Basics of Fluid Construction Grammar

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Tutorial on Fluid Construction Grammar
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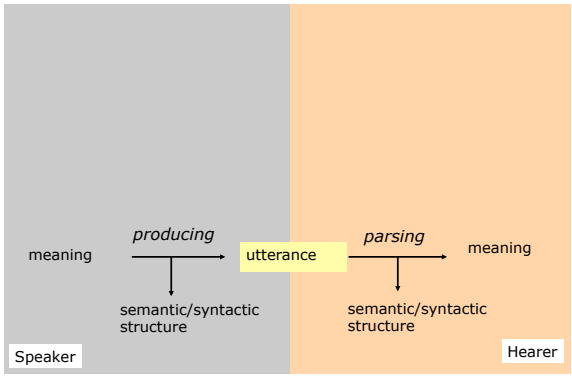
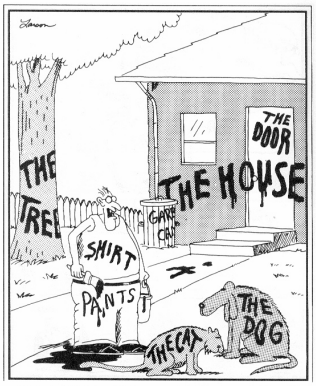
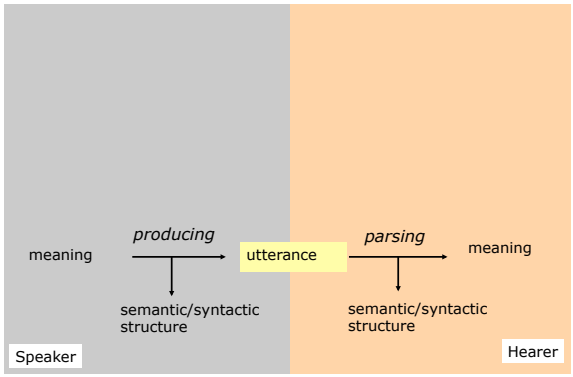


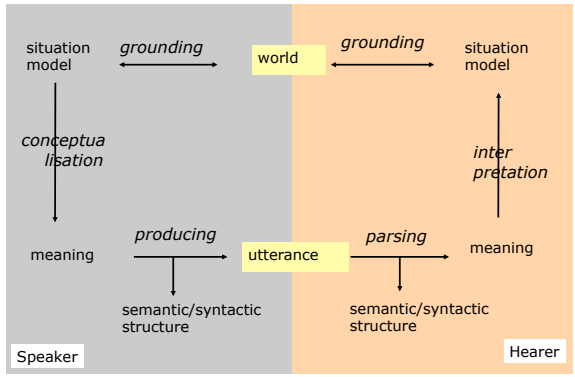


"Now!... *That* should clear up a few things around here!"

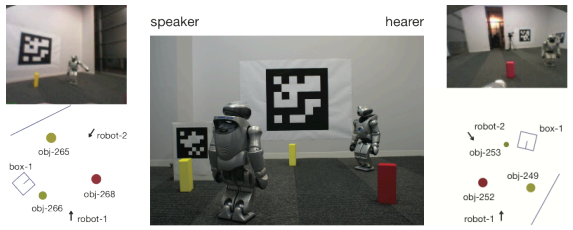
Issue (1): The world does not become nicely segmented and labeled

Issue (2): Not all meaning is expressed explicitly

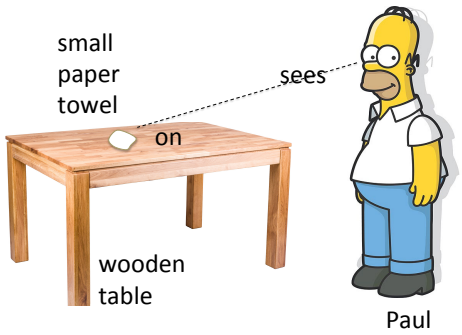




Semiotic cycle



Spranger, M., M. Loetzsch and L. Steels (2012) A perceptual system for language game experiments. In: In: Steels, L. and M. Hild (eds.) (2012) Language Grounding in Robots. Springer-Verlag, New York. pp. 95-116.



