LING5702: Lecture Notes 20
Anaphora

Contents

20.1 Anaphora

Anaphora are words (e.g. pronouns like *it* and *they*) that re-use or inherit constraints.

The constraints they inherit are translated from an **antecedent** (e.g. a preceding noun phrase).

Some common anaphora (indexed *i* and underlined), with antecedents (indexed but not underlined):

1. **pronouns**:

   (1) *Etna$_i$ erupted. It$_i$ is in Italy.*

   (2) *[Two volcanoes]$_i$ erupted. They$_i$ are in Italy.*

   (3) *It is not true that [fewer than three volcanoes]$_i$ erupted. They$_i$ are in Italy.*

2. **possessive pronouns**:

   (4) *Italy$_i$ is in Europe. Its$_i$ capital is Rome.*

3. **definite references**:

   (5) *Italy contains [two volcanoes]$_i$. [The volcanoes]$_i$ erupted.*

   (6) *Italy contains [two volcanoes]$_i$. [Italy's volcanoes]$_i$ erupted.*

4. **deictic pronouns**:

   (7) a. *Italy contains [Two volcanoes]$_i$. [These volcanoes]$_i$ erupted.*
   b. *Italy contains [Two volcanoes]$_i$. [Those volcanoes]$_i$ erupted.*

   (8) a. *Italy contains [Two volcanoes]$_i$. These$_i$ erupted.*
   b. *Italy contains [Two volcanoes]$_i$. Those$_i$ erupted.*

5. **temporal anaphora**:

   (9) *Etna erupted$_i$. It$_i$ was recent.*

6. **propositional anaphora**:

   (10) *Etna erupted$_i$. France wanted it$_i$.*

7. **bridging anaphora**:

   (11) *Etna$_i$ erupted. The lava []$_i$ was hot.*

   (12) *Etna$_i$ erupted. Other volcanoes []$_i$ did not erupt.*

20.2 Easy case in logic: intra-sentential anaphora

How can we express anaphora in logic? Some anaphora can just re-use variables.

For example in translating 13a, which entails 13b:

(13) a. *Fiji contains [several provinces]$_i$ and funds them$_i$.*
   b. (entailed by 13a:) *Fiji funds the provinces it contains.*

we can't just copy the antecedent (*Fiji contains several provinces and funds several provinces*):

$$\text{Several Province } (\lambda_x \text{ Contain } x \text{ Fiji}) \wedge \text{Several Province } (\lambda_x \text{ Fund } y \text{ Fiji})$$

because that would let the funded provinces be different than the contained ones.

But we can re-use the variable x:

$$\text{Several Province } (\lambda_x \text{ Contain } x \text{ Fiji} \wedge \text{Fund } x \text{ Fiji})$$

(Don't worry about how to compose that analysis; we'll see it has other problems.)

20.3 Difficult case in logic: discourse anaphora [King, 2004]

When anaphora have antecedents in other sentences this shared-variable analysis doesn't work.

For example, we probably have an intuition that the following claims hold:

(14) a. Assume: *Nine provinces are in Gabon. Exactly three of Gabon's provinces are coastal.*
   b. (entailed by 14a:) *Exactly three coastal provinces are in Gabon.*
   c. (not entailed by 14a:) *[Exactly three provinces]$_i$ are in Gabon. They$_i$ are coastal.*

Separate sentences don't seem able to reach in and constrain restrictors in preceding sentences.

This is the translated meaning of 14b but not 14c:

$$\text{Three } (\lambda_x \text{ Province } x \wedge \text{Coastal } x) \text{ (In Gabon)}$$

How to translate 14c? First, assume separate sentences are equivalent to sentential conjunction:

(15) a. *Exactly three provinces are in Gabon. They are coastal.*
   b. (entailing/entailed by 15a:) *Exactly three provinces are in Gabon and they are coastal.*

Next we introduce new functions Antecedent and Anaphor to be expanded in interpretation.

They don't mean anything in ordinary **sentence-level** interpretation: $[\![\text{Antecedent } i\ q]\!]^M = [\![q]\!]^M$,

but they are expanded in a **discourse-level** interpretation function $[\![\varphi]\!]'^M$ using access function $[\![\varphi]\!]^g$:

$$[\![\varphi]\!]'^M = [\![[\![\varphi]\!]^g]\!]^M$$

where g is an **assignment** — a function from antecedent indices i to expressions φ, ψ, etc.

