Tecnologie del Linguaggio Naturale

Parte Prima

Lezione n. 04-1

Sintassi: la competence

15-03-2021

relaz. tra le varie parole
- di gruppo ← a costituenti
- puntuali ← a dipendenze

Prologo

This is the cat that caught the rat that stole the cheese.

ricorsività

The man who wrote the book that you told me about

Aspects of the theory of syntax (1957)

N. Chomsky

Prologo

- English Center-Embedding

ricorsione "centrale"

A man that a woman loves

A man that a woman that a child knows loves

A man that a woman that a child that a bird saw knows loves

A man that a woman that a child that a bird that I heard saw knows loves

Prologo

E venne il macellaio,
che uccise il toro,
che bevve l'acqua,
che spense il fuoco,
che bruciò il bastone,
che picchiò il cane,
che morse il gatto,
che si mangiò il topo
che al mercato mio padre comprò.

Alla fiera dell'est (1976)
A. Branduardi

Prologo

Elena e Maria odiano il latte e il caffè rispettivamente

importante

Outline

- 1 Sintassi e grammatiche generative cfr LFT
- 2 La gerarchia di Chomsky e il linguaggio naturale

  classe di linguaggi che contiene le lingue naturali
- 3 Mildly-Context Sensitive Languages, Tree Adjoining Grammars, Combinatory Categorial Grammars

Outline

- Sintassi e grammatiche generative
- La gerarchia di Chomsky e il linguaggio naturale
- Mildly-Context Sensitive Languages, Tree Adjoining Grammars, Combinatory Categorial Grammars

NLP pipeline

Phonetics acoustic and perceptual elements

Phonology inventory of basic sounds (phonemes) and basic rules for combination, e.g. vowel harmony

Morphology how morphemes combine to form words, relationship of phonemes to meaning

Syntax sentence formation, word order and the formation of constituents from word groupings

Semantics how do word meanings recursively compose to form sentence meanings (from syntax to logical formulas)

Pragmatics meaning that is not part of compositional meaning

Syntax and Semantics

(Paolo (ama Francesca))

s vp

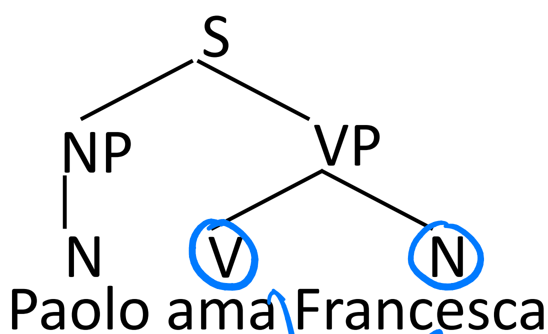
vs ← la sintassi è importante!

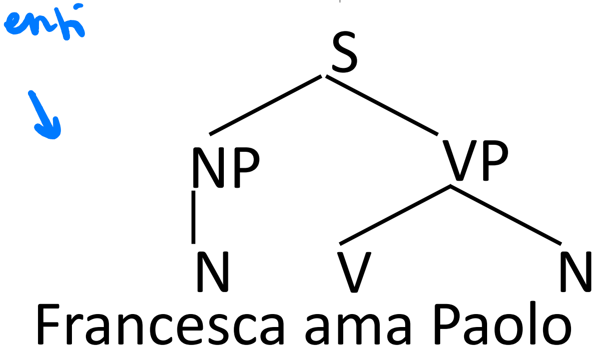
Francesca ama Paolo

Syntactic Parsing

Syntactic Parsing

albero a costituenti





Part of speech: provengono
· dal livello morfologico, oppure
· dal livello sintattico stesso

"la conoscenza statica che abbiamo nel cervello che riguarda la sintassi"

quella conoscenza linguistica che tutti i nativi hanno

Competence/Performance

"la diff. tra avere una grammatica e usarla"

"Linguistic theory is concerned primarily with an ideal speaker-listener, in a completely homogeneous speech-communication, who know its (the speech community's) language perfectly and that it is unaffected by such **grammatically irrelevant conditions** as memory limitations, distractions, shifts of attention and interest, and errors (random or characteristic) in applying his knowledge of this language in actual performance."

