LING4400: Lecture Notes 7
Substances

Contents

7.1   Substances and quantifiers

Substances (e.g. *land*) behave like entities (e.g. *islands*) in quantifiers:

(1)   a.   *8 islands are in Samoa.*
     b.   *4 islands in Samoa are in Atau.*
     c.   (entailed by 1a and 1b:) *Half the islands in Samoa are in Atau.*

(2)   a.   *2,800 square kilometers of land are in Samoa.*
     b.   *400 square kilometers of land in Samoa are in Atau.*
     c.   (entailed by 2a and 2b:) *A seventh of the land in Samoa is in Atau.*

and in comparatives:

(3)   a.   *1,600 islands are in Cuba.*
     b.   *300 islands are in Fiji.*
     c.   (entailed by 3a and 3b:) *More islands are in Cuba than are in Fiji.*

(4)   a.   *110,000 square kilometers of land are in Cuba.*
     b.   *18,000 square kilometers of land are in Fiji.*
     c.   (entailed by 4a and 4b:) *More land is in Cuba than is in Fiji.*

Three ways to model substances like land:

1. We can model land like an operator:

$$[\![\text{LandAreaOf}]\!]^{M} = \boxed{\begin{array}{ll} \text{input} & \text{output} \\ \textbf{Cuba} : \textbf{110,000km}^2 \\ \textbf{Fiji} \;\; : \textbf{18,000km}^2 \end{array}} .$$

But this would require a different **More** function that compares **...km**^{2} entities.

We'd have to learn these two **More**'s separately, making this analysis less appealing.

2. Or we can model land like a predicate with an area argument:

$[\![\text{LandAreaOf}]\!]^M =$

input	output
⋮	⋮
Cuba :	input / output: $110{,}000\text{km}^2$: **True**; $18{,}000\text{km}^2$: **False**; ⋮ ⋮
Fiji :	input / output: $110{,}000\text{km}^2$: **False**; $18{,}000\text{km}^2$: **True**; ⋮ ⋮

This still requires different functions for normal ('count') entities and **...km^2** entities.

3. Or we can model land as a predicate that takes each particle of land as an argument:
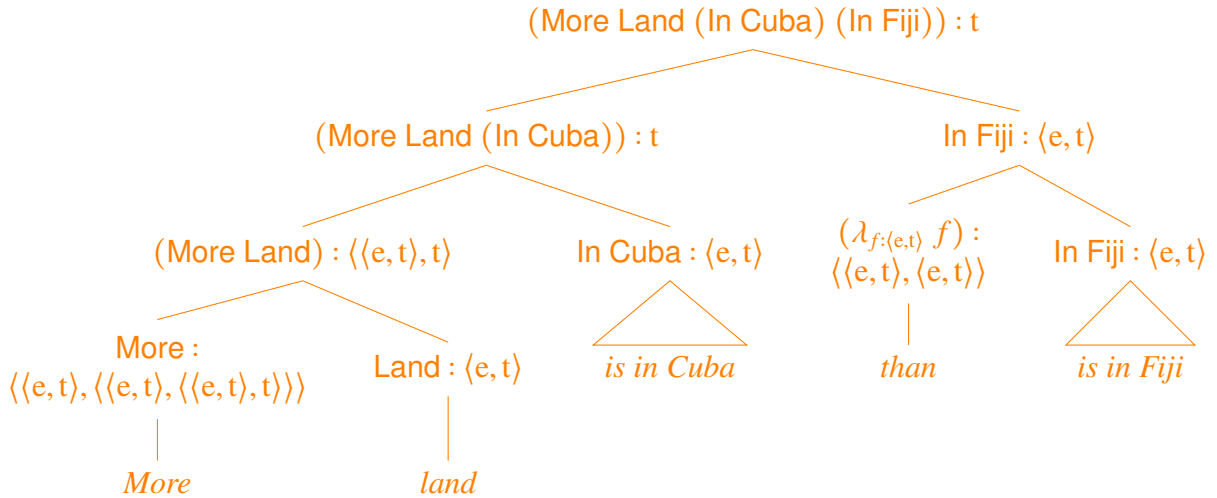
$[\![\text{In}]\!]^M =$

input	output
⋮	⋮
Cuba :	input / output: **PartOfLand1** : **True**; **PartOfLand2** : **True**; **PartOfLand3** : **False**; **PartOfLand4** : **False**; ⋮ ⋮
Fiji :	input / output: **PartOfLand1** : **False**; **PartOfLand2** : **False**; **PartOfLand3** : **True**; **PartOfLand4** : **True**; ⋮ ⋮

This allows the same quantifier functions to be used for substances and entities.

$$[\![\text{Most}]\!]^M = [\![\ \lambda_{r:\langle e,t\rangle}\ \lambda_{s:\langle e,t\rangle}\ |\lambda_{x:e}\ r\ x \wedge s\ x| \times 2 > |r|\ ]\!]^M$$
$$[\![\text{More}]\!]^M = [\![\ \lambda_{r:\langle e,t\rangle}\ \lambda_{s:\langle e,t\rangle}\ \lambda_{t:\langle e,t\rangle}\ |\lambda_{x:e}\ r\ x \wedge s\ x| > |\lambda_{x:e}\ r\ x \wedge t\ x|\ ]\!]^M$$

This requires lots of particles in our world model, but they don't need to be learned.

