PARSING AND INTERPRETING QUANTIFIERS WITH *GETARUN*

Denise Dibattista, Emanuele Pianta, Rodolfo Delmonte

Section of Linguistic Studies - DSAO

Università Ca' Foscari - Ca' Garzoni-Moro
San Marco, 3417 - 30124 Venezia (Italy)
Tel.:041-2578464/52/19 E-mail:delmont@unive.it
WebSite:byron.cgm.unive.it

Abstract

GETARUN the system for text understanding developed at the University of Venice contains an integrated set of algorithms to compute quantifier scope efficiently. The algorithm for Quantifier Raising is coupled to a procedure that checks whether a given utterance may be interpreted as generic assertion on the basis of a certain number of linguistic conditions dependent on tense, mood, frequency temporal adjuncts etc. Then QR is started and in case quantifiers need to be given scope this will be indicated by introducing an operator-variable pair in the f-structure. This information is then used by the algorithm of Pronominal Binding in order to find antecedent-pronominal pairs. Subsequently, the Discourse Level Anaphora Resolution Module may inherit information modified by the presence of a quantifier. The Semantic Interpretation Module will look for scope information when applying semantic rules for the creation of semantic individuals. This distributed architecture allows a treatment of quantifiers which is then finally recorded in the unscoped Discourse Model, which is used as input for both the Generation and the Reasoning Modules.

1. Quantifier Raising

In our system, quantifiers are assigned scope at f-structure level, before entering the anaphoric binding module. In this way, NPs which fall under their scope may have received a quantified interpretation thus allowing for their number to be left unspecified. Consider as an example sentences like,

1a. The women who were carrying a baby each, dropped them.
b. Three women who were carrying a baby each, dropped them.
c. The women who were carrying a piano, dropped it.
d. A woman who wants to marry every man, doesn't have to disappoint them.

In these examples, as in donkey sentences, the antecedent of the pronoun *them/it* is contained within a restrictive relative clause, and is an indefinite NP *a baby* which is in the scope of the universal distributive quantifier *each* or itself a universally quantified NP, *every man*.

Two things should happen in a./b. in order for the indefinite NP to be taken as antecedent for the plural pronoun: the number of the indefinite NP should be neutralized to allow for anaphoric binding. Besides, whereas in b. cardinality of the babies is inherited from the quantifier which has scope over the indefinite NP, in case a. the cardinality of the indefinite NP should be entirely determined by contextual conditions in the discourse model. The same thing might have happened in case the antecedent were in a separate clause, subordinate or coordinate clause, or even a nonrestrictive relative clause. Remember that the net result of the binding module, is to prevent the pronoun to pop up at discourse level as a free external pronoun. In case the indefinite NP has distributive reading, it will be computed as a set; otherwise, a new individual will be asserted in the world. Finally in d., the quantified NP can bind the reference of the plural pronoun *them*.

Also definite NPs may be understood as being in the scope of some quantified expression: however, this might either be the result of external knowledge of the world in some case or the presence of a possessive:

2a. Every husband loves his wife
b. Every/each man left the bar at ten
c. Every man wants to buy the car of his dreams

As may be easily noted, both in a. and c. the definite NP may be understood as quantified owing to the fact that the universally quantified NP has scope over it and there is a possessive pronoun bound to it. On the contrary, in b. we might surmise that there is only one bar and the men left it all at the same time. At f-structure level, this fact can only be explained in case we take grammatical functions as carrier of structural information. In all examples, the dominance relation is determined by the presence of a SUBJect quantified NP and an OBJect definite NP. In addition, in a. we have a case of generic

assertion; in b. on the contrary, a specific spatiotemporal location anchors the main relation and its arguments; finally, in c. an intensional predicate "want" makes the reading of the main relation "buy" opaque and devoids it of a specific anchoring, as was the case with 1d. above.

Given the fact that anaphoric binding should capitalize on the results of the module for quantifier scope assignment, we compute quantifier raising before anaphoric binding and after syntactic binding. This has already been discussed in Delmonte, 1990, where we also stated how we followed Halvorsen's proposal in his paper on semantics(1983). The algorithm for quantifier raising operates on f-structures and proceeds as follows:

a. quantified NPs are individuated from the content of their Spec: the "quant" attribute should be present and filled with some value;

b. a q-marker or quantified variable is added at f-structure level;

c. the quantifier/s is/are raised by a recursive procedure which stops at the first q-barrier: a q-barrier is simply the first closed grammatical function f-commanding the f-structure in which the quantifier is construed. A q-operator is added at this level in a list which has q_ops as functional attribute;

d. the same applies to indefinite NPs, which are locally disambiguated: not every indefinite NP can be treated as a quantifier;

e. when we come to definite NPs, these are computed as indefinite quantified NPs in case a number of conditions are met, as specified above;

f. finally, we might end up with a list of q-operators which has more than one member: at this point we only want to swap their linear order in case the quantifying force of the first q-operator is less than the force of the second, and so on;

g. in the remaining cases we take the quantifier which is higher at f-structure or it has been assigned the hierarchically higher grammatical function - where SUBJect is the highest - to assume scope of the remaining q-operators. The result is marked at f-structure level with the attribute-value pair "interpretation:quantified".