Representing meaning: predicate calculus (first order)

- Objects (table, Paul, paper, towel)
  -> symbols
  e.g. O-1, O-2, … , O-n
- Predication = fact about certain objects

- Using properties (wooden, paper, small)
  -> Unary predicates: p(o)
  e.g. wooden(O-1), paper(O-2), small(O-2), table(O-1)
- Using relations (on, moves)
  – > N-ary predicates: p(o1,o2, …)
  e.g. on(O-1, O-2), moves-away-from(O-1,O-2)

Representing meaning: predicate calculus (second order)

Properties and relations can be objects as well

- Examples of properties:
  wooden(P-1, O-1), paper(P-2, O-2),
  small(P-3, O-2), table(P-4, O-1)
- Examples of relations:
  on(R-1, O-1, O-2),
  moves-away-from(R-2, O-1,O-2)
- Intensional relations:
  – Believes (R-3, P, R-2)

Representing meaning: prefix list-notation

Predication is written as a list without comma's
First element is always the predicate

(wooden P-1 O-1) ; wooden(p-1, o-1)
(paper P-2 O-2) ; paper(p-2, o-2)
(on R-1 O-1 O-2) ; on(r-1,o-1,o-2)
(moves-away-from O-1 O-2)

Representing meaning: typed predicate calculus

Predicate is decomposed into type (attribute) and value

(material wooden P-1 O-1)
(physobj table P-2 O-1)

(spatial on R-1 O-1 O-2)
(moving away R-2 O-1 O-2)

Representing meaning: explicit arguments

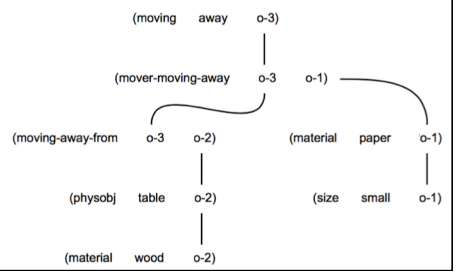
Arguments are themselves represented as predicates

(spatial-relation on R-1)
(on-arg1 R-1 O-1)
(on-arg2 R-1 O-2)

(moving away R-2)
(mover-moving-away R-2 O-1)
(moving-away-from R-2 O-2)

Representing meaning: graphical notation

Nodes in the graph are predications
Links between arguments: if there is a co-reference relation

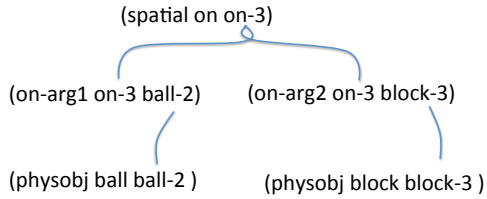


Exercise

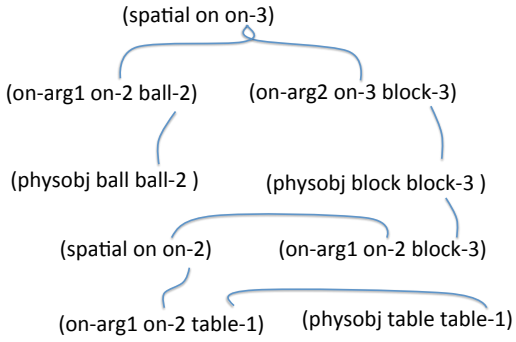
Try to represent:

1. (the) ball on (the) block

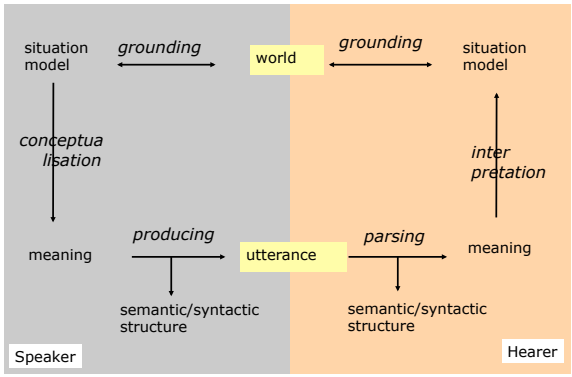
2. (the) ball on (the) block on (the) table