R

competence vs performance
"
conoscenza
"
algoritmo

la diff. tra teoria e pratica

Competence/Performance in CL

- **Competence** = **Grammatica Formale**

- **Performance = Algoritmo di Parsing**

Competence/Performance in CL

- **Competence = Grammatica Formale**

- **Performance = Algoritmo di Parsing**

-> Prox. lezione: “Anatomia di un parser”

Rewriting Systems

vogliamo una rappr. della conoscenza FORMALE
↓
sulla forma
↓
su regole

Emil Post , Alan Turing

Rewriting rule

$$\psi \to \theta$$

Generative grammar

↳ è una grammatica formale : si basa sulla forma degli ogg. che la compongono

$G=(\Sigma,V,S,P)$

Σ = alphabet ← dizionario

simboli NON terminali della grammatica

$V = \{A,B,\dots\}$

simbolo di start

↳ $S \in V$

insieme di regole di riscrittura/produzioni

insieme delle produzioni →

$P = \{\Psi \rightarrow \theta,\dots\}$

Generative Grammars and Natural Languages

- Generative Grammars models the natural languages as a formal languages
- The derivation tree can model the **syntactic structure** of the sentence

Context-Free Grammars

$G=(\Sigma,V,S,P)$ $A \to \beta$

simbolo non terminale

li posso usare per associare i nodi ai miei costituenti

x dare i tipi alle parentesi

- Costituency
- Grammatical relations
- Subcategorization

chomsky

Constituency

Context-Free Grammars Constituency Hypothesis:

associazione

Constituent <=> non terminal symbols V

Toy Grammar

$$G_4=(\Sigma_4,\{S,NP,VP,V_1,V_2\},S,P_4\})$$

sono parole (non è ancora stato legato un significato)

Σ_4 = {I,Anna,John,Harry,saw,see,swimming}

P_4 = {S→ NP VP, VP→V_1S, VP→V_2,

"or"

NP→I|John|Harry|Anna,

V_1→saw|see, V_2→swimming}

Toy Grammar

$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I | John | Harry | Anna$
$V_1 \rightarrow saw | see$
$V_2 \rightarrow swimming$

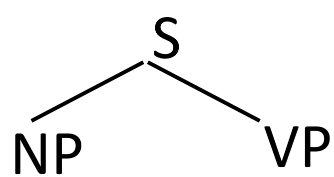
S

S

Toy Grammar

$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I|John|Harry|Anna$
$V_1 \rightarrow saw|see$
$V_2 \rightarrow swimming$

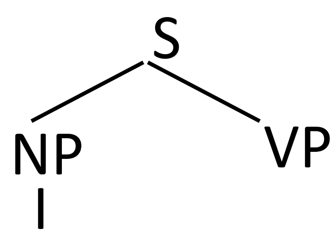
$S \Rightarrow$ **NP VP**



Toy Grammar

$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I \mid John \mid Harry \mid Anna$
$V_1 \rightarrow saw \mid see$
$V_2 \rightarrow swimming$

$S \Rightarrow NP\ VP \Rightarrow \mathbf{I\ VP}$



Toy Grammar

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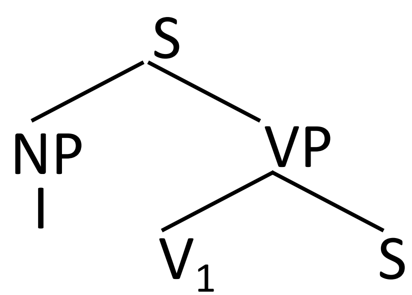
$V_2 \rightarrow swimming$

$S \Rightarrow NP\ VP \Rightarrow I\ VP \Rightarrow \mathbf{I\ V_1 S}$



Toy Grammar

$S \rightarrow NP\ VP$
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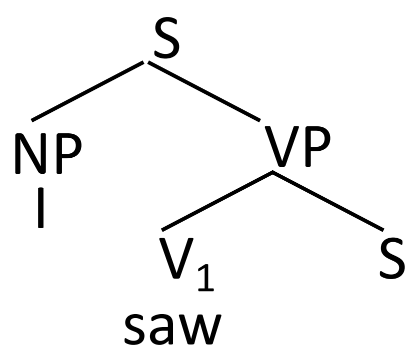
$VP \rightarrow V_2$
$NP \rightarrow I \mid John \mid Harry \mid Anna$
$V_1 \rightarrow saw \mid see$
$V_2 \rightarrow swimming$

