Sum Individuals and Proportion Problem

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This paper proposes that the so-called proportion problem, which was observed in Kadmon (1987, 1990) as a problem to the analyses of Kamp (1981) and Heim (1982), can be overcome by adopting the notion of 'sum individuals.' It will be suggested that given a donkey sentence with an asymmetric reading, a set of sum individuals of the 'dependent' variable is computed and this is introduced to the antecedent level as a variable of sum individuals. In this way, we can make the dependent variable accessible from the consequent level and avoid the proportion problem. In addition, it will be shown that the process of computing the sum individuals is necessary in order to explain the existence of weak and strong readings of quantified sentences.

1. Asymmetric Readings and Proportion Problem

It is well-known that Kadmon (1987, 1990) observed, among others including Heim (1982) and Partee (1984), that the analyses of donkey sentences by Kamp (1981) and Heim (1982) wrongly assign the interpretation (2) to both sentences (1a) and (1b):

(1) a. If a man owns a dog, he usually takes good care of it.
b. Most men who own a dog take good care of it.

(2) $\text{MOST}(\{<x, y> \mid \text{man}(x) \wedge \text{dog}(y) \wedge \text{own}(x, y)\},$
$\{<x, y> \mid \text{take-good-care-of}(x, y)\})$

What (2) amounts to is that (1a, b) are true iff most man-dog pairs such that the man owns the dog are such that the man takes good care of the dog. The quantifier unselectively binds both variables x and y, which results in the so-called symmetric reading.

The problem is, however, that intuitively, the prominent reading of (1a) and probably the only reading of (1b) should have the following interpretation:

(3) $\mathrm{MOST}(\{x \mid \exists y[\mathrm{man}(x) \wedge \mathrm{dog}(y) \wedge \mathrm{own}(x, y)]\},$
$\{x \mid \text{take-good-care-of}(x, y)\})$

In (3), the quantifier does not unselectively bind both variables x and y. It asymmetrically quantifies over variable x only, which consequently produces the so-called subject-asymmetric reading.

The existence of asymmetric readings as well as symmetric readings in donkey sentences is now well-observed. But one problem remains that the dependent variable y in the nuclear scope of (3) is not bound.

There are various proposals to overcome this problem. One of them is Chierchia's (1990) proposal, which makes use of the fact that natural language determiners are always conservative, that is:

(4) $D(X)(Y) \Leftrightarrow D(X)(X \cap Y)$
where D(eterminer) is treated as a two-place relation between sets.

By means of this restriction for quantifiers, he came up with the following analysis:

(5) $\mathrm{MOST}(\lambda x \exists y[\mathrm{man}(x) \wedge \mathrm{dog}(y) \wedge \mathrm{own}(x, y)])$
$(\lambda x \exists y[\mathrm{man}(x) \wedge \mathrm{dog}(y) \wedge \mathrm{own}(x, y) \wedge \text{take-good-care-of}(x, y)])$

Groenendijk and Stokhof's (1991) 'dynamic predicate logic' also does without this problem, which is a compositional interpretation of the language of first-order predicate logic that allows for the modelling of binding phenomena, as with intersentential anaphora and donkey sentences.

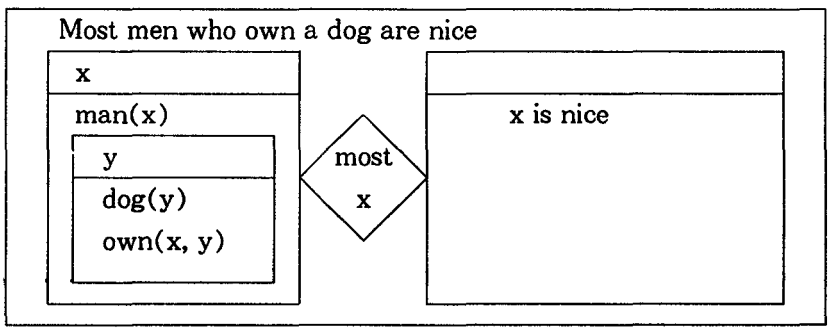
However, no analysis based on Discourse Representation Theory (DRT) seems to provide a satisfactory solution to the binding problem. One of the main purposes of this paper will be to come up with a solution based on DRT. Another main purpose will be to provide a proper interpretation for the dependent variable.

2. Kadmon's Proposal

Kadmon (1987, 1990) proposes that the sentence with an asymmetric reading differs in the internal structure of the restriction from the sentence with a symmetric reading. She introduces another DRS inside the anteced-

ent DRS and argues that the embedded DRS is bound by existential quantification as the following:

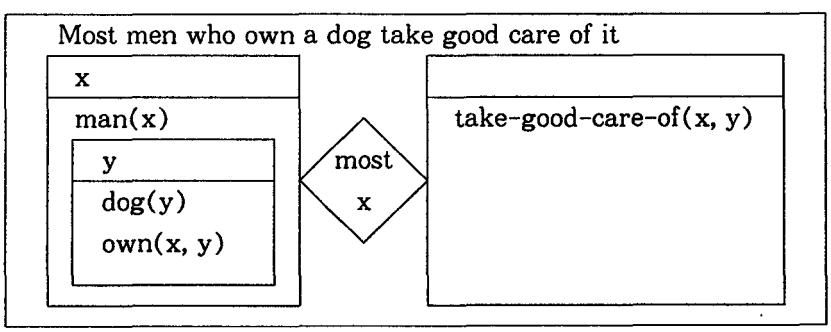
(6)



In this way, we can have only the 'man' variable bound by the quantifier *most* and have the dependent used to ascribe a property to the man.