The same procedure applies to wh- words in case they appear in the same proposition where a quantified NP is present: they behave like indefinite NPs. The well-known subject-object asymmetry applies to both types of elements(see Delmonte, 1990), as shown by the following examples:

3a. Who bought everything for the party?

b. What did everybody buy for the party?

where the universal quantifier may assume higher scope than the wh- word in case they are both contained within the same proposition and the wh- word is not in a chain with a SUBJect. As we said, we simply compute wh-binding and establish a syntactic chain by coindexing: in this way we do not need to go through reconstruction of the wh- element into the extraction place.

Here below we show the output of the parser on a typical example of donkey sentences, where a universal quantifier takes scope over an indefinite NP and arbitrary reading is produced: this can be read out at propositional level, where the attribute perf(ormative) is present:

```
8. [every farmer who owns a donkey beats it]
perf:generic
index:f6
pred:beat
lex_form:[np/subj/agent/[human], np/obj/theme_aff/[human,
animate]]
mood:ind
tense:pres
cat:activity
subj/agent:index:sn2
        cat:[human]
        pred:farmer:[gen:mas,num:sing,pers:3]
        spec:def:'0':[part:-,quant:every]
        interpretation:arbitrary
        mods:mod/predic:topic:topic_type:relative
                    index:sn5
                    cat:[human]
                    pred:who:[gen:mas,num:sing,pers:3,case:nom]
                    controller:sn2
                     tab_ref:[+ ref, + pro, + ana, - me]
                perf:generic
                   index:f5
                   pred:own
                    lex_form:[np/subj/owner/[human],
np/obj/actor/[human,animate,object]]
                   mood:ind
                   tense:pres
                   cat:state
                   subj/owner:index:sn24
                               cat:[human]

pred:pro:[gen:mas,num:sing,pers:3,case:nom]
                               spec:def:+
                               controller:sn5
                                tab_ref:[+ ref, + pro, - ana, - me]
                   obj/actor:index:sn26
                            cat:[animate]
                            pred:donkey:[gen:neut,num:sing,pers:3]
                            spec:def:-
                            subj/nil:index:sn29
                                    pred:vbl
                                    controller:sn24
                                     tab_ref:[+ ref, - pro, - ana, - me]
                             tab_ref:[+ ref, - pro, - ana, + class]
                            qmark:q2
                            interpretation:quantified
                   aspect:state
                    rel1:[td(f5_es06)=tr(f5_es06)]
                    rel2:[included(tr(f5_es06), tes(f5_es06))]
                   specificity:-
                    ref_int:[tr(f5_es06)]
                   qops:[q2]
        tab_ref:[+ ref, - pro, - ana, + class]
        qmark:q1
obj/theme_aff:index:sn35
         cat:[object, animate]
         pred:it:[gen:neut,num:sing,pers:3,case:acc]
         spec:def:+
         tab_ref:[+ ref, + pro, + ana, + me]
         antecedent:sn26
aspect:activity
rel1:[td(f6_es06)=tr(f6_es06)]
rel2:[included(tr(f6_es06), tes(f6_es06))]
specificity:-
ref_int:[tr(f6_es06)]
qops:[q1]
```

As said above (but see also Pollack & Pereira, 1988:83-84), at first QR applies adding q-markers q1 and q2, locally for each quantified f-structure; then an operator is raised accordingly at propositional level; Modifiers, Attributes , and Predicative Adjuncts in NPs have their quantifiers raised as higher as possible, i.e. in coincidence with closed GFs or complements.

Finally, quantifier scope is executed and a functional annotation is added where required. In our case, the f-structure where the indefinite NP "a donkey" is described receives the annotation, interpretation:quantified.
Then, anaphoric binding is computed and pronouns are coindexed with their possible antecedents: in our case, the pronoun "it" is coindexed with the NP "a donkey" contained in the relative clause. F-command is suspended in this case and the relative portion of f-structure is made visible to the binding algorithm by a specific call.
At this point, the algorithm for arbitrary interpretation is called and functional annotations are added both at NP level and at propositional level with the attribute-value pair perf:generic. These annotations are used by the model as well as by the interpretation to compute adequate representations for the situations described by the utterance. In particular, as discussed at length here below, arbitrary readings arise owing to tense and aspect specifications and will produce - in case it is lacking - a quantification over events or states, so that we can understand that a given event/state will hold at any temporal location, assuming a specific anchoring for spatial locations. In turn, an arbitrary reading for an NP amounts to computing a quantified NP where we are dealing with a "class" rather than with sets of or singleton individuals - in other words, reference in the world is suspended and there is no specific set or group of people we are referring to. Though, since we describe classes as infons, we always intend them to be classes of individuals or entities related to some spatiotemporal coordinate, and not universally valid. In addition, a generic assertion is usually the subjective statement of some individual or other, and is computed from a given perspective.