$S \Rightarrow NP\ VP \Rightarrow I\ VP \Rightarrow I\ V_1 S \Rightarrow$

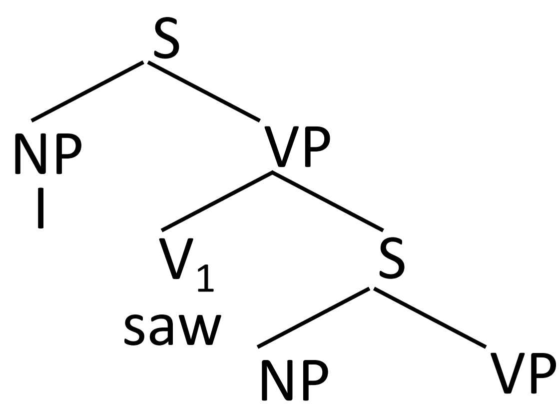
I saw S



Toy Grammar

$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I | John | Harry | Anna$
$V_1 \rightarrow saw | see$
$V_2 \rightarrow swimming$

$S \Rightarrow NP\ VP \Rightarrow I\ VP \Rightarrow I\ V_1 S \Rightarrow$
$I\ saw\ S \Rightarrow$ **I saw NP VP**



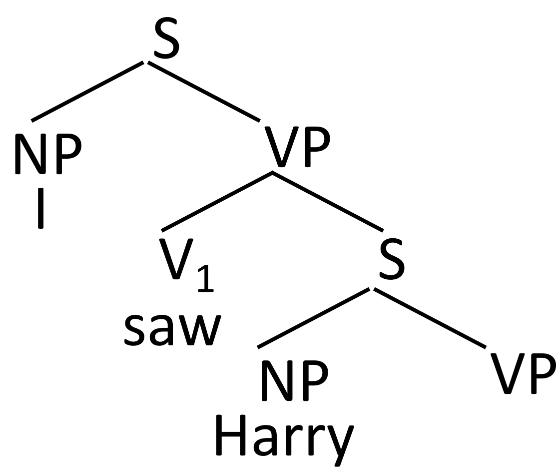
Toy Grammar

S→ NP VP
VP→V_1 S
VP→V_2
NP→I|John|Harry|Anna
V_1→saw|see
V_2→swimming

S⇒NP VP⇒I VP⇒I V_1S⇒

I saw S ⇒I saw NP VP ⇒

I saw Harry VP



Toy Grammar

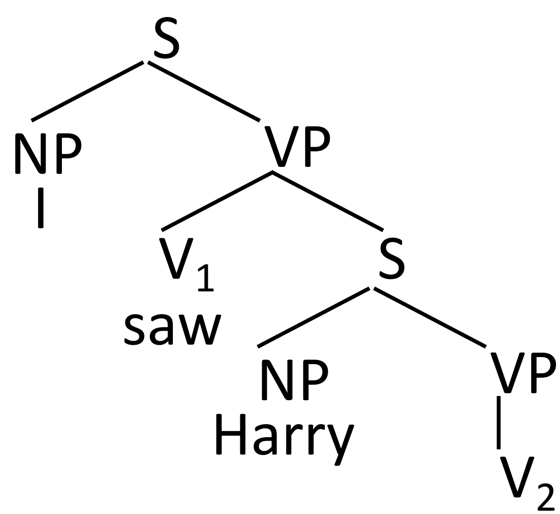
$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I | John | Harry | Anna$
$V_1 \rightarrow saw | see$
$V_2 \rightarrow swimming$

