

Cross-linguistic compositional classifier semantics for numerical expressions

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Introduction

What's this all about?

- ▶ numerals
 - ▶ simplex forms
 - ▶ multiple uses
 - ▶ semantically complex expressions
- ▶ numerical expressions
 - ▶ understudied yet revealing
 - ▶ morphological complexity
 - ▶ derived complex meanings
- ▶ unified semantics
 - ▶ core meaning \Rightarrow reference to numbers
 - ▶ shifting operators
 - ▶ classifier semantics

Introduction

Various uses of numerals

Bultinck (2003), Geurts (2006), Rothstein (2013, 2017)

- ▶ no unique meaning?
- ▶ polysemous?

- | | | | |
|-----|----|--------------------------------------|--------------|
| (1) | a. | Five is the fourth Fibonacci number. | arithmetical |
| | b. | Five ducks entered the lobby. | quantifying |
| | c. | These are five buckets. | predicative |
| | d. | the five girls | adjectival |
| | e. | five pounds of buckwheat | measure |
| | f. | Chanel number five | label |

Introduction

Derivationally complex numerical expressions in Polish

- (2)
- a. **dwóch** studentów
two students
'two students' 2 entities
 - b. **dwoje** studentów
two_{G_{NDR}} students
'two students (male and female)' 2 entities
gender inference
 - c. **dwójka** studentów
two_{COLL} students
'group of two students' 2 entities
collectivity

Introduction

Derivationally complex numerical expressions in Polish

- (3) a. **dwóch** studentów
two students
'two students' 2 entities
- b. **podwójna** korona
double crown
'double crown' *2 entities
2 parts
- c. **dwukrotny** prezydent
two-time president
'two-time president' *2 entities
2 events

Introduction

Mainstream research

Barwise & Cooper (1981), Scha (1981), Landman (2004)

- ▶ English data
- ▶ numerous prolific insights
- ▶ influential theories
- ▶ focus: derivationally simplex expressions
- ▶ English: no rich morphology
- ▶ derivationally complex expressions \Rightarrow neglected

Introduction

Basic cardinal numerals

- ▶ gender morphology
- ▶ non-trivial semantic effects
- ▶ semantic compositionality
- ▶ grammatical gender \Rightarrow classifier system

Complex numerical expressions

- ▶ morphological complexity
- ▶ non-trivial quantificational effects
- ▶ semantic compositionality
- ▶ different affixes \Rightarrow distinct classifiers

Cardinals

Recent research

- ▶ gender as a grammaticalized classifier system
 - ▶ Serbo-Croatian neuter nouns
Arsenijević (2016)
 - ▶ Arabic numerals
Fassi Fehri (2016, 2018)

Focus

- ▶ virile/non-virile alternation in Polish cardinal numerals

- (4)
- Pięć** dziewczyn spało.
five_{NV} girls_{NV} slept
 - Pięciu** chłopców spało.
five_V boys_V slept

Cardinals

Novel data

- ▶ referential use of cardinals
- ▶ cardinals in contexts calling for numerical arguments
- ▶ cross-linguistic correspondences

Claims

- ▶ Polish cardinals \Rightarrow reference depends on gender
- ▶ gender on cardinals \Rightarrow grammaticalized classifier
- ▶ semantic asymmetry
 - ▶ non-virile cardinals \Rightarrow names of number concepts
 - ▶ virile cardinals \Rightarrow classifier semantics

Cardinals

Markedness

- ▶ virile forms \Rightarrow morphologically and semantically marked

- (5)
- a. dw-a
root-NV.marker
 - b. dw-a-j
root-marker-V.marker

- ▶ numeral roots \Rightarrow often homophonous to non-virile forms

- (6)
- a. $\sqrt{\text{pięć}}$
 - b. pięć- \emptyset
root-NV.marker
 - c. pięci-u
root-V.marker

Cardinals

Semantic functions of English cardinal numerals

Rothstein (2013, 2017)

- ▶ nominal modifiers

(7) The four cats lay on the sofa.

- ▶ predicates

(8) My reasons for saying this are four.

- ▶ names of number concepts

(9) Six is bigger than two.