But consider the following example:

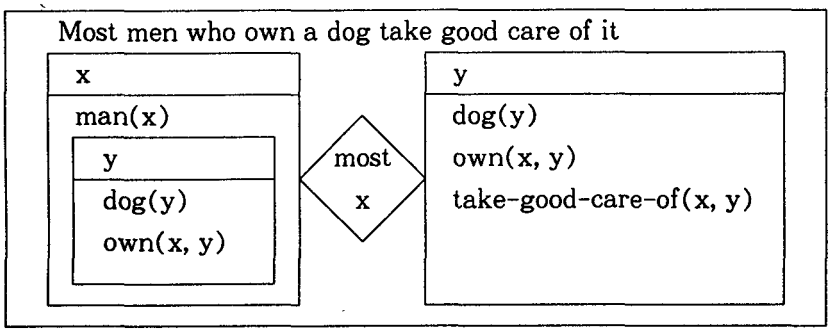
(7)



The variable y in the consequent DRS is not bound, since the discourse referent introduced in the embedded DRS is not accessible from the consequent DRS.

In order to remedy this problem, Kadmon suggests that the discourse referent and the conditions in the DRS embedded in the antecedent DRS are accommodated to the consequent DRS as follows:

(8)



She also proposes that sentence (1b) is only about men who own a unique dog.

As for the uniqueness implication, it is now well-accepted that it is counterintuitive. Sentences like (1b) are not only about those men who have only one dog, but also about the men who have more than one dog.

However, when the speaker talks about those men who have more than one dog, he is likely to say the following sentence instead of (1b):

(9) Most men who own dogs take good care of them.

Lee Baker (p.c.) pointed out that when you talk about Iowa farmers who typically raise a large number of turkeys, not just one or several turkeys, you use (10b) instead of (10a): [1]

(10) a. *Most Iowa farmers who raise a turkey sell it for Thanksgiving.
b. Most Iowa farmers who raise turkeys sell them for Thanksgiving.

On the other hand, it seems that (1b), for example, is used when the majority of the men own only one dog. But this does not entail that (1b) is only about the men who own only one dog.

Furthermore, the uniqueness presupposition runs into other problems. As pointed out by Heim (1990), even though some counterexamples to the E-Type analysis including the 'sage plant' example could be explained by Berman's (1987) version of situation-based analysis, the following example poses another problem to the situation-based E-Type analysis of multi-case conditionals:

[1] Lee Baker calls sentences like (10b) 'turkey' sentences.

(11) If a man shares an apartment with another man, he shares the housework with him.

According to the situation-based analysis, if *he* and *him* are represented as $f^1(s)$ and $f^2(s)$ respectively, $f^1(s)$ must be the unique man in s who in s shares an apartment with another man. However, there does not exist a function like f^1, since for each situation s, there are two men who share an apartment with another man.[2]

Kadmon's proposal on accommodation is also problematic. Heim (1990, p. 175) also argues that "Kadmon's proposal resorts extensively to accommodation." Furthermore, the rule of accommodation explained above seems to be a mere stipulation without any formal preconditions.

All in all, it is now well-accepted that the uniqueness implication is counterintuitive and the accommodation also is not an independently-motivated process.

3. Sum Individuals

Now the question is how to account for the asymmetry in donkey sentences and how to represent it formally. When we consider the interpretation of a sentence with an asymmetric reading, what we are supposed to do is to count the number of individuals represented by the independent variable that satisfy the predication. But what about the dependent variable? Let's reconsider (1b), repeated in the following:

(1b) Most men who own a dog take good care of it.

As for the indefinite *a dog* in (1b), we discussed above that it shouldn't be interpreted to have a uniqueness presupposition. In other words, (1b) is about men who own only one or more than one dog. But the question is how we should interpret the pronoun in the nuclear scope.

From this does the issue of weak and strong interpretations arise. Say, some dog-owning men who own more than one dog behave in an inconsistent way toward their dogs. In other words, they take good care of only some of their dogs. The question is whether we should count these men as

[2] In other words, a 'sharing' relation cannot be formed with only one man. Hence a function like f^1 cannot exist.

those who take good care of their dogs or not. Two interpretations, namely, weak and strong interpretations, (12a) and (12b) respectively, are available for sentence (1b), repeated as (12) in the following:

(12) Most men who own a dog take good care of it.
  a. Most men who own a dog take good care of at least one dog they own.
  b. Most men who own a dog take good care of every dog they own.