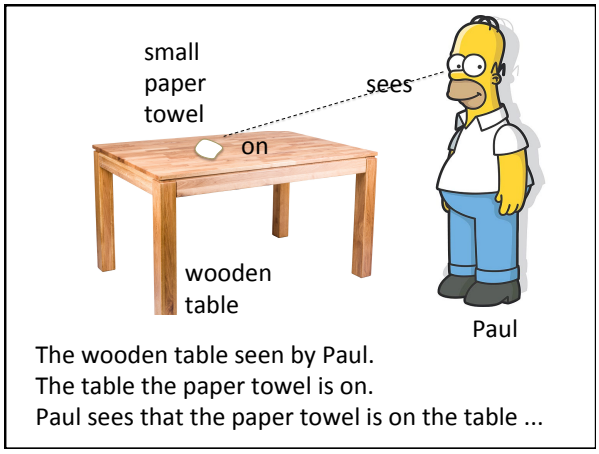
(the) ball on (the) block



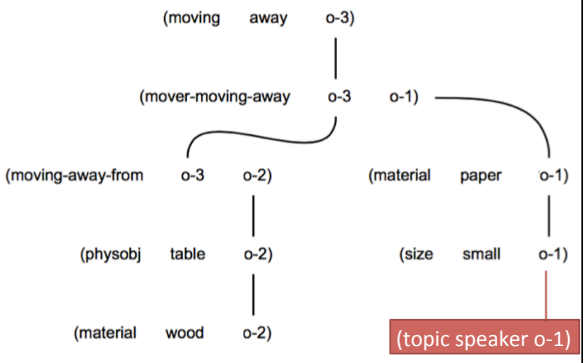
(the) ball on (the) block on (the) table)



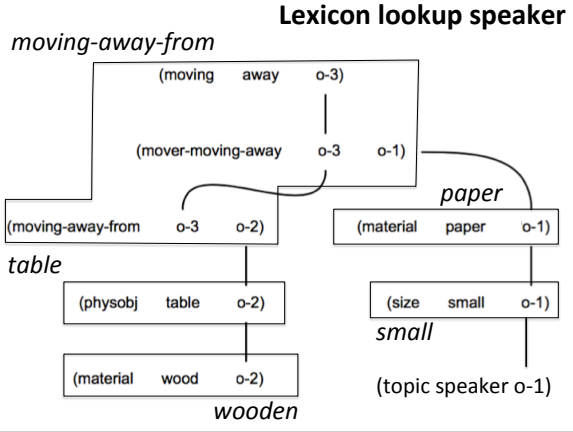
Semiotic cycle



The wooden table seen by Paul.
The table the paper towel is on.
Paul sees that the paper towel is on the table ...



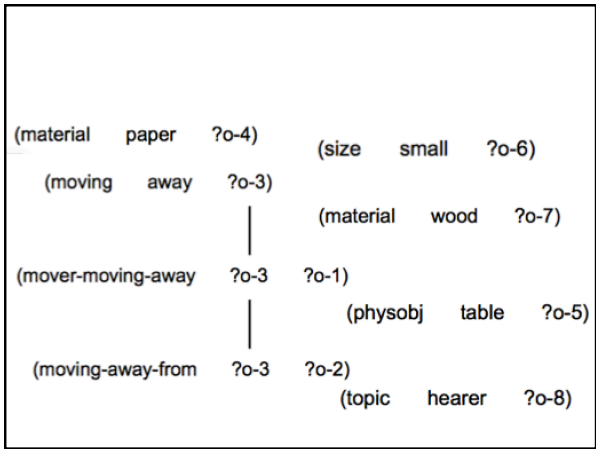
Lexicon lookup speaker

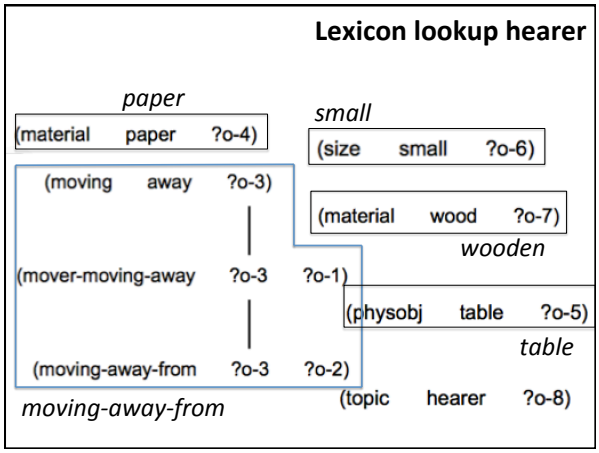


Representing meaning: variables

Variables are written as symbols with question-mark:

?table-1, ?O-2, ?X, ?on-relation-5, …





Interpretation

Compare meaning derived from words against situation model derived from perception using UNIFICATION