Cardinals

Polish cardinals

- ▶ virile/non-virile \Rightarrow not reducible to syntactic agreement
- ▶ both forms can modify NPs and occur in predicate position

- (10) a. Tych **pięć** dziewczyn przyszło.
these five_{NV} girls_{NV} came
- b. Tych **pięciu** chłopców przyszło.
these five_V boys_V came
- (11) a. Tych dziewczyn było **pięć**.
these girls_{NV} was five_{NV}
- b. Tych chłopców było **pięciu**.
these boys_V was five_V

Cardinals

Asymmetry in numerical contexts

- ▶ virile forms cannot name numbers

- (12) a. liczba pięć
number five_{NV}
b. #liczba pięciu
number five_V

- ▶ virile forms cannot appear in a counting list

- (13) a. jeden, dwa, trzy, cztery, pięć...
one_{NV} two_{NV} three_{NV} four_{NV} five_{NV}
b. #jeden, dwaj, trzej, czterej, pięciu...
one_V two_V three_V four_V five_V

Cardinals

- ▶ virile forms cannot appear in mathematical statements

- (14) a. Dwa razy pięć równa się dziesięć.
two times five_{NV} equals REFL ten
- b. *Dwa razy pięciu równa się dziesięć.
two times five_V equals REFL ten

- ▶ similar other marked forms

- (15) a. Dwa razy dwa równa się cztery.
two times two_{NV} equals REFL four
- b. *Dwa razy dwie równa się cztery.
two times two_{FEM} equals REFL four

Cardinals

Non-virile forms as names of numbers \Rightarrow distinctive properties

- ▶ resist adjectival modification

cf. Babby (1987), Miechowicz-Mathiasen (2011)

- (16) a. dobre_i pięć_i butelek
good five bottles
- b. *liczba dobre_i pięć_i
number good five

- ▶ incompatible with the universal quantifier

cf. Corbett (1978), Gvozdanović (1999), Miechowicz-Mathiasen (2011)

- (17) a. wszystkie pięć butelek
all five bottles
- b. *liczba wszystkie pięć
number all five

Interim summary

Polish cardinal numerals

- ▶ virile/non-virile alternation
- ▶ non-virile forms
 - ▶ unmarked
 - ▶ felicitous as modifiers and predicates
 - ▶ felicitous as names of number concepts
 - ▶ when used as names of numbers \Rightarrow distinctive properties
- ▶ virile forms
 - ▶ marked
 - ▶ felicitous as modifiers and predicates
 - ▶ infelicitous as names of number concepts
 - ▶ incompatible with numerical contexts

Cross-linguistic perspective

Bulgarian virile cardinals

Cinque & Krapova (2007), Pancheva (2018)

- ▶ special forms for numerals 2–10 ending in *-ma* or *-ima*
- ▶ infelicitous in contexts calling for numerical arguments

(18) a. Tezi **pet** ženi dojdoxa.

these two_{NV} women_{NV} came

b. Tezi **petima** mâže dojdoxa.

these five_V men_V came

(19) a. Deset deleno na **pet** e dva.

ten divided on five_{NV} is two

‘Ten divided by two is five.’

b. #Deset deleno na **petima** e dva.

ten divided on five_V is two

Cross-linguistic perspective

Slovak masculine animate cardinals

- ▶ special numeral forms in *-aja*, *-ia* or *-i*
- ▶ infelicitous in contexts calling for numerical arguments

(20) a. Týchto päť žien prišlo.
these five_{NMA} women_{NMA} came

b. Títo piati muži prišli.
these five_{MA} men_{MA} came

(21) a. Dvokrát päť je desať.
two.times five_{NMA} is ten
'Two times five is ten.'

b. #Dvokrát piati je desať.
two.times five_{MA} is ten

Cross-linguistic perspective

Specialized numerals across languages

Hurford (1998, 2001)