$S \Rightarrow NP\ VP \Rightarrow I\ VP \Rightarrow I\ V_1 S \Rightarrow$

$I\ saw\ S \Rightarrow I\ saw\ NP\ VP \Rightarrow$

$I\ saw\ Harry\ VP \Rightarrow$

I saw Harry V_2



una grammatica vera è nell'ordine delle 20/30 mila regole

Toy Grammar

10 regole

$S \rightarrow NP\ VP$
$VP \rightarrow V_1\ S$
$VP \rightarrow V_2$
$NP \rightarrow I|John|Harry|Anna$
$V_1 \rightarrow saw|see$
$V_2 \rightarrow swimming$

poi non posso andare più avanti, perché

$S \Rightarrow NP\ VP \Rightarrow I\ VP \Rightarrow I\ V_1 S \Rightarrow$

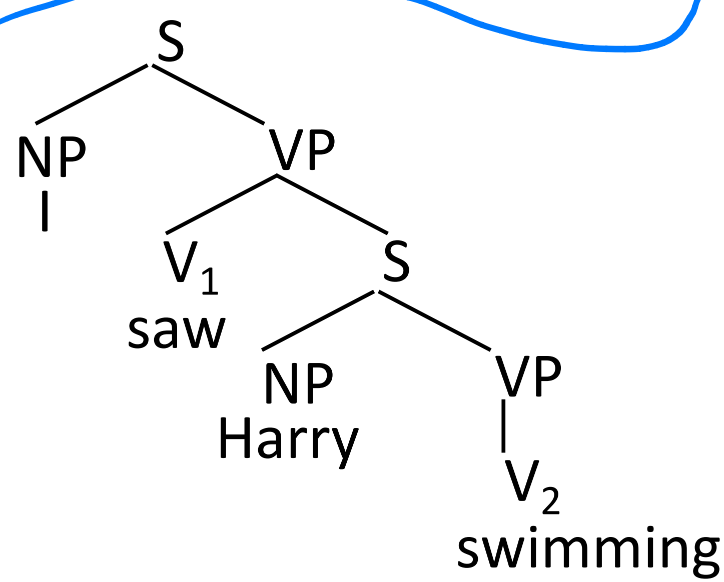
$I\ saw\ S \Rightarrow I\ saw\ NP\ VP \Rightarrow$

$I\ saw\ Harry\ VP \Rightarrow$

$I\ saw\ Harry\ V_2 \Rightarrow$

I saw Harry swimming

sono tutti simboli terminali



Outline

- Sintassi e grammatiche generative

"la sua idea è applico una gramm. generativa → formulare che alcune frasi nel nostro cervello sono grammaticali e altre no"

- La gerarchia di Chomsky e il linguaggio naturale
- Mildly-Context Sensitive Languages, Tree Adjoining Grammars, Combinatory Categorial Grammars

Languages Chomsky hierarchy

nessuna limitazione sulla forma di produzione

A 1 Φ → Φ Φ

Type 0

$\Psi \rightarrow \theta$

Context-sensitive

$Caa \rightarrow aaCa$

la lunghezza può solo aumentare
(dx maggiore sx)

sulla sx ci deve essere
un simb. NT

Context-free

$S \rightarrow aSb$

hanno una complessità
comput. lineare
(≈ regex)

