Bringing machine learning & compositional semantics together: central concepts

https://github.com/cgpotts/annualreview-complearning

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CS 244U: Natural language understanding

Linguistic objects

$$\langle u, t, r, d \rangle$$

- u: the utterance (sequence of strings/words)
- t: the syntactic structure (tree structure)
- r: the semantic representation (a.k.a. logical form)
- d: the denotation (meaning)

Interpreted grammar

Syntax	Logical form	Denotation
$\text{N} \to \text{one}$	1	1
$\text{N} \to \text{two}$	2	2
$\vdots$	$\vdots$	$\vdots$
$\text{R} \to \text{plus}$	$+$	the R such that $R(x, y) = x + y$
$\text{R} \to \text{minus}$	$-$	the R such that $R(x, y) = x - y$
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$\text{S} \to \text{minus}$	$\neg$	the f such that $f(x) = -x$
$\text{N} \to \text{S N}$	$\ulcorner \text{S} \urcorner \ulcorner \text{N} \urcorner$	$[\![\ulcorner \text{S} \urcorner]\!]([\![\ulcorner \text{N} \urcorner]\!])$
$\text{N} \to \text{N}_L \text{ R N}_R$	$(\ulcorner \text{R} \urcorner \ulcorner \text{N}_L \urcorner \ulcorner \text{N}_R \urcorner)$	$[\![\ulcorner \text{R} \urcorner]\!]([\![\ulcorner \text{N}_L \urcorner]\!], [\![\ulcorner \text{N}_R \urcorner]\!])$

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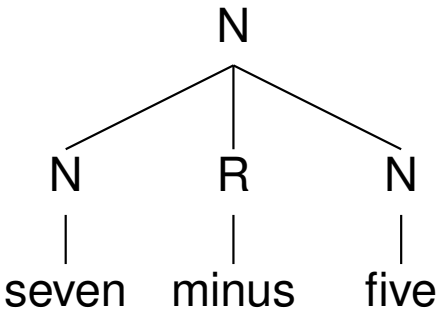
N → S N	$\ulcorner S \urcorner \ulcorner N \urcorner$	$[\![\ulcorner S \urcorner]\!]([\![\ulcorner N \urcorner]\!])$
N → N_L R N_R	$(\ulcorner R \urcorner \ulcorner N_L \urcorner \ulcorner N_R \urcorner)$	$[\![\ulcorner R \urcorner]\!]([\![\ulcorner N_L \urcorner]\!], [\![\ulcorner N_R \urcorner]\!])$

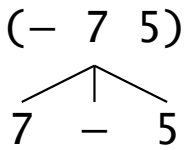
- $\ulcorner u \urcorner$ is the translation of syntactic expression u
- $[\![r]\!]$ is the denotation of semantic representation r

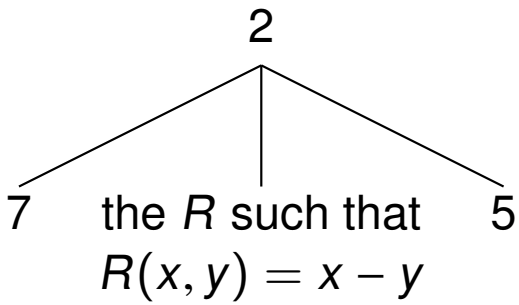
Examples

Utterance	Logical form	Denotation
A. seven minus five	(− 7 5)	2
B. minus three plus one	(+ ¬3 1)	−2
C. two minus two times two	(× (− 2 2) 2)	0
D. two plus three plus four	(+ 2 (+ 3 4))	9

Examples







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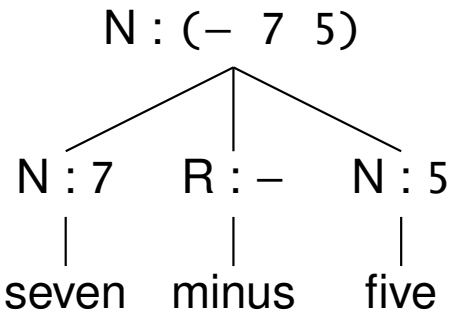