The **access function** substitutes anaphors with antecedents, converted by a closure function $[\![\varphi]\!]^C_i$:

$$[\![\text{Anaphor } i]\!]^g = \lambda_{x_i:e}\ [\![g\ i]\!]^C_i$$

$$[\![\ldots \wedge \varphi_i \wedge \ldots \wedge \psi]\!]^g = [\![\ldots \wedge \varphi_i \wedge \ldots]\!]^g \wedge [\![\psi]\!]^{\boxed{\substack{i\ :\ \varphi_i \\ \text{other } i' :\ g\ i'}}} \quad \text{(for ea. anaphor } i \text{ in } \psi \text{ w. antecedent } i \text{ in } \varphi_i)$$

$$[\![\pi\ (\lambda_{x:\alpha}\ \varphi)\ (\lambda_{x:\alpha}\ \psi)]\!]^g = \pi\ (\lambda_{x:\alpha}\ [\![\varphi]\!]^g)\ (\lambda_{x:\alpha}\ [\![\psi]\!]^{\boxed{\substack{i\ :\ \varphi \\ \text{other } i' :\ g\ i'}}}) \quad \text{(quant. } \pi\text{, antecedent } i \text{ in } \varphi\text{, anaphor } i \text{ in } \psi)$$

$$[\![\pi\ (\lambda_{x:\alpha}\ \varphi)\ (\lambda_{x:\alpha}\ \psi)]\!]^g = \pi\ (\lambda_{x:\alpha}\ [\![\varphi]\!]^{\boxed{\substack{i\ :\ \psi \\ \text{other } i' :\ g\ i'}}})\ (\lambda_{x:\alpha}\ [\![\psi]\!]^g) \quad \text{(quant. } \pi\text{, anaphor } i \text{ in } \varphi\text{, antecedent } i \text{ in } \psi)$$

$$[\![\varphi\ \psi]\!]^g = [\![\varphi]\!]^g\ [\![\psi]\!]^g \quad \text{(any other function application)}$$

$$[\![\lambda_{x:\alpha}\ \varphi]\!]^g = \lambda_{x:\alpha}\ [\![\varphi]\!]^g \quad \text{(any abstraction)}$$

$$[\![\varphi]\!]^g = \varphi \quad \text{(if constant or variable)}$$

(Some theories also posit constraints on this accessibility [Heim, 1982].)

The **closure function** replaces any quantifier outscoping the antecedent with an existential:

$$[\![\text{Antecedent } i\ \pi\ \rho\ \sigma]\!]^C_i = (\rho\ x_i \wedge \sigma\ x_i) \quad \text{(for quantifier } \pi\text{, restrictor } \rho\text{, nuclear scope } \sigma)$$

$$[\![\pi\ \rho\ \sigma]\!]^C_i = (\text{Some } [\![\rho]\!]^C_i\ \sigma) \quad \text{(for quantifier } \pi\text{, if antecedent } i \text{ in } \rho)$$

$$[\![\pi\ \rho\ \sigma]\!]^C_i = (\text{Some } \rho\ [\![\sigma]\!]^C_i) \quad \text{(for quantifier } \pi\text{, if antecedent } i \text{ in } \sigma)$$

$$[\![\varphi\ \psi]\!]^C_i = [\![\varphi]\!]^C_i\ \psi \quad \text{(if antecedent } i \text{ in } \varphi)$$

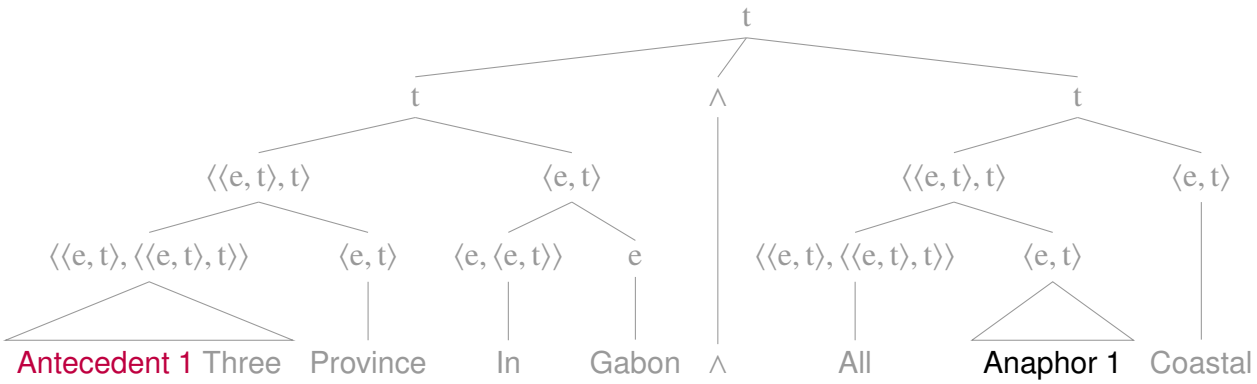
$$[\![\varphi\ \psi]\!]^C_i = \varphi\ [\![\psi]\!]^C_i \quad \text{(if antecedent } i \text{ in } \psi)$$