1.1 Generic vs Specific Quantifiers

Generally speaking, all quantifiers can enter into specific or generic readings according to temporal and aspectual interpretation at clause level. This interpretation may in turn be propagated or inherited by other clauses, in case the quantifier be the head of a chain. Consider well-known examples such as:
4a. Everybody loves the films he saw.
b. Everybody thinks he is a nice fellow.
In a. the embedded clause “he saw” can no longer be interpreted as specific in reading (or extensional) because the pronoun “he” is bound to a quantifier and this chain is assigned arbitrary reading due to the temporal aspectual interpretation of the matrix clause. The same would apply to the definite plural NP “the films” which cannot be used to cospecify with some entity existing in the discourse model, nor can it be used to establish a new set. The same would apply to the “he” in b. which at least in one interpretation must be taken to be bound to the quantifier and assigned arbitrary reading.
Another well known set of examples is constituted by indefinite NPs which can be assigned specific or generic reading according to domain restrictions. In particular, two cases can be found:
5a. the indefinite NP is in the scope of a distributive universal quantifier and is itself quantified;
b. the clause with the indefinite NP is governed by an opaque predicate like “want, intend, prefer, expect, etc.”;
in both cases no specific reading for the indefinite NP is available, as shown by the following examples,
6a. John dates every woman who love a fish.
b. Tom expects to catch a fish and wants to fry it for dinner.
In both cases, the indefinite NP will refer to generic sets or to classes of individuals with a given class restriction, "fish". In the model, both the relations and the participants in the relations are computed as sits, not as facts, thus indicating that there is no extensional reading available for them but only an intensional one. To check this, consider possible continuations:
c. Everybody loves the films he saw. *They were by Fellini.
d. Tom expects to catch a fish and wants to fry it for dinner. *It was a sole.
Habitual or generic modality characterizes propositions about genera which do not pertain to specific individuals at specific time-place locations, or else pertain to referential individuals (subjects) with respect to which a proposition in the habitual modality holds true. No claim is made about an event spatiotemporally anchored. In both cases, universal quantification on events is involved: in the model, we introduce a quantification on events if lacking, in the form of a quantifier like "always" or "usually".
See the difference in interpretation ensuing from the presence of specific antecedents in the text,
7A. C’erano una volta tre porcellini che vivevano nella campagna./Once upon a time there were three little pigs who lived in the countryside.
B. I porcellini decisero di costruirsi una casetta ciascuno.
The little pigs decided to build a little house each.
In this case a set of houses is asserted in the discourse, its cardinality being determined by the cardinality of the owner’s set, “the little pigs”.

2. Quantifiers and Anaphoric Binding

2.1 Quantifiers and f-command

As a first approach to the problem of quantifiers, the algorithm for anaphoric binding takes care of precedence whenever a quantified NP is indicated as possible antecedent for a pronoun. Quantified antecedents are individuated by the presence of the q-marker introduced by the algorithm for QR.
However, when we want to deal with quantifiers and quantified NPs as possible antecedents of little pros, clitics or independent pronouns, a different procedure must be called in, which should prevent the pronoun

from taking them as possible antecedents in case they are not f-commanding it.
In this way we can account for lack of coreference between a clitic pronoun contained in a fronted subordinate clause and a quantified NP contained in the main clause, as in the a. example
8a. When I insulted him, every student went out of the room.
b. When I insulted him, John went out of the room.
as opposed to the b. example, where coreference is allowed as usual. As said above, quantifiers can bind pronominals in case they precede them.

