Measurement and Quantification Revisited*

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Abstract

This paper reformulates the semantics part of our previous paper (Gunji & Hasida, 1998), which is notoriously obscure and hard to understand. Even though our arguments for the proposed analysis of the so-called 'floating quantifiers' in Japanese remain intact, the semantics is given in a relatively straightforward representation language called minimal recursion semantics (MRS) and thus another utility of the MRS representation will be shown.

1. Introduction

In Gunji and Hasida (1998), we discussed the treatment of so-called 'floating quantifiers' as adverbials. Thus, in the following sentence, the 'floating quantifier' *3-ko* '3-CL'[1] is an adverbial that modifies the verb *tabe-ta* 'eat-PAST'.

(1) Gakusei-ga ringo-wo 3-ko tabe-ta.
student-NOM apple-ACC 3-CL eat-PAST
'A student/students ate three apples.'

Semantically, the interpretation of the above sentence is very close to the following adnominal modification:

(2) Gakusei-ga 3-ko-no ringo-wo tabe-ta.
student-NOM 3-CL-GEN apple-ACC eat-PAST
'A student/students ate three apples.'

Syntactically, however, they have quite different structures:[2]

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[1] I will use CL for the gloss of Japanese classifiers. *ko* is a general purpose classifier to count discrete things.

[2] ADN stands for 'adnominal', a nominal modifier. Since only the constituency is at issue here, I use rather traditional category symbols such as S here.

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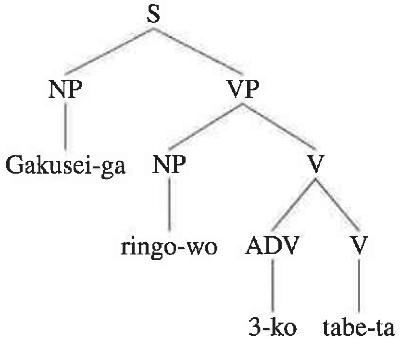
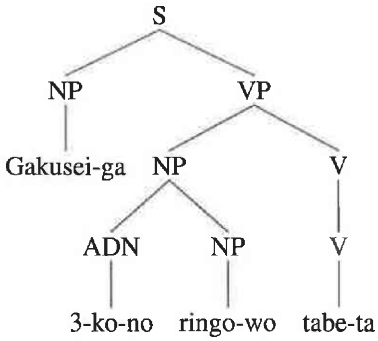
(3) a.



b.



In the following, I will give an explicit semantics for these sentences based on the idea of 'flat semantic' representation called *minimal recursion semantics* (Copestake, Flickinger, Pollard, & Sag, 2003). In essence, both (3a) and (3b) will be given the following semantic representation:

(4) h_1: **student**(x), h_2: **apple**(y), h_3: **eat**(x, y), h_4: **measure**(h_2, ko, 3)

The above representation intuitively says the following:

(5) a. there is an eating event labeled as h_3.
b. the event includes two arguments x and y.
c. the first argument x is a student/a set of students.
d. the second argument y is an apple/a set of apples.
e. the second argument is *measured* with respect to the dimension 'ko' as 3.

In the next section, I will first give a very brief introduction of minimal recursion semantics to the extent of explicating the notation used in this paper. Then, in Section 3, I will give the compositional semantics of both the adnominal and adverbial measurement phrases. In section 4, I will give an analysis of what we called *quantification* in terms of generalized quantifier. In Section 5, I will give an example to show how possible and impossible interpretations are derived in a systematic manner in this framework.

Due to lack of time and space, this short paper is not intended to be self-contained. In particular, I will not repeat the arguments we presented for taking particular approaches to 'floating quantifiers'. See Gunji and Hasida (1998) for relevant discussion.

2. Minimal Recursion Semantics

Minimal Recursion Semantics (MRS) is a framework for representing semantics used in computational treatment of natural language. Its advantages over other more traditional representation have been discussed by Copestake et al. (2003) and Egg and Kordoni (2004), among others. Essentially, the use of flat representation, as well as underspecified labeling, allows to express ambiguity in a concise way.