$$[\![\lambda_{x:\alpha}\ \varphi]\!]^C_i = \lambda_{x:\alpha}\ [\![\varphi]\!]^C_i \quad \text{(any abstraction)}$$

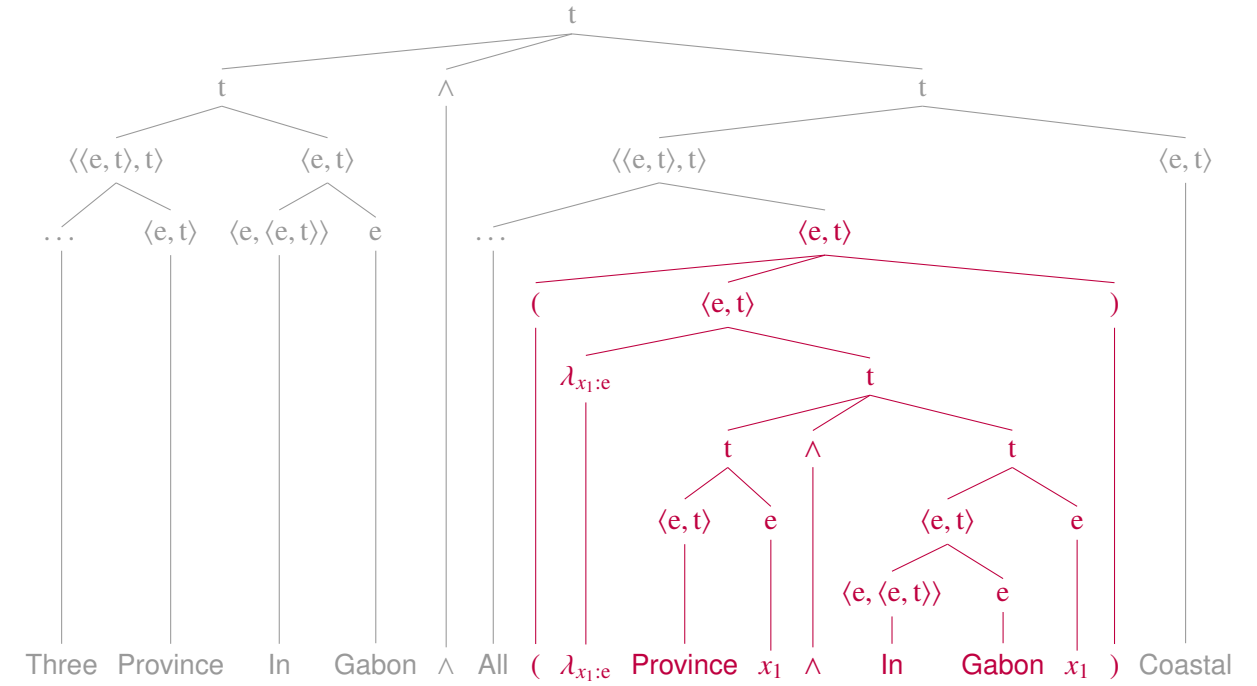
Here's an example of the whole process (I chose $i = 1$ arbitrarily):

$$[\![(\text{Antecedent } 1 \text{ Three Province (In Gabon))} \wedge (\text{All (Anaphor } 1) \text{ Coastal})]\!]^{E,M}$$
$$= [\![(\text{Three Province (In Gabon))} \wedge (\text{All } (\lambda_{x_1:e} \text{ Province } x_1 \wedge (\text{In Gabon } x_1)) \text{ Coastal})]\!]^M$$

Here's the logic expression before expansion:



And here's the expression after expansion:



This is for the sentences:

Gabon contains exactly three provinces. They are coastal.

Note this is different than:

Gabon contains exactly three coastal provinces.

Also note that *they* is translated as All (Anaphor 1).

This assumes the meaning is that all of the provinces are coastal.