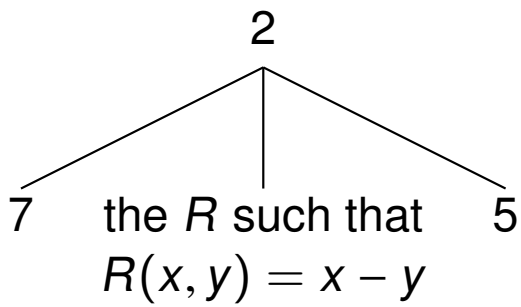

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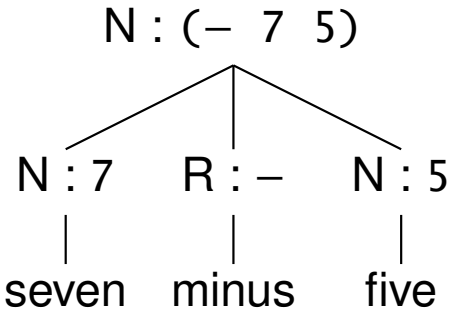
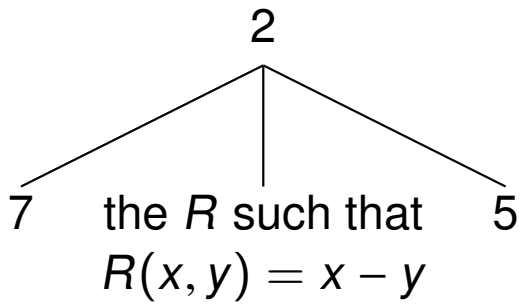
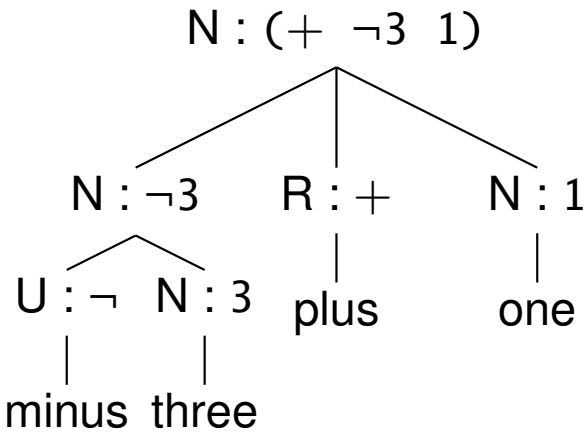
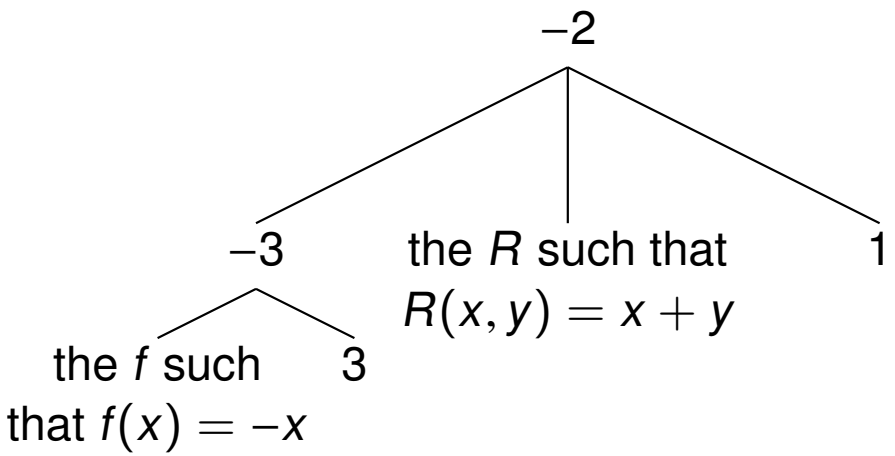