2.2 Quantifiers as Pronominals

In our system, all [+ana] marked pronouns do not possess intrinsic reference, being also marked [-ref] and two consequences ensue: they must be bound in their sentence and cannot look for antecedents in the discourse, unless there are additional conditions intervening, i.e. tense must be specific and not generic, mood must be real. Else, they can be assigned ARBITRARY interpretation, when a controller is lacking, and a series of semantic conditions are met as to tense and mood specification. Since ARBITRARY interpretation is a generic quantification on events this can be produced with untensed propositions or tensed ones, but with no deictic or definite import. The notion of binding relevant for quantifiers, is shown by the pair
9a. A woman requires/demands that many/every men be in love with her, *and John knows her.
b. A woman believes that many men like her, and John knows her.
in a., in English as in Italian, the indefinite *a woman* is computed as generic in the main clause and the same happens to the pronoun *her* in the complement clause introduced by *that*. However, the conjoined sentence contains a presuppositional predicate "know" which requires its complement to be existing in the world, the pronoun "her". The only antecedent available for the pronoun is the NP "a woman": but in this case, the antecedent should be computed as referential and not as generic, so the result is ungrammaticality. The opposite happens in b., where the indefinite is taken to refer to a specific woman in the discourse, and the two occurrence of *her* are to be bound to this individual. As clearly shown, the referential capabilities of pronouns are tightly linked to the ones of their antecedent: but the opposite may happen, i.e. the referential abilities of the antecedents are bound by those of the pronouns, and these in turn are conditioned by the referential nature of the RD- referential domain - in which they are contained: an [-BOUND] domain is one containing indicative mood and reference is free, whereas a [+BOUND] domain is one containing subjunctive mood and reference not free but locally bound, for anaphors, or lacking in referential import for lexical pronouns.
With plural pronouns, the algorithm checks at first whether there is a single plural antecedent, if not, as a second move, indefinite expressions and quantifiers are searched for. This would apply for such simple cases which dub similar examples used by Webber(1983) as,
10.Ogni uomo in Italia vuole comprarsi la Ferrari, perché sono auto molto di moda/Every man in California wants to buy a Ferrari because they are very fashionable.
However, we find some of Webber's examples(hers D18-3/4) too contrived to constitute well-formed English cases, which we report here below:
11. a.Three men who tried to lift a piano dropped them
b.The three men who tried to lift a piano dropped them
The absence of the quantifier "each" which contributes to the distributed reading, makes these examples quite awkward - to say the least, considering also the fact that lifting a piano in the commonsense world requires more than one man, unless he is a gorilla.
If we look at pronouns, they may be free, controlled or bound. A pronominal is bound only when its antecedent is a quantifier, a quantified NP or in case no controller is available at sentence level, a number of semantic conditions are met at the level of tense and mood specification and arbitrary reading is assigned to the whole proposition. In the latter case, Italian provides both for empty pronominal expression like a little pro, or a big PRO; as well as for lexical pronouns, like the nominative clitic ***si*** roughly corresponding to English "one". Sentences with arbitrary or generic reading can in turn be assigned either universal quantification or existential quantification: only in the former case, when introduced in discourse, they may be iterated without producing incoherence.

3. Quantifiers and Discourse Anaphora

It is a well known fact that quantifiers and quantified NPs do not refer in the text or discourse, in the sense that they are unable to pick up a specific individual as antecedent to which they may corefer. However, when computing reference, quantifiers either lexically expressed or unexpressed may be used by speakers to continue the topic of discourse.
Are quantifiers and quantified NPs like other referential expressions? A first answer requires the two to be set apart:
a. Quantified NPs behave like ordinary NPs in that they may be treated as referential or not according to domain restrictions;
b.Quantifiers are different in that they do not possess any explicit set restriction and may only individuate broad classes defined in terms of selectional restrictions of their governing verbal predicate. Domain restrictions are crucial in the determination of what quantifiers may contribute to text or discourse.
We can identify two main cases:
CASE 1. Domain restrictions may trigger two different strategies:

- A quantifier is computable as a referential entity, which however requires as antecedent a superset of the sets or individuals previously made available in the text or discourse;
- A quantifier is itself used as such a superset and the following definite NPs may corefer with it.

CASE 2. Domain restrictions may prevent any of the two previous strategies to apply and impose a non referential or arbitrary reading.

3.1 Quantifiers and quantified NPs as coreferents

In her works, Webber(1977, 1983) extensively deals with the problem of the interpretation of quantified expressions and their role in binding coreferring pronouns. In order to decide whether a singular indefinite expression can be treated as a plural one, scope must be computed: in particular, its scope must be included in that of a universal quantifier with a distributive reading. We shall quote one of her examples(1983,363-d25):

12.i Last week Wendy bought each boy a green T-shirt at Macy's.

ii She prefers them in more subdued colors, but these were on sale.

13. Most people who own a gun a. never use it

b. never use them

This is a typical example which requires at first scope assignment to be computed for the two quantified NP's, "each boy" and a "green shirt". As Webber remarks, a definite plural anaphor may also specify a generic set entity and this is possible even with a singular definite noun phrase as antecedent. The only condition seems to be procedural and based on "recency": quoting from Webber, ".. the listener can generate new generic-set entities whose IDs are based on generalizations of a recent description the listener has either heard or derived." the only restriction being constituted by the fact that these generalizations must somehow be shared by the speaker. We might add that such a generalization is reached through the interpretation process: a generic reference to a definite description is interpreted as such if it is not referential. In other words, there are strong restrictions to interpret an assertion as a generic statement, and they mainly concern the interpretation of tense and its modifiers. In order to compute the reference of a definite NP as generic, tense cannot be specific, and adverbial modifiers cannot be deictic. This is clear if we look at some of Webber's examples(hers d22 through d28), as for instance(the underlining is mine):

