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The syntax and semantics of Chinese classifiers

I. Introduction

(1) **Bare nouns** are nouns that have not been modified by quantifiers or determiners. In English, bare nouns may co-occur with numerals or quantifiers to indicate quantity of the noun, e.g.:

a. two apples
b. some water

(2) However, in other languages, such as Chinese, bare nouns typically require **classifiers (CL)**, sometimes called **measure words**, to intervene before the bare noun, e.g.:

a. yi tiao yu
one CL fish
'One fish'

We will go more into detail about Chinese nouns and classifiers later.

II. Count nouns vs. mass nouns

(3) Nouns can also be classified into **count nouns** and **mass nouns**. Typically, count nouns and mass nouns are differentiated based on their syntax and their distribution with certain words. A basic morpho-syntactic distinction for English count nouns and mass nouns is as follows (from Gillon 1999):

MORPHO-SYNTACTIC CRITERIA:	MASS NOUN	COUNT NOUN
modified by cardinal numerals	–	+
modified by quasi-cardinal numerals[1]	–	+
modified by indefinite article	–	+
modified by *many* and *few*	–	+
modified by *much* and *less*	+	–
SG/PL contrast	–	+
one antecedent[2]	–	+

Table 1: Morpho-syntactic criteria for English mass nouns and count nouns.

[1] Quasi-cardinal numbers include those such as *several*.
[2] From Gillon (1999): "The pronoun *one* may serve as the antecedent of count nouns, not of mass nouns.
(1.1) Mary gave Jill advice and John gave her some/*one too.
(1.2) Mary gave Jill a suggestion and John gave her one too."

(4) Some (e.g. Rothstein 2010) have argued that Chinese does not have a mass vs. count noun distinction, having instead only mass nouns, which become count nouns with the use of a classifier. We will explore this argument later.

A. Diagnostics for mass vs. count distinctions

(5) Semanticists have attempted to differentiate mass nouns and count nouns based on their denotations. Two basic tests to distinguish between mass nouns and count nouns are the **cumulativity test** and the **homogeneity test**. Rothstein (2010: 350–351) defines both as follows, where $\sqcup$ stands for "join" or "sum", $\sqsubseteq$ stands for "part of", O stands for "overlap", and y and z are not empty:

a. Cumulativity:
P is cumulative iff: $\forall x \forall y[x \in P \wedge y \in P \rightarrow x \sqcup y \in P]$
'P is a cumulative predicate if when x and y are in P, then the sum of x and y is also in P.'

b. Homogeneity (divisiveness):
P is homogeneous iff $\forall x \in P$: $\exists y \exists z\ [y \sqsubseteq x \wedge z \sqsubseteq x \wedge \neg O(y,z) \wedge y \in P \wedge z \in P]$
'P is a divisive (homogeneous) predicate if for every x in P, there is a way of splitting x into two non-overlapping parts, both of which are also in P.'

(c) and (d) provide examples of mass and count nouns that pass and fail the cumulativity and homogeneity tests:

c. A mass noun that passes both tests: Water + water is still water; water divided into multiple parts is still water.

d. A count noun that fails both tests: One apple + one apple is not still one apple; the pieces of one apple divided into multiple parts are not still each one apple.

(6) These tests, however, are not perfect and run into a number of problems:

a. At some point, a mass entity reaches a level where it cannot be divided and still identified as the entity (e.g. water, at some point, reaches an atomic level H and O where the parts are no longer recognized as water);

b. Not all mass nouns are necessarily homogeneous (e.g. jewelry may consist of non-homogeneous pieces); and

c. Some nouns may act as both count and mass nouns, making the distinction between them difficult (e.g. stone, which may be both individual stones, as well as a homogeneous mass stone).

(7) Another criterion for the mass/count distinction is that of **atomicity**. Rothstein (2010: 352) provides the following model:

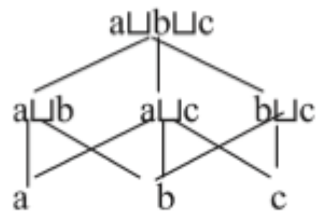

Figure 1. A Boolean lattice with three individuals in it.

Rothstein (2010) notes that mass nouns are grammatically singular, but semantically plural, and remarks that "a grammatically singular count noun denotes a set of atoms, and the plural of the count noun denotes that set closed under the sum operation[.]" (352) Mass nouns are usually thought of (cf. Link (1983)) as not having a bottom level of atoms, instead having subdivisions that can further be subdivided; see Figure 2.

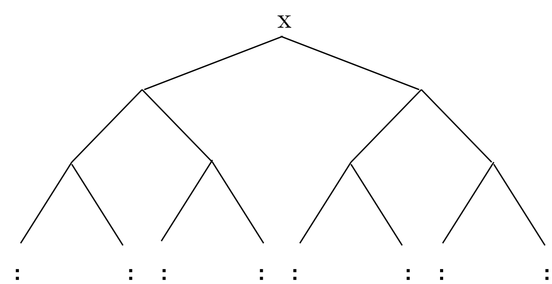

Figure 2. A representation of a mass noun, such as *water*.