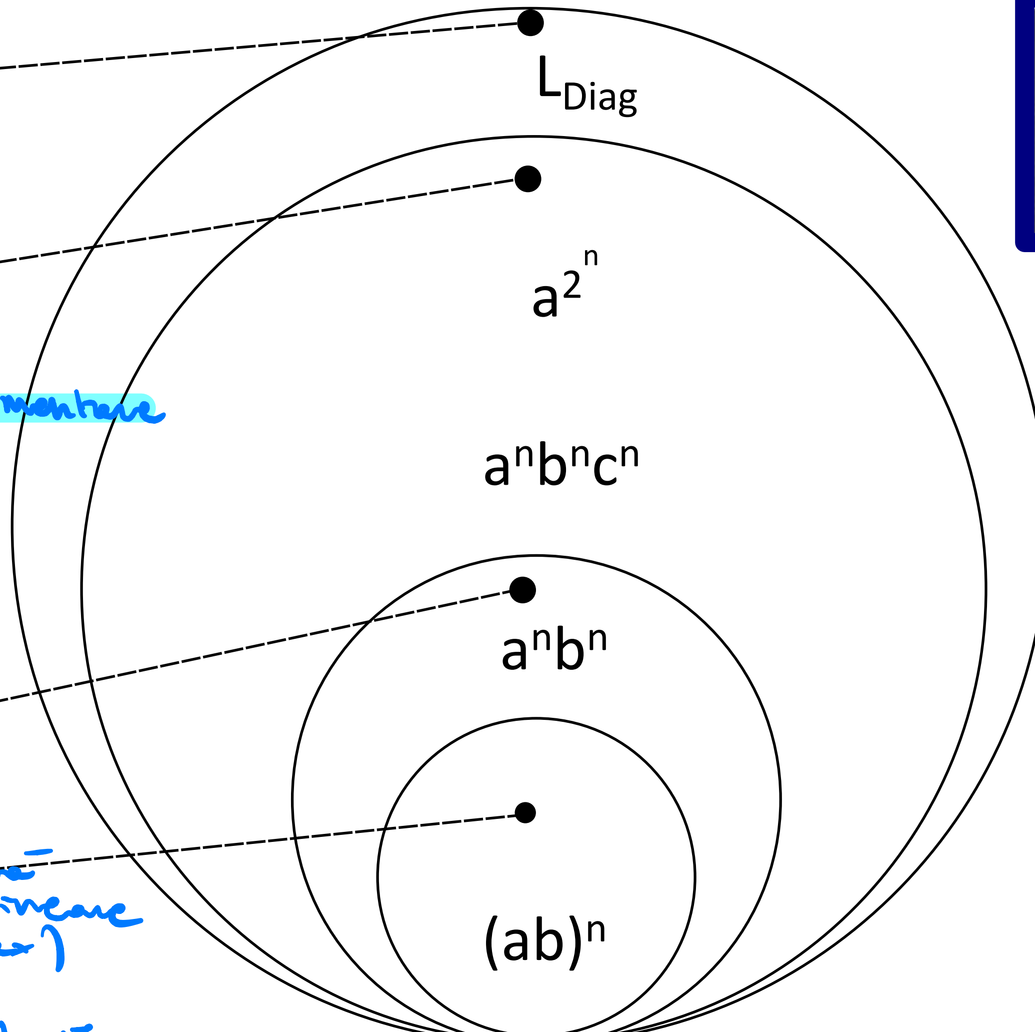
Linear

$A \rightarrow aB$

"non terminale"

simbolo NT → simb. T simb. NT

"terminale"



quale di queste grammatiche c'è nel nostro cervello?

Swiss-German is NOT CF

context-free

(Shieber,1985)

potenzialm. tutte le lingue NON sono CF

(ma x poco, perché spesso lo sono)

... das mer em Hans es huus h¨alfed aastriiche

... that we Hans-Dat house-Acc helped paint

'... that we helped Hans paint the house'

ricorsività di livello 3

... das mer d'chind em Hans es huus l¨ond h¨alfe aastriiche

relaz. incrociate che NON possono essere generate da una CF

... that we the childrenAcc HansDat houseAcc let help paint

'... that we let the children help Hans paint the house'

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"tiepidamente"

Mildly context sensitive languages

[Joshi, 85]

- Include CFG languages
- Nested ~~and~~ cross-serial dependencies ← OR: le grammatiche delle lingue naturali sono o nested o cross-serial

$a_1\ b_1\ c_1\ c_2\ b_2\ a_2$ ← tedesco

$a_1\ b_1\ c_1\ a_2\ b_2\ c_2$ ← olandese

- Polynomially parsable
- Constant growth property, lineare

i ling. naturali possono essere definiti da 4 proprietà

Constant growth property

- **Definition** A language L is constant growth if there is a constants c_0 and a finite set of constant C such that for all w ε L where $|w| > c_0$ there is a w' ε L such that $|w| = |w'| + c$ for some c ε C.

- This property is the formal version of the linguistic intuition that the sentence belonging to a natural language can be built from a finite set of bounded structures using the same linear operations [Wei88].