14.1 Last week Wendy again bought each boy a green T-shirt at Macy's.

2 She's always buying them.

15.1 I see seven Japanese cars in the parking lot.

2 They're really selling like hot cakes.

16.1 Last week Wendy bought each boy a green T-shirt at Macy's.

2 She gives them to everyone.

17.1 Wendy bought some T-shirt yesterday.

2 Usually she charges them, but yesterday she paid cash.

18.1 Wendy wouldn't buy a green T-shirt, because they always run in the wash.

All the items underlined are either the main verb or the adverbial modifier: tense is simple present, or progressive, and adverbials are "always, usually, really". The intended meaning conveyed by the sentences in 2. is iteration on events, the events are those of buying, selling, charging, giving. In other words it is quantification on events introduced by tense and adverbial modifiers which acts on propositions, just like quantifiers and determiners act on NPs(see Hinrichs, 1988; Bianchi & Delmonte, 1989a).

Consider now a short text in which quantifiers are introduced both as antecedents and as coreferential expressions: the story tells about habitual activities people used to carry out in a region big enough to encompass a microcosm in which the participants of the story feel as their only possible world in which they are trapped.

Text A.

"1.Everybody used to sow hemp, and then they laid it to rot in the river, and from that they got the hemp ready to be spinned. 2.Only on Sundays one (the people) did not work, one (the people) did not spin. 3.But Monday morning the women had to wake up at three - my father's sisters did so - to spin the cloth they hadn't spinned Sunday night. 4.Also when husking corn-cobs, they used to wake up at three on Monday, to make up for lost work on Sunday night. 5.The young used to go and check whether the girls worked, if they spinned: 6.the lazy girl did not get married."

In utterance 1. we see that we are dealing with a habitual event occurring in the past and the subject is a universal quantifier which binds a number of pronouns in the following conjoined sentences. In utterance 2. "one" or "the people" should be made to corefer with the generic set of individual characterized by a class membership to "human", the subject NP of the predicate "sow". However, when we get to utterance 3. we are in serious trouble because the subject NP is the plural "the women", which should be understood as a subset of "the people" or the impersonal "one". Notice that in this utterance tense specification as well as aspectual and semantic attributes of the main predicates indicate the passage from a habitual into a more specific description. Also the temporal adverbial "Monday morning" no longer indicates habituality, as happened with "on Sundays" in the previous utterance. The same applies to the parenthetical "my father's sister did so", where the same inference should be triggered: from a generic class specification "everybody", "one", "the people", we pass through inclusion into "women", and now into a specific instance of a woman, a "sister". Finally in utterance 5. we go back to the general entity "the people" in order to infer that "the young men" are in an inclusion relation, and that we are still analyzing the behaviour of a subset

of the people indicated by the universal quantifier at the beginning of the text. The NP "the girls" however, should be understood as cospecifying "the women" again through an inclusion relation. The final generic assertion is expressed in the past and simply means that at that time it was habitual to have that kind of situation hold for a girl.

4. Quantifiers and Interpretation

As Cooper comments (1991, 39), the computation of quantifier scope is one of the central problems to be solved when building a general system: however, there is then the further problem of what to do with the correct scopings thus obtained. It is clearly much better to have QR rather than not having it. However, scopings is not all there need to be as to contextual information necessary to compute quantified interpretation: in particular, in the case of indefinite NPs local information might not be sufficient. The general framework as to the relation intervening between quantifiers and interpretation which can be gathered from the previous sections, can be summarized as follows:

i. since we work from a linguistic perspective, we assume interpretation to be the by-product of the processes independently set up by a certain number of modules organized in a given sequence which might be paraphrased as follows: lexical properties of categories and predicates associated with the input sentence conspire to produce an adequate syntactic and functional representation for the utterance which contains all information to be passed to discourse and interpretation modules;

ii. as a consequence, we take antecedent-pronoun relations to be represented by a coindexing which is computed by a separate module, the one of anaphoric binding;

iii. quantifiers as antecedents of pronouns are computed accordingly as other coindexing relations: interpretation of quantifiers relies heavily on propositional properties and other grammatical issues, such as grammatical function, predicative relations, etc.

iv. generic statements are treated as non-factive clauses in that they don't contribute direct facts to be added to the model: their main relation is quantified over by some temporal quantifier that suspends its extensionality in space and time, and quantifies over spatiotemporal locations(see Barwise, 1985:3);

v. definite noun NPs do not assert the existence of some individual, they only refer to it and in doing so they presuppose its existence(see Hess, 9). They do not even assert the uniqueness of the individual. The use of the definite article with singular NP for generic statements presuppose the existence of the concept referred to, an intensional rather than extension assertion(see Chapter VII).

vi. indefinite NPs may be computed as quantified NPs in case they fall under the scope of some quantifier and the proposition they are in has been interpreted as a generic statement; or else they may be computed as quantified NP and receive cardinality from the quantifier that has scope over it, as discussed at the beginning of this section; finally their interpretation may be suspended : in this case, the system generates the description of a undefined entity which is converted in the following discourse either in an individual - in case some singular definite NP is used to corefer with it, or as a set - in case no such definite NP is used, or the NP is plural or quantified. Tense may contribute an existential reading if the main verb is in the past tense, in the progressive tense or in the perfective aspect; it will contribute a non factual or generic reading in case main verb is in the future tense or in the present tense. The same will apply with modality.