(More Land (In Cuba) (In Fiji)) : t

- (More Land (In Cuba)) : t
  - (More Land) : $\langle\langle e,t\rangle,t\rangle$
    - More : $\langle\langle e,t\rangle,\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle\rangle$
      - *More*
    - Land : $\langle e,t\rangle$
      - *land*
  - In Cuba : $\langle e,t\rangle$
    - *is in Cuba*
- In Fiji : $\langle e,t\rangle$
  - $(\lambda_{f:\langle e,t\rangle}\ f)$: $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
    - *than*
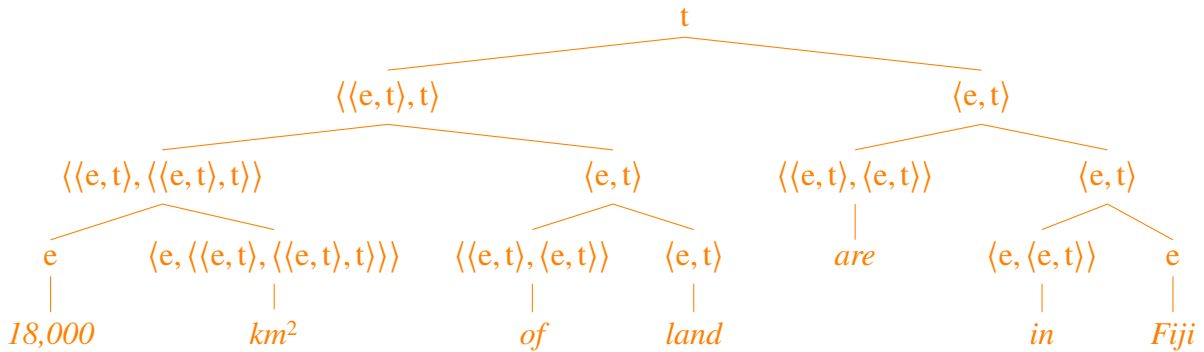 - In Fiji : $\langle e,t\rangle$
    - *is in Fiji*

7.2 Measure phrases as quantifiers over substances

We can have absolute quantifiers over substances using measure phrases.

For example, suppose our particles are square millimeters:

$$[\![\mathsf{SquareKilometer}]\!]^{M} = [\![\lambda_{n:e}\ \lambda_{r:\langle e,t\rangle}\ \lambda_{s:\langle e,t\rangle}\ |\lambda_{x:e}\ r\ x \wedge s\ x| = n \times 1,000,000,000,000]\!]^{M}$$

t

- $\langle\langle e,t\rangle,t\rangle$
  - $\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle$
    - e
      - *18,000*
    - $\langle e,\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle\rangle$
      - *km²*
  - $\langle e,t\rangle$
    - $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
      - *of*
    - $\langle e,t\rangle$
      - *land*
- $\langle e,t\rangle$
  - $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
    - *are*
  - $\langle e,t\rangle$
    - $\langle e,\langle e,t\rangle\rangle$
      - *in*
    - e
      - *Fiji*

7.3 Comparative adjectives use substances

This observation:

(5) a. *Cuba is larger than Fiji.*
    b. (entails and entailed by 5a:) *More land is in Cuba than is in Fiji.*

means we can do this:

$$[\![\mathsf{LargerThan}]\!]^{M} = [\![\lambda_{y:e}\ \lambda_{x:e}\ \mathsf{More\ Land\ (In}\ x)\ (\mathsf{In}\ y)]\!]^{M}$$

7.4 Superlative adjectives use substances

And this observation:

(6) a. *Greenland is the largest island.*
b. (entails and entailed by 6a:) *Greenland is an island and no island is larger than it.*

means we can do this:

$$[\![\mathsf{Largest}]\!]^M = [\![\lambda_{r:\langle e,t\rangle}\ \lambda_{x:e}\ r\ x \wedge \mathsf{None}\ r\ (\lambda_{y:e}\ \mathsf{More}\ \mathsf{Land}\ (\mathsf{In}\ y)\ (\mathsf{In}\ x))]\!]^M$$

Also, ordinal superlatives:

$$[\![\mathsf{ThirdLargest}]\!]^M = [\![\lambda_{r:\langle e,t\rangle}\ \lambda_{x:e}\ r\ x \wedge \mathsf{ExactlyTwo}\ r\ (\lambda_{y:e}\ \mathsf{More}\ \mathsf{Land}\ (\mathsf{In}\ y)\ (\mathsf{In}\ x))]\!]^M$$

7.5 Antonyms

Adjectives that are **gradable** (which have comparatives and superlatives) also have **antonyms**.

Antonyms are gradable in opposite directions, using comparative quantifier Less instead of More:

$$[\![\mathsf{Smallest}]\!]^M = [\![\lambda_{r:\langle e,t\rangle}\ \lambda_{x:e}\ r\ x \wedge \mathsf{None}\ r\ (\lambda_{y:e}\ \mathsf{Less}\ \mathsf{Land}\ (\mathsf{In}\ y)\ (\mathsf{In}\ x))]\!]^M$$