(8) Count nouns thus presuppose atoms and make atoms grammatically accessible, whereas mass nouns do not. (Rothstein 2010: 353–354)

(9) Again, atomicity runs into problems when we encounter count nouns that may pass the homogeneity test, such as *fence*, *hedge*, and *bouquet*.

(10) To sum up: Nouns can be divided into mass and count nouns, and a number of diagnostic criteria facilitate this division. However, the diagnostics are imperfect. For further reading, Rothstein (2010) and Gillon (1999) make arguments for a more complex and detailed understanding of the mass vs. count division.

III. Chinese classifiers

(11) Under Allan (1977)'s classification types, Chinese falls under the numeral classifier type. Under this language type, classifiers must occur in expressions of quantity, anaphora, and deixis:

a. yi zhi gou (quantity)
one CL dog
'One dog'

b. si ge (anaphora)
four CL [thing, object]
'Four [things, objects]'

c. na ben shu (deixis)
that CL book
'That book'

(12) The bare noun constrains which classifiers may be used[3]. For the most part, the classifiers that go with the noun must be memorized, although there are occasionally semantic cues that can be used to determine the classifier (e.g., *tiao* typically co-occurs with long, thin objects, such as snakes and rivers, although *zhi* may also be used with long, thin objects, such as pencils and arrows).

(13) If the noun itself is a measurement, it does not require a classifier (examples from Li & Thompson 1981: 105–106):

a. san tian
three day
'Three days'

b. *san ge tian
three CL day

c. ba kuai
eight piece
'Eight pieces'

d. *ba ge kuai
eight CL piece

[3] There is typically a single classifier that is used to indicate one of a certain noun, although various different classifiers may be used to denote different interpretations of the noun (e.g. a piece of, a box of, etc.). See (23).

(14) Additionally, if the noun itself denotes measurement, it can also be used as a classifier:

a.

san	tian	yu
three	day	rain

'Three days of rain'

b.

ba	kuai	rou
eight	piece	meat

'Eight pieces of meat'

(15) In addition to indicating individuals and measurements, classifiers can also indicate aggregates or containers, creating further subdivisions of mass:

a.

yi	dui	laji
one	pile	garbage

'A pile of garbage'

b.

liang	xiang	shu
two	box	book

'Two boxes of books'

(16) Classifiers may also indicate instances of events (examples from Li & Thompson 1981: 110):

a.

na	chang	qiu	hen	jinzhang
that	CL	ball	very	tense

'That ball game was very tense.'

b.

dao	Xinjiapo	yi	tian	you	ji	ban	feiji?
to	Singapore	one	day	exist	how many	trip (CL)	plane

'How many flights a day are there to Singapore?'

(17) Classifiers can also indicate body parts or enclosed areas, occurring with *yi* 'one' to produce a special meaning of '____ful of':

a.

yi	tou	bai	fa
one	head (CL)	white	hair

'A headful of white hair'

b.

yi	di	mianfen
one	floor (CL)	flour

'A floorful of flour'

(18) Finally, the classifier *xie* occurs with *yi* 'one' and demonstratives (but not *mei* 'every') to indicate plurality:

a. yi xie pingguo
one CL apple
'Some apples'

b. na xie shu
that CL book
'Those books'

c. nei xie dongxi
which CL thing
'Which things?'

d. *mei xie ren
every CL person
*'Every people'

A. Nouns without classifiers

(19) In some instances, mainly those where counting, anaphora, and deixis are not required, Chinese nouns may occur without classifiers:

a. wo chi pingguo
I eat apple
'I [will] eat apple'

b. nei ge dan'gao shi yong pingguo zuo de
that CL cake is use apple make PART
'That cake is made with apples.'

c. pingguo cong shu shang diao xia lai
apple from tree on fall down come
'[The?] apple falls from the tree." (See 20c)

(20) Examples (19a)–(19c) provide interesting examples of how Chinese bare nouns blur the boundary between count nouns and mass nouns, if they are not interpreted only as mass nouns entirely:

a. (19a) is typically given as a response to a question, such as *Ni xiang chi pingguo, li, haishi juzi?* 'Do you want to eat apple, pear, or orange?'; the response is *Wo chi pingguo* 'I [will] eat apple'. There is no indication of singular or plural in the interpretation of *pingguo* 'apple', and the speaker can eat part of an apple (e.g. apple slices), one apple, or multiple apples.

b. In (19b), *pingguo* 'apple' is interpreted as already being apple 'stuff' and not inherently count or plural, although the apples are typically realized as plural (e.g., in creating a cake, one would put in multiple apples and not just one).

c. (19c) typically indicates that more than one apple fell from the tree—however, if one is looking up at one specific apple in the tree, and that apple falls (or if the tree only has one apple), then (19c) can also be used to express the situation.[4]

(21) If we interpret bare nouns as entirely mass, then they denote something akin to '[noun] stuff', similar to English interpretations of conventionally count nouns:

a. Apple was all over the floor.
[Indicates that apple 'stuff' was all over the floor and not necessarily that one whole apple was on the floor.]