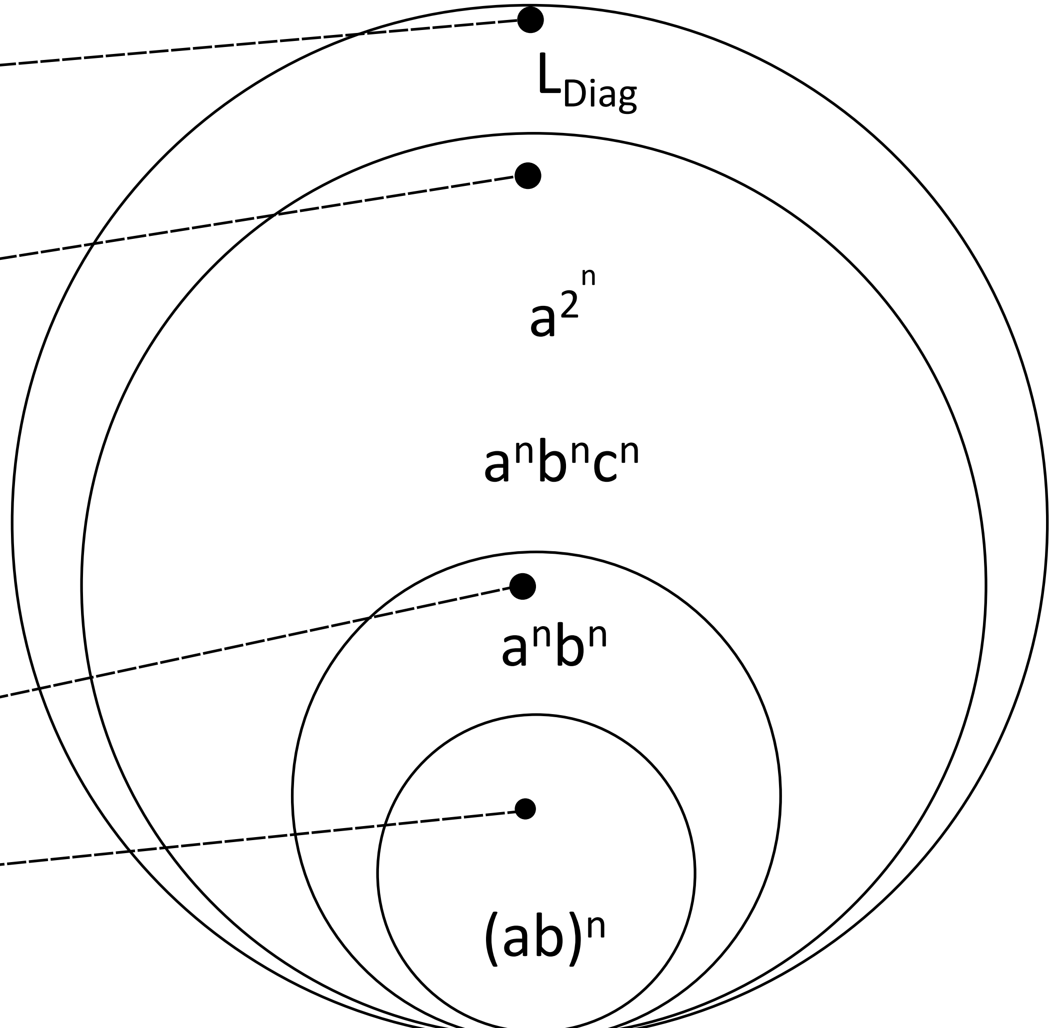
Languages Chomsky hierarchy

Type 0
$\Psi \rightarrow \theta$

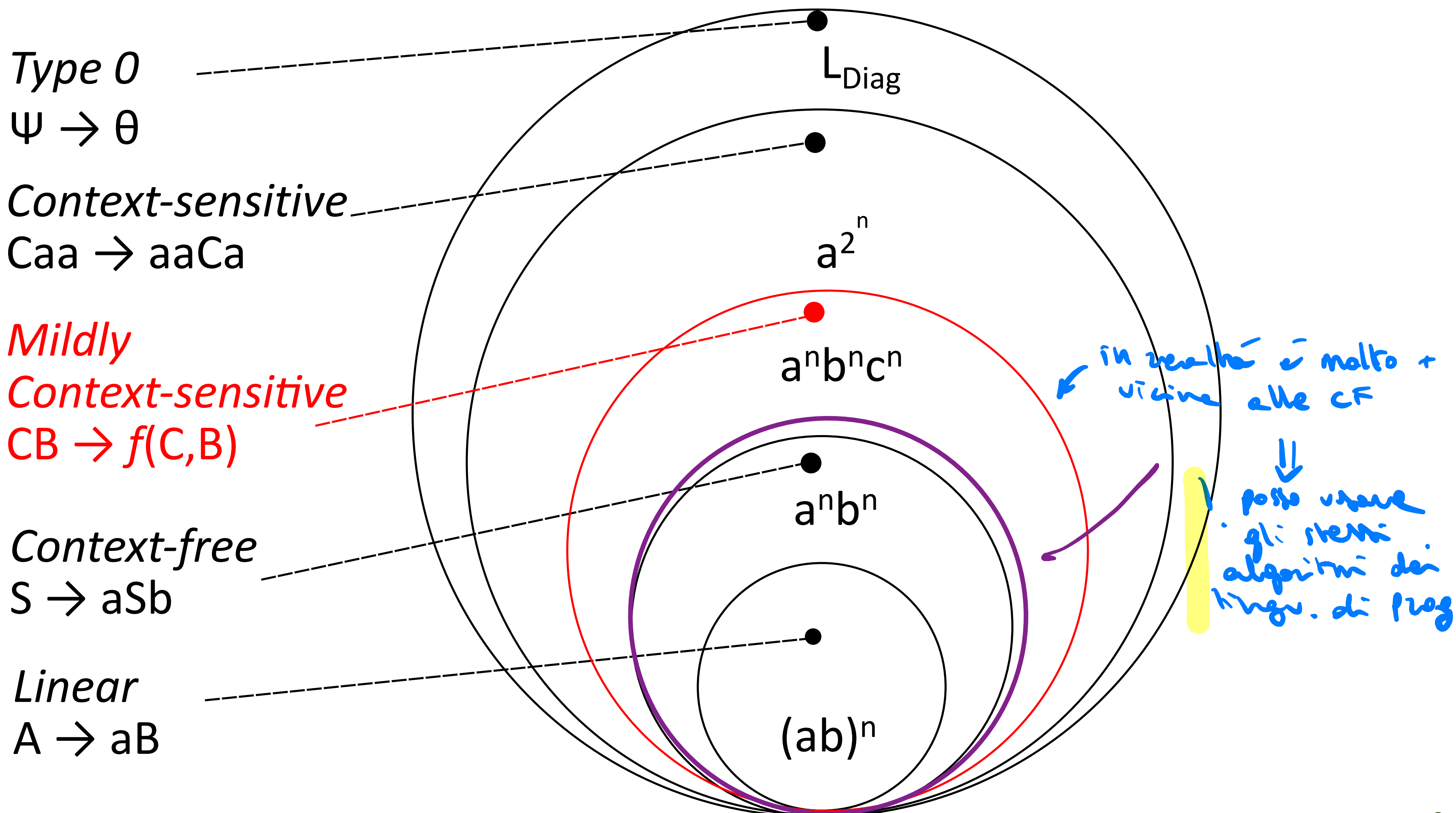
Context-sensitive
$Caa \rightarrow aaCa$

Context-free
$S \rightarrow aSb$

Linear
$A \rightarrow aB$



Languages Chomsky hierarchy



MCL ⇔ TAG,HG,LIG,CCG

le mildly context-sensitive, possono essere scritte attraverso grammatiche + semplici?

diverse proposte

- Tree Adjoining Grammars (Joshi et al. 1975)
- Head Grammars (Pollard 1984)
- Linear Indexed Grammars (Gazdar 1985)
- Combinatory Categorial Grammars (Steedman 1985, Satta 2010)