MRS is closely related to Davidson's (1967) event semantics. To take a simple example, in a Davidsonian semantic representation, the following sentence will have the semantic representation shown in (6b).

(6) a. Gakusei-ga ringo-wo tabe-ta.
student-NOM apple-ACC eat-PAST
'A student/students ate an apple/apples'

b. $\exists e \exists x \exists y\,[\text{eat}(e, x, y)\ \&\ \text{student}(x)\ \&\ \text{apple}(y)]$

where e is an event variable and x and y are individual variables.

The MRS representation for the above sentence becomes the following:[3]

(7) h_1: **student**(x), h_2: **apple**(x), h_3: **eat**(x, y)

where each predication is called an *elementary predication* (EP). Unlike the Davidsonian representation, no event variable is introduced but each EP has a *handle* that can be used when referring to the EP from other EPs. Apparently unbound variables are implicitly understood to be existentially quantified, and the comma-separated EPs are understood to be conjuncts of a conjunction.

The use of handles is not utilized so much in the above simple example. Take a sentence that involves a generalized quantifier such as *oozei* 'many':

(8) Gakusei-ga oozei ringo-wo tabe-ta.
student-NOM many apple-ACC eat-PAST
'Many students ate an apple/apples.'

The MRS representation will become the following:

(9) h_0: **many**(x, h_1, h_3), h_1: **student**(x), h_2: **apple**(y), h_3: **eat**(x, y)

where **many**(x, h_1, h_3) intuitively means that the number of x's that satisfy both the EP with handle h_1 and the EP with handle h_3 is large according to some criterion.[4] This corresponds to the generalized quantifier notation (10):

(10) $\text{MANY}(\text{student}, \lambda x\, \exists y\, [\text{apple}(y)\ \&\ \text{eat}(x, y)])$

(9) is 'flatter' than (10) in that the counterpart of the generalized quantifier **many** takes only an individual variable and handles (which are assumed to be of type e), while MANY in (10) takes two properties (of type $\langle e, t\rangle$) as arguments.

[3] The presentation of MRS in this paper is significantly simplified so that only the relevant portion for giving semantics for 'floating quantifier' is represented. See Copestake et al. (2003) for a fuller introduction of MRS.

[4] There are several ways to define this criterion, e.g., absolute value, say 1,000, or relative to the number of students, say, 2/3, etc. How to define this criterion is not at issue here. See Partee, ter Meulen, and Wall (1990) for such definitions.

Another utility of MRS is that it enables us to express ambiguous expressions in a concise fashion. For example, the following sentence (11) is ambiguous between the interpretation 'There are many students who didn't eat an apple/apples' and 'Not many students ate an ap-ple/apples'.[5]

(11) Gakusei-ga oozei ringo-wo tabe-naka-ta.
student-NOM many apple-ACC eat-NEG-PAST
'Many students didn't eat an apple/apples.'

(12) a. MANY(student, $\lambda x \neg\exists y$ [apple(y) & eat(x, y))))
'There were many students who didn't eat an apple.'

b. ¬MANY(student, $\lambda x \exists y$ [apple(y) & eat(x, y))))
'Not many student ate an apple.'

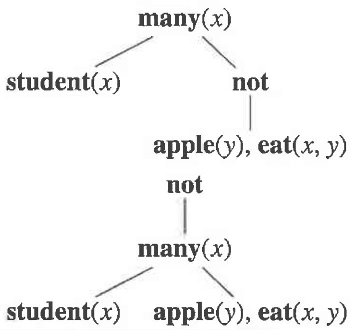
In the MRS representation, the sentence will be expressed in the following way:

(13) h_0: **many**(x, h_1, h_7), h_1: **student**(x), h_2: **apple**(y), h_3: **eat**(x, y), h_4: **not**(h_8)

Note that the two handles h_7 and h_8 are not associated with any EP. If we make $h_7 = h_4$ and $h_8 = h_3$, then we have the interpretation corresponding to (12a), where *oozei* has a wide scope. In such a case, we say **many** *outscopes* **not**. On the other hand, if we make $h_7 = h_3$ and $h_8 = h_0$, we have the interpretation corresponding to (12b), where the negation has a wide scope, i.e., **not** outscopes **many**. Thus the above representation captures the ambiguity without resorting to two different syntactic structures (e.g., LFs) or to additional semantic device (e.g., Cooper storage).

