Continuation-Based CCG of Japanese Quantifiers

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Abstract
This paper suggests that Continuation Passing Style, which is a classic technique in Computer Science but recently successfully applied to Linguistics as in Barker (2002) and others, accounts for different interpretations between floating and non-floating quantifiers. In a determiner-less language such as Japanese, word order changes the interpretation, i.e., non-split quantifiers correspond to exhaustive definites, while split NPs are considered to be non-exhaustive wide-scope indefinites in meaning. I will argue that the left category assumes wider scope to facilitate the creation of differences between floating and non-floating quantifiers. It is also observed that generalized quantifier theory does not directly apply to Japanese quantifiers since the number of NP arguments is unspecified, and Japanese generally expresses quantities by predicative adjectives. CPS transform successfully handles otherwise polymorphic adjectival quantifiers.

1 Interpretations of (Non)-Split NPs

1.1 The Contribution of Word Order
We observe that word order marks the definiteness of quantifier noun phrases in Japanese. While English floating quantifiers (FQ) are limited to universals such as all and each (Sportiche 1988) (1a), Japanese FQs have more variety (1b). In addition, English FQs do not allow long distance dependencies (1a), whereas Japanese numeral quantifier and a modified noun can be split by adverbials (Miyagawa 1989) under certain restrictions.

(1) a. The students (*yesterday) all came.
b. Gakusei-ga zen-in/mina/hotondo/ student-NOM all-member/all/mostly/ 3-nin/roku-wari kita. 3/60 percent came
‘All/all/most/three/60 percent students came’

Szabolcsi (1986) discusses the NP split of the definite superlative in Hungarian. The NP split is allowed with a comparative indefinite reading, but not with the absolute definite reading of the superlative adjective.

(2) \[ \text{Leftdisl } zöld \hspace{1em} \text{[FOCUS itt]} \hspace{1em} \text{hóval} \]\n\[ \text{találkoztam a legszebb-el met-I the prettiest-with} \]
‘I met a prettier green horse here than anywhere else’
‘*As for green horses, it was here that I met the prettiest of them, i.e., the prettiest green horse that there is’

In Japanese, the use of a non-split quantifier phrase presupposes a limited number referents, and thus corresponds to definite description. On the other hand, the referents of a postnominal quantifier are not presupposed so that split quantifiers correspond to indefinites.

(3) a. \{Zo-ga \hspace{1em} 2-to / \hspace{1em} # 2-to-no elephant-NOM 2-CL 2-CL-GEN zo-ga\} hashit-te, hoka-no elephant-NOM run-and other-GEN zo-wa suwat-teiru.
elephant-TOP sit-PROG
‘Two elephants are running and other elephants are sitting’
b. {Gakusei-ga 3-nin / student-NOM 3-CL 3-CL-GEN student-NOM} kino hataraita. More 2-CL-also worked. ‘Three students worked yesterday. Two others worked, too’

c. Asa-kara morning-since 3-nin-to / friend-with # tomodachi friend 3-nin-to hanashi-ta-ga but nokori-no rest-GEN 3-nin-to-wa hanasa-nakat-ta. ‘I spoke with three friends in the morning but I did not speak with the (remaining) other three’

Prenominal quantifier phases 2-to-no zo (two elephants) and 3-nin-no gakusei (three students) comprise exhaustive interpretations so that no other elephants or students can be mentioned in the following sentence. 2-to-no zo (two elephants) and 3-nin-no gakusei (three students) each corresponds to definite NPs – the two elephants and the three students – in which the number of elephants or students are limited. On the contrary, the FQs zo-ga 2-to (two elephants) and gakusei-ga 3-nin (three students) are not so exhaustive that other elephants and students can be mentioned in the following sentences.¹

(4) a. \( \exists X. [\text{elephant}'(X) \land |X| = 2 \land \forall y. [\text{elephant}'(y) \rightarrow y \subseteq X] \land \text{ran}'(X)] \)

Note that the split NPs (FQ) are scope insensitive and always take wider scope over a bare noun phrase. The split NP allows a distributive reading but not a collective one (Terrada 1990, Nakanishi 2004). In (5a), three students may either bake a cake together (a cake > three students) or bake three cakes each

(5) a. 3-nin-no gakusei-ga keeki-o cake-ACC made [✓collective, ✓distributive]

b. Gakusei-ga 3-nin keeki-o student-NOM cake-ACC made [✓collective, ✓distributive]

‘The three students made a cake’

1.2 Continuation

Regardless of how we categorize numerals and bare noun phrases, assigning identical categories to each lexical item does not explain the differences between FQs and non-FQs.

(6)

(7) CPS Translation

The differences between FQs and non-FQs imply that word order contributes to meaning. In other words, the meaning of (non)-FQs is sensitive to word order, and the order of evaluation affects interpretations. The (in)definiteness appears to be the result of the left-to-right evaluation, and definite interpretation is the result of processing a prenominal numeral first.

In Continuation Passing Style (CPS), every function takes the extra function k, to which some continuation can apply. CPS transform introduces continuation parameters. A continuation parameter is introduced though \( \lambda \)-abstraction (Plotkin 1975, Parigot 1992, de Groote 1994, Barker 2004).