MATCH: Variables get bound in a matching process
Variables can be bound to other variables

BINDING-LIST: associations between variables and their bindings ((?v1 . O1) (?v2 . ?table-1) …)

Interpretation

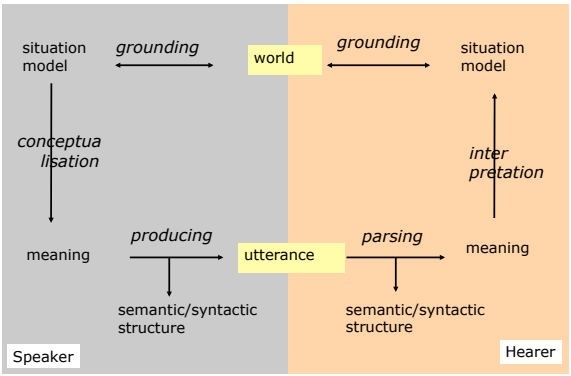
(material paper ?o4)
=> (material paper o1)
((?o4 . o1))

(size small ?o6)
=> (size small o1)
((?o4 . o1) (?o6 . o1))

?o4 and ?o6 are co-referential

Exercise: construct binding-list

((?o-1 . o-1)
(?o-2 . o-2)
(?o-3 . o-3)
(?o-4 . o-1)
(?o-5 . o-2)
(?o-6 . o-1)
(?o-7 . o-2)
(?o-8 . o-1)
)

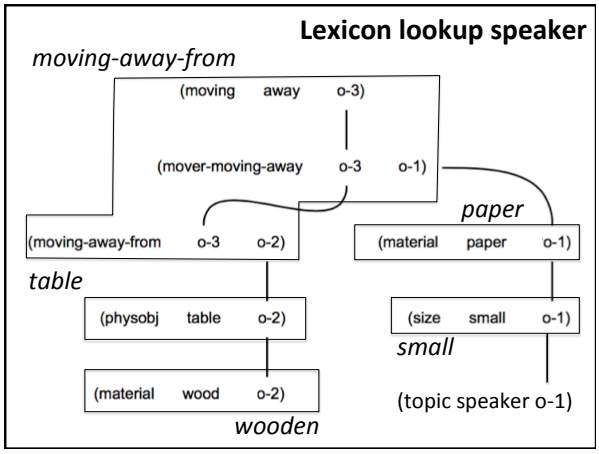


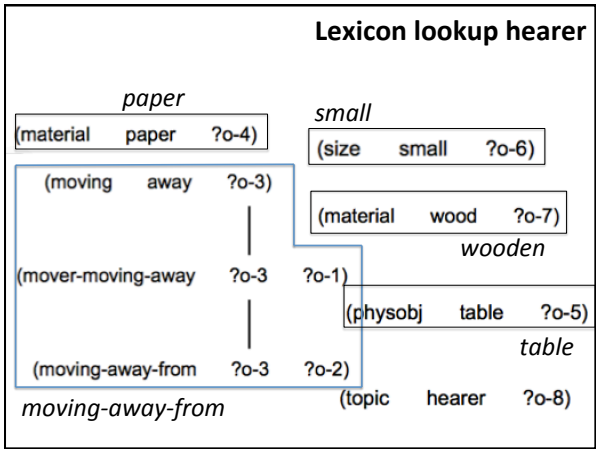
Semiotic cycle

Basic assumptions

Bi-directional mapping

meaning ⟷ form



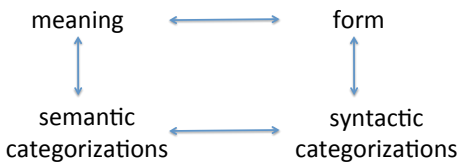


(1) **Grammar is meaningful**

- Grammar provides cues on how the meaning of individual words combine
  = what co-referential links exist between the arguments
- Grammar may also provide additional meaning (= additional predications)
  - ``The wind blew the small paper towel off the wooden table"
  - X blows Y off Z
  - X *action-on* Y *cause-state* Z

(2) Grammar works through intermediary of syntactic and semantic categorizations

- Lexical categories (noun, adjective, adverb..)
- Phrasal categories (noun phrase, verb phrase, …)
- Functional categories (subject, modifier, …)
- Agreement features (number, gender, ….)
- Case (nominative, accusative, dative, …)
- Information structure (topic, comment)
- Tense, aspect, mood, modality ….
- Sem-cats: Phys object, animate/inanimate, …
- Semantic roles (agent, patient, recipient …) …