N : (− 7 5)
N : 7
R : −
N : 5
seven
minus
five

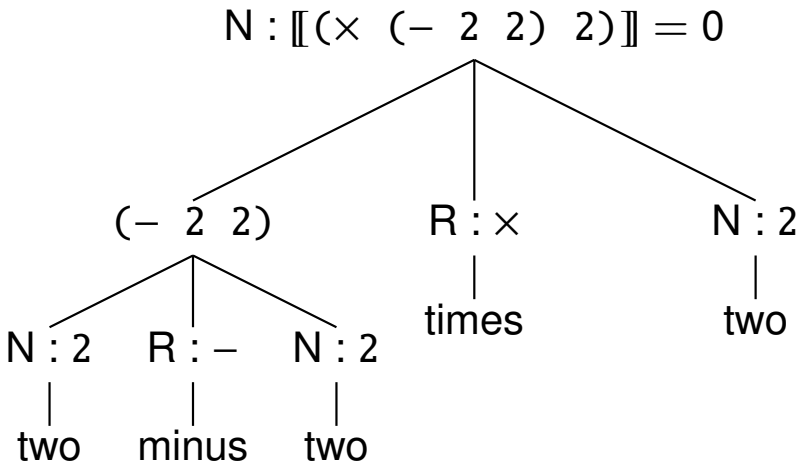

2
7
the R such that
R(x, y) = x − y
5

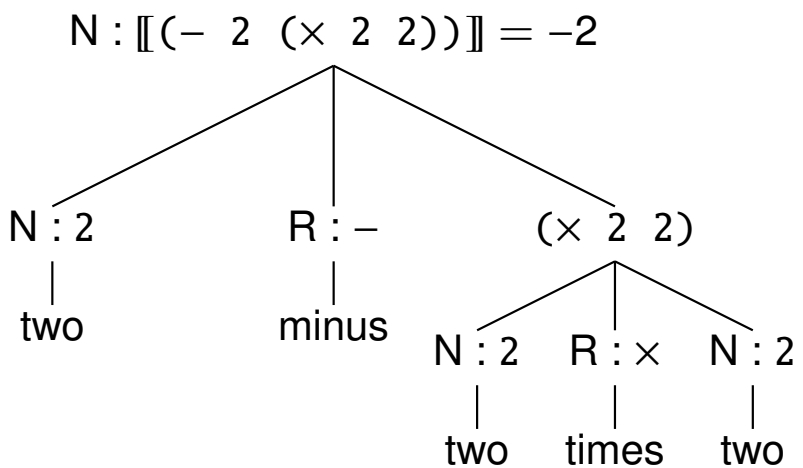

N : (+ ¬3 1)
N : ¬3
R : +
N : 1
U : ¬
N : 3
plus
one
minus
three


−2
−3
the R such that
R(x, y) = x + y
1
the f such
that f(x) = −x
3

Ambiguity

GEN(*two minus two times two*) =





Analogies with full natural language

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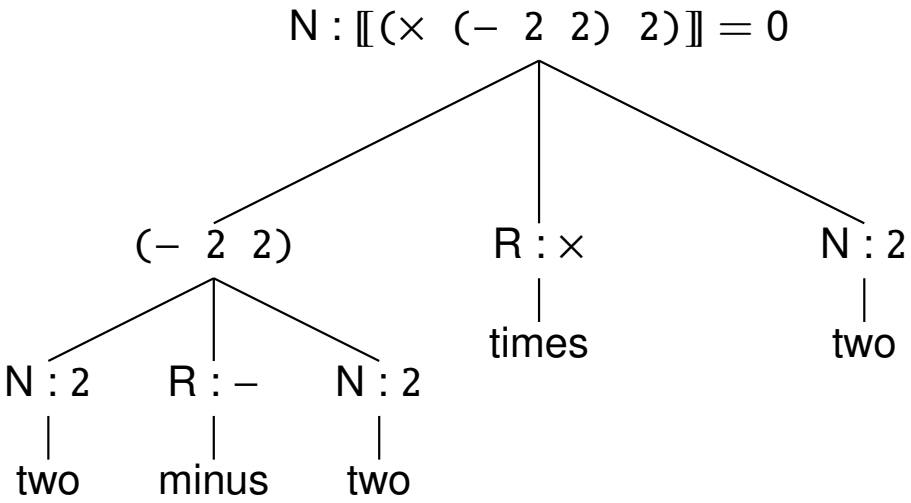