This denotation can account for the interpretations of (19a)–(19c) in (20): instead of being marked as singular or plural inherently, all the nouns in (19a)–(19c) denote the property of [noun], or the presence of [noun] stuff.

(22) Chinese nouns, then, can be interpreted as being mass and denoting '[noun] stuff' until a numeral classifier intervenes and produces individuated instances of '[noun] stuff'.

(23) Also of relevance in the interpretation of nouns in Chinese as mass nouns of '[noun] stuff' that are not individuated until combined with a count classifier is the fact that different classifiers can change the nature of the same noun (examples adapted from Zhang 2007: 48–49):

a. yi gen xiangyan
one CL cigarette
'a cigarette'

b. yi xie xiangyen
one CL cigarette
'some cigarettes'

c. yi jie xiangyan
one CL cigarette
'a piece of cigarette'

d. yi bao xiangyan
one CL cigarette
'a pack of cigarettes'

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[4] Additionally, (19c) would be ungrammatical (or perhaps infelicitous) to describe pieces of apple, or 'apple stuff', falling from a tree—for instance, if a squirrel were sitting in a tree and eating an apple and pieces of the apple were falling down, then a speaker typically would not use (19c) and would instead modify *pingguo* 'apple' with a word like *zha* 'piece' to indicate that pieces of apple were falling from the tree.

e. yi xiang xiangyan
one CL cigarette
'a box of cigarettes [may also be interpreted as cigarette packs]'

The ability of different classifiers to change the denotation of individuated instances of the noun also suggests that nouns consist of a mass denotation that is not specified or interpreted until a count classifier forces an interpretation.

(24) To summarize: Chinese classifiers are required before nouns in instances of count, anaphora, and deixis. These classifiers may be count classifiers or may further subdivide nouns into mass units, such as boxes; additionally, some other classifiers have specialized functions, such as denoting instances of events, [noun]fuls of entities, and plurality. In instances where classifiers are not required, we encounter interesting interpretations of nouns that suggest that Chinese nouns are all mass nouns denoting '[noun] stuff' that are not individuated until a numeral classifier forces an interpretation.

IV. The syntax of Chinese classifiers

(25) Ueda (2009) analyzes Chinese classifiers as being part of a classifier phrase (see Figure 3). Either a numeral, the quantifier *mei* 'every', or a demonstrative such as *na* 'that' can act as a determiner. All NPs containing a classifier must have a determiner attached; a classifier and a noun (e.g. **ge ren* CL-person) on its own is ungrammatical.

a. liang ge ren
two CL person
'Two people'

b. mei ge ren
every CL person
'Every person'

c. na ge ren
that CL person
'That person'

(26) From the tree in Figure 3, we can see that the classifier combines first with the noun before the numeral is attached.

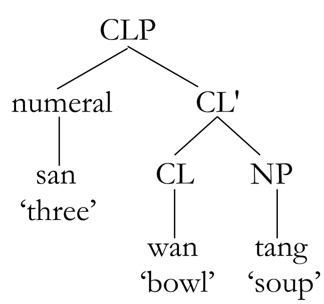

Figure 3. A syntax tree for the phrase *san wan tang* 'three bowls of soup'.

(27) Ueda (2009) further argues that some mass classifiers can co-occur with count classifiers, although native speaker judgment on the resultant sentence varies. See Figure 4.

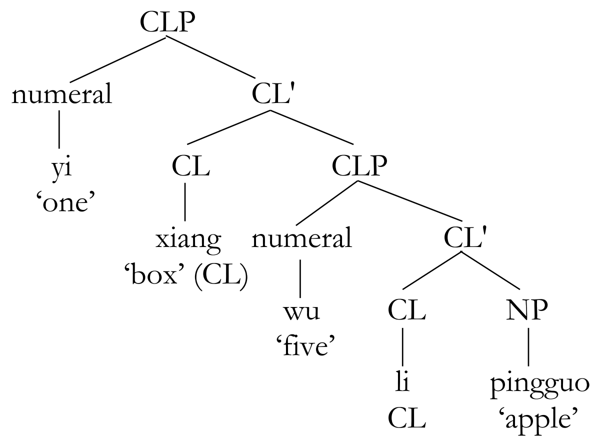

Figure 4. A syntax tree for the phrase *yi xiang wu li pingguo* 'a box of five apples'.

(28) If we convert these syntax trees into categorial grammar format, we have the following categories for nouns, classifiers, and numbers:

TYPE	EXAMPLE		CATEGORY
numeral	*yi*	'one'	CN/CN
classifier	*dai*	'bag'	CN/CN^{mass}
noun	*pingguo*	'apple'	CN^{mass}

Table 2. Categories for numerals, classifiers, and nouns.