(3) Mappings are organized as constructions

A *construction* is a usage pattern associating meaning and form through the intermediary of syntactic and semantic categorizations

- Lexical constructions (words, morphemes)
- Grammatical constructions
- Constructome = set of all constructions

(4) Constructions are computationally 'real'

A *construction schema* is a data structure representing information relevant for a particular construction:

= meaning + form

= syntactic + semantic categorizations

We call it also a *construction* for short

Contrast

In a minimalist approach to grammar, "the notion of grammatical construction is eliminated, and with it, the construction-particular rules. Constructions such as verb phrase, relative clause, and passive remain only as taxonomic artifacts, collections of phenomena explained through the interaction of the principles of UG (Universal Grammar), with the values of the parameters fixed." (Chomsky, 1993:4)

(5) Language processing = problem solving process

- Speaker starts from meaning to be expressed and builds utterance
- Hearer starts from utterance and reconstructs the meaning
- On the way they both construct a variety of syntactic and semantic structures

Problem solving

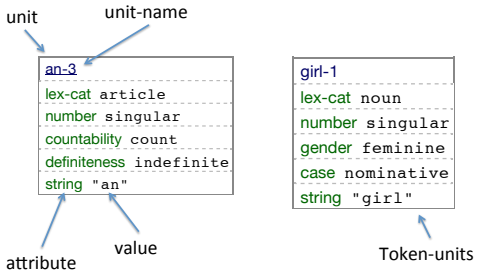
- Initial state
- Goal state
- Operators transforming states
- Search organization (e.g. Depth first)

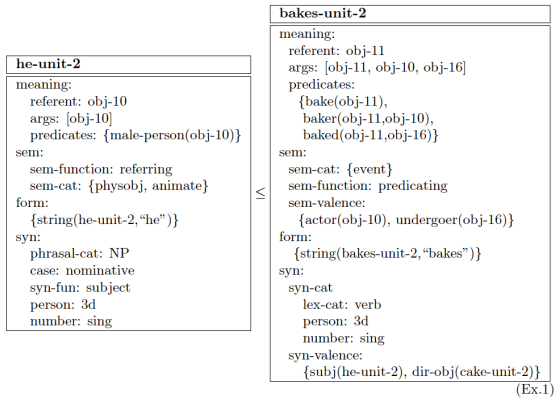
Fluid Construction Grammar

1. How to represent the current state of processing a particular utterance?
   – > transient structures
2. How to represent a construction?
   – > construction schemas
3. What is the basic machinery for applying constructions?
   – > match+merge
4. How can the application process be organized?
   – > heuristic depth-first search

Construction grammar cuts the pie in vertical slices (as opposed to horizontal ones)

Feature structures: units





(Ex.1)

Poles

- Semantic pole: groups everything related to meaning
  - Meaning (= set of predications)
  - Referent
  - Semantic categorizations
- Syntactic pole: groups everything related to form
  - Form (= set of predications)
  - Syntactic Categorizations

Transient structure (ts)

Set of units relevant for parsing/producing a particular utterance

Represent information at any level of linguistic structure (pragmatics, semantics, syntax, morphology, phonology, phonetics, prosody, gestural)

<example>

he-unit-2

meaning:
- referent: obj-10
- args: [obj-10]
- predicates: {male-person(obj-10)}

sem:
- sem-function: referring
- sem-cat: {physobj, animate}

form:
- {string(he-unit-2, "he")}

syn:
- phrasal-cat: NP
- case: nominative
- syn-fun: subject
- person: 3d
- number: sing

$\leq$

bakes-unit-2

meaning:
- referent: obj-11
- args: [obj-11, obj-10, obj-16]
- predicates:
  - {bake(obj-11),
  - baker(obj-11,obj-10),
  - baked(obj-11,obj-16)}

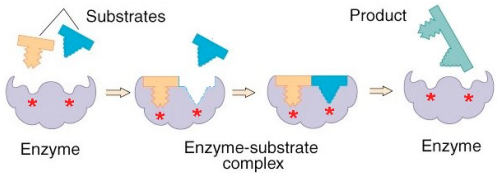
sem:
- sem-cat: {event}
- sem-function: predicating
- sem-valence:
  - {actor(obj-10), undergoer(obj-16)}

form:
- {string(bakes-unit-2, "bakes")}

syn:
- syn-cat
  - lex-cat: verb
  - person: 3d
  - number: sing
- syn-valence:
  - {subj(he-unit-2), dir-obj(cake-unit-2)}

