Introduction to compositional semantics

Lesson 1: Language as a meaning machine

Wenkai Tay

UCL Linguistics Autumn
School 2023

17 Oct 2023

taywenkai.com

Outline

Language as a meaning machine

Agnetha smiled. $\rightarrow$ 

Language as a meaning machine

Agnetha smiled. → 

(Who is Agnetha?)

Machines in the real world

argument function value

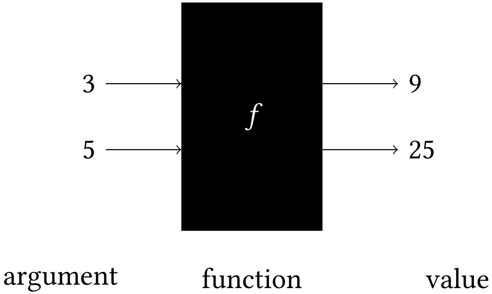
Machines in the language of λ-functions

$x \longrightarrow$

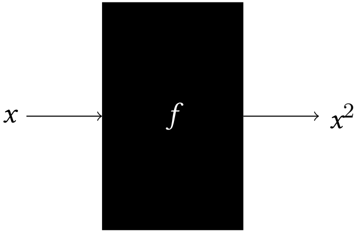
$\longrightarrow \text{Juice}(x)$

$$\rightsquigarrow \lambda x.[\text{Juice}(x)]$$

Functions in mathematics

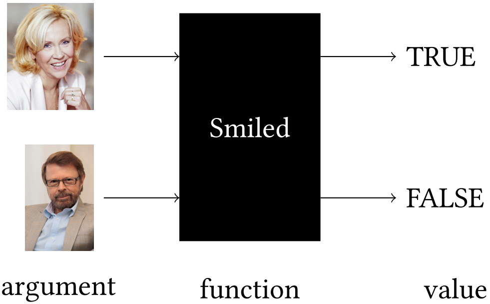


Mathematical functions in the language of λ-functions

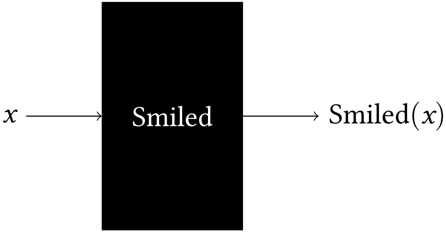


$$\rightsquigarrow \lambda x.x^2$$

Predicates in natural language



Predicates in the language of λ-functions



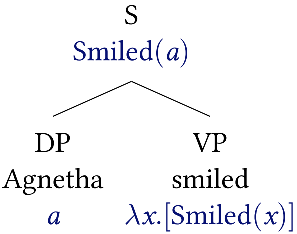
$$\rightsquigarrow \lambda x.[\text{Smiled}(x)]$$

Compositionality

The meaning of a sentence is built from the meaning of its parts.

Compositionality

Agnetha smiled.



Compositionality

The meaning of a sentence is built from the meaning of its parts.

Compositionality

The meaning of a sentence is built from the meaning of its parts.

But what is "meaning"?

Semantic denotation

Semantic denotation (or semantic value):
the “interpretation” of an expression in the “real world”

Semantic denotation

Semantic denotation (or semantic value):
the “interpretation” of an expression in the “real world”

Represented by ⟦ ⟧

Semantic denotation

$[\![a]\!] =$ 

Semantic denotation

$$[\![a]\!] =$$ 

$$[\![\text{Smiled}(a)]\!] = \text{TRUE}$$

Semantic denotation

$$
\begin{aligned}
[\![\text{Smiled}]\!] &= [\![\lambda x.[\text{Smiled}(x)]]\!] \\
&= \begin{cases} \text{TRUE for all entities that smiled} \\ \text{FALSE for all entities that did not smile} \end{cases}
\end{aligned}
$$

$= \{<$  $,\text{TRUE} > ,<$  $,\text{FALSE} > , \ldots \}$

Isomorphism between syntax and semantics

Agnetha smiled.

S
$\text{Smiled}(a)$

DP | VP
Agnetha | smiled
a | $\lambda x.[\text{Smiled}(x)]$

$\rightarrow$

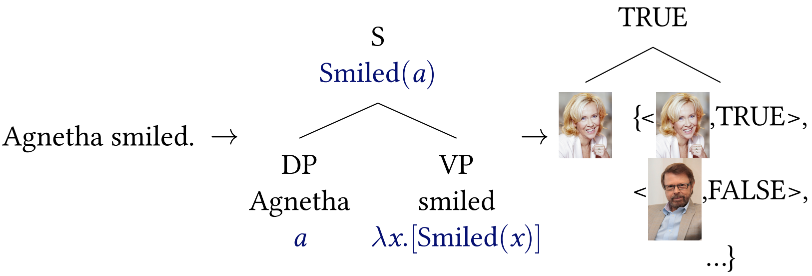
TRUE

{<,TRUE>,

<,FALSE>,

...}

Lambda calculus is a bridge



Aim of this module

- To learn how to translate natural language expressions into expressions in lambda calculus.

