IA165
Combinatory Logic for Computational Semantics

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Application of the combinators to natural language analysis: basic

example of the formal semantic analysis

some structures: cooridination

Summing up: last lecture

- How to apply the combinators to natural language analysis

  1) using introduction and elimination rules by beta-reduction of combinators: control heurstic of combinatorial application and bracketing

  2) using a syntactic tool for controlling the application of combinators

  : CCG assumes the preliminary steps to find a well-structured normal form, that is, a formal semantic structure

Example: use the combinators as a logical tool of semantic analysis

a. apply directly the β *-reduction* rules of combinators

b. use the CCG types and rules by integrating the β *-reduction* rules of combinators into the CCG rules

Remind 1....METHOD

- <u>Goal:</u> Formal semantic structure in term of operator and of operand

  : bracketed expression written by convention: (operator(operand))

- Two methods of application of the combinators: both can be useful

  a. useful for defining some specific operators: passivisation, reflexivisation, quantification..

  b. useful for general formal semantic analysis; can handle the analysis at the syntactic level and semantic level in one representation; informatic implementation more systemactic → see the nexe slides "Remind 2 & 3"

Remind 2... TYPES

- **CCG types**

  primitive types: S for sentence, NP for noun phrase, N for noun

  derived types: S/NP, N/N, N\N, (S/NP)/NP, NP/N...

- **Directionality: / (over) and \ (under)**

  a/b: a applies to b, a\b: b is applied to a

  → direction of application of operator to operand

Remind 3...RULES

1. Forward(>) and backward (<) functional application rules

```
x/y:e1    y:e2
--------------->(>)
 x:(e1(e2))
```

```
(S\NP)/NP:loves   NP:Anna
--------------------------> (>)
(S\NP):(loves (Anna))
```

2. Function composition (FC) rules with the combinator B

e1: (x/y) e2:(y/z)

*-------------------->(>**B**)*

*(x/z): **B** e1 e2*

```
(S\NP)/NP:likes  (NP/N):a
-----------------------> (>B)
(S\NP)/N: (B likes a)
```

3. Type-raising rules with the combinator C*

e1:x

---------------> (>**C***)

*S/(S\x): **C*x***

For NP subj

```
e1:John
--------> (>C*)
S/(S\NP):C*John
```

Some preliminary exercises to introduce the combinators:

Finding a ccg type adequate to the given lexique

Adverbs

Adverb of verb

(S\NP)/(S\NP)
(S\NP)/NP/
(S\NP)/NP

Adverb of adverb

(S\NP)/(S\NP)/(S\NP)/(S\NP)
(S\NP)/NP/(S\NP)/NP/(S\NP)/NP/
(S\NP)/NP

Adverb of adjective

(N/N)/(N/N)
(N\N)/(N\N)

Adverb of proposition

S/S

Preposition

Prep. 1:
constructor of adverbial phrase

(S\NP)\(S\NP)/NP
(S/S)/NP
(S/S)/N

Prep. 2:
constructor of adjectival phrase

(N\N)/NP
(N\N)/N

Example: Dictionary of typed words

Syntactic categories	Syntactic types	Lexical entries
Nom.	N	*Olivia, apple...*
Completed nom.	NP	*an apple, the school*
Pron.	NP	*She, he...*
Adj.	(N/N), (N\N)	***pretty** woman,...*
Adv.	(N/N)/(N/N), (S\NP)\(S\NP)...	***very** delicious,...*
Vb	(S\NP), (S\NP)/NP...	*run, give...*
Prep.	(S\NP)\(S\NP)/NP (NP\NP)/NP...	*run **in** the park,* *book **of** John,...*
Relative	(S\NP)/S...	*I believe that...*

Some structures of natural language: coordination

- *Cecila picks the pear.*
- *Cecilia eats the pear.*
- *Cecilia picks and eats the pear.*

- Any logical form of this kind must of course express that the arguments appear in two predications.

```
((and (picks (the pears)) (eats (the pears))) Cecilia)
```

Coordination (Φ)

X CONJ X $\Rightarrow_{\Phi}$ X (Coordination Φ)

```
x:e1   CONJ   x:e2
------------------> (>Φ)
x: Φ CONJ e1 e2
```

e1 of type x coordinated with *e2* of type x by the conjonction '*and*'

```
(S\NP)/NP:pick    CONJ:'and'    (S\NP)/NP:eat
          ----------------------------------> (>Φ)
             (S\NP)/NP: Φ and pick eat
```

Follow the next steps.

(1) Attribute first the CCG types to each linguistic expression

(2) calculate theses types to obtain the syntactic analysis by applying the CCG rules.

(3) eliminate the applied combinators with respect to each b-reduction of combinators

(4) check if your semantic representation is well-structured normal form.

- Example : *Cecilia picks and eats the pear.*

1/[NP:Cecilia]-[(S\NP)/NP: picks]-[CONJ:and]-[(S\NP)/NP: eats]-[NP: the pear]

2/[(S/(S\NP):**C***Cecilia]-[(S\NP)/NP: picks]-[CONJ:and]-[(S\NP)/NP: eats]-[NP: the pear] (>**C***)

3/[(S/(S\NP):**C***Cecilia]-[(S\NP)/NP: Φ and picks eats]-[NP: the pear] (>**Φ**)

4/[(S/(S\NP):**C***Cecilia]-[(S\NP)/NP: Φ and picks eats]-[NP: the pear] (>**B**)

5/[(S/NP:**B**(**C***Cecilia) (Φ and picks eats)]-[NP: the pear] (>**B**)

6/[(S:(**B**(**C***Cecilia) (Φ and picks eats))(the pear)] (>)

7/(**B**(**C***Cecilia) (Φ and picks eats))(the pear)

8/(**C***Cecilia) ((Φ and picks eats))(the pear)) (elimination of **B**)

9/((Φ and picks eats))(the pear))(Cecilia) (elimination of **C***)

10/((and **(**picks**(**the pear**)**) (eats**(the pear)**))(Cecilia)) (elimination of Φ)

- We get the well-formed semantic structure of the sentence *Cecila picks and eats the pear.*
-
- ((and **(**picks**(**the pear**)**) (eats**(the pear)**))(Cecilia))

Next week...

- Continue about the application of the combinators to natural language analysis: extraction asymmetries, subordinative structure and relative