For example, according to Neale's theory (1990a, b), (12) amounts to the strong interpretation, i.e., (12b), only. This is one of the problems of his analysis in the sense that his theory cannot account for the existence of the weak reading, given the fact that the existence of both weak and strong interpretations is confirmed by the intuitions of quite a few linguists including Heim, Rooth, Chierchia, Barker, and Kanazawa.

Given this, what seems to happen here is that when we process a sentence with an asymmetric reading we take into consideration all the individuals represented by the dependent variable as a group for each individual represented by the independent variable. Here I propose that the 'sum individuals' of the dependent variable are computed before we process the nuclear scope of the sentence. Based on this, sentence (12) could be paraphrased as follows:

(13) Most men who own a dog take good care of the dog or the dogs that they own.

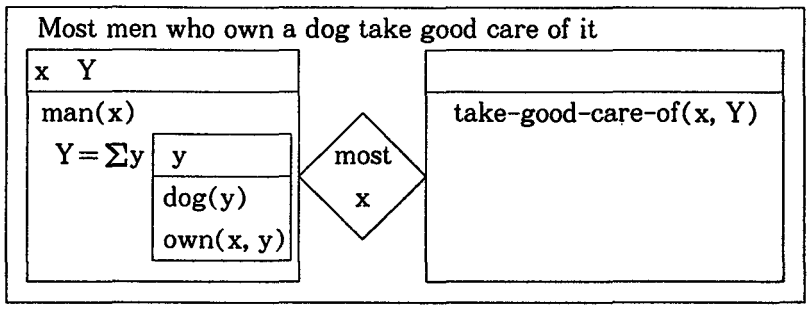
This could be also formally represented by means of a model-theoretic version of Neale's (1990a, b) analysis:

(14) $\mathrm{MOST}x\ ([\mathrm{man}(x) \wedge \exists y[\mathrm{dog}(y) \wedge \mathrm{own}(x, y)]],$
$[\mathrm{take\text{-}good\text{-}care\text{-}of}(x, \sigma y[\mathrm{dog}(y) \wedge \mathrm{own}(x, y)])])$

where $\sigma y\ \Phi$ stands for the sum individual of the y that satisfy Φ (Link 1983).

We further propose that the sum individuals computed introduce a new discourse referent to the antecedent DRS as the following so that the problem of inaccessibility could be solved:

(15)



The sum individuals of the dependent variable y introduce another discourse referent Y to the antecedent DRS, and the variable Y in the consequent DRS now can access to the discourse referent Y in the antecedent DRS.

The motivation for this process of sum individual calculation seems to be well accounted for by the existence of weak and strong interpretations.

4. Weak and Strong Predicates

Once the sums of individuals are computed, how are these sum individuals interpreted? I propose that once the sum individuals are calculated, we decide on whether the nuclear scope is true of at least one element of the sum individual, i.e., the weak reading, or true of all elements of the sum individual, i.e., the strong reading.

As for the question of how the choice between the weak and the strong readings is made, I propose that predicates could be divided into weak or strong predicates depending on which of the two readings is likely to be triggered by the meaning postulates of the predicates.

Consider a couple of examples:

(16) a. Most farmers who own a donkey keep it healthy during the dry season.

b. Most farmers who own a donkey let it get sick during the rainy season.

As for (16a), our intuition seems to be such that if a farmer who owns more than one donkey keeps only some of his donkeys healthy during the dry season while letting the other donkeys get sick, then we are not likely

to count him as one of the cases that verify the nuclear scope. Consequently, the reading sentence (16a) is more likely to receive is the strong interpretation.

On the other hand, without any specific context given, our intuition about (16b) tells that if a farmer who owns more than one donkey lets only some of his donkeys get sick while keeping the other donkeys healthy, it seems to be enough for him to be counted as one of the confirming cases. This means that (16b) is more likely to receive the weak interpretation, unlike (16a).

Consider another similar pair of examples:

(17) a. Most boys who have a baseball card in their pockets keep it clean while playing in the mud.
b. Most boys who have a baseball card in their pockets soil it while playing in the mud.

For (17a), if we have 5 boys who have one or several baseball cards in their pockets and at least 3 of them keep all of their cards clean while playing in the mud, then the sentence seems to be true. However, if at least 3 out of the 5 boys do not keep at least one of their baseball cards clean, then the sentence seems to be false. Concerning (17b), given a situation in which there are 5 boys, 3 of whom soil at least one of their cards while playing in the mud, the sentence seems to be true without any specific context given.

I call predicates such as (16a) and (17a) strong predicates while I name predicates such as (16b) and (17b) weak predicates.[3]

Back to the interpretation of the sum individuals. In sum, when we have a weak predicate, only a part of the sum individual being true of the predicate seems to be enough. When it comes to a strong predicate, every part of the sum individual being true of the predicate seems to be necessary.