  (cf. English $\to$ French)

Composition rules

1. Function Application
2. Predicate Modification
3. Lambda Abstraction

Schedule

1. Session 1: Language as a meaning machine (Function Application)
2. Session 2: Combining multiple machines (Predicate Modification)
3. Session 3: Creating a homemade machine (Lambda Abstraction)
4. Sessions 4 & 5: Feeding machines into machines

Suggested reading

1. Main reading: Coppock and Champollion (2022)
2. Supplementary reading: Heim and Kratzer (1998)

Important notes

- I will omit very important technical details in order to develop your intuition. Refer to suggested reading for details.
- I want to encourage you to participate fully while you are in class.
  - I will not provide any model answers outside of class.
- Therefore, if you have any questions about the material presented here, ask them in class!

Outline

How to make orange juice

1. Put the orange in the machine.
2. Switch the machine on.

Step 1: put orange in machine

→

orange

machine

Step 1: put orange in machine

()

machine(orange)

Step 1: put orange in machine

()

$$[\lambda x.[\text{Juice}(x)]](\text{orange})$$

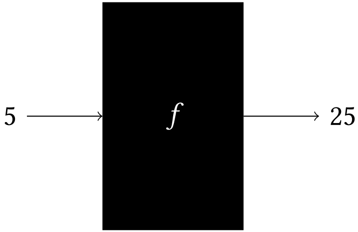
Step 2: switch the machine on

() = 

$$[\lambda x.[\text{Juice}(x)]](\text{orange}) = \text{Juice}(\text{orange})$$

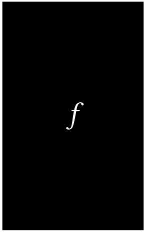
Replace all instances of x in the output with orange.

Function Application



$$\lambda x.x^2$$

Function Application: step 1



(5)

$$[\lambda x.x^2](5)$$

Function Application: step 2

$$\boxed{f}\,(5) = 25$$

$$[\lambda x.x^2](5) = 5^2$$

Replace all instances of x in the output with 5.

Function Application

 → Smiled → TRUE

a $\lambda x.[\text{Smiled}(x)]$

Function Application: step 1

Smiled ()

$$[\lambda x.[\text{Smiled}(x)]](a)$$

Function Application: step 2

Smiled

() = TRUE

$$[\lambda x.[\text{Smiled}(x)]](a) = \text{Smiled}(a)$$

Replace all instances of x in the output with a.

Putting inputs into machines

[λ-function](argument)

⟶

⟶

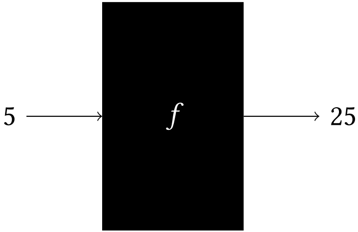
orange

$\lambda x.[\text{Juice}(x)]$

$[\lambda x.[\text{Juice}(x)]](\text{orange})$
$=\text{Juice}(\text{orange})$

Putting inputs into mathematical functions

[λ-function](argument)



$\lambda x.x^2$

$[\lambda x.x^2](5)$
$=5^2$

Putting inputs into predicates

[λ-function](argument)

$\longrightarrow$ Smiled $\longrightarrow$ TRUE

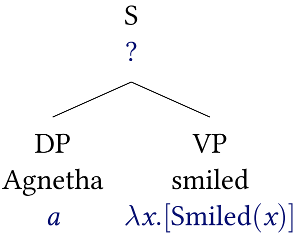
a $\quad$ $\lambda x.[\text{Smiled}(x)]$ $\quad$ $[\lambda x.[\text{Smiled}(x)]](a)$

$= \text{Smiled}(a)$

Composition rule 1: Function Application

Example: Intransitive verbs

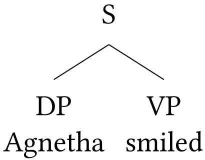
Agnetha smiled.



Composition rule 1: Function Application

Step 1: Draw a syntactic tree.

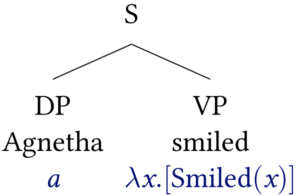
Agnetha smiled.



Composition rule 1: Function Application

Step 2: Give the translations for the terminal nodes.

Agnetha smiled.

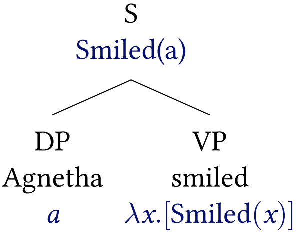


$$\textit{Agnetha} \rightsquigarrow a$$
$$\textit{smiled} \rightsquigarrow \lambda x.[\text{Smiled}(x)]$$

Composition rule 1: Function Application

Step 3: Give the translations for the remaining nodes by applying Function Application.

Agnetha smiled.



$$\text{S} \rightsquigarrow [\lambda x.[\text{Smiled}(x)]](a) \qquad (FA)$$
$$= \text{Smiled}(a)$$

Activity 1: Predicate nouns

Give the derivation of the following sentence:

(1) Agnetha is a singer.