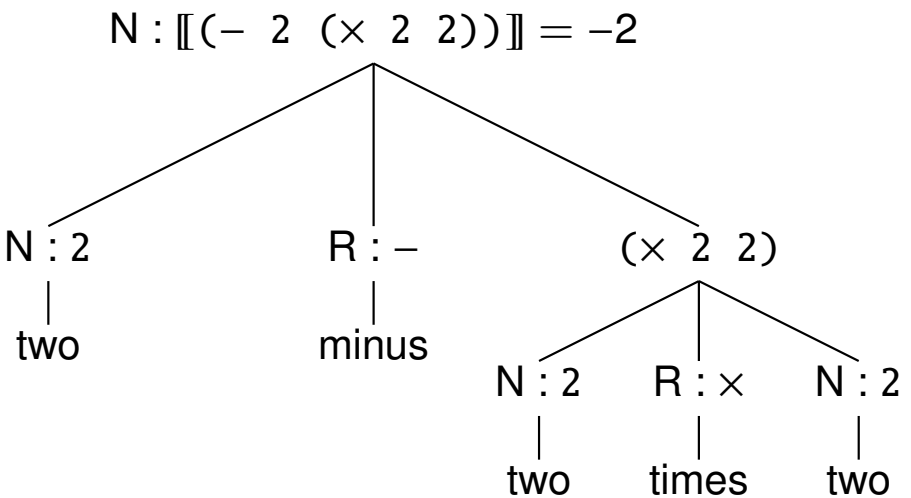

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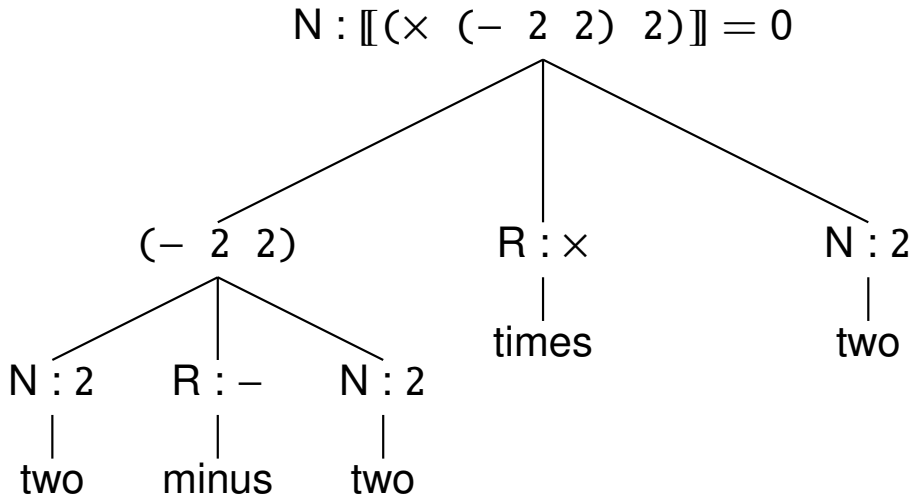