In the following section, in order to show how my proposal based on the notion of sum individuals generates new consequences in terms of semantic representations, I will provide semantic representations for two donkey sentences, one of which receives the weak reading and the other receives the strong reading, by means of Discourse Representation Theory.

[3] Here I won't go into the details of this proposal. For a detailed discussion on this issue, please refer to Yoon (To appear).

5. Semantic Representations

My proposal based on the notion of sum individuals and my observations about the availability of weak and strong readings have consequences for the semantic representation of donkey sentences. I will illustrate this within DRT (Kamp 1981, Kamp & Reyle 1993). In doing this, I will assume not only basic knowledge of DRT, but also the technical details of Kamp & Reyle (1993), such as P-S rules, lexical insertion rules, and DRS (Discourse Representation Structure) construction rules.

5. 1. DRS Interpretation

In this subsection, the DRS interpretation algorithm is provided.

5. 1. 1. Models

DRSs are interpreted with respect to a model $M = \langle U, F, \sqcup \rangle$, which consists of a universe U, a function F, and a join operation $\sqcup$, where F has the following property:

(a) For every proper name α, $F(\alpha) \in U$
(b) For every intransitive verb or every noun α, $F(\alpha) \subseteq U$
(c) For every transitive verb α, $F(\alpha) \subseteq U \times U$

and $\sqcup$ is the join operation of a join semi-lattice, which has mathematical properties such as being idempotent, commutative, and associative.

For example, say that j, k, l denote the three individuals John, Kirk, and Linda, with student(j), student(k), and student(l). Then $j \oplus k \oplus l$, where $\oplus$ is a summation, denotes the sum individual of John, Kirk, and Linda. That is, if we have two individuals x, y, then $x \oplus y$ is an individual as well.

The object denoted by $j \oplus k \oplus l$ is in the denotation of *student*, which is represented by **student***. In general, a plural predicate like **student*** is defined as the closure of the singular predicate under $\oplus$:

(a) For all x, if **student**(x), then **student***(x)
(b) For all x, y, if **student***(x) and **student***(y), then **student***($x \oplus y$)

What an expression like $\sigma x\ \Phi$ stands for is the greatest element x that satisfies the description Φ. For example, σx[student*(x)] denotes the sum individual of all the students.

Def: $\sigma x\, \Phi[x]$ = that a such that $\Phi[a]$ is true and for all b such that $\Phi[b]$ is true, $a \oplus b = a$. (i.e., b is a part of a)

5.1.2. Accessibility

The notion of **accessibility** is defined in terms of the notion of **subordination** as the following:

Def: A DRS K_1 is **subordinate** to a DRS K_2 iff:

(a) K_2 contains $\neg K_1$ as a condition

(b) K_2 contains one of the following conditions:

$$K_1 \Diamond K_3,\ K_3 \Diamond K_1$$

(c) K_2 occurs in a condition

$$K_2 \Diamond K_1$$

(d) There is a K_3, and K_1 is subordinate to K_3, and K_3 is subordinate to K_2.

Def: A discourse referent d in a DRS K_1 is **accessible** from a DRS-condition c in DRS K iff:

(a) either $K_1 = K$

(b) or K is subordinate to K_1.

5.1.3. Truth

The **truth** of a DRS is defined in terms of the notion of **verification**, which uses partial assignment functions, as the following:

Def: A DRS K is **true** in a model $M = \langle U, F, \sqcup \rangle$
iff there is a function $f: U(K) \rightarrow U$ that verifies K in M
(where U(K) denotes the universe of a DRS K).

Def: (i) f **verifies** the DRS K in M iff f verifies every condition of K in M
(ii) f **verifies** the condition γ in M iff:

a) γ is of the form $d = \alpha$, and $f(d) = F(\alpha)$.

b) γ is of the form $\alpha(d)$, and $f(d) \in F(\alpha)$.

c) γ is of the form $[d\ \alpha]$, and $f(d) \in F(\alpha)$.

d) γ is of the form $[d\ \alpha\ d']$ and $\langle f(d), f(d') \rangle \in F(\alpha)$.

e) γ is of the form $\neg K'$, and there is no extension g of f with $Dom(g) = Dom(f) \cup U(K)$, such that g verifies K' in M
(where Dom(f) denotes the domain of function f).

f) γ is of the form $K_1 \Rightarrow K_2$,
and for every extension g of f with $Dom(g)=Dom(f) \cup U(K_1)$ that verifies K_1 in M,
there is an extension h of g with $Dom(h) = Dom(g) \cup U(K_2)$ that verifies K_2 in M
(where g is called an **extension** of f iff $f \subseteq g$).

g) γ is of the form

$$K_1 \quad \langle Q \; d \rangle \quad K_2$$

and for Q d, there is a g, where $Dom(g)=Dom(f) \cup U(K_1)$ such that g verifies K_1 in M, which can be extended to h, where $Dom(h)=Dom(g) \cup U(K_2)$ such that h verifies K_2 in M.

h) γ is of the form $D=d_1 \oplus \cdots \oplus d_n$, and $f(D)=f(d_1) \cup \cdots \cup f(d_n)$.

i) γ is of the form $d \leq D$[4], and D is the sum individual of all d.

j) γ is of the form $D=\sum d\ K$, and $f(D)=\sigma a \exists g[f \subseteq g \wedge DOM(g)=DOM(f) \cup U(K) \wedge g(d)=a \wedge g$ verifies K in M]

5. 2. Examples[5]

Let's reconsider the following a couple of donkey sentences with a relative clause, which have been already discussed in the previous section:

(16) a. Most farmers who own a donkey keep it healthy during the dry season.

b. Most farmers who own a donkey let it get sick during the rainy season.