(Ex.1)

Lock and key model



INDUCED FIT MODEL

Construction (schemas)

- Lock + Key model
  - Lock = specifies what has to be there
    - Production lock
    - Comprehension lock
  - Key = transient structure

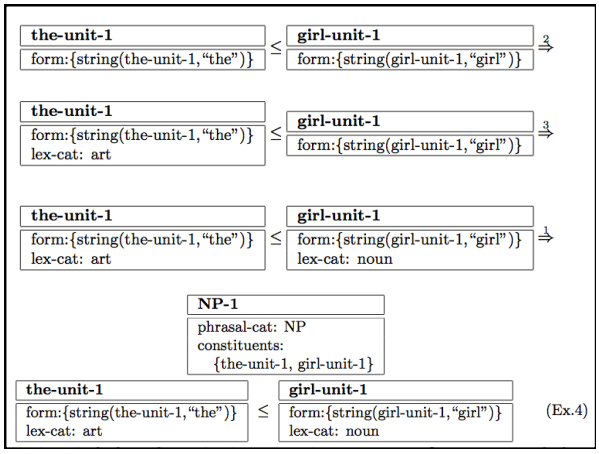
Contributing Unit$_1$	...	**Contributing Unit$_n$**	$\rightarrow$

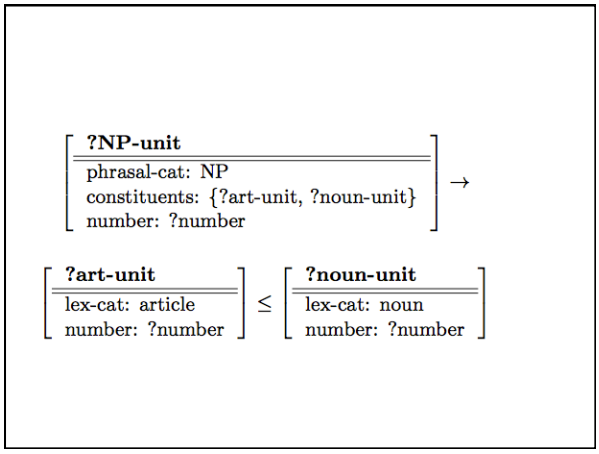
Conditional Unit$_1$	...	**Conditional Unit$_m$**
production-lock$_1$	...	production-lock$_m$
comprehension-lock$_1$		comprehension-lock$_m$

[1] NP $\rightarrow$ art noun
[2] art $\rightarrow$ the
[3] noun $\rightarrow$ girl

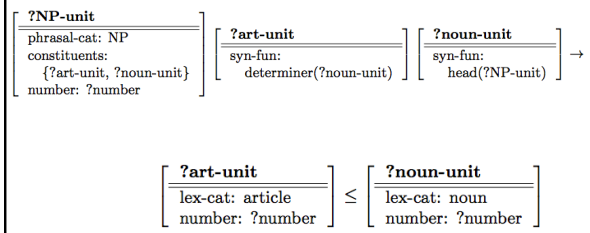
NP $\overset{1}{\Rightarrow}$ art noun $\overset{2}{\Rightarrow}$ "the" noun $\overset{3}{\Rightarrow}$ "the girl"

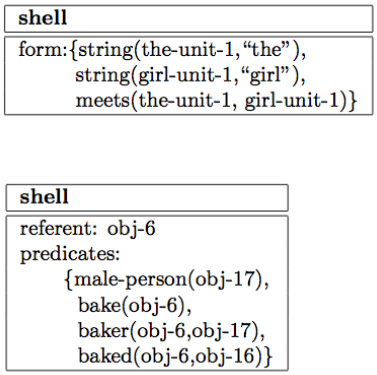
"the girl" $\overset{2}{\Rightarrow}$ art "girl" $\overset{3}{\Rightarrow}$ art noun $\overset{1}{\Rightarrow}$ NP