Graphically, these scopal relations can be represented in the following trees:

(14) a. b.



[5] The latter interpretation may be weak and must be supported by an appropriate context, e.g., when many students are expected to eat an apple but only a few did.

The sentence could theoretically have a third scope relation corresponding to the following formula:

(i) MANY(student, $\lambda x \exists y$ [apple(y) & ¬eat(x, y))))
'Many students have an apple that she/he didn't eat.'

I think this interpretation is hard to get from (11). So, there might actually be no existential quantification and conjunction suggested in (10), but rather a representation like the following would be more suitable:

(ii) MANY(student, eat-apple)

For this representation, there can be only two ways to put negation:

(iii) a. MANY(student, $\lambda x\neg$ eat-apple(x))
b. ¬MANY(student, eat-apple)

In the following, an MRS representation like (13) will be given a feature structure representation so that its relation with syntax (for which I assume an HPSG representation) becomes clearer. Thus, (13) will be represented by a feature structure like the following:

(15)

$$\left[\text{RELS}\left\langle \begin{bmatrix}\text{RELN} & \textbf{many}\\ \text{LBL} & \boxed{0}\\ \text{ARG1} & \boxed{5}\\ \text{RSTR} & \boxed{1}\\ \text{BODY} & \boxed{7}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{student}\\ \text{LBL} & \boxed{1}\\ \text{ARG1} & \boxed{5}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{apple}\\ \text{LBL} & \boxed{2}\\ \text{ARG1} & \boxed{6}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{eat}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{5}\\ \text{ARG2} & \boxed{6}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{not}\\ \text{LBL} & \boxed{4}\\ \text{BODY} & \boxed{8}\end{bmatrix}\right\rangle\right]$$

where the name of the predication is given as the value of the feature RELN (relation), and the handles are given as the value of the feature LBL (label). For the sake of simplicity, Each argument position of the EPs are simply called ARG1, ARG2, ..., rather than giving them such loaded names as AGENT, PATIENT, etc. For the (generalized) quantifiers, they have additionally two arguments: RSTR (restriction) and BODY (i.e., scope). As usual, the boxed numbers show structure sharing.

3. Adnominal and Adverbial Measurement

In this section, I will present compositional semantics for both adnominal and adverbial expressions in Japanese. As argued in Gunji and Hasida (1998), they will be analyzed as *measure phrases* and the key semantic component is the EP called **measure** with three arguments:

(16) a. h_4: **measure**(h_2, ko, 3)

b. $$\begin{bmatrix}\text{RELN} & \textbf{measure}\\ \text{LBL} & h_4\\ \text{ARG1} & h_2\\ \text{DIM} & \text{ko}\\ \text{NUM} & 3\end{bmatrix}$$

Intuitively, this gives the magnitude of the entity designated by the EP with handle h_2. Since the amount (the value of the NUM(ber) feature) depends on the classifier, the kind of classifier is given as the value of the feature DIM(ension). Thus, the above measure predication gives the magnitude of something measured as *3-ko*.

3.1 Adnominal Measurement

Let us consider a sentence with an adnominal measure phrase *3-ko-no*, (2), repeated here:

(2) Gakusei-ga 3-ko-no ringo-wo tabe-ta.
Gakusei-NOM 3-CL-GEN apple-ACC eat-PAST
'A student/students ate three apples.'

First, we assume the following semantic representations for common nouns:

(17) a. gakusei (-ga)

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{noun} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{5} \\ \text{LTOP} & \boxed{1} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{student} \\ \text{LBL} & \boxed{1} \\ \text{ARG1} & \boxed{5} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

b. ringo (-wo)

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{noun} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{6} \\ \text{LTOP} & \boxed{2} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{apple} \\ \text{LBL} & \boxed{2} \\ \text{ARG1} & \boxed{6} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

where the relations **student** and **apple** take either a set of individuals or an individual (i.e., a singleton set) as arguments.[6] The value of the HOOK feature collects necessary information to be used by other EPs. In addition to the usual INDEX, LTOP (local top) keeps the value of the handle of one of the constituents of the phrase (usually the (semantic) head).