The categorial derivation for *yi xiang wu li pingguo* 'a box of five apples' is shown in Figure 4.

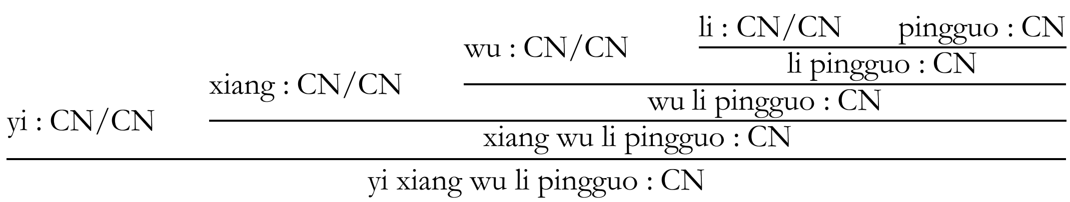

Figure 4. Categorial derivation of *yi xiang wu li pingguo* 'a box of five apples'.

This derivation preserves the observation that the classifier combines first with the noun, and then with the numeral.

(29) The numeral is necessarily CN/CN because of its ability to also combine with the quantifier *mei* 'every', a quantifier of type NP/CN, as in the following example:

a. mei liang ge ren you haizi
every two CL person have child
'Every two people has children.'

Mei 'every' is the only pre-classifier quantifier with which the numeral may co-occur:

b. *yi xie liang ge ren you haizi
one CL-PL two CL person have child
*'Some two people have children.'

c. *suoyou liang ge ren you haizi
all two CL person have child
*'All two people have children.'

While it functions similarly to a quantifier, *dou* 'every' is actually an adverbial, modifying the verb and coming after the classifier phrase:

d. liang zhang zhi shang dou you tuhua
two CL paper on all have drawing
'All two [both] pieces of paper have drawings on them.'

We will not explore the syntax of *dou* 'all' in this presentation.

(30) A classifier phrase like *yi dai pingguo* 'one bag of apples' can also stand on its own as the complement to a verb:

a. wo you yi dai pingguo
I have one bag (CL) apple
'I have one bag of apples'.

(31) As only NPs can act as the arguments of verbs, we must devise a null nominalizer that transforms the CN *pingguo* 'apple' or *yi dai pingguo* 'one bag of apples' into an NP. This null nominalizer is of the category NP/CN and has the denotation $\lambda P_{<e,t>} \exists x_e P(x)$. Furthermore, when the bare noun is used as an argument, the nominalizer forces a generic interpretation of the noun. We will not explore the semantics of the null nominalizer in this presentation, as we will not go into the semantics of verbs with arguments and will focus only on classifier phrases.

(32) To summarize: Numerals and classifiers are both of the category CN/CN, and bare nouns are of the category CN. Numerals can co-occur with the quantifier *mei* 'every', which is of the category NP/CN. In order to allow bare nouns and classifier phrases, both of which are of the category CN, to be used as the complements of verbs, we must use a null nominalizer of the type NP/CN and the denotation $\lambda P_{<e,t>} \exists x_e P(x)$.

V. The semantics of classifiers

(33) In our preliminary discussion of the semantics of classifiers, we will use the classifiers *li* (used for small, round things; glossed as 'li') and *dai* 'bag' as examples.

(34) Classifiers are of the category CN/CN and the type <<e, t>, <e, t>>. A classifier such as *dai* 'bag' would denote the property of being *dai* 'bag(s)' of entities in the extension of CN[5]; a classifier such as *li* 'li' would also denote the property of being *li* amount of the entity in the extension of CN.

(35) A count classifier such as *li* 'li' has only one property: the classifier takes a mass noun and countifies it, creating a count interpretation of the mass noun:

a. Zhangsan you san li pingguo
Zhangsan have three CL apple
'Zhangsan has three apples.' (count)

(36) A mass classifier such as *dai* 'bag' (and *xiang* 'box', *dui* 'pile', and similar classifiers) can have two properties: the classifier can either act as a count classifier for a CN itself (see example a), creating a division that retains the mass properties of the CN, or as a count classifier of another classifier phrase (see example b), creating a division that does not massify the CN but rather retains its count properties:

a. Zhangsan you san dai pingguo
Zhangsan have three bag (CL) apple
'Zhangsan has three bags of apples.' (count-mass)

b. Zhangsan you san dai wu li pingguo
Zhangsan have three bag (CL) five CL apple
'Zhangsan has three bags of five apples [each].' (count)

(37) The translation of *li* 'li' is as follows[6]:

a. $[[li]] = F(li) = \lambda P \lambda x[x \in {}^*P \wedge \textbf{li-amount}'(x) \wedge |x| = 1]$

(38) The denotation of the resultant count noun *P is the atomic lattice with base elements belonging to P (as in Figure 1 in (7)) and roughly translates to 'the property of being one or more Ps'.