- ▶ attributive numerals \Rightarrow modification
- ▶ counting numerals \Rightarrow reference to number concepts

| LANGUAGE | NUMBER | ATTRIBUTIVE | COUNTING |
|-----------|--------|-------------|----------|
| German | 2 | zwei | zwo |
| Maltese | 2 | żewg | tnejn |
| Chinese | 2 | liǎng | èr |
| Hungarian | 2 | két | kettő |
| Basque | 2 | bi | biga |

Cross-linguistic perspective

Interaction between gender and reference in Arabic

- ▶ specialized numeral forms
- ▶ only feminine cardinals are felicitous in numeric contexts

Fassi Fehri (2017)

- (22) a. taalat-at-un t-usawii 2+1
three-FEM-NOM FEM>equals 2+1
'Three equals 2+1.'
- b. *taalat-un t-usawii 2+1
three-NOM FEM>equals 2+1

Arabic

Cross-linguistic perspective

Classifiers

- ▶ numerals and classifiers are always adjacent

Greenberg (1972)

| LANGUAGE | ORDERING |
|------------|------------|
| Vietnamese | [NUM-CL]-N |
| Thai | N-[NUM-CL] |
| Ibidio | [CL-NUM]-N |
| Bodo | N-[CL-NUM] |

- ▶ classifiers are often suffixes on numerals

Aikhenvald (2000)

(23) **pajluhua-na** yahui
one-CL dog
'one dog'

Yucuna

Cross-linguistic perspective

Classifier constructions in Japanese

- ▶ bare numerals cannot be used as modifiers or predicates

Sudo (2016)

- (24) a. ***ichi**-no hana
one-GEN flower
- b. **ichi-rin**-no hana
one-CL-GEN flower
'one flower'

Japanese

- (25) a. *kyoo-no okyakusan-wa **juu-ni**-da.
today-GEN guest-TOP ten-two-COP
- b. kyoo-no okyakusan-wa **juu-ni-nin**-da.
today-GEN guest-TOP ten-two-CL-COP
'The number of guests today is twelve.'

Cross-linguistic perspective

Classifier constructions in Japanese

- ▶ classifier constructions do not fit unambiguously numerical contexts

- (26) a. **juu** waru **ni**-wa go-da.
ten divide.by two-TOP five-COP
'Ten divided by two is five.'
- b. ***juu-ko** waru **ni-ko**-wa go-ko-da.
ten-CL divide.by two-CL-TOP five-CL-COP

Cross-linguistic perspective

Partly classifier languages

Bale & Coon (2014)

- ▶ intriguing data from Mi'gmaq and Chol
- ▶ some cardinals require classifiers
- ▶ others do not
- ▶ different cardinals \Rightarrow distinct semantics

(27) a. **na'n** (*te's)-ijig ji'nm-ug
five CL-AGR man-PL
'five men'

b. **asugom** *(te's)-ijig ji'nm-ug
six CL-AGR man-PL
'six men'

Mi'gmaq

Background

Standard approach

Borer (2005), Chierchia (1998, 2010), Rothstein (2010), Li (2011), Scontras (2013)

- ▶ mass-like semantics of nouns in classifier languages
- ▶ classifiers compensate semantic deficits of nouns

Alternative view

Krifka (1995), Bale & Coon (2014), Sudo (2016)

- ▶ different semantics of numerals in classifier languages
- ▶ classifiers compensate semantic deficits of numerals

Background

Measure functions

Krifka (1989, 1990, 1995)

- ▶ operations that map entities to numbers
 - ▶ LITER maps an entity to a number of liters of that entity

(28) a. $\llbracket \textit{Measure}P \rrbracket = \lambda x[\text{N}(x) \wedge \mu(x) = n]$
b. $\llbracket \textit{two liters of water} \rrbracket = \lambda x[\text{WATER}(x) \wedge \text{LITER}(x) = 2]$

- ▶ natural unit/object unit operation
 - ▶ $\#(P)$ maps a plurality to a number of individuals
 - ▶ $\#(P)$ is compatible only with quantized predicates

(29) a. $\llbracket \textit{Numeral}P \rrbracket = \lambda x[*\text{N}(x) \wedge \#(\text{N})(x) = n]$
b. $\llbracket \textit{two cats} \rrbracket = \lambda x[*\text{CAT}(x) \wedge \#(\text{CAT})(x) = 2]$