In turn, quantifiers and quantified NP may contribute either a collective or a distributive reading for the participants in the event denoted by the main relation. This will cause participants to be involved in a single event or in multiple events according to the semantic features of the main verbal predicate.This depends on the role of participants and their semantic nature, and requires the solution of the problem of interpreting the internal structure of the event in which participants are involved. As we know, subevents are different according to the type of event and in turn this may be characterized on the basis of conceptual representation as instantiating a certain template.

Adequate lexical information is then needed to account for the interaction existing between the interpretation of the event/participants relation as defined above and the internal structure of the event. The mapping from participants to event structure requires conceptual representation of subevents be adequately mapped onto the inferential engine of the reasoning module.

4.1 Uniqueness and Genericity

As to the number of remaining problems, we subscribe to what R. says about determiners and distributivity: in other words, it seems possible to classify NPs according to the nature of their determiners. In this way, compositionality should be preserved when computing semantic interpretation. Coming now to the problem of "uniqueness" raised and discussed among others in Heim(1990) and Kadmon(1990), this is treated in our model as follows:

vi. we split the problem of characterizing indefinites into two parts: the description of the individual and the function applying over the relation in which that individual is involved. As to the description of the individual, in case it is an indefinite quantified over by some operator, be it an "if" modal operator, or another NP, quantified or quantifier itself, the system computes at first an "entity" description with a class restriction in the form of infon, i.e. a sit with a polarity and spatiotemporal location indices; this entity might become an individual or a set in the following text in case some pieces of information are made available about that individual.

Note that this treatment is not available for indefinite NPs contained in generic assertions: in this case the interpretation is straightforward. Let's take the example whose f-structure was shown above,

20. Every farmer who owns a donkey beats it.

the meaning we want to get is approximately the following,

- there is an indefinite set of farmers and an indefinite set of donkeys which are however contextually bound by spatiotemporal indices - indefinite sets are described by the attribute "class" in our model which have as cardinality the value of the quantifier associated to the "card" attribute;
- there is a one-to-one function that applies on the owing relation and the beating relation requiring its arguments to be thus distributed;
- there is a quantification over events which is the unexpressed "always" that quantifies over the spatio-temporal locations of the event described by the main situation; the owing event is computed as being implied by the main situation. This might be an overgeneralization: in fact, the spatial location might be simply inherited from the previous text and thus equated with the one computed for the subject uttering the generic assertion, since we always want utterances to be associated to a perspective or other. In that case, the index corresponding to the spatial location would be filled rather than corresponding to nil. As to temporal locations, its event/state time is the location whose reference time which might be included in some more comprehensive main location inherited from the previous portion of text. Suppose now that we are in 1950, in Boston, and these are the actual main locations, this might be the description of the utterance in the model as produced by our system:

loc(infon1, id1, [arg:main_tloc, arg:1950)
loc(infon2, id2, [arg:main_sloc, arg:boston)
fun(id9, one_to_one, [arg:id3, arg:id4], 1, id1, id2)
quant(id9, always, [main_tloc:id1, main_sloc:id2], 1)
sit(id9, imply, [arg:id7, arg:id5], 1, id1, id2)
class(infon1, id3)
card(infon2, id3, every)
sit(infon3, isa, [ind:id3, class:farmer, 1, id1, id2)
sit(infon4, isa, [ind:id3, class:man], 1, id1, id2)
class(infon5, id4)
card(infon6, id4, some)
sit(infon7, isa, [ind:id4, class:donkey], 1, id1, id2)
sit(infon8, isa, [ind:id4, class:animal], 1, id1, id2)
sit(id5, own, [owner:id3, actor:id4], 1, tes(f5_aa1), id2)
sit(infon13, isa, [arg:id5, arg:ev], 1, tes(f5_aa1), id2)
sit(infon14, isa, [arg:id6, arg:tloc], 1, tes(f5_aa1), id2)
sit(infon16, time, [arg:id5, arg:id6], 1, tes(f5_aa1), id2)
sit(id7, beat, [agent:id3, theme_aff:id4], 1, tes(f6_aa1), id2)
sit(infon17, isa, [arg:id7, arg:ev], 1, tes(f6_aa1), id2)
sit(infon18, isa, [arg:id8, arg:tloc], 1, tes(f6_aa1), id2)
sit(infon20, time, [arg:id7, arg:id8], 1, tes(f6_aa1), id2)
included(tr(f6_aa1), id1)