(39) It is necessary to include the cardinality of the entity, as *wu li pingguo* five-CL-apple 'five apples' cannot indicate five apples of the cardinality 2, i.e., 10 apples. That is, since x is specified as a member of the atomic lattice, that membership suggests that it can also be a plural entity, e.g., a+b, or a+b+c, as the lattice is not bound to only the lowest level {a, b, c}. We cannot have five apples on the duplet tier, or on the triplet tier; we can only have five atomic singular apples.

(40) The translation of *dai* 'bag' is as follows:

a. $[[dai]] = F(dai) = \lambda P \lambda x[x \in P \wedge \textbf{bag-amount}'(x)]$

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[5] Thanks to Craige Roberts for this definition.

[6] Although I have made some modifications from the originals, I have retained the main structure of the translations and definitions originally provided by Craige Roberts.

(41) The lack of an asterisk before the P in the translation of *dai* 'bag' indicates that P is in the mass domain, i.e., is a mass lattice and not an atomic lattice. *Dai* 'bag' is grammatical regardless of the cardinality of the contents; in fact, the cardinality of the contents is irrelevant, because the mass lattice cannot be described in terms of cardinality.

(42) We can apply this translation to an argument, such as **apple′**:

a. [[**li apple**]] = [[**li**]](**apple′**)

1. λPλx[x ∈ *P ∧ **li-amount′**(x) ∧ |x| = 1](**apple′**)
2. λx[x ∈ ***apple′** ∧ **li-amount′**(x) ∧ |x| = 1] beta-reduction

'the property of being one atomic li of apple-stuff'

b. [[**dai apple**]] = [[**dai**]](**apple′**)

1. λPλx[x ∈ P ∧ **bag-amount′**(x)](**apple′**)
2. λx[x ∈ **apple′** ∧ **bag-amount′**(x)] beta-reduction

'the property of being a bag amount of apple-stuff'

(43) However, the second use of *dai* 'bag' requires a different translation, the function of which will become apparent once we begin to combine expressions in section VII. The translation for the use of *dai* 'bag' as in (36b) is as follows:

a. [[*dai*]] = F(*dai*) = λPλx[P(x) ∧ **bag-amount′**(x)]

We will see in section VII how to translate [[*dai wu li pingguo*]] bag (CL)-five-li-apple 'bag of five apples'. This translation *cannot* be used to produce [[*dai pingguo*]] bag (CL)-apple 'bag of apples'; [[*dai pingguo*]] bag (CL)-apple 'bag of apples' *must* use the translation given in (40).

(44) To summarize: Most classifiers take a mass CN and countify it, forming a count CN; this function of the classifier can be translated as λPλx[x ∈ *P ∧ **CL-amount′**(x) ∧ |x| = 1]. A classifier that takes a mass CN and forms another mass entity out of it, such as *dai* 'bag', can be translated as λPλx[x ∈ P ∧ **CL-amount′**(x)]. Mass classifiers that can denote masses of count nouns (e.g., one bag of five apples) require a separate translation, λPλx[P(x) ∧ **CL-amount′**(x)]. The reason for this distinction will become apparent in section VII.

VI. The semantics of numerals

(45) A simplistic understanding of cardinal numbers involves interpreting them as denoting individuals that belong to a set with a certain cardinality, e.g. (adapted from Ionin & Matushansky (2006)):

a. [[two]] = $\lambda P_{<e,t>}\lambda x_e[P(x) \wedge |x| = 2]$

b. [[two books]] = λx_e [[[books]](x) $\wedge$ |x| = 2]

(46) However, the account of cardinal numbers in (45) breaks down under compositionality if we assume that a complex cardinal number such as *two hundred* consists of the cardinal number *hundred* modified by *two*:

a. [[two]] = $\lambda P_{<e,t>}\lambda x_e[P(x) \wedge |x| = 2]$
b. [[hundred]] = $\lambda P_{<e,t>}\lambda x_e[P(x) \wedge |x| = 100]$
c. [[two hundred books]] = λx_e [[[books]](x) $\wedge$ |x| = 2 $\wedge$ |x| = 100]

(c) produces an ungrammatical utterance, as the cardinality of something cannot simultaneously be 2 and 100.

(47) Instead, Ionin & Matushansky (2006: 318–319) propose the another interpretation of cardinal numbers that involves the use of partitions. The definition of [[two]] and [[hundred]] are then as follows[7]:

a. [[two]] = $\lambda P_{<e,t>}\ \lambda x_e.\exists S\ [\prod(S)(x) \wedge |S| = 2 \wedge \forall s \in S$ [[P]](s)]
b. [[hundred]] = $\lambda P_{<e,t>}\ \lambda x_e.\exists S\ [\prod(S)(x) \wedge |S| = 100 \wedge \forall s \in S$ [[P]](s)]

(48) These numerals then combine with CNs to produce the following phrases from Ionin & Matushansky (2006):

a. [[hundred books]] = $\lambda x_e.\ \exists S\ [\prod(S)(x) \wedge |S| = 100 \wedge \forall s \in S$ [[book]](s)]
λx_e . x is a plural individual divisible into 100 non-overlapping individuals p_i such that their sum is x and each p_i is a book

b. [[two hundred books]] = $\lambda x_e.\ \exists S\ [\prod(S)(x) \wedge |S| = 2 \wedge \forall s \in S\ \exists S'\ [\prod(S')(s) \wedge |S'| = 100 \wedge \forall s \in S'$ [[book]](s')]]
λx_e. x is a plural individual divisible into 2 non-overlapping individuals p_i such that their sum is x and each p_i is divisible into 100 non-overlapping individuals p_k such their sum is p_i and each p_k is a book.