As discussed above, sentences (16a, b), which include a relative clause, always receive a subject-asymmetric reading, as the quantificational NP is in subject position. But the classic DRT does not have the capacity to han-

[4] Here I use the general part relation, $\leq$, in order to capture the properties of total and partial predicates.

[5] One thing to note is that I will not go to the trouble of explaining every detail of the derivation of each condition of DRSs under discussion. I will simply refer to the rules that have been applied and focus on the construction of the structures we are mainly concerned with here.

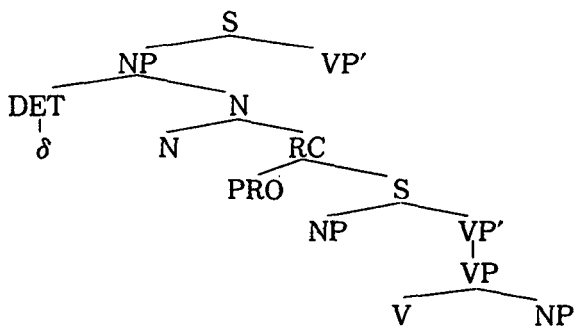
dle asymmetric readings. Therefore, we need a pair of rules like the following, (CR 1a) for donkey sentences with relative clauses and (CR 1b) for donkey sentences with if-clauses which receive an asymmetric reading: [6]

(CR 1a)

CR. ASYMM.READ.REL.CL.

Triggering Configurations

$\gamma \subseteq \gamma' \in Con_K$:



where γ is RC and δ is a quantifying determiner.

Operations: (a) Since condition γ' satisfies the triggering configuration for (CR 2), (CR 2) should apply before this CR.

(b) An NP, β, in RC, which is not a trace, introduces a new DRS D in the antecedent DRS of DRS K.

(c) Introduce a new DRS condition

$D = \Sigma D'$

D′
$[_{NP}\ \beta]\ (D')$

(d) Replace $[_{NP}\ \beta]$ in the triggering condition by D.

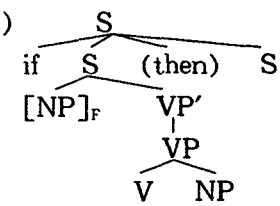
[6] DRS construction rules (1a) and (1b) are my innovations.

(CR 1b)

CR.ASYMM.READ.CONDITIONALS.

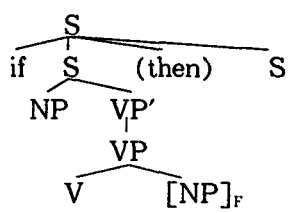
Triggering Configurations

$\gamma \subseteq \gamma' \in Con_K$: 1)

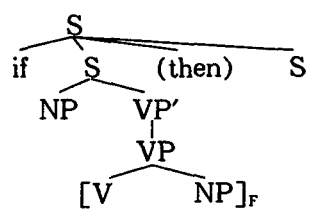


or

2)



or 3)



where γ is $[NP]_F$ (or $[V\ NP]_F$) in the if-clause, and δ is a quantifying determiner.

Operations: (a) Since condition γ' satisfies the triggering configuration for the CR for conditionals, the CR for conditionals should apply before this CR.

(b) $[NP]_F$, β, introduces a new DRS D in the antecedent DRS of DRS K.

(c) Introduce a new DRS condition

$D = \Sigma D'$

D′
$[_{NP}\ \beta](D')$

(d) Replace $[_{NP}\ \beta]$ (D′) in the triggering condition by D.

In (CR 1b), triggering configuration 1) is for sentences with if-clauses that receive an object-asymmetric reading, while 2) and 3) are for sentences with if-clauses that receive a subject-asymmetric reading. The NP or the

VP in brackets with a little F on the right indicates that it is *in focus.*[7] This means that the constituent is actually accented in speech.