The CPS translation \( M \) of a \( \lambda \mu \)-term \( M \) is:

¹ See discussions on the uniqueness effects of English definite noun phrases in Roberts (2003).
(8) a. \[ x = \lambda k.kx; \]
b. \[ M_N = \lambda k.M(\lambda m.N(\lambda n.k(mn))) \]

CPS transform of the lexical items:

(9) a. \[ [gakusei] \]
\[ \text{NP}: x = \text{student'}; \]
\[ = \lambda k.k(x = \text{student'}); \]
b. \[ [5 - \text{nin}] \]
\[ \text{N}: \lambda x.\lceil x = 5 \rfloor = \lambda k.k(\lambda x.\lfloor x \rfloor = 5); \]
c. \[ [kita] \]
\[ \text{NP}\backslash S: \lambda k.k(\lambda x.\text{came'}(x)); \]

Syntactic combination:

(10) a. \[ [gakusei\_5 - \text{nin}] \]
\[ = NPQP \]
\[ = \lambda k.N(\lambda m.QP(\lambda n.k(mn))) \]
\[ = \lambda k.(\lambda l.l(x = \text{student'}))(\lambda m.\text{ao}(\lambda x.\lfloor x \rfloor = 5))(\lambda n.k(mn)) \]
b. \[ [5 - \text{nin} - \text{no}_gakusei] \]
\[ = QPnP \]
\[ = \lambda k.QP(\lambda n.NP(\lambda m.k(mn))) \]
\[ = \lambda k.(\lambda l.l(x = \text{student'}))(\lambda m.\text{ao}(\lambda x.\lfloor x \rfloor = 5))(\lambda n.k(mn)) \]

Since floating numerals such as five, many, most, every, each, and all also appear as predicative adjectives, they are assigned type (e, t) here. In the absence of continuations, (non-)FQs would receive the same interpretations. Due to scopal interactions, differences between the interpretations of FQs and non-FQs are predicted. In (10a), a common noun, student, has higher scope than five. The reverse holds true for (10b).

Let us add a raising rule into a continuized type and a combination rule into basic rules in the Combinatory Categorial Grammar (CCG) (Steedman 2000, Szabolcsi 1987, Barker 2002, Shan & Barker 2006):

(11) a. Type Raising into a Continuized Type
\[ A: a \Rightarrow B(A \backslash B): \lambda k.k(a) \]
b. Syntactic Composition
\[ C/(A \backslash B)\backslash C: \lambda k.k(f) \]
\[ C(A \backslash C): \lambda m.m(g) \]
\[ C/(B)\backslash C: \lambda k.f(\lambda m.g(\lambda n.k(mn))) \]

The type raising rule into a continuized type (11a) enables any type of syntactic category to be lifted into higher order.

(12) The non-exhaustive interpretation of post-nominal quantifier phrases results from the narrower scope of the numeral while exhaustive interpretation results from the wide scope of the numeral.

2 Limitations of Generalized Quantifier Theory

2.1 Predicative Adjectival Quantifiers

In English, quantifiers are normally noun phrases, such as in Many people attended. However, numbers and quantities are more naturally expressed as predicates in Japanese (Imani 1990). While English-type quantifiers are possible, as in (14a), predicative adjectives such as the ones in (14b) are more natural.

many-GEN Japanese-TOP A-type-be 'Many Japanese are type A'

Japanese-TOP A-type-NOM many 'Many Japanese are type A'

Unlike in English, in Japanese, strong determiners like every and most can appear as predicative adjectives in addition to weak determiners such as many, few, and five (15b).\(^\text{2}\)

\(^\text{2}\) Weak quantifiers are admitted in there-sentences while strong quantifiers are not (Milsark 1977, Barwise & Cooper 1981).

\(^\text{3}\) Partee (1986) states that every NP and most NP cannot appear in the complement of consider.
a. The number of attendants was {many/few/forty/*most/*every}.

b. Kessekisha-ga
absentee-NOM
{okat/yonju-nin-dat/
many/40-CL/
hotondo-dat/zen-in-dat} -ta.
most/every PAST
‘There were many/40/most/all people who were absent’

Since adjectives denote a property, Partee (1986) proposes the function BE which shifts generalized quantifiers such as an authority in type (et, t) into (et) in a predicate position (Mary considers John competent in semantics and an authority on unicorns). However, many or three in the (et) type cannot predicate the relations between two sets. As far as adjectival quantifiers predicate only one argument and cardinal numbers are concerned, the (et) analysis works. However, Japanese quantificational adjectives predicate more than one argument.

2.2 An Unspecified Number of Arguments


Such an analysis works provided quantificational words take exactly two arguments. However, in an arguably non-configurational language such as Japanese, the number of argument is not specified. Hale (1980) proposes generating sentences by means of a phrase structure rule: $X \rightarrow X \star X$. In an X-bar schema, the head (X) is preceded by any number of complements, including zero. At the sentence level, any number of noun phrases may appear provided there is a predicate – either a verb or an adjective – in sentence-final position: $S \rightarrow NP* V$ or $S \rightarrow NP* AP$.

(16) a. Shussekisha$_{NP}$-ga
attendants-NOM
{sukunakat/okat}$A_{P}$-ta.
few/many-PAST
‘There were few/many attendants (Lit. The attendants were few/many’

b. Gakusei$_{NP}$-ga amerikajin$_{NP}$-ga
student-NOM American-NOM
josei$_{NP}$-ga $o_{A_{P}}$ (koto).
female-NOM many fact
‘Many students are female Americans’

2.3 CPS Transform

Such adjectival quantifiers would be polymorphic in order to predicate an unspecified number of arguments. Nevertheless, CPS transform avoids a problem related to a polymorphic category, in other words, $\lambda$-abstraction and composition rules of continuized types enable each argument to compose with the predicate one by one.

(i) Mary considers that two islands/*every island/*most islands.