A verb such as *tabe* 'eat' has the following representation:

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[6] As argued in Gunji (2000), I assume that Japanese common nouns essentially denote a class rather than an individual. Thus, an EP for a common noun like *ringo* 'apple' is actually ambiguous between the following two interpretations:

(i) a. $\begin{bmatrix} \text{RELN} & {}^{\cap}\text{apple} \\ \text{LBL} & h \\ \text{FPART} & I \end{bmatrix}$ b. $\begin{bmatrix} \text{RELN} & \text{apple} \\ \text{LBL} & h \\ \text{INST} & i \end{bmatrix}$

where the first EP means that I is a subpart of the class corresponding to the apple, and the second means that i is a member of the set of apples. The notation of the relations in the EPs in (17) are meant to be deliberately ambiguous in these two interpretations. Cf. (3.1) and footnote 2 in Gunji and Hasida (1998).

(18) tabe (-ta)

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix}\text{HEAD} & \textit{verb}\end{bmatrix} \\ \text{ARG-ST} & \begin{bmatrix} \text{EXT} & \left\langle \begin{bmatrix}\text{INDEX} & \boxed{5} \\ \text{LTOP} & h_1\end{bmatrix}\right\rangle \\ \text{INT} & \left\langle\begin{bmatrix}\text{INDEX} & \boxed{6}\\ \text{LTOP} & h_2\end{bmatrix}\right\rangle\end{bmatrix} \\ \text{SEM} & \begin{bmatrix}\text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{3}\end{bmatrix} \\ \text{RELS} & \left\langle\begin{bmatrix}\text{RELN} & \textbf{eat}\\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5}\\ \text{ARG2} & \boxed{6}\end{bmatrix}\right\rangle\end{bmatrix}\end{bmatrix}$$

where, following Imaizumi and Gunji (2002), the values of ARG-ST (argument structure) are divided as external and internal arguments. The value of the EXT(ernal) part of the argument structure is the external argument (i.e., usually the grammatical subject and/or semantic agent) and the value of the INT(ernal) part of the ARG-ST is the internal argument(s) (i.e., usually the grammatical object(s) and/or semantic patient (and other arguments)). The INDEX value of these arguments appear as the value of the arguments of the **eat** relation.

As for the adnominal modifier *3-ko-no*, since it forms a constituent with the following nominal, it has a MOD feature whose value is a nominal.[7]

(19) 3-ko-no

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix}\text{HEAD} & \begin{bmatrix}\textit{adn} & \\ \text{MOD} & \left\langle\begin{bmatrix}\text{SYN} & \begin{bmatrix}\text{HEAD} & \textit{noun}\end{bmatrix}\\ \text{SEM} & \begin{bmatrix}\text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle\end{bmatrix}\end{bmatrix} \\ \text{SEM} & \begin{bmatrix}\text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{4}\end{bmatrix}\\ \text{RELS} & \left\langle\begin{bmatrix}\text{RELN} & \textbf{measure}\\ \text{LBL} & \boxed{4}\\ \text{ARG1} & \boxed{2}\\ \text{DIM} & \text{ko}\\ \text{NUM} & 3\end{bmatrix}\right\rangle\end{bmatrix}\end{bmatrix}$$

[7]The MOD feature corresponds to the **dep** feature in Gunji and Hasida (1998).

Note the EP **measure** takes the LTOP of the modified nominal as the argument. Thus, a phrase like *3-ko-no ringo* will have the following semantic representation:[8]

(20) 3-ko-no ringo

$$\begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{6} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{apple} \\ \text{LBL} & \boxed{2} \\ \text{ARG1} & \boxed{6} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{2} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$$

This representation intuitively says that *3-ko-no ringo* is a set of apples whose magnitude in terms of *ko* is 3.