Background

Cardinal numerals as predicates

Rothstein (2012, 2013, 2017)

- ▶ names of numbers
 - ▶ abstract objects of a primitive type n

Scha (1981)

- (30)
- a. $\llbracket \textit{Numeral} \rrbracket = n$
 - b. $\llbracket \textit{two} \rrbracket = 2$

- ▶ cardinal predicates
 - ▶ the type of adjectives $\langle e, t \rangle$

Landman (2003)

- (31)
- a. $\llbracket \textit{Numeral} \rrbracket = \lambda x[|x| = n]$
 - b. $\llbracket \textit{two} \rrbracket = \lambda x[|x| = 2]$

Background

- ▶ shifting mechanism relating n and $\langle e, t \rangle$
 - ▶ Fregean property theory
Chierchia (1985)
 - ▶ properties are basic
 - ▶ \cap and $\cup \Rightarrow$ shifts between properties and numbers

(32)

- $\llbracket \text{Numeral} \rrbracket_{\langle e, t \rangle} = \lambda x[|x| = n]$
- $\llbracket \text{Numeral} \rrbracket_n = \cap \lambda x[|x| = n]$
- $\cup \cap \llbracket \text{Numeral} \rrbracket_{\langle e, t \rangle} = \llbracket \text{Numeral} \rrbracket_{\langle e, t \rangle}$

(33)

- $\llbracket \text{two} \rrbracket_{\langle e, t \rangle} = \lambda x[|x| = 2]$
- $\llbracket \text{two} \rrbracket_n = \cap \llbracket \text{two} \rrbracket_{\langle e, t \rangle} = 2$

Proposal

Morpho-syntactic assumptions

- ▶ roots are category-free
Halle & Marantz (1993)
- ▶ *numeral* head assigns gender
- ▶ adding more structure is possible

Semantic assumptions

- ▶ names of numbers are basic
- ▶ overt/covert element **CL** ('classifier')
 - ▶ shift: $n \Rightarrow \langle \langle e, t \rangle, \langle e, t \rangle \rangle$
 - ▶ measure function $\#(P)$
 - ▶ atomicity requirement \Rightarrow presupposition $AT(P)$
- ▶ classifier construction \Rightarrow modifier or predicate

Proposal

Composition of Polish cardinals

- ▶ numeral roots \Rightarrow type n
 - ▶ names of numbers
 - ▶ often homophonous to non-virile forms
 - ▶ never homophonous to virile forms
- ▶ cardinal suffixes
 - ▶ operations on numbers \Rightarrow type $\langle n, n \rangle$
- ▶ inflectional morphology
 - ▶ virile forms \Rightarrow marked
 - ▶ markedness \Rightarrow specific meaning
 - ▶ non-virile marker \Rightarrow [NV] gender value
 - ▶ CL can be applied later in the derivation
 - ▶ virile marker \Rightarrow [V] gender value + CL

Proposal

Semantics of numeral roots

- ▶ singular terms

$$(34) \quad \begin{array}{l} \text{a. } \llbracket \sqrt{\text{Numeral}} \rrbracket = n \\ \text{b. } \llbracket \sqrt{\text{pięć}} \rrbracket = 5 \end{array}$$

Semantics of CL

- ▶ classifier element \Rightarrow shift
- ▶ measure function
- ▶ atomicity presupposition
- ▶ pluralization

$$(35) \quad \llbracket \text{CL} \rrbracket = \lambda n \lambda P \lambda x. \text{AT}(P)[*P(x) \wedge \#(P)(x) = n]$$

Proposal

Cardinal suffixes

- ▶ operators of type $\langle n, n \rangle$
- ▶ attach to numeral roots
- ▶ yield a value enlarged via addition or multiplication
- ▶ compatible only with natural numbers

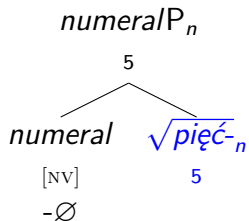
- (36) a. pięć-naście
five-teen
'fifteen'
- b. *pół-naście
half-teen