But, it is possible the quantifier is weaker than that:

I hate mosquitoes. They carry malaria.

This doesn't mean all mosquitoes carry malaria, just more than you might think.

This is called a **generic** [Leslie, 2015]. It's a context-dependent quantifier.

Practice 20.1:

Translate the following sentences into **logic** using Antecedent and Anaphor functions:

Two volcanoes erupted. They are in Italy.

Practice 20.2:

Translate the following sentences into **logic** by **expanding** Antecedent and Anaphor functions:

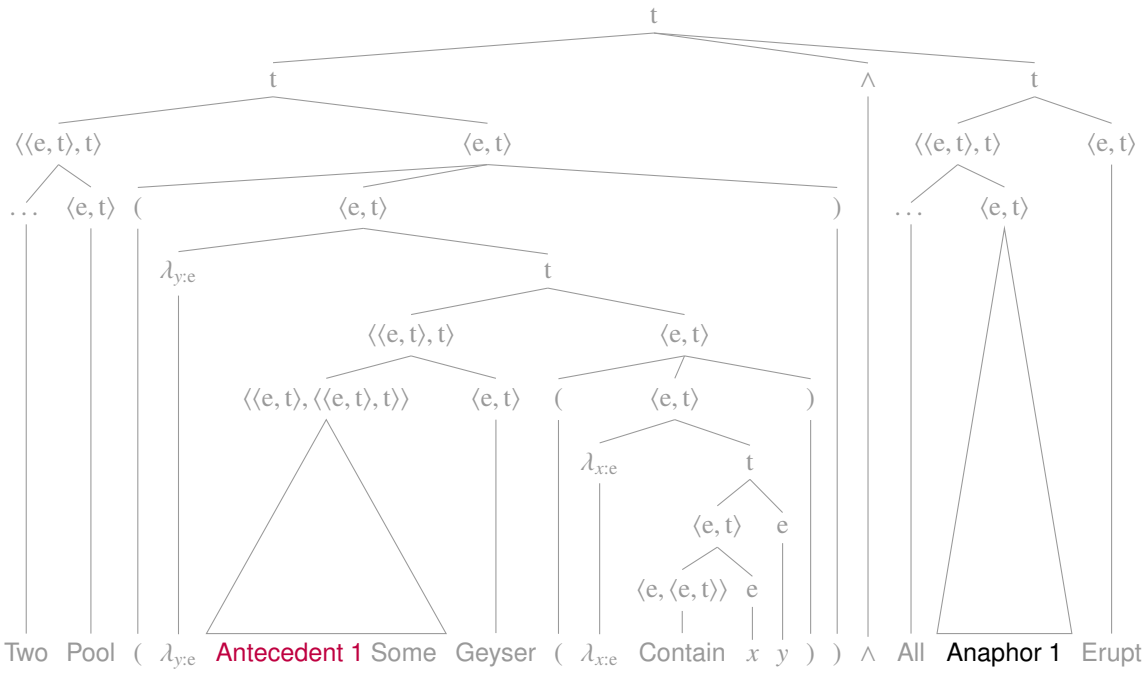
Two volcanoes erupted. They are in Italy.