If we put together all the semantic contributions from other constituents in the sentence, we will get the following semantics for sentence (2).[9]

(21) Gakusei-ga 3-ko-no ringo-wo tabe-ta.

$$\begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{3} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{student} \\ \text{LBL} & \boxed{1} \\ \text{ARG1} & \boxed{5} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{apple} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{6} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{eat} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \\ \text{ARG2} & \boxed{6} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{2} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$$

3.2 Adverbial Measurement

Now, let's turn to the adverbial modifier *3-ko*. The relevant sentence is (1):

(1) Gakusei-ga ringo-wo 3-ko tabe-ta.
student-NOM apple-ACC 3-CL eat-PAST
'A student/students ate three apples.'

Semantically, the only difference is the syntax and semantics of *3-ko* as opposed to that of *3-ko-no*. Since *3-ko* forms a constituent with the following verb or verb phrase, it has a MOD feature whose value is a verbal.

[8] Since the **measure** EP is a scopal EP, according to the scopal combination rule in Copestake et al. (2003), the LTOP of the combined phrase *3-ko-no ringo* is identical to that of *3-ko-no*, the semantic head daughter. The EPs of the daughters in a phrase are simply collected and become the value of the mother's RELS feature.

[9] For intersective combination, including head-argument combination, the value of LTOPs of the daughters are equated with each other. As with scopal combination, the EPs are collected and become the value of the mother's RELS feature.

(22) 3-ko

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{adv} & \\ \text{MOD} & \left\langle \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \end{bmatrix} \\ \text{ARG-ST} & \begin{bmatrix} \text{INT} & \left\langle \begin{bmatrix} \text{LTOP} & \boxed{2} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{2} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

Unlike the case of adnominal modification, what is measured is not the LTOP of the following constituent (i.e., verb) but one of its arguments. As discussed in Gunji and Hasida (1998) in detail, adverbial measure phrases measure the incremental theme argument of the following verb. Here, we assume a little bit of simplification and let the internal argument be measured by adverbial measure phrase. Thus, the ARG1 of the **measure** EP in *3-ko* is identified with the LTOP value of (one of) the internal argument(s) of the modified verb.

Thus, the semantics of *3-ko tabe-ta* becomes the following:[10]

(23) 3-ko tabe-ta

$$\begin{bmatrix} \text{ARG-ST} & \begin{bmatrix} \text{EXT} & \left\langle \begin{bmatrix} \text{INDEX} & \boxed{5} \end{bmatrix} \right\rangle \\ \text{INT} & \left\langle \begin{bmatrix} \text{INDEX} & \boxed{6} \\ \text{LTOP} & \boxed{2} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{eat} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \\ \text{ARG2} & \boxed{6} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{2} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

As the semantics of other constituents are the same as the adnominal measurement, the semantics of the entire sentence (1) becomes the following:

[10]Since the semantics of the phrase *3-ko tabe-ta* has to have access to the internal argument of the head verb, I will assume that the ARG-ST feature is preserved at this phrasal level.

(24) Gakusei-ga ringo-wo 3-ko tabe-ta.

$$\begin{bmatrix} \text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{4}\end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix}\text{RELN} & \textbf{student}\\ \text{LBL} & \boxed{1}\\ \text{ARG1} & \boxed{5}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{apple}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{6}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{eat}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{5}\\ \text{ARG2} & \boxed{6}\end{bmatrix}, \begin{bmatrix}\text{RELN} & \textbf{measure}\\ \text{LBL} & \boxed{4}\\ \text{ARG1} & \boxed{2}\\ \text{DIM} & \text{ko}\\ \text{NUM} & 3\end{bmatrix} \right\rangle \end{bmatrix}$$

Note that the semantics of *3-ko* only refers to the internal argument. Even though the internal argument is usually a grammatical object of a transitive verb, it can also be a grammatical subject of a so-called *unaccusative* intransitive verb, such as *oti* 'fall':

(25) Ringo-ga 3-ko oti-ta.
apple-NOM 3-CL fall-PAST
'Three apples fell.'

