Classwork N°11
due to 11th May 2012

Exercise: "Application of combinators to natural language analysis: Quantification"

1. Universal and existential quantifiers

Please represent the following sentences using the operators of the universal or existential quantification. Are there ambiguous sentences having more than one reading?

a) All cats are mammals. → *Universal quantification*

Answer:

a) (∀x)[cats' (x) =>are-mammals'(x)]
b) (λP.λQ((∀x)[P(x) => Q(x)])(cats)(are-mammals'))

b) Some cats were sleeping by the fire. → *Existential quantification*

a) (∃x)[cat'(x) & were-slepping'(x)]
b) (λP.λQ((∃x)[P(x) & Q(x)])(cat)(were-slepping'))

c) Some chairs are in the lounge. → *Existential quantification*

a) (∃x)[chairs'(x) & are-in the lounge'(x)]
b) (λP.λQ((∃x)[P(x) & Q(x)])(chairs)(are-in the lounge'))

d) Every man loves a woman. → *Universal and Existential quantification*

Answer: It has two readings.

1. There is one woman who is loved by every man.
2. For each man there is one woman whom he loves.

2.

a) ∀x [man (x) → ∃y [woman (y) & loves (x,y)]]

1.

a) $\exists$ y [woman (y) & $\forall$x [man (x) $\rightarrow$ loves (x,y)]]

e) A boy kissed every girl. → *Universal and Existential quantification*

<u>Answer:</u> It has two readings.

1. There is one individual boy who kissed each girl (in a particular domain).
On this analysis, the existential phrase (a boy) takes score over the universal quantifier (every girl).
2. There are as many boys as there are girls. For every girl, there is at least one boy who kissed her.
On this analysis, the universal quantifier (every girl) takes score over the existential (a boy).

1. a) $\exists$ x [boy (x) & $\forall$y [girl (y) $\rightarrow$ kissed (x,y)]]

2. a) $\forall$y [girl (y) $\rightarrow$ $\exists$x [boy (x) & kissed (x,y)]]

2. Formal semantic analysis of the quantifiers

Give the analysis of the following sentences which contain the quantifiers using the combinators. The illative quantifiers Π_2 and Σ_2 are defined in term of the combinators.

[$\Pi_2 =_{def} ((B(CB^2)\Phi) \Rightarrow \Pi_1)$]   [$\Sigma_2 =_{def} (B(CB^2)\Phi) \,\&\, \Sigma_1$]

f) Some girl likes Fred

1/ (some(girl))(like-Fred)
2/(Σ_2(girl))(like-Fred)
3/ ((B(CB^2)Φ) & Σ_1(girl)) (like-Fred)
4/ ((CB^2) (Φ &) Σ_1(girl)) (like-Fred)
5/ (B^2 Σ_1 (Φ &) (girl)) (like-Fred)

6/ Σ_1 ((Φ &) (girl) (like-Fred))
7/ ((Φ &) (girl) (like-Fred)) x
8/ & (girl(x)) ((like-Fred) x)

g) Every boy admires a saxophonist (ambiguous)

<u>Answer:</u> It has two readings

1. There is one saxophonist who is admired by every boy.

$\exists$ y [saxophonist (y) & $\forall$x [boy (x) $\rightarrow$ admires (x,y)]]

1/(a saxophonist) (is-admired-by every boy)
2/ Σ_2 saxophonist (is-admired-by every boy)
3/ ((B(CB^2)Φ) & Σ_2) saxophonist (is-admired-by every boy)
4/ (CB^2)(Φ &) Σ_2 saxophonist (is-admired-by every boy)
5/ B^2 Σ_2 (Φ &) saxophonist (is-admired-by every boy)
6/ Σ_2((Φ &) saxophonist (is-admired-by every boy))
7/ ((Φ &) saxophonist (is-admired-by every boy)) x
8/ & (saxophonist *x*) ((is-admired-by every boy) *x*)

2. For each boy there is one saxophonist whom he admires.

$\forall$x [boy (x) $\rightarrow$ $\exists$y [saxophonist (y) & admires (x,y)]]

1/(every boy) (admires a Saxophonist)
2/ Π_2 boy (admires a Saxophonist)
3/ ((B(CB^2)Φ) => Π_1) boy (admires a Saxophonist)
4/ (CB^2)(Φ =>) Π_1 boy (admires a Saxophonist)
5/ B^2 Π_1 (Φ =>) boy (admires a Saxophonist)
6/ Π_1 ((Φ =>) boy (admires a Saxophonist))
7/ ((Φ =>) boy (admires a Saxophonist)) x
8/ => (boy *x*) ((admires a Saxophonist) *x*)

h) Every man knows Dexter

1/(every man) (knows Dexter)

2/ Π_2 man (knows Dexter)

3/ $((B(CB^2)\Phi) \Rightarrow \Pi_1)$ man (knows Dexter)

4/ $(CB^2)(\Phi \Rightarrow) \Pi_1$ man (knows Dexter)

5/ $B^2 \quad \Pi_1 (\Phi \Rightarrow)$ man (knows Dexter)

6/ $\Pi_1 ((\Phi \Rightarrow)$ man (knows Dexter))

7/ $((\Phi \Rightarrow)$ man (knows Dexter)) x

8/ => (man x) ((knows Dexter) x)

i) Several girls carried a box

Answer: It has two readings

1. There is one box who is carried by several girls → A box was carried by several girls

$\exists$ y [box (y) & $\exists$x [girls (x) & carries (x,y)]]

1/(a box) (was-carried-by several girls)

2/ Σ_2 box (was-carried-by several girls)

3/ $((B(CB^2)\Phi)$ & $\Sigma_2)$ box (was-carried-by several girls)

4/ $(CB^2)(\Phi$ &) Σ_2 box (was-carried-by several girls)

5/ $B^2 \quad \Sigma_2 (\Phi$ &) box (was-carried-by several girls)

6/ $\Sigma_2 ((\Phi$ &) box (was-carried-by several girls)

7/ $((\Phi$ &) box (was-carried-by several girls) x

8/ & (box x) ((was-carried-by several girls) x)

2. For several girls, there is one box which they carries

$\exists$x [girls (x) & $\exists$y [box (y) & carries (x,y)]]

1/(several girls) (carried-a-box)

2/ Σ_2 girls (carried-a-box)

3/ $((B(CB^2)\Phi)$ & $\Sigma_2)$ girls (carried-a-box)

4/ $(CB^2)(\Phi$ &) Σ_2 girls (carried-a-box)

5/ $B^2 \quad \Sigma_2 (\Phi$ &) girls (carried-a-box)

6/ $\Sigma_2 ((\Phi$ &) girls (carried-a-box)

7/ ((Φ &) girls (carried-a-box) x

8/ & (girls *x*) ((carried-a-box) *x*)