1. Draw a syntactic tree.
2. Give the translations for the terminal nodes.
   (Assume that *is* and *a* have "no meaning".)
3. Give the translations for the remaining nodes by applying Function Application.

Activity 2: Predicate adjectives

Give the derivation of the following sentence:

(2) Björn is kind.

1. Draw a syntactic tree.
2. Give the translations for the terminal nodes. (Assume that *is* has "no meaning".)
3. Give the translations for the remaining nodes by applying Function Application.

Feedback

Please give me feedback on this session so far.

Activity 3: Transitive verbs

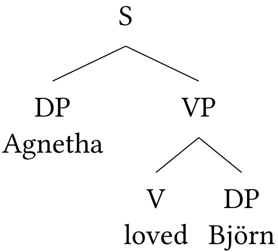
Give the derivation of the following sentence:

(3) Agnetha loved Björn.

1. Draw a syntactic tree.
2. Give the translations for the terminal nodes *Agnetha* and *Björn*.
3. Give the translation for the top node.
4. Give the translations for the remaining nodes. What is the translation of *loved*?

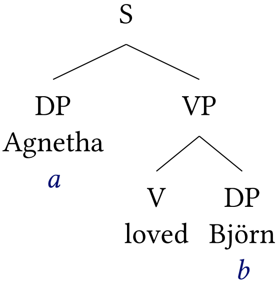
Activity 3: Transitive verbs

Agnetha loved Björn.



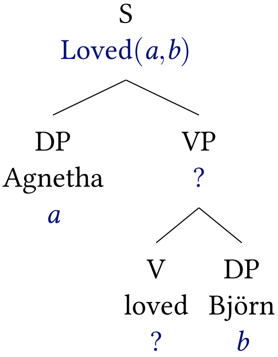
Activity 3: Transitive verbs

Agnetha loved Björn.



Activity 3: Transitive verbs

Agnetha loved Björn.



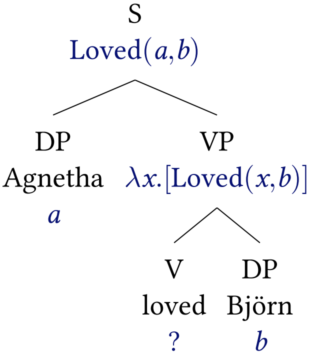
Activity 3: Transitive verbs

$a \longrightarrow$  $\longrightarrow \text{Loved}(a, b)$

$$\rightsquigarrow \lambda x.[\text{Loved}(x, b)]$$

Activity 3: Transitive verbs

Agnetha loved Björn.



Activity 3: Transitive verbs

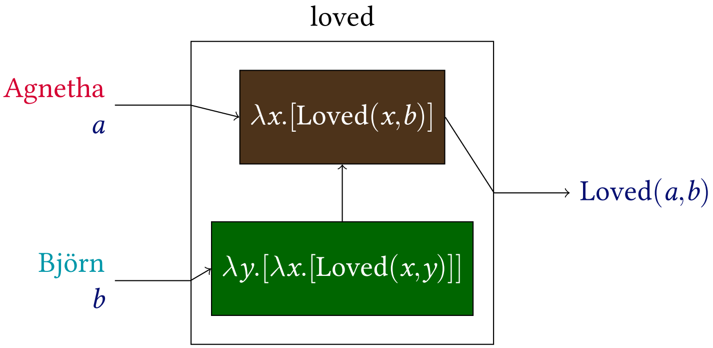
$b \longrightarrow$ 

$\longrightarrow \lambda x.[\text{Loved}(x, b)]$

$\rightsquigarrow \lambda y.[\lambda x.[\text{Loved}(x, y)]]$

Activity 3: Transitive verbs

Agnetha loved Björn.



Activity 4: Prepositions

Give the derivation of the following sentence:

(4) Frida is with Benny.

(Assume that *is* and *of* have "no meaning".)

Activity 5: Two-place adjectives

Give the derivation of the following sentence:

(5) Benny is proud of Frida.

(Assume that *is* and *of* have "no meaning".)

Summary

- Compositionality
- Composition Rule 1: Function Application

References I

Coppock, Elizabeth, and Lucas Champollion. 2022. *Invitation to formal semantics.* Ms. https://eecoppock.info/bootcamp/semantics-boot-camp.pdf.

Heim, Irene, and Angelika Kratzer. 1998. *Semantics in generative grammar*. Malden, MA: Blackwell.

Image credits

- Agnetha Fältskog: Stockholm Pride, CC BY 3.0
- Björn Ulvaeus: Västerviks kommun from Västervik, Sweden, CC BY 2.0
- apple: Abhijit Tembhekar from Mumbai, India, CC BY 2.0
- apple juice: City Foodsters, CC BY 2.0
- orange: Camera Eye Photography from Oshawa, Canada, CC BY 2.0
- orange juice: Geoff Peters from Vancouver, BC, Canada, CC BY 2.0
- juicer: Breville USA, CC BY 2.0

via Wikimedia Commons