The lexical specification of the unaccusative verb *oti* is the following:

(26) oti(-ta)

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix}\text{HEAD} & \textit{verb}\end{bmatrix} \\ \text{ARG-ST} & \begin{bmatrix}\text{EXT} & \langle\ \rangle \\ \text{INT} & \left\langle \begin{bmatrix}\text{INDEX} & \boxed{5}\\ \text{LTOP} & \boxed{1}\end{bmatrix} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix}\text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{3}\end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix}\text{RELN} & \textbf{fall}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{5}\end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

Note that an unaccusative verb only has an internal argument.

Thus, the relevant features of *3-ko oti-ta* are the following:

(27) 3-ko oti-ta

$$\begin{bmatrix} \text{ARG-ST} & \begin{bmatrix} \text{EXT} & \langle\ \rangle \\ \text{INT} & \left\langle \begin{bmatrix} \text{INDEX} & \boxed{5} \\ \text{LTOP} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{fall} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{1} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

Adding *ringo-ga* as the subject, we get the following semantic representation:

(28) Ringo-ga 3-ko oti-ta

$$\begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{apple} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{fall} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{measure} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{3} \\ \text{DIM} & \text{ko} \\ \text{NUM} & 3 \end{bmatrix} \right\rangle \end{bmatrix}$$

4. Quantification as Coercion

Now, consider the case where a measure phrase is associated with the subject of a non-unaccusative verb, such as a transitive verb.

(29) Gakusei-ga 3-nin ringo-wo tabe-ta.
student-NOM 3-CL apple-ACC eat-PAST
'Three students ate an apple/apples.'

Since *gakusei-ga* is the external argument and not the internal argument, it cannot be simply measured by *3-nin*. As with Gunji and Hasida (1998), a measure phrase like *3-nin* in such a situation is assumed to be coerced to have a somewhat different semantics. Here, I will give the semantics of such coerced expressions in terms of generalized quantifier as the following:

(30) 3-nin (coerced)

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{adv} & \\ \text{MOD} & \left\langle \begin{bmatrix} \text{SYN} & \begin{bmatrix}\text{HEAD} & \textit{verb}\end{bmatrix} \\ \text{ARG-ST} & \begin{bmatrix}\text{EXT} & \left\langle \begin{bmatrix}\text{INDEX} & \boxed{5} \\ \text{LTOP} & \boxed{1}\end{bmatrix}\right\rangle\end{bmatrix} \\ \text{SEM} & \begin{bmatrix}\text{HOOK} & \begin{bmatrix}\text{LTOP} & \boxed{3}\end{bmatrix}\end{bmatrix} \end{bmatrix}\right\rangle \end{bmatrix}\end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{1} \\ \text{LTOP} & \boxed{4}\end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{quant} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{5} \\ \text{RSTR} & \boxed{1} \\ \text{BODY} & \boxed{3} \\ \text{DIM} & \text{nin} \\ \text{NUM} & 3 \end{bmatrix}\right\rangle \end{bmatrix}\end{bmatrix}$$

where the INDEX of the external argument of the modified verb is used as the bound variable of the EP **quant**(ification). The EP **quant** takes five arguments: DIM(ension), NUM, ARG1 (bound variable), RSTR (restriction), and BODY (scope). Intuitively, it is a quantification over the INDEX of the external argument of the modified verb. The restriction is the handle of the external argument and the body (scope) is the handle of the verb.

Thus, the semantics for *3-nin tabe-ta* is given as:

(31) 3-nin tabe-ta

$$\begin{bmatrix} \text{HOOK} & \begin{bmatrix}\text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4}\end{bmatrix} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{eat} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \\ \text{ARG2} & \boxed{6} \end{bmatrix}, \begin{bmatrix} \text{RELN} & \textbf{quant} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{5} \\ \text{RSTR} & \boxed{1} \\ \text{BODY} & \boxed{3} \\ \text{DIM} & \text{nin} \\ \text{NUM} & 3 \end{bmatrix}\right\rangle \end{bmatrix}$$

The semantics of the entire sentence (29) is given by the following:

(32) Gakusei-ga 3-nin ringo-wo tabe-ta.

$$
\begin{bmatrix}
\text{HOOK} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{LTOP} & \boxed{4} \end{bmatrix} \\
\text{RELS} & \left\langle
\begin{bmatrix} \text{RELN} & \textbf{student} \\ \text{LBL} & \boxed{1} \\ \text{ARG1} & \boxed{5} \end{bmatrix},
\begin{bmatrix} \text{RELN} & \textbf{apple} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{6} \end{bmatrix},
\begin{bmatrix} \text{RELN} & \textbf{eat} \\ \text{LBL} & \boxed{3} \\ \text{ARG1} & \boxed{5} \\ \text{ARG2} & \boxed{6} \end{bmatrix},
\begin{bmatrix} \text{RELN} & \textbf{quant} \\ \text{LBL} & \boxed{4} \\ \text{ARG1} & \boxed{5} \\ \text{RSTR} & \boxed{1} \\ \text{BODY} & \boxed{3} \\ \text{DIM} & \text{nin} \\ \text{NUM} & 3 \end{bmatrix}
\right\rangle
\end{bmatrix}
$$

This is equivalent to the following generalized quantifier notation:

(33) 3NIN(student, $\lambda\exists$y [appley & eat(x,y)])
or more simply (cf. footnote 5),
3NIN(student, eat-apple)

5. Scopal Ambiguity

Finally, let us consider the following ambiguous sentence:

(34) Gakusei-ga 3-nin ringo-wo 2-ko tabe-ta.
student-NOM 3-CL apple-ACC 2-CL eat-PAST
'Three students ate two apples.'

This sentence can be interpreted either as *3-nin* having a wide scope (what we called distributive reading in Gunji and Hasida (1998, Figure 3.3)) 'Each of the three students ate two apples' or as involving no scopal relation (what we called cumulative reading in Gunji and Hasida (1998, Figure 3.2)) 'Total of three students ate total of two apples'.

This is due to the scopal interaction between quantification and measurement, which both correspond to scopal EPs. The MRS representation where the scope relation is not resolved is the following. Note that $\boxed{8}$ is not equated to any handle yet.

(35) a. h_1: **student**(x), h_3: **apple**(y), h_3: **eat**(x, y),
h_4: **quant**(x, h_1, h_8, nin, 3), h_5: **measure**(h_3, ko, 2)

b.

$$\left[\begin{array}{ll} \text{HOOK} & \left[\begin{array}{ll}\text{INDEX} & \boxed{3}\\ \text{LTOP} & \boxed{3}\end{array}\right]\\ \text{RELS} & \left\langle \begin{array}{l} \left[\begin{array}{ll}\text{RELN} & \textbf{student}\\ \text{LBL} & \boxed{1}\\ \text{ARG1} & \boxed{6}\end{array}\right], \left[\begin{array}{ll}\text{RELN} & \textbf{apple}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{7}\end{array}\right], \left[\begin{array}{ll}\text{RELN} & \textbf{eat}\\ \text{LBL} & \boxed{3}\\ \text{ARG1} & \boxed{6}\\ \text{ARG2} & \boxed{7}\end{array}\right], \\ \left[\begin{array}{ll}\text{RELN} & \textbf{quant}\\ \text{LBL} & \boxed{4}\\ \text{ARG1} & \boxed{6}\\ \text{RSTR} & \boxed{1}\\ \text{BODY} & \boxed{8}\\ \text{DIM} & \text{nin}\\ \text{NUM} & 3\end{array}\right], \left[\begin{array}{ll}\text{RELN} & \textbf{measure}\\ \text{LBL} & \boxed{5}\\ \text{ARG1} & \boxed{3}\\ \text{DIM} & \text{ko}\\ \text{NUM} & 2\end{array}\right] \end{array} \right\rangle \end{array}\right]$$

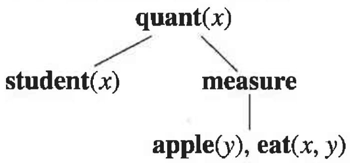
If we make $\boxed{8} = \boxed{5}$, we have the interpretation where *3 nin* (quantification) has a wide scope, which is shown in the non-feature representation below, and which corresponds to the following generalized quantifier notation, where 'eat-2-apple' is an informal notation for the property of eating two apples:

(36) *Distributive Reading*

a. h_1: **student**(x), h_3: **apple**(y), h_3: **eat**(x, y)),
h_4: **quant**(x, h_1, h_5, nin, 3), h_5: **measure**(h_3, ko, 2)

b. 3NIN(student, eat-2-apple)

c.