5. Quantifiers and Ambiguous or Negated Antecedents

We will comment on some examples which could be a problem for our approach. They have all been extensively commented in the literature: in particular we shall draw from J.M.Gawron et al.(1991). The first example is the following one, which is their (87)

21a. Every student revised *a paper he wrote*. ≠*It* was accepted by L&P

b. Every student revised *a paper John wrote*. *It* was accepted by L&P

In example a. the anaphoric relation is impossible, while in b. it is. Example a. contains an indefinite NP which falls in the scope of the universal quantifier since it has a pronoun "he" bound to that quantifier; example b. contains an indefinite NP which is computed as specific, so it is able to escape scopal effects by the universal quantifier and be assigned wide scope.

The second example has a possessive pronoun bound by a quantified NP,

22a. Every boy washed his car. ≠I inspected it.

b. Ogni ragazzo ha lavato la propria/≠sua macchina. ≠Io l"ho controllata.

The first thing to notice is the impossibility for the NP "his car" to become the antecedent of a singular pronoun "it" in the following utterance. As the authors comment (ibid.,336), this is due to the fact that the possessive is bound to/is in the scope of the universal quantifier and thus there is no single individual available in the world for the pronoun to corefer to. Before looking at another example, let us comment briefly on the Italian version of 36. The long distance reflexive possessive pronoun "proprio" can be used in this context, because it can be bound to quantified antecedents; the personal possessive pronoun "suo", however is banned. In case we use "proprio" there is only one reading available: it is the same one made available in the Norwegian examples discussed by Sem et al.(1991), where the pronoun "sin" appears. We can also notice that, if we use "sua" in this context, it cannot possibly be bound by the quantified subject, but it will receive a discourse antecedent. In this sense, Norwegian "sin" and "hans" reduplicate Italian "proprio" and "suo" but only in quantified contexts.

We shall now comment on some examples involving negation and coreference,

23a. John didn't plant any daisies. They need water.

b. John doesn't have a car. ≠ It's green./≠ They are green

c. John doesn't have a car. They are too expensive./It's too expensive.

The semantic description of the content of the first utterance, omitting irrelevant details, is as follows,

class(infon1, id2)
card(infon2, id2, any)
sit(infon3, isa, [ind:id2, class:daisy, 1, univ, univ)
sit(infon4, isa, [ind:id2, class:[object]], 1, univ, univ)
ind(infon5, id1)
fact(infon6, isa, [ind:id1, class:man], 1, univ, univ)
fact(infon8, name, [john, id1], 1, univ, univ)
fact(id3, plant, [agent:id1, aff_theme:id2], 0,
tes(f5_free_aa1), univ)

In the following sentence, "daisies" is a possible antecedent for the pronoun "they": we assume that the

second utterance is a generic statement and coreference may be established between an entity which is a generic class, a sit and not a fact. However, in 38b. we see that coreference is blocked since we are trying to predicate a property which is an individual level predicate, or a permanent state inherently predicated of the subject: since we don't have a specific fact, or extensional entity in the world we cannot predicate extensional or objective properties with the aim of constituting a distinguishing property of that entity.
Coming now to 61c. we notice that the same entity "car" can be used as antecedent for a plural personal pronoun "they", and is also available for coreference by a singular pronoun. The reason is now clear: the kind of predication is no longer made by an adjective which represents an individual level predicate, but it is a stage level predicate, or an evaluative predication. Being "expensive" is not a pervasive property of cars: people who cannot afford one judge it so, and the inference we are now allowed to make simply tells us that John belongs to this group of people.
Finally let us take into account cases of opaque or intensional context, with an intensional predicate like "want", in the following examples,
24a. John thinks that he will catch a fish, and he hopes I will grill it tonight.
b. Every boy wants to eat a fish. ≠ It is boiled./≠ It is a sole./≠ They are boiled./ They are soles
c. John wants to eat a fish. ≠ It is boiled./ It is a sole./≠ They are boiled./ ≠ They are soles
d. Every boy ate a fish. They were boiled./They were soles.
In all a.-c. cases the indefinite is present in world only as an intensional object, and not as a fact: as in previous examples, we can only predicate a general property which is a stage level predicate and not an individual level property. Singular pronouns at intersentential or intrasentential level when they corefer to the indefinite NP indicate that it has been interpreted as an individual in the world which however is a sit and not a fact. Example d. has an indefinite in the scope of a universal quantifier as before, but the context is now transparent and referential: thus both types of predications are possible, and the pronoun must be plural.