- (37) a. $\llbracket \text{-naście} \rrbracket = \lambda n. \text{INTEGER}(n)[n + 10]$
- b. $\llbracket \text{-dziesiąt} \rrbracket = \lambda n. \text{INTEGER}(n)[n \times 10]$

Proposal

Composition of number-denoting *pięć* ('five')

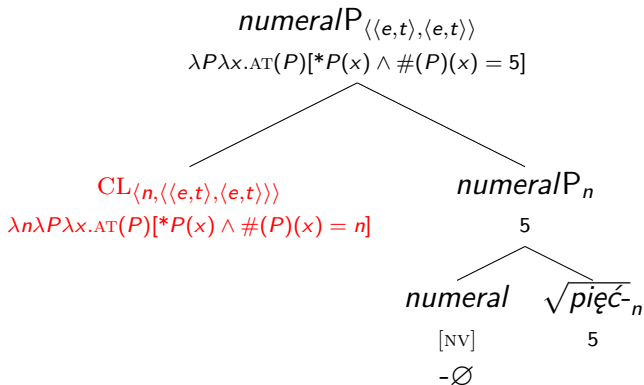
(38)



Proposal

Composition of classifier *pięć* ('five')

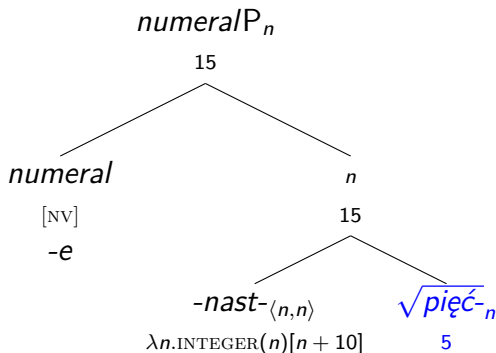
(39)



Proposal

Composition of number-denoting *piętnaście* ('fifteen')

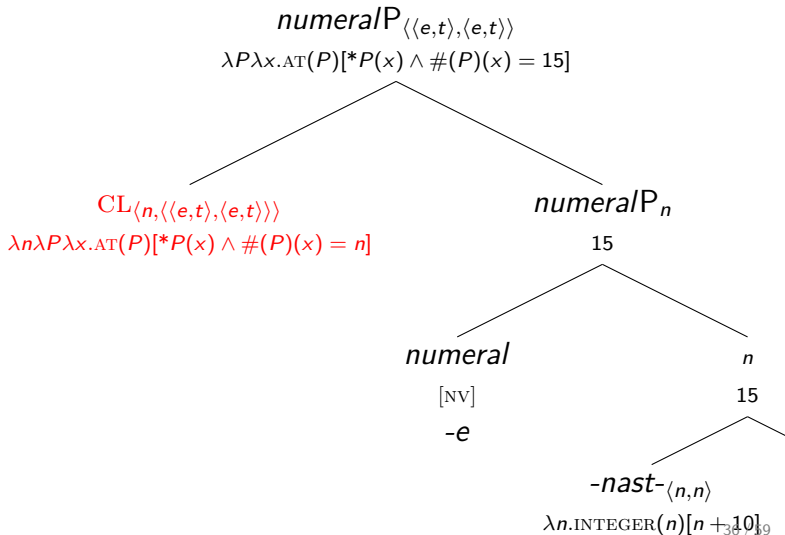
(40)



Proposal

Composition of classifier *piętnaście* ('fifteen')

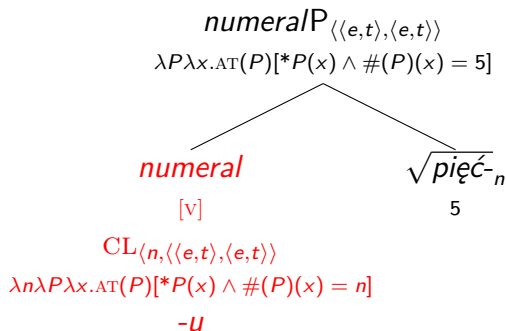
(41)



Proposal

Composition of virile *pięciu* ('five')