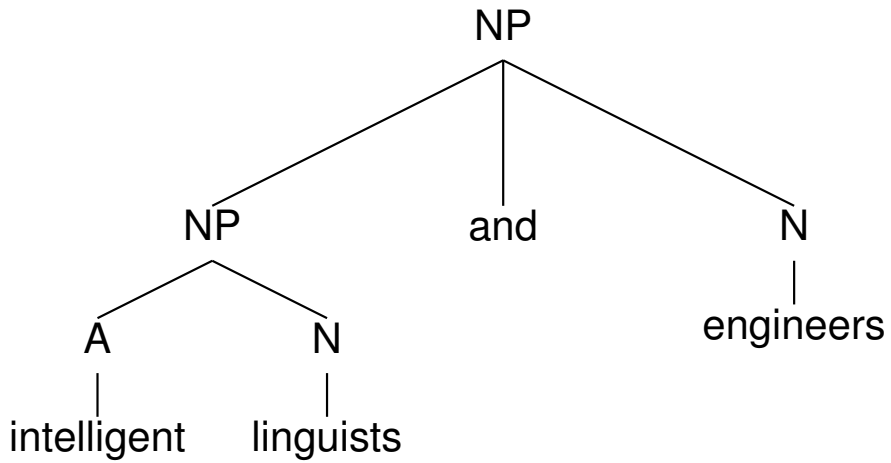

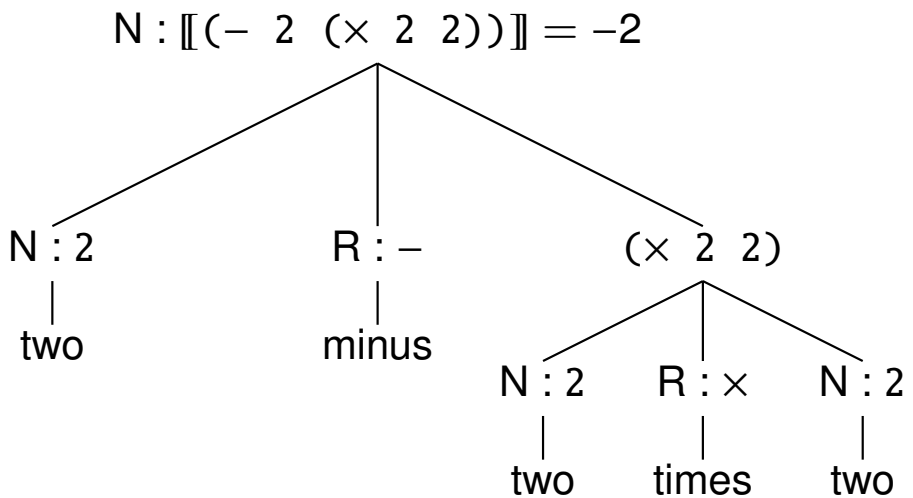

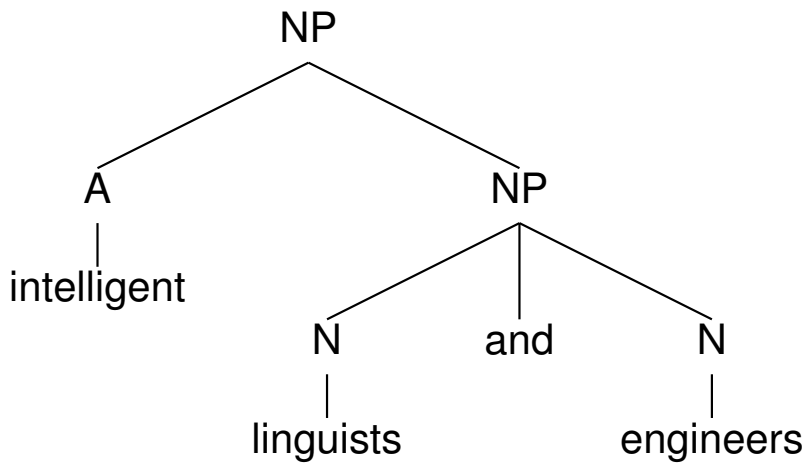

Analogies with full natural language

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S $\rightarrow$ minus	$\neg$	the f such that $f(x) = -x$

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R → minus	$-$	the R such that $R(x, y) = x - y$
S → minus	$\neg$	the f such that $f(x) = -x$

- tell (*a tell*; *tell the time*; *tell the distance to shore*)
- crane (as in ‘a bird’; as in ‘a piece of equipment’)
- mean (as in ‘average’; as in ‘unpleasant’; as in ‘excellent’)