In this interpretation, quantification *outscopes* measurement and there are three students each of whom ate two apples. Thus, there are total of three students and (the maximum of) six apples.

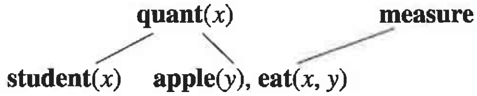
On the other hand, by making $\boxed{8} = \boxed{3}$, we get the cumulative reading. This interpretation involves total of two apples and three students. In this interpretation, the quantification and measurement don't have a scope relationship. There doesn't seem to be a straightforward generalized quantifier counterpart.[11]

(37) *Cumulative Reading*

a. h_1: **student**(x), h_3: **apple**(y), h_3: **eat**(x, y)),
h_4: **quant**(x, h_1, h_3, nin, 3), h_5: **measure**(h_3, ko, 2)

[11] According to the well-formedness conditions of MRS in Copestake et al. (2003), EPs have to form a *tree* in the sense that a node has only one mother. The representation in (37) is thus not well-formed in this sense. It may be an interesting future research topic whether there needs to be an extension of the definition of well-formed MRS representations to include dependency that cannot be captured by a tree or not.

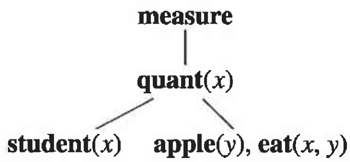
b.



Note that, since **measure** takes a handle of the internal argument as its argument, the value of ARG1 of **measure** cannot be [4], the handle of **quant**. Thus, an MRS MRS representation such as the following, where apparently measurement outscopes quantification, cannot be obtained.

(38) a. h_1: **student**(x), h_3: **apple**(y), h_3: **eat**(x, y)),
h_4: **quant**(x, h_1, h_3, nin, 3), h_5: **measure**(h_4, ko, 2)

b.



If the above were a legitimate representation, it would correspond to the following first-order-generalized quantifier representation.

(39) $\exists 2y$ [apple(y) & 3NIN(student, λx eat(x, y))]

where $\exists 2y \ldots$ intuitively means that there exists two $y \ldots$. In this interpretation, there are two apples each of which three students ate. Thus there are total of two apples and (the maximum of) six students. As we argued in Gunji and Hasida (1998), this interpretation is actually hard to get. Thus, measurement cannot *outscope* quantification. This is a natural consequence in the current approach, since the **measure** EP cannot take a quantificational handle ([4] or h_4 in (35)) as its argument.

6. Concluding Remarks

In this paper, I have reformulated the semantics of what we called *measurement* and *quantification* in the MRS system. The MRS notation allows us to have a more straightforward representation and yet it has the power to express underspecification relevant for the semantic representation. Our motivation for the particular notation we used for semantics in Gunji and Hasida (1998) was partly the need to have a compact representation that allows us to have fairly underspecified representations. Even though I don't believe I have reconstructed every detail of our previous representation, many of the most important aspects are now represented in the MRS representation.

I have formalized what we called *quantification* in Gunji and Hasida (1998) as generalized quantifiers. This may sound a little disturbing since our assumption in Gunji and Hasida (1998) is that measurement is more straightforward and less costly and quantification only occurs as coercion. However, generalized quantifiers in general are not regarded as coercion.

Thus, as a potential improvement of the approach taken in this paper, there might be a way to make clearer distinction between measurement and (generalized) quantification in the system of EPs, and thus the stipulative evaluation of quantification as 'costly' could be derived from more general assumptions. That may worth another paper.

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