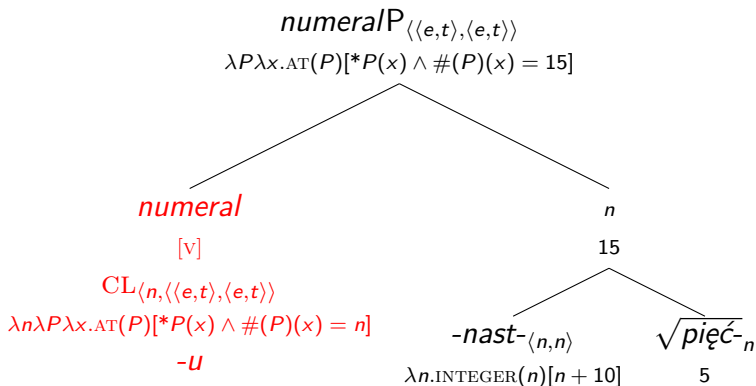
(42)



Proposal

Composition of virile *piętnastu* ('fifteen')

(43)



Extensions

Unified semantics

- ▶ one mechanism to derive distinct meanings
- ▶ non-classifier languages
- ▶ classifier languages
- ▶ interaction between classifier semantics and gender
- ▶ cardinals
- ▶ complex numerical expressions
- ▶ different morphemes \Rightarrow distinct classifiers

Numerical expressions

Slavic derivationally complex numerical expressions

Dočekal (2012, 2013), Wągiel (2014, 2015, to appear)

- ▶ numerals specialized for pluralia tantum

(46) **dv-oj-e** makaze
 two-suffix scissors
 ‘two pairs of scissors’

BCS

- ▶ mixed gender numerals

(47) **dw-oj-e** studentów
 two-suffix students
 ‘two students (one male and one female)’

Polish

Numerical expressions

Slavic derivationally complex numerical expressions

Dočekal (2012, 2013), Wągiel (2014, 2015, to appear)

- ▶ multipliers

- (48) dv-oj-n-oj hamburger
two-suffix hamburger
'double hamburger'

Russian

- ▶ frequency numerals

- (49) dw-u-krotn-y prezydent
two-suffix president
'two-time president'

Polish

Numerical expressions

Denumeral group nouns

- ▶ obligatory collective inferences

- (50)
- a. Dwóch studentów napisało esej.
two students wrote essay
'Two students wrote an essay.'
- (i) collective: total = 1 essay
 - (ii) distributive: total = 2 essays
- b. **Dwójka** studentów napisała esej.
two_{coll} students wrote essay
'A group of two students wrote an essay.'
- (i) collective: total = 1 essay
 - (ii) ***distributive**: total = 2 essays

Numerical expressions

Denumeral group nouns

- ▶ incompatible with distributive predicates

- (51) a. Dwóch studentów jest wysokich.
two students is tall
'Two students are tall.'
- b. Dwóch studentów spłodziło czworo dzieci.
two students fathered four children
'Two students fathered four children.'
- (52) a. #Dwójka studentów jest wysoka.
two_{coll} students is tall
- b. #Dwójka studentów spłodziła czworo dzieci.
two_{coll} students fathered four children

Numerical expressions

Frequency numerals

- ▶ hidden 'becoming' event \Rightarrow acquiring a property

- (53)
- a. Obama to **dwukrotny** prezydent.
Obama this two-time president
'Obama is a two-time president.'
 - b. \models Obama został prezydentem dwa razy.
Obama became president two times
'Obama became a president twice.'

Figure 1: Obama's presidency

Numerical expressions

Frequency numerals

- ▶ only stage-level properties
- ▶ can be repetitively acquired and lost
- ▶ the *again* test

- (54) a. Obama ponownie został prezydentem.
Obama again became president
'Obama became a president again.'
- b. #Obama ponownie został mężczyzną.
Obama again became man
'Obama became a man again.'

Multipliers

Expressions dedicated to counting parts

- ▶ entailment \Rightarrow complex inner structure

- (55)
- Pszent to **podwójna** korona.
Pschent this double crown
'The Pschent is a double crown.'
 - \models Pszent składa się z dwóch części.
Pschent consists from two parts
'The Pschent consists of two parts.'