⋮

Analogies with full natural language

- *every* $\sum$
- *tallest* $\arg\max$

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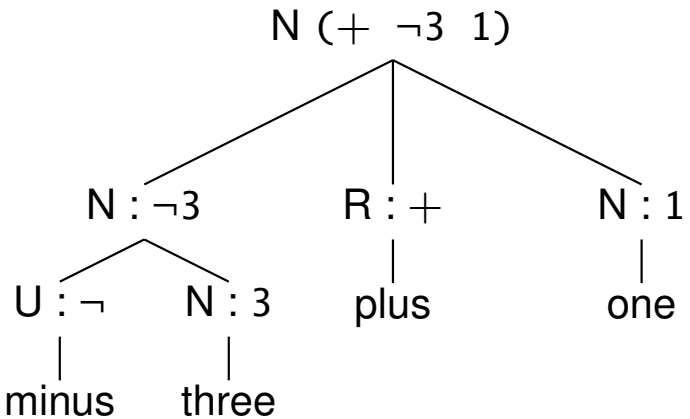

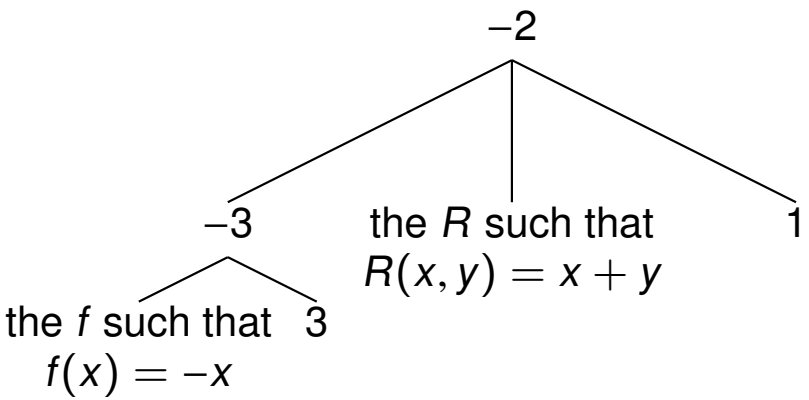

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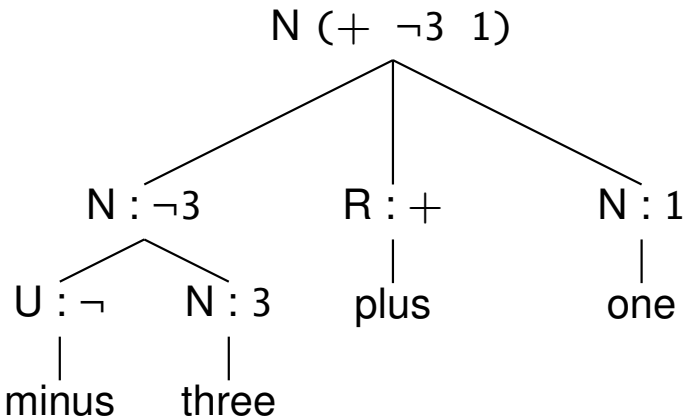

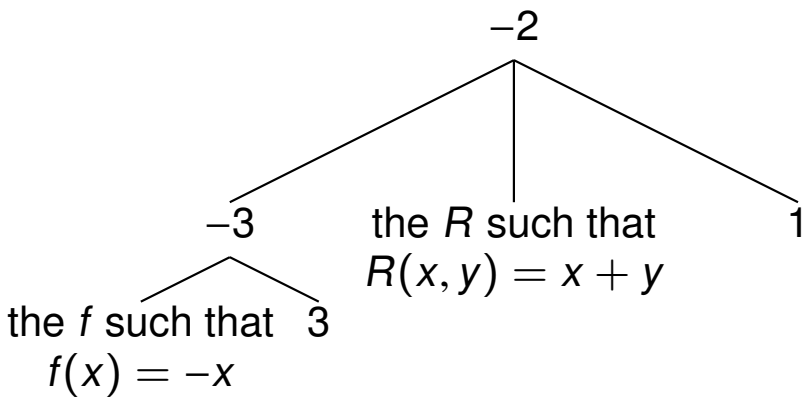

Bringing machine learning and compositional semantics together

"the claim of compositionality is that being a semantic interpreter for a language L amounts to mastering the syntax of L, the lexical meanings of L, and the modes of semantic combination for L. This also suggests the outlines of a learning task."

Learning tasks

The grammar frames the task; different parts of it can be learned.

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