Figure 5 provides a visual representation of (48b), where y and z together form S', and each of y and z (the top nodes of the triangles) has a cardinality of 100 with 100 atomic books at the bottom.

[7] Modified from Ionin & Matushansky (2006); thanks to Craige Roberts for the modified translation.

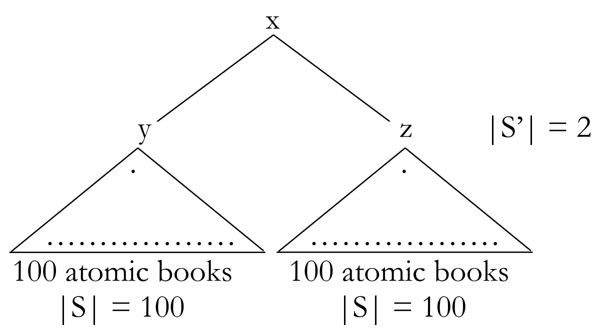

Figure 5. A visual representation of [[two hundred books]] under Ionin & Matushansky (2006).

(49) The terms of (47) are defined as follows:

a. "S is a **partition ∏** of an entity x if it is a **cover** of x and its cells do not overlap." (Ionin & Matushansky 2006: 318; emphasis SQL)

b. A **cover** contains all and only the parts of x. A cover can overlap, with atomic parts a, b, and c also being included as a+b, b+c, a+c, etc. However, to be considered a partition under this definition, its cells cannot overlap.

(50) Ionin & Matushansky (2006) thus provide a way to interpret cardinal numbers that preserves the compositionality of complex cardinals.

(51) Crucially, cardinal numbers cannot join with mass nouns because there are no atomic pieces (non-overlapping individuals) to form the cells of the cover, and thus no cardinality to calculate to satisfy the requirements of the lambda expression:

a. *two mud

b. *liang pingguo
two apple
*'Two apples'

(52) To summarize: Cardinal numbers can be represented by lambda expressions invoking the concept of partitions whose cardinality involving cells of atomic pieces corresponds to the numeral. This interpretation allows us to represent the compositionality of complex cardinal numbers. Furthermore, cardinal numbers require atomicity to function; cardinal numbers thus cannot occur with mass nouns, as there are no atomic pieces to count.

VII. Putting it together

(53) We have seen how to translate classifiers and cardinal numbers into lambda calculus. In this section, we will see how to put them together to form complex classifier phrases.

(54) We will begin with a simple phrase, *wu li pingguo* five-CL-apple 'five apples':

1.	**pingguo**	⇒	**apple′**	lexical
2.	**li**	⇒	λPλx[x ∈ *P ∧ **li-amount′**(x) ∧ |x| = 1]	lexical
3.	**li pingguo**	⇒	λPλx[x ∈ *P ∧ **li-amount′**(x) ∧ |x| = 1] (**apple′**)	1, 2, FA
4.		⇝	λx[x ∈ ***apple′** ∧ **li-amount′**(x) ∧ |x| = 1]	3, beta-reduction
5.	**wu**	⇒	λPλx ∃S [∏(S)(x) ∧ |S| = 5 ∧ ∀s ∈ S [[P]](s)]	lexical
6.	**wu li pingguo**	⇒	λPλx ∃S [∏(S)(x) ∧ |S| = 5 ∧ ∀s ∈ S [[P]](s)](λx[x ∈ ***apple′** ∧ **li-amount′**(x) ∧ |x| = 1])	4, 5, FA
7.		⇝	λx∃S[∏(S)(x) ∧ |S| = 5 ∧ ∀s ∈ S [λx[x ∈ ***apple′** ∧ **li-amount′**(x) ∧ |x| = 1]](s)]	6, beta-reduction
8.		⇝	λx∃S[∏(S)(x) ∧ |S| = 5 ∧ ∀s ∈ S [s ∈ ***apple′** ∧ **li-amount′**(s) ∧ |s| = 1]]	7, beta-reduction

So, the final translation of **wu li pingguo** five-CL-apple 'five apples' is λx[∃S[∏(S)(x) ∧ |S| = 5 ∧ ∀s ∈ S [s ∈ ***apple′** ∧ **li-amount′**(s) ∧ |s| = 1]]]. This roughly translates to 'for some x, x is a partition with five parts, and for all parts in the partition, each one is one atomic li of apple.' That is, some x has five parts, each of which is one atomic li of apple.