Figure 2: Pschent

Figure 3: Deshret

Figure 4: Hedjet

Cross-linguistic perspective

Complex numerical expressions in English

- ▶ no rich morphology
- ▶ but still many different expressions
- ▶ overlooked

- (56)
- a. two
 - b. twosome
 - c. twofold
 - d. two-time
 - e. two times
 - f. twice
 - g. double
 - h. doubly

Cross-linguistic perspective

Multipliers

- ▶ cross-linguistically widespread category
- ▶ attested also in non-IE languages

| | | | |
|------|----|----------|------------|
| (57) | a. | double | |
| | b. | doppelt | German |
| | c. | doppio | Italian |
| | d. | dvigubas | Lithuanian |
| | e. | dupla | Hungarian |
| | f. | shuāng | Mandarin |

Cross-linguistic perspective

Multipliers

- ▶ Romance, Germanic, Hungarian \Rightarrow Latin borrowings
- ▶ derivationally complex in many languages

| LANGUAGE | NUMBER | CARDINAL | MULTIPLIER |
|------------|--------|----------|-----------------|
| Russian | 2 | dva | dvojnoj |
| Lithuanian | 2 | du | dvigubas |
| Finnish | 2 | kaksi | kaksinkertainen |

Proposal

Composition of complex numerical expressions

Composition of complex numeral expressions

- ▶ the same compositional mechanism
 - ▶ numeral root \Rightarrow object of type n
 - ▶ different suffixes \Rightarrow different classifiers
- ▶ collective affix
 - ▶ CL selecting for groups
 - ▶ group-formation \Rightarrow collective inference
 - ▶ measure function \Rightarrow counts groups
- ▶ taxonomic affix
 - ▶ CL selecting for subkinds
 - ▶ kind shift \Rightarrow taxonomic meaning
 - ▶ measure function \Rightarrow counts subkinds

Proposal

Composition of complex numerical expressions

- ▶ multiplicative affix
 - ▶ CL selecting for parts
 - ▶ access to the subatomic part-whole structure
 - ▶ measure function \Rightarrow counts salient comparable parts
- ▶ frequency affix
 - ▶ CL selecting for 'becoming' events
 - ▶ association of 'becoming' events with an individual
 - ▶ measure function \Rightarrow counts events of acquiring a property

Conclusion

Observations

- ▶ Polish cardinal numerals
 - ▶ gender plays a role in reference to numbers
 - ▶ non-virile \Rightarrow can name numbers
 - ▶ marked forms \Rightarrow cannot name numbers
- ▶ classifier constructions
 - ▶ can only be used as predicates and modifiers
 - ▶ unlike bare numerals cannot name numbers
- ▶ cross-linguistic correspondences
 - ▶ different forms for attributive and counting numerals
 - ▶ Arabic feminine numerals
 - ▶ Japanese classifier constructions

Conclusion

Proposal

- ▶ Polish cardinal numerals
 - ▶ non-virile \Rightarrow names of numbers or cardinal predicates
 - ▶ marked forms \Rightarrow only cardinal predicates
- ▶ claim
 - ▶ virile gender \Rightarrow grammaticalized classifier
- ▶ ingredients
 - ▶ numeral roots: names of number concepts born at type n
 - ▶ CL: shift $n \Rightarrow \langle e, t \rangle +$ measure function
- ▶ virile/non-virile alternation
 - ▶ virile *numeral* head introduces CL
 - ▶ non-virile *numeral* head does not (CL can be added later)

Conclusion

Extensions and further research

- ▶ cross-linguistic applications
 - ▶ gender on cardinals
 - ▶ classifier constructions
- ▶ complex numerical expressions
 - ▶ complex morphology \Rightarrow complex semantics
 - ▶ different affixes \Rightarrow distinct classifiers
- ▶ (morpho)syntax-semantics interface
 - ▶ gender value and CL \Rightarrow one node or more?
 - ▶ relationship between gender and quantification

cf. Arsenijević 2016, Fassi Fehri 2016

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Thanks!