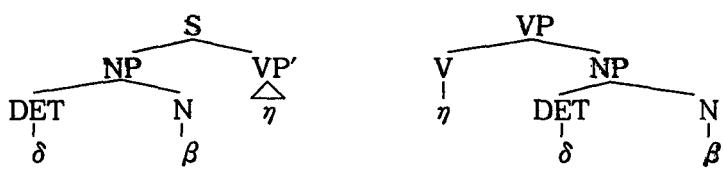
If we apply the construction rule for quantified NPs, i.e., (CR 2),[8] to sentence (16a), then we get (16a′):

(CR 2)

CR.NP[Quant = +]

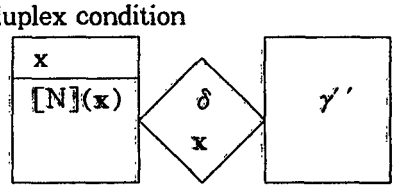
Triggering Configurations

$\gamma \subseteq \gamma' \in Con_K$: 1) or 2)



with δ a quantifying determiner.

Operations: Choose a new discourse referent x. Replace γ' by the duplex condition

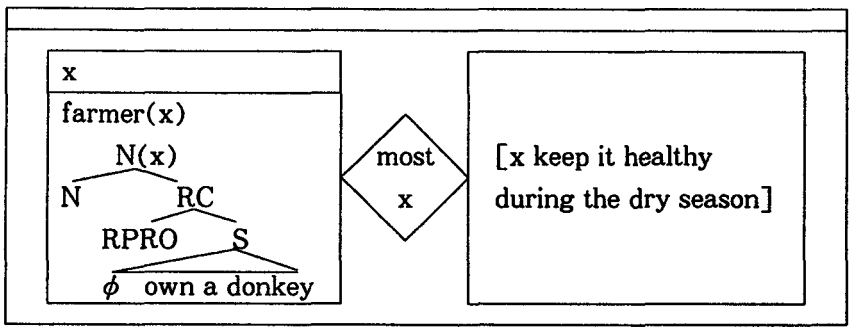


where γ'' results from γ' by substituting x for $\underset{\delta\beta}{\overset{\triangle}{NP}}$.

[7] According to Krifka (1992, 1993), "indices introduced by expressions in the background of a conditional clause are bound by the quantifier, whereas the indices introduced by expressions in the focus are subjected to existential closure and thus are prevented from being quantified over." For more details on this focus sensitivity, refer to Krifka (1992, 1993).

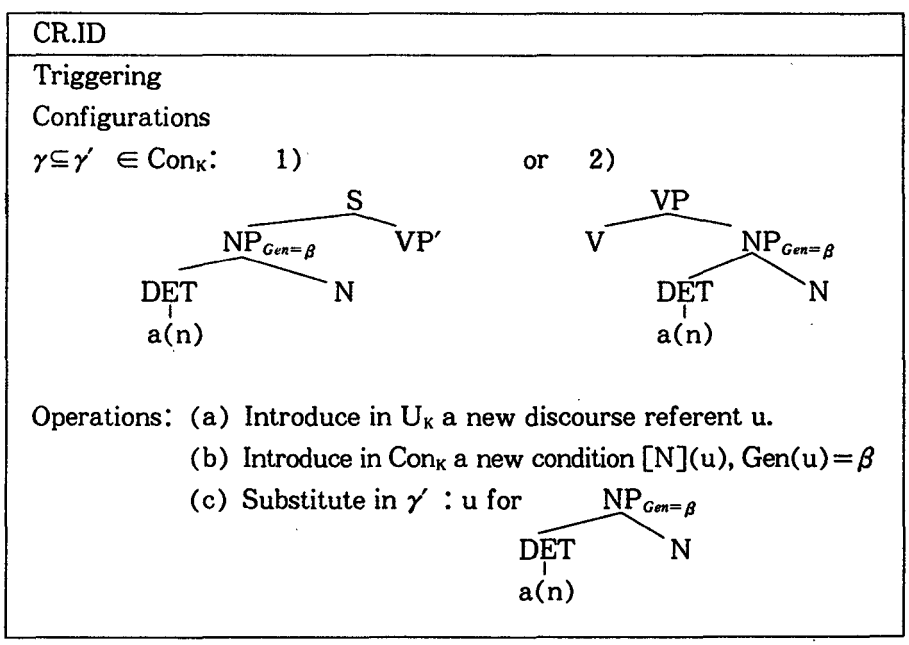
[8] This construction rule is a revised version of the rule given in Kamp & Reyle (1993).

(16a′)



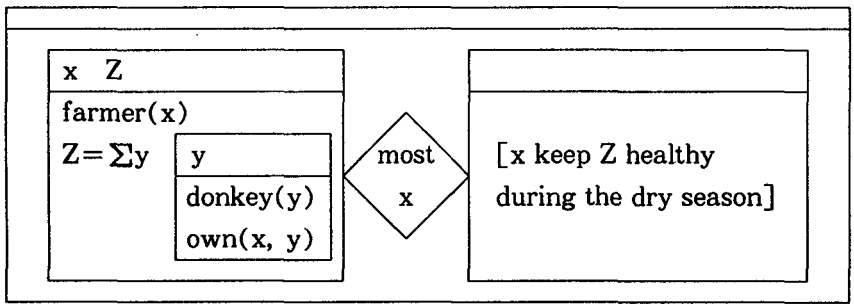
Then the RC will trigger (CR 1a) to apply, and the CR for indefinite NPs, (CR 3),[9] will be applied to *a donkey*, to get (16a″):