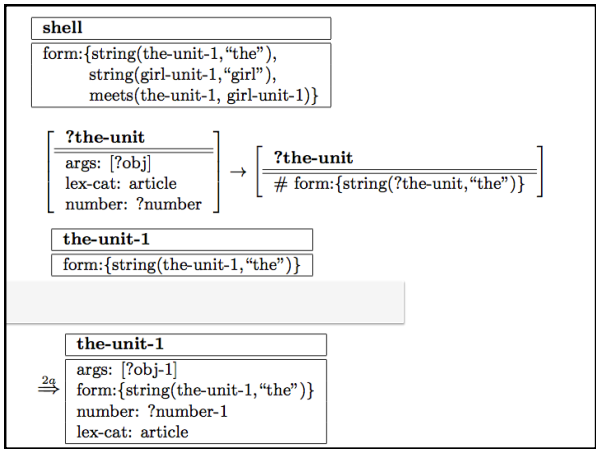


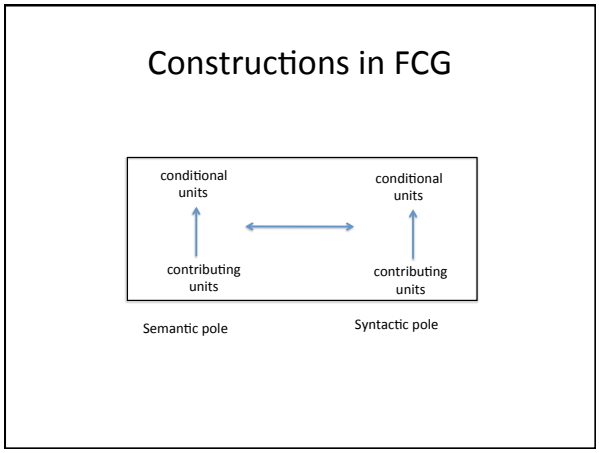


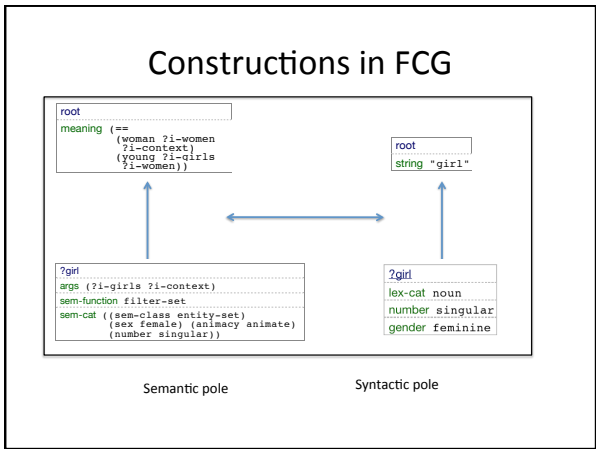
More info on the right hand side

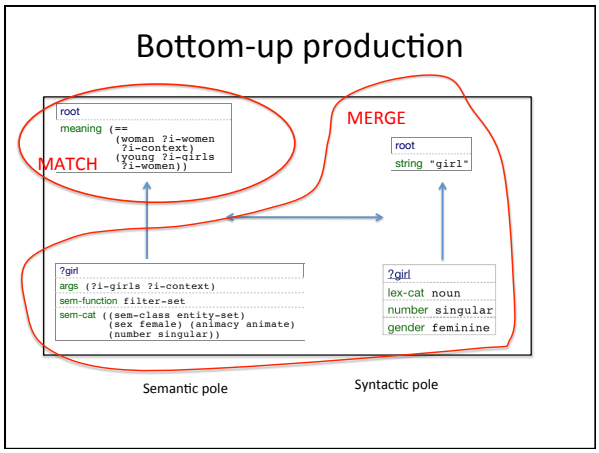





shell
form:{string(the-unit-1,"the"),
string(girl-unit-1,"girl"),
meets(the-unit-1, girl-unit-1)}
?the-unit
args: [?obj]
lex-cat: article
number: ?number
?the-unit
form:{string(?the-unit,"the")}
the-unit-1
form:{string(the-unit-1,"the")}
the-unit-1
args: [?obj-1]
form:{string(the-unit-1,"the")}
number: ?number-1
lex-cat: article
2a


Constructions in FCG
conditional units
contributing units
conditional units
contributing units
Semantic pole
Syntactic pole


Constructions in FCG
root
meaning (== (woman ?i-women ?i-context) (young ?i-girls ?i-women))
root
string "girl"
?girl
args (?i-girls ?i-context)
sem-function filter-set
sem-cat ((sem-class entity-set) (sex female) (animacy animate) (number singular))
?girl
lex-cat noun
number singular
gender feminine
Semantic pole
Syntactic pole


