Moved out	Sentence
	$\forall x\,(\mathrm{letter}(x)\ \&\ \mathrm{write}(\textsc{j},\ x,\ \textsc{m})) \rightarrow \mathrm{send}(\textsc{m},\ x,\ \textsc{r})$.

A complicated NP

Every letter$_x$ John had sent to Maxine

$\forall\, x\ \mathsf{letter}(x)\ \&\ \mathsf{write}(\mathrm{J},\ x,\ \mathrm{M})$

1. Recognize this Noun phrase contains a SENTENCE (relative clause).

every letter	[$_{\mathrm{S}}$ John	had sent	to Maxine]
	SUBJ	VERB	PP

A complicated NP

Every letter_x John had sent to Maxine
$\forall x\, \text{letter}(x)\ \&\ \text{write}(\textsc{j},\ x,\ \textsc{m})$

1. Recognize this Noun phrase contains a SENTENCE (relative clause).

every letter	$[_S$ John	had sent	to Maxine]
	SUBJ	VERB	PP

That sentence says something about x

?	John had sent to Maxine.
every letter x	[John had sent x to Maxine]
	$\text{send}(\textsc{j},\ x, \textsc{m})$

A complicated NP

Every letter$_x$ John had sent to Maxine

$\forall\, x\ \text{letter}(x)\ \&\ \text{write}(\textsc{j},\ x,\ \textsc{m})$

1. Recognize this Noun phrase contains a SENTENCE (relative clause).

every letter	$[_{\text{S}}$ John	had sent	to Maxine]
	SUBJ	VERB	PP

That sentence says something about x

?	John had sent to Maxine.
every letter x	[John had sent x to Maxine]
	$\text{send}(\textsc{j},\ x, \textsc{m})$

2. Find where x goes, and translate the sentence on its own; add the translation to the translation of the NP:

$$\forall x\ \text{letter}(x)\ \&\ \text{send}(\textsc{j},\ x, \textsc{m})$$

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Separating NP meanings from sentences

- Unpassivize the sentence, if necessary.
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- Translate each NP into logic, making sure you understand how each modifier relates to the NP variable.

Summary

Separating NP meanings from sentences

- Unpassivize the sentence, if necessary.
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Summary

Separating NP meanings from sentences

- Unpassivize the sentence, if necessary.
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- Find all Qtfd NPs and choose variable for each.
- Remove Qtfd NPs, leaving behind their variables.
- Translate each NP into logic, making sure you understand how each modifier relates to the NP variable.
- Translate the main S into logic.
- Move the NPs back. Putting the NPs back in different orders will capture different readings.

Translations discussed

(20) a. A young woman arrived.
b. Utopia welcomes every traveler from Spain.
c. Every prize was won by some high school student.
d. Maxine sent every letter John had written to her to Ruth.

Other translations

1. No spider plants dance.

Other translations

1. No spider plants dance.

$$\sim \exists x \; \text{spider-plant}(x) \;\&\; \text{dance}(x)$$

2. There is a Santa Claus. [Paraphrase this as *A Santa Claus exists*]

Other translations

1. No spider plants dance.

$$\sim \exists x \text{ spider-plant}(x) \ \& \ \text{dance}(x)$$

2. There is a Santa Claus. [Paraphrase this as *A Santa Claus exists*]

$$\exists x \text{ Santa Claus}(x) \ \& \ \text{exists}(x)$$

3. There's no business like show business. [Treat *show business* as a name; treat *there is* as before, paraphrase: *No business like show business exists*, treat *like* as a preposition]

Other translations

1. No spider plants dance.

   $$\sim \exists x \text{ spider-plant}(x) \;\&\; \text{dance}(x)$$

2. There is a Santa Claus. [Paraphrase this as *A Santa Claus exists*]

   $$\exists x \text{ Santa Claus}(x) \;\&\; \text{exists}(x)$$

3. There's no business like show business. [Treat *show business* as a name; treat *there is* as before, paraphrase: *No business like show business exists*, treat *like* as a preposition]

   $$\sim \exists \text{ business}(x) \;\&\; \text{like}(x, \textsc{sb}) \;\&\; \text{exists}(x)$$

Other translations: Conjunction

Conjunction can often be treated by producing a paraphrase with two conjoined sentences:

4. Grammar A generates all and only well-formed formula. [paraphase this as *Grammar A generates all well-formed formula and Grammar A generates only well-formed formula.*; translate each conjoined sentence on its own.]