(CR 3)



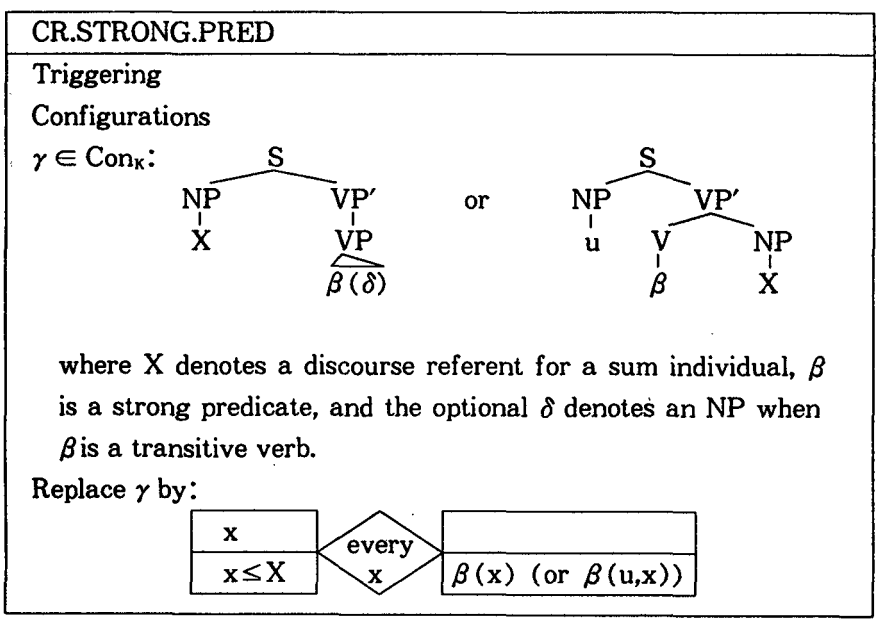
[9] This rule is a slightly revised version of the rule given in Kamp & Reyle (1993).

(16a″)



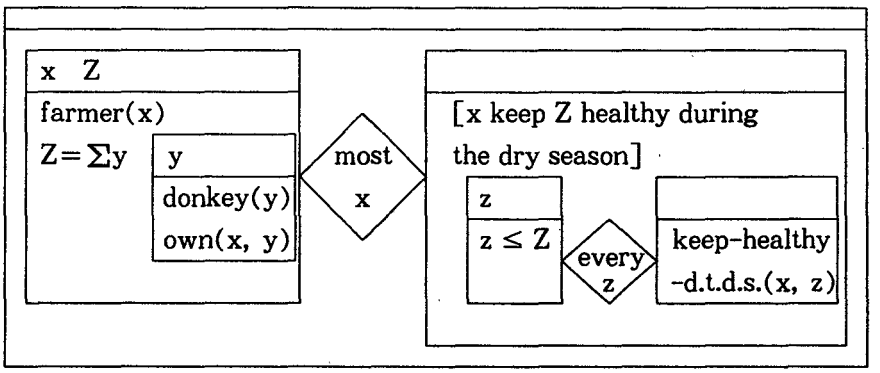
The condition in the consequent DRS will be further reduced by the CR for strong predicates, (CR 4)[10], to get (16a‴):

(CR 4)



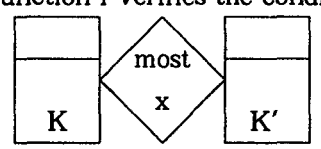
[10] (CR 4) for strong predicates and (CR 5) for weak predicates are my innovations.

(16a''')



If we call the antecedent box DRS K and the consequent box DRS K′, then the truth of DRS (16a''') will be defined:

A function f verifies the condition

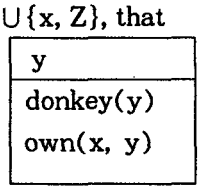


in M iff:

most({g | f ⊆ g ∧ Dom(g)=Dom(f)∪U(K) ∧ g verifies K in M})
({g | ∃h[g⊆h ∧ Dom(h)=Dom(g)∪U(K′) ∧ h verifies K′ in M}).

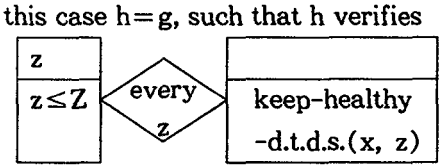
Therefore, a function f verifies (16a''') iff:

most extentions of g of f, where Dom(g)=Dom(f)∪{x, Z}, that verify the conditions in K, farmer(x) and z=Σy



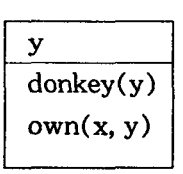
,

can be extended to h, where in this case h=g, such that h verifies



.