Bottom-up production
MERGE
MATCH
root
meaning (== (woman ?i-women ?i-context) (young ?i-girls ?i-women))
root
string "girl"
?girl
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sem-function filter-set
sem-cat ((sem-class entity-set) (sex female) (animacy animate) (number singular))
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lex-cat noun
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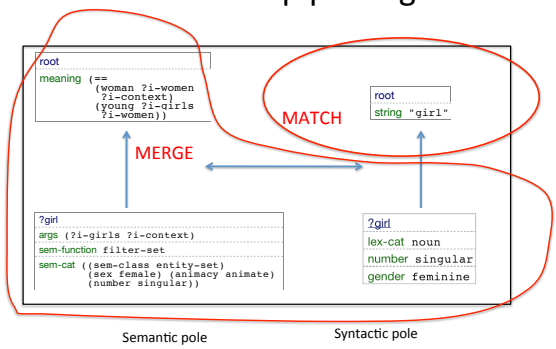
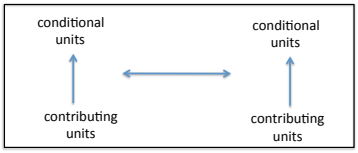
Semantic pole
Syntactic pole

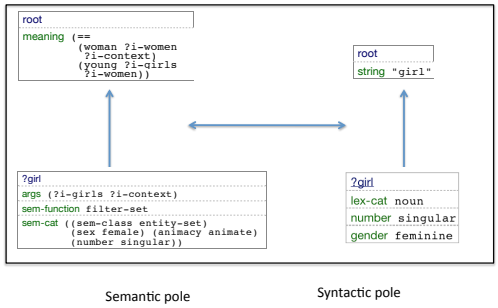
Bottom-up parsing



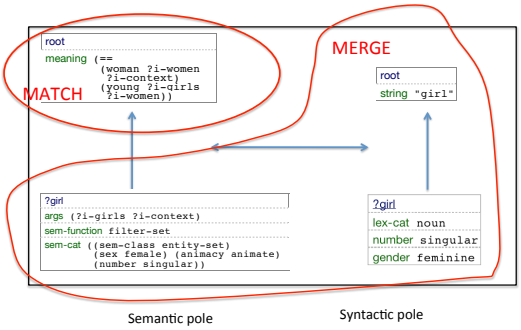
Constructions in FCG



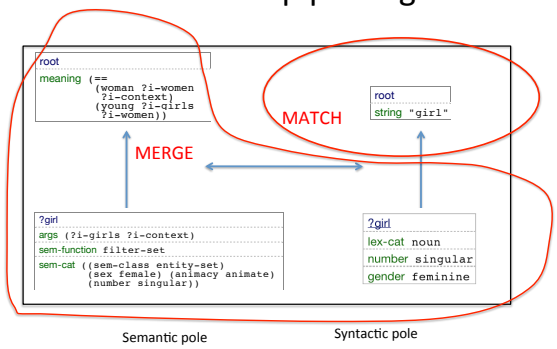
Constructions in FCG

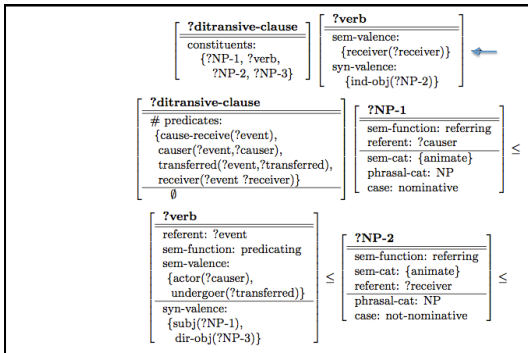


Bottom-up production



Bottom-up parsing

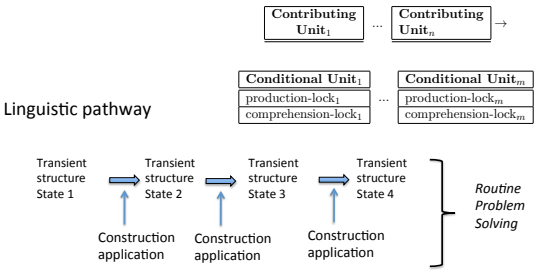




"He baked Mary a cake"

Ditransitive construction

Construction application



Further references

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http://www.fcg-net.org/