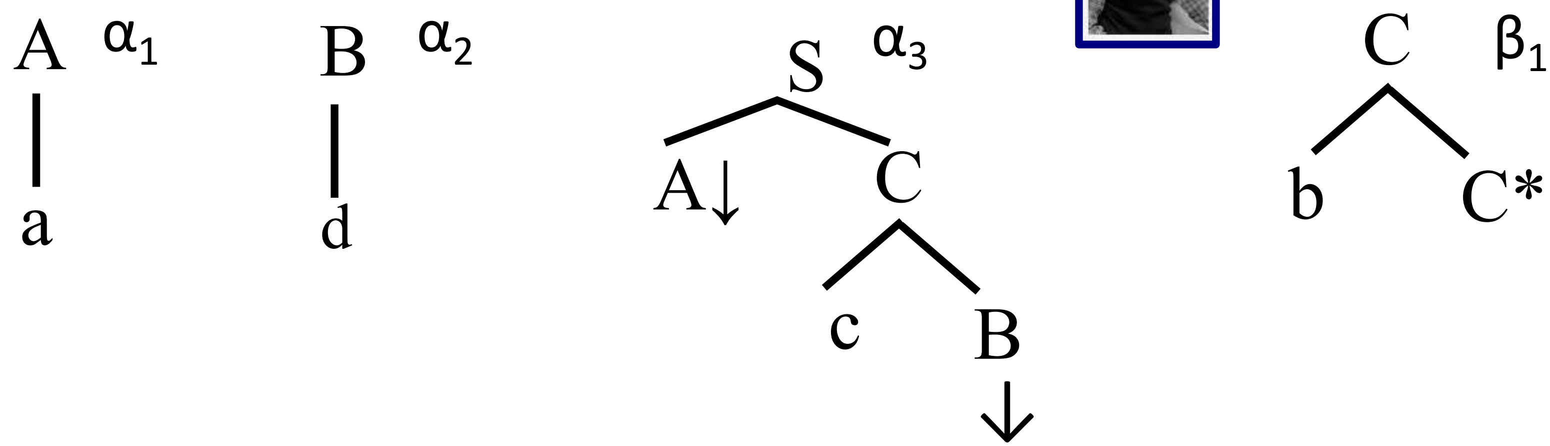
! idea: ho sempre una grammatica generativa, ma invece che usare stringhe, uso strutture + complesse e regole di riscrittura + complesse

-> elementary structures

-> combination rules

Tree Adjoining Grammars

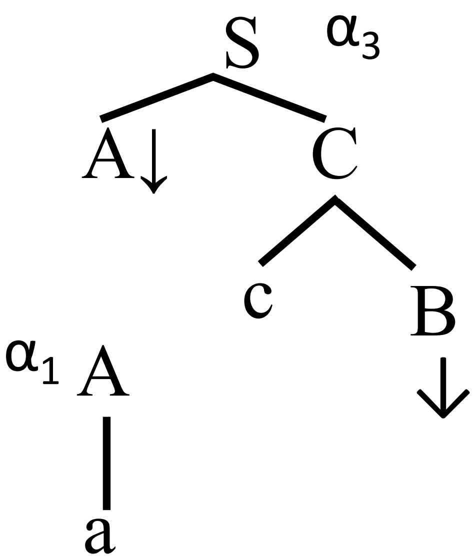
idea: invece di usare stringhe, uso alberi



`Elementary structures =` **`multilevel trees`**

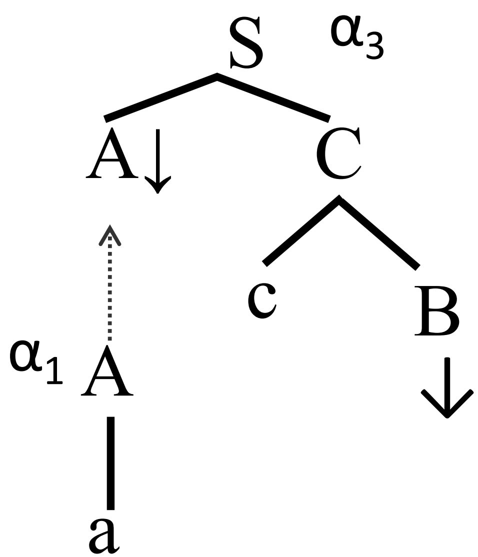
Tree Adjoining Grammars

idea: invece che 1 singola generativa, ho regole + complesse



TAG operations: 1) substitution

Tree Adjoining Grammars



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