(55) The same translation process happens for *san dai pingguo* three-bag (CL)-apple 'three bags of apples':

1.	**pingguo**	⇒	**apple′**	lexical
2.	**dai**	⇒	λPλx[x ∈ P ∧ **bag-amount′**(x)]	lexical
3.	**dai pingguo**	⇒	λPλx[x ∈ P ∧ **bag-amount′**(x)](**apple′**)	1, 2, FA
4.		⇝	λx[x ∈ **apple′** ∧ **bag-amount′**(x)]	3, beta-reduction
5.	**san**	⇒	λPλx ∃S [∏(S)(x) ∧ |S| = 3 ∧ ∀s ∈ S [[P]](s)]	lexical
6.	**san dai pingguo**	⇒	λPλx ∃S [∏(S)(x) ∧ |S| = 3 ∧ ∀s ∈ S [[P]](s)](λx[x ∈ **apple′** ∧ **bag-amount′**(x)])	4, 5, FA

7.		$\rightsquigarrow$	$\lambda x\exists S[\prod(S)(x) \wedge \lvert S\rvert = 3 \wedge \forall s \in S\ [\lambda x[x \in \textbf{apple}' \wedge \textbf{bag-amount}'(x)]](s)]$	6, beta-reduction
8.		$\rightsquigarrow$	$\lambda x\exists S[\prod(S)(x) \wedge \lvert S\rvert = 3 \wedge \forall s \in S\ [s \in \textbf{apple}' \wedge \textbf{bag-amount}'(s)]]$	7, beta-reduction

The translation for **san dai pingguo** three-bag (CL)-apple 'three bags of apples' is $\lambda x[\exists S[\prod(S)(x) \wedge \lvert S\rvert = 3 \wedge \forall s \in S\ [s \in \textbf{apple}' \wedge \textbf{bag-amount}'(s)]]]$. This roughly translates to 'for some x, x is a partition with three parts, and for all parts in the partition, each one is a bag of apple-stuff.' That is, some x has three parts, each of which is a bag of apple/s.

(56) Finally, we can derive the translation for a complex phrase such as *san dai wu li pingguo* three-bag (CL)-five-CL-apple 'three bags of five apples'.

1.	**pingguo**	$\Rightarrow$	$\textbf{apple}'$	lexical
2.	**li**	$\Rightarrow$	$\lambda P\lambda x[x \in {}^*P \wedge \textbf{li-amount}'(x) \wedge \lvert x\rvert = 1]$	lexical
3.	**li pingguo**	$\Rightarrow$	$\lambda P\lambda x[x \in {}^*P \wedge \textbf{li-amount}'(x) \wedge \lvert x\rvert = 1](\textbf{apple}')$	1, 2, FA
4.		$\rightsquigarrow$	$\lambda x[x \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(x) \wedge \lvert x\rvert = 1]$	3, beta-reduction
5.	**wu**	$\Rightarrow$	$\lambda P\lambda x\ \exists S\ [\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [[P]](s)]$	lexical
6.	**wu li pingguo**	$\Rightarrow$	$\lambda P\lambda x\ \exists S\ [\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [[P]](s)](\lambda x[x \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(x) \wedge \lvert x\rvert = 1])$	4, 5, FA
7.		$\rightsquigarrow$	$\lambda x\exists S[\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [\lambda x[x \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(x) \wedge \lvert x\rvert = 1]](s)]$	6, beta-reduction
8.		$\rightsquigarrow$	$\lambda x\exists S[\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [s \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(s) \wedge \lvert s\rvert = 1]]$	7, beta-reduction
9.	**dai**	$\Rightarrow$	$\lambda P\lambda x[P(x) \wedge \textbf{bag-amount}'(x)]$	lexical
10.	**dai wu li pingguo**	$\Rightarrow$	$\lambda P\lambda x[P(x) \wedge \textbf{bag-amount}'(x)](\lambda x\exists S[\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [s \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(s) \wedge \lvert s\rvert = 1]])$	8, 9, FA
11.		$\rightsquigarrow$	$\lambda x[\lambda x[\exists S[\prod(S)(x) \wedge \lvert S\rvert = 5 \wedge \forall s \in S\ [s \in {}^*\textbf{apple}' \wedge \textbf{li-amount}'(s) \wedge \lvert s\rvert = 1]]](x) \wedge \textbf{bag-amount}'(x)]$	10, beta-reduction