20.4 Existential closure

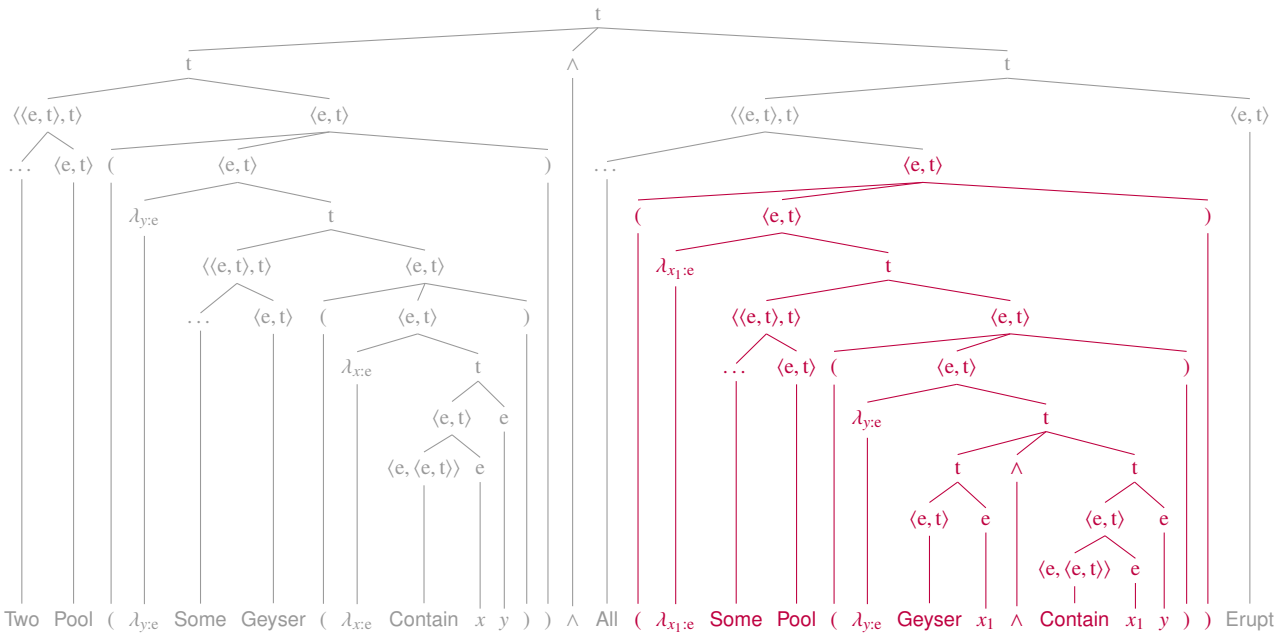
You may have noticed quantifiers above the Antecedent are replaced with Some.

This is another form of existential closure for variables outside the antecedent.

For example, here is a logic representation for: *Two pools contain a geyser. They erupt.*



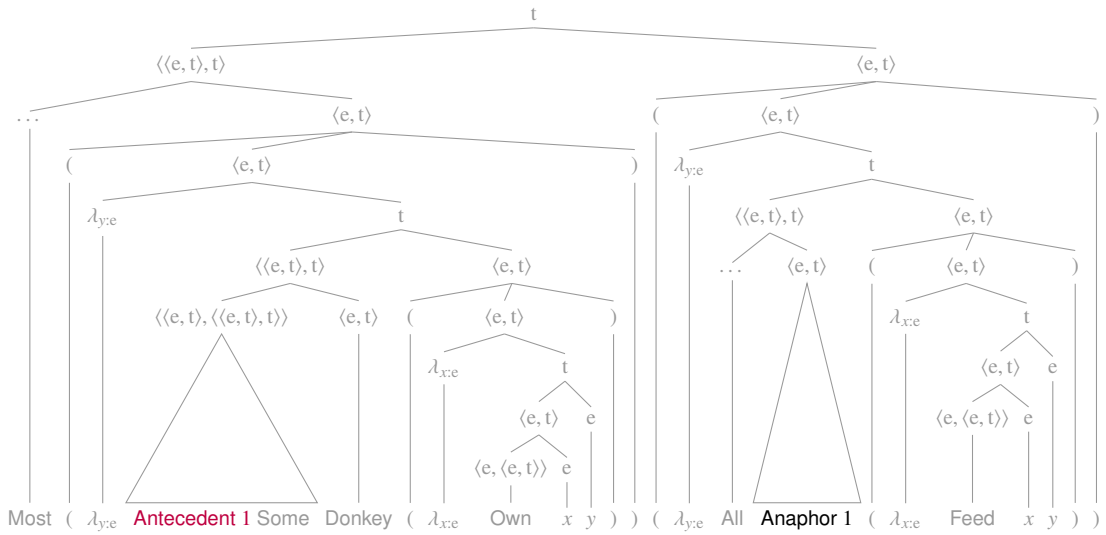
The expansion requires existential closure of variable y:



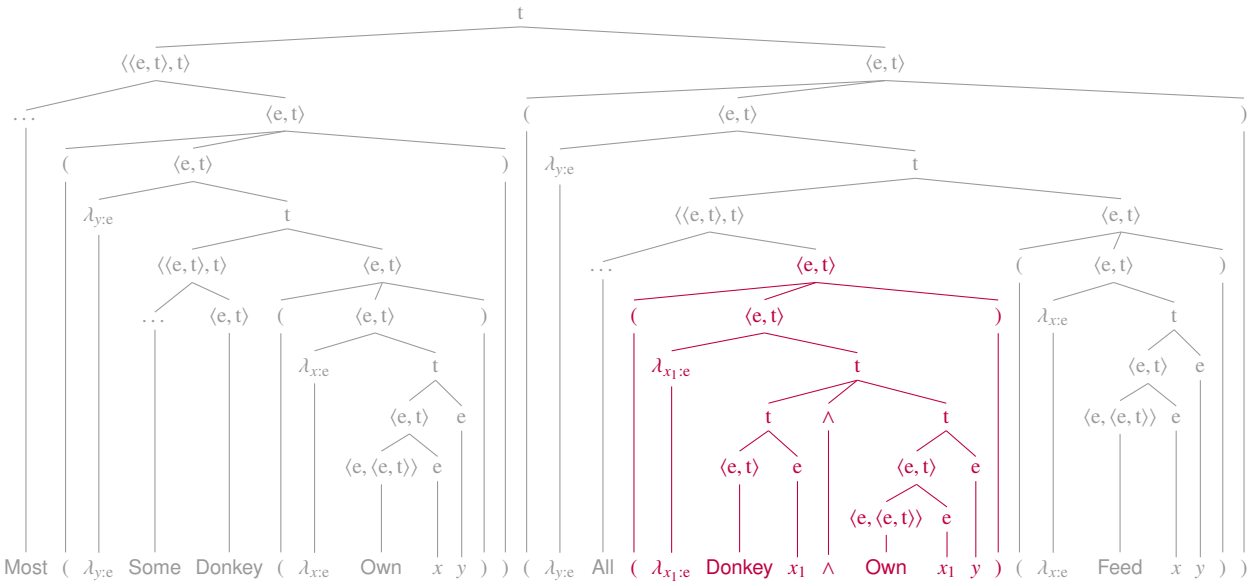
20.5 'Donkey' anaphora

A historically interesting case has anaphors and antecedents in different quantifier arguments.

Here is a logic representation for *Most who own a donkey feed it*:

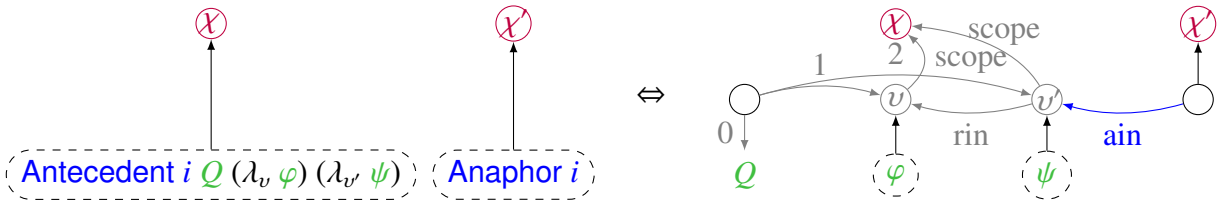


and here's the result of expanding these functions:

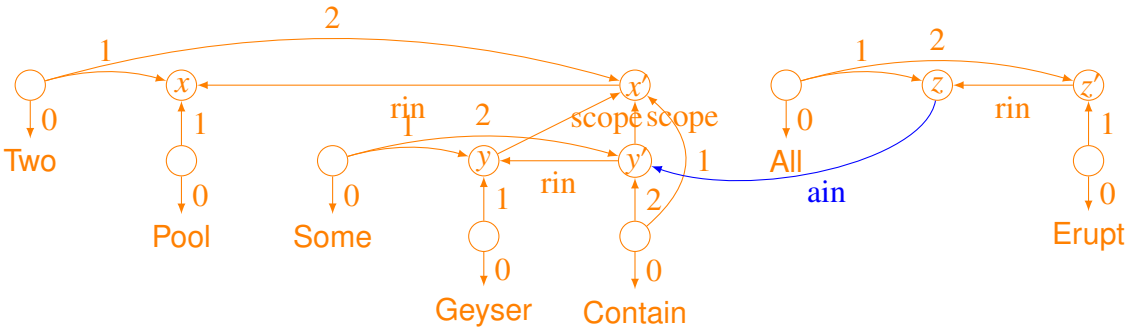


20.6 An algorithmic-level model

We can model a co-indexed anaphor-antecedent pair using another inheritance cued association:



For example, here are the cued associations for *Two pools contain a geyser. They erupt.*:



The different interpretation (with extra existentials) comes from the local topology of the variable.

References

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[King, 2004] King, J. C. (2004). Context dependent quantifiers and donkey anaphora. *Canadian Journal of Philosophy*, 34(sup1), 97–127.

[Leslie, 2015] Leslie, S.-J. (2015). Generics oversimplified. *Nous*, 49(1), 28–54.