A function f verifies Z=Σy

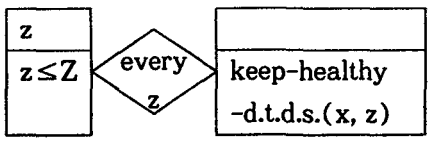


in a model M iff:

f(Z)=σa∃g[f⊆g ∧ Dom(g)=Dom(f)∪{y} ∧ g(y)=a ∧ g(y) ∈ F(donkey) ∧ g(x, y) ⊆ F(own)].

$\therefore f(Z) = \sigma a$[a are the donkeys that x owns].

A function f verifies



in a model M iff:

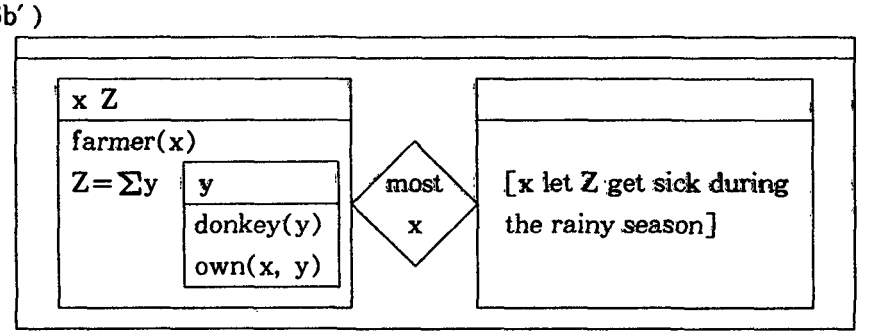
$$\text{every}(\{g \mid f \subseteq g \wedge \text{Dom}(g) = \text{Dom}(f) \cup \{z\} \wedge g(z) \leq F(Z)\})$$
$$(\{g \mid \exists h[g \subseteq h \wedge \text{Dom}(h) = \text{Dom}(g) \cup \{\phi\} \wedge$$
$$h(x, z) \subseteq F(\text{keep-healthy-d.t.d.s.})\}).$$

Now consider sentence (16b), which is repeated in the following:

(16b) Most farmers who own a donkey let it get sick during the rainy season.

Sentence (16b) is exactly the same as sentence (16a), except for the fact that it involves a weak predicate in the nuclear scope. Hence we apply the same rules, the CR for quantified NPs (CR 2), the CR for asymmetric readings of donkey sentences with relative clauses (CR 1a), and the CR for indefinite NPs (CR 3), to get:

(16b′)



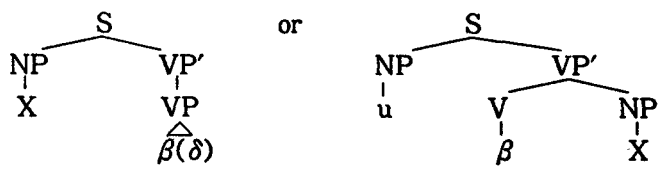
Then apply the CR for weak predicates (CR 5) to get (16b″):

(CR 5)

CR.WEAK.PRED

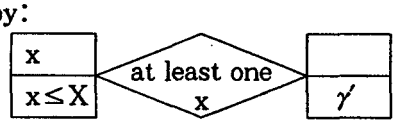
Triggering Configurations

$\gamma \in Con_K$:



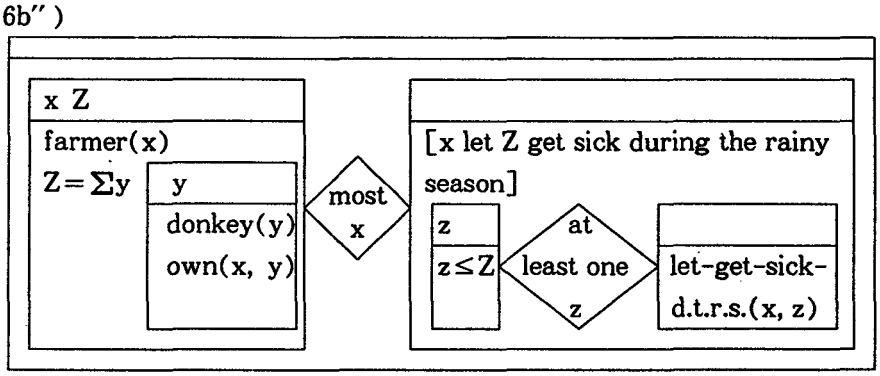
where X denotes a discourse referent for a sum individual, β is a weak predicate, and the optional δ denotes an NP when β is a transitive verb.

Replace γ by:



where γ' results from γ by substituting x for the NP which is the mother node of X.

(16b″)



5. 3. Conclusion

I have shown above how the consequences of my proposal can be rendered in semantic representation by means of DRT. In doing that, I have shown that in donkey sentences with an asymmetric reading, we can avoid the "accessibility" problem by introducing a new discourse referent for the sum individual to the antecedent DRS. Furthermore, I have provided a for-

mal representation for the weak and strong interpretations of the sum individuals predicated in the nuclear scope.

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