12.	↝	$\lambda x[\exists S[\prod(S)(x) \wedge \lvert S \rvert = 5 \wedge \forall s \in S$ $[s \in *\mathbf{apple'} \wedge \mathbf{li\text{-}amount'}(s) \wedge \lvert s \rvert = 1]]$ $\wedge \mathbf{bag\text{-}amount'}(x)]$	11, beta-reduction
13. **san**	⇒	$\lambda P\lambda x \exists S [\prod(S)(x) \wedge \lvert S \rvert = 3 \wedge$ $\forall s \in S [[P]](s)]$	lexical
13. **san dai wu li pingguo**	⇒	$\lambda P\lambda x \exists S [\prod(S)(x) \wedge \lvert S \rvert = 3 \wedge$ $\forall s \in S [[P]](s)](\lambda x[\exists S[\prod(S)(x) \wedge \lvert S \rvert = 5 \wedge$ $\forall s \in S [s \in *\mathbf{apple'} \wedge \mathbf{li\text{-}amount'}(s) \wedge$ $\lvert s \rvert = 1]] \wedge \mathbf{bag\text{-}amount'}(x)])$	12, 13, FA
14.	↝	$\lambda x \exists S [\prod(S)(x) \wedge \lvert S \rvert = 3 \wedge$ $\forall s \in S\ \lambda x[\exists S[\prod(S)(x) \wedge \lvert S \rvert = 5 \wedge$ $\forall s \in S [s \in *\mathbf{apple'} \wedge \mathbf{li\text{-}amount'}(s) \wedge$ $\lvert s \rvert = 1]] \wedge \mathbf{bag\text{-}amount'}(x)](s)]$	13, beta-reduction
15.	↝	$\lambda x \exists S [\prod(S)(x) \wedge \lvert S \rvert = 3 \wedge$ $\forall s \in S [\exists S[\prod(S)(s) \wedge \lvert S \rvert = 5 \wedge$ $\forall s \in S [s \in *\mathbf{apple'} \wedge \mathbf{li\text{-}amount'}(s) \wedge$ $\lvert s \rvert = 1]] \wedge \mathbf{bag\text{-}amount'}(s)]]$	14, beta-reduction

So, the final translation of **san dai wu li pingguo** three-bag (CL)-five-CL-apple 'three bags of five apples' is $\lambda x \exists S [\prod(S)(x) \wedge \lvert S \rvert = 3 \wedge \forall s \in S [\exists S[\prod(S)(s) \wedge \lvert S \rvert = 5 \wedge \forall s \in S [s \in *\mathbf{apple'} \wedge \mathbf{li\text{-}amount'}(s) \wedge \lvert s \rvert = 1]] \wedge \mathbf{bag\text{-}amount'}(s)]]$. This roughly translates to 'for some entity x, x is a partition with three parts such that for all parts of the partition, there exists another partition with five parts, and for all parts in that partition, each part is one atomic li of apple, and each partition [with five apples] is a bag amount of it.' That is, for some x, x has three bag-amount parts, each of which has five parts, each consisting of one atomic li of apple.

(57) The justification for the separate translation of *dai* 'bag' for this use is in steps 11 and 12 of the translation for *san dai wu li pingguo* three-bag (CL)-five-CL-apple 'three bags of five apples': without the translation of P(x) instead of $x \in P$, beta reduction is not possible, which makes the entire translation impossible.

(58) To summarize: We have provided semantic translations of the phrases *wu li pingguo* five-CL-apple 'five apples', *san dai pingguo* three-bag (CL)-apple 'three bags of apples', and *san dai wu li pingguo* three-bag (CL)-five-CL-apple 'three bags of five apples'. The translations agree with the syntactic combining order and demonstrate the complex partitioning that the cardinal numbers create.

VIII. Conclusion

(59) Bare nouns are typically divided into two groups, mass nouns and count nouns, with imperfect diagnostics, such as cumulativity, homogeneity, and atomicity, available to determine which category a noun falls into.

(60) However, in Chinese, bare nouns are interpreted as being mass nouns by default, and are not interpreted as count nouns until a classifier intervenes.

(61) Classifiers are thus required in instances of count, anaphora, and deixis. These classifiers typically create count nouns, although some (e.g. *dui* 'pile') can create another mass noun out of the bare noun; other classifiers have specialized idiomatic uses.

(62) Instances where classifiers are not used provide illustrations of how the bare noun in Chinese is interpreted as mass rather than count.

(63) Syntactically, bare nouns are of the category CN; classifiers, CN/CN; and numerals, CN/CN. Quantifiers such as *mei* 'every' that can co-occur with classifier phrases are of the category NP/CN.

(64) Because classifier phrases can occur as the complements to verbs, we require a null nominalizer that converts the CN classifier phrase to an NP.

(65) The semantics of classifiers can be represented in lambda calculus. Regular count classifiers have one definition, and special mass classifiers have another.

(66) The semantics of cardinal numbers co-occurring with classifiers can also be represented in lambda calculus with the use of partitions. These partitions preserve the semantic compositionality of cardinal numbers.

(67) We provided translations into lambda calculus of three classifier phrases, two simple ones and one complex one. We showed that the translation of the complex classifier phrase preserves the partitioning of the cardinal numbers.

(68) This presentation has provided a wide but simplified overview of the complex topic of Chinese classifiers, as well as mass vs. noun and number representations. Further, more in-depth reading on each section can be found in the bibliography.

(69) Future research can also examine the interaction between classifiers and quantifiers, determiners, and modifiers.

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