6. The Quantifier Raising Algorithm

1. Find alla quantified NPs, i.e. filled quant attribute in the Spec subsidiary f-structure, and each time do:
- add a q-marker at PRED level
- raise in f-structure as higher as possible to assign the q-op (coinciding with the first q-barrier
2. The same applies to indefinite NPs

6.1 quantifiers_raising :-

```
np_quantified(QDescs),
add_qmarks(QDescs, NewQDescs),
raise_quantifiers(NewQDescs),
np_indefinits(IndefDescs),
add_qmarks(IndefDescs, NewIndefDescs),
raise_indefinites(NewIndefDescs),
solve_same_level_scope,
mark_quantified_interpretation.

raise_quantifiers([q(_, _, Nodo, Type, Qmark) | QDescs])
:-
  raise_quantifier(Nodo, Type, Qmark),
  !,
  raise_quantifiers(QDescs).
raise_quantifiers([]).

raise_quantifier(Node, Type, Qmark) :-
  node(NodeTo)::_::node(Node),
  (
  q_barrier(Type, NodeTo)
  ->
  add_qop(NodeTo, Qmark, Type)
  ;
  raise_quantifier(NodeTo, Type, Qmark)
  ).
```

Rather than simply adding a q-op, when indefinite NPs are scoped they need at first to be qualified as to the presence of opaque quantified barriers, i.e. propositional level boundaries which may be opaque or transparent according to the presence of certain linguistic markers.

```
mark_qop(Node, Type, Qmark) :-
  opaque_q_barrier(Type, Node),
  !,
  add_qop(Node, Qmark, Type),
  raise_indefinite(Node, Type, Qmark).

mark_qop(Node, Type, Qmark) :-
  q_barrier(Type, Node),
  !,
  add_qop(Nodo, Qmark, Type).
```

As extensively commented above, a q-barrier at propositional level is an assertion with indicative mood. Gerundives, Infinitives and Participials or Subordinate Clauses are treated accordingly. In case subjunctive mood is present, this case is typologically marked: in Italian, negative quantifiers may be raised through their propositional level barrier.

```
q_barrier(_, Node) :-
  node(Node)::mood::ind.

q_barrier(Type, Nodo) :-
  node(Node)::mood::subj,
  (gr(italian),
   not on(Type, [nessuno, niente]);
   gr(Language), Language\=italian).
```

6.2 Solving Scope Ambiguities for Same Level Quantifiers

Whenever two or more quantifiers are collected in the Qops List, they must be ordered according to their relative strength:
- ordering qops at the same level on the basis
  - of their relative strength
  - of their Grammatical Function
- eliminating double qops (changing from potential to effective qop)

6.3 Interaction between GFs, quantifiers, indefinite NPs and negation

- Generally speaking, a negative quantifier is raised to the same level of the negative operator if it is in the same scope;

- With the remaining quantifiers, GFs are used to spell out negation scope from quantifier scope: when GF is SUBJect or TOPic or FOCus, and their composite GF – SUBJ_TOP and SUBJ_FOC for languages like Italian which allow fully inverted structures, no scope is assigned to negation apart from the actual event meaning and the Affected Theme. This takes care with no additional cost of passive constructions be they canonical or marked, with inverted SUBJect as would be used in Italian and Chinese.

In case an indefinite NP falls in the scope of a distributive quantifier like "each", or an universival quantifier like "every, all", its number feature is neutralized (i.e. set to :nil), in order to allow for pronominal binding at sentence or discourse level of pronoun with singular or plural number.
If the indefinite NP is in the scope of a quantifier and the sentence has been assigned generic interpretation, then we add an attribute value pair, interpretation:arbitrary to prevent QR to apply (e.g. every farmer who owns a donkey, beats it).
FOCalized SUBJect indefinite NPs are to be treated as specific, not allowing plural interpretation and number neutralization (e.g. in the same place lived a terrible wolf).

```
np_quantified(Fun, Index, Node, Quant) :-
  node(Node)::tab_ref::[+ ref, -pro, -ana, Att],
  on(Att, [+class, +me]),
  spec_quantified(Node, Quant),
  node(Node)::index::Index,
  node(_)::Fun/Role::node(Node),
  quantifiable_function(Fun, Role).

spec_quantified(Node, Quant) :-
  node(Node)::spec::quant::Quant,
  Quant \= exist.
```

6.4 Quantifiable Functions

Grammatical function information allows the QR algorithm to select and filter appropriately quantifers contained in predicative vs. non-predicative functions which are contained in closed rather than open GFs. In addition, floating quantifiers, which have been computed as a case of open adjunct, are treated accordingly (e.g. they built a little house each).

```
quantifiable_function(adj, quantitative).

quantifiable_function(Fun, Role) :-
  grammatical_function(Fun, closed),
  Role \= nil.
```

7. References

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