ANLP Tutorial Exercise Set 5 (for tutorial groups in week 10)

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Exercise 1: First-order logic

a) Consider the following "world" (knowledge base):

cat(Zoot)	*owns(Mary, Zoot)*	*walks(Spot)*
cat(Whiskers)	*owns(Mary, Spot)*	*walks(Whiskers)*
dog(Spot)	*owns(Li, Whiskers)*	*walks(Mary, Zoot)*
brown(Spot)		*walks(Li, Spot)*
brown(Zoot)		

Give the denotation of each of the following FOL expressions with respect to this world.

(a) *owns(Li, Zoot)*
(b) *owns(Mary, x)*
(c) *walks*/2
(d) *dog*/1
(e) $dog(Zoot) \Rightarrow walks(Zoot)$
(f) $\forall x.\ cat(x) \Rightarrow walks(x)$
(g) $\forall x.\forall y.\ walks(x, y) \Rightarrow walks(y)$
(h) $\exists x.\forall y.\ walks(x, y) \Rightarrow walks(y)$

b) Convert the following FOL expressions into natural language sentences.

(a) $\forall x.rabbit(x) \Rightarrow furry(x)$
(b) $\exists e.help(e) \wedge helper(e, Franz) \wedge helpee(e, Marie)$
(c) $\exists e.x.eating(e) \wedge sandwich(x) \wedge eater(e, Liang) \wedge eaten(e, x)$
(d) $\exists e.x.y.eating(e) \wedge sandwich(x) \wedge fork(y) \wedge eater(e, Liang) \wedge eaten(e, x) \wedge instrument(e, y)$
(e) $\forall x.student(x) \Rightarrow \exists e.lifting(e) \wedge lifter(e, x) \wedge liftee(e, Marie)$
(f) $\exists e.lifting(e) \wedge \forall x.student(x) \Rightarrow lifter(e, x) \wedge liftee(e, Marie)$

c) Convert the following natural language sentences into FOL expressions. Use reified event semantics. If a sentence is ambiguous, list all possible interpretations and give paraphrases of the different meanings.

(a) Fiona hates Ewan
(b) Partha eats pizza
(c) Every student likes Juan
(d) Some student likes every class
(e) Ella sees herself
(f) Ella dances every Tuesday

Exercise 2: Semantic analysis Suppose we have the following grammar fragment with semantic attachments. Grammar rules are numbered in case we need to refer to them in tutorial groups.

#	Syntactic Rule	Semantic attachment
1.	Det → `a`	$\lambda P.\lambda Q.\exists x.P(x) \wedge Q(x)$
2.	Det → `the`	$\lambda P.\lambda Q.\exists !x.P(x) \wedge Q(x)$
3.	N → `dog`	$\lambda x.dog(x)$
4.	N → `park`	$\lambda x.park(x)$
5.	NP → `Sam`	$\lambda P.P(Sam)$
6.	NP → `Spot`	$\lambda P.P(Spot)$
7.	P → `in`	$\lambda P.\lambda Q \lambda x.P(\lambda y.in(x,y)) \wedge Q(x)$
8.	Vi → `walks`	$\lambda x.\exists e.walking(e) \wedge walker(e,x)$
9.	Vi → `sees`	$\lambda x.\exists e.seeing(e) \wedge seer(e,x)$
10.	Vt → `walks`	$\lambda P \lambda x.P(\lambda y.\exists e.walking(e) \wedge walker(e,x) \wedge walkee(e,y))$
11.	Vt → `sees`	$\lambda P \lambda x.P(\lambda y.\exists e.seeing(e) \wedge seer(e,x) \wedge seen(e,y))$
12.	Nom →N	N.sem
13.	Nom →Nom PP	PP.sem(Nom.sem)
14.	NP →Det Nom	Det.sem(Nom.sem)
15.	PP →P NP	P.sem(NP.sem)
16.	VP →Vi	Vi.sem
17.	VP →Vt NP	Vt.sem(NP.sem)
18.	VP →VP PP	PP.sem(VP.sem)
19.	S →NP VP	NP.sem(VP.sem)

a) Show how the meanings of `Sam sees` and `The dog walks` are built up using this grammar. (*Note:* the $\exists !$ symbol in the MR for `the` means "there exists a unique"—where the uniqueness is normally assumed to be determined by context. In other words, "the dog walks" would be true if there is a dog that walks, and it is the only dog currently salient to the speaker. One could argue whether this is a good enough semantics, but it will do for us here.)

b) Why are the transitive verb meanings so much more complicated than their intransitive counterparts? That is, why didn't we define the meaning of `walks` to be just

$$\lambda y.\lambda x.\exists e.walking(e) \wedge walker(e,x) \wedge walkee(e,y)?$$

(*Hint:* what happens when you combine the Vt with the object NP?)

c) Consider the sentences "Sam walks Spot" and "Sam walks", and compute their MRs using the grammar given above. Does the first sentence entail the second? Does the MR of the first sentence entail the MR of the second? If you feel there is a mismatch between the entailments of the sentences and their MRs, how might you fix it? (Note the difference between this pair of sentences/MRs and the pair "Sam sees Spot"/"Sam sees".)

If you are having trouble deriving the MRs for these sentences using the grammar, can you see what they are supposed to be? If so, you may be still able to answer this question, although computing the MRs will give you practice with complicated lambda reductions.

d) (Optional challenge question) Compute the meanings of the two different syntactic parses of the sentence "Sam sees a dog in the park". There is a problem with one of the meanings (that is, it isn't really correct). Identify the problem and say what the correct meaning should be. You *don't* need to fix the grammar to make that meaning come out, but you may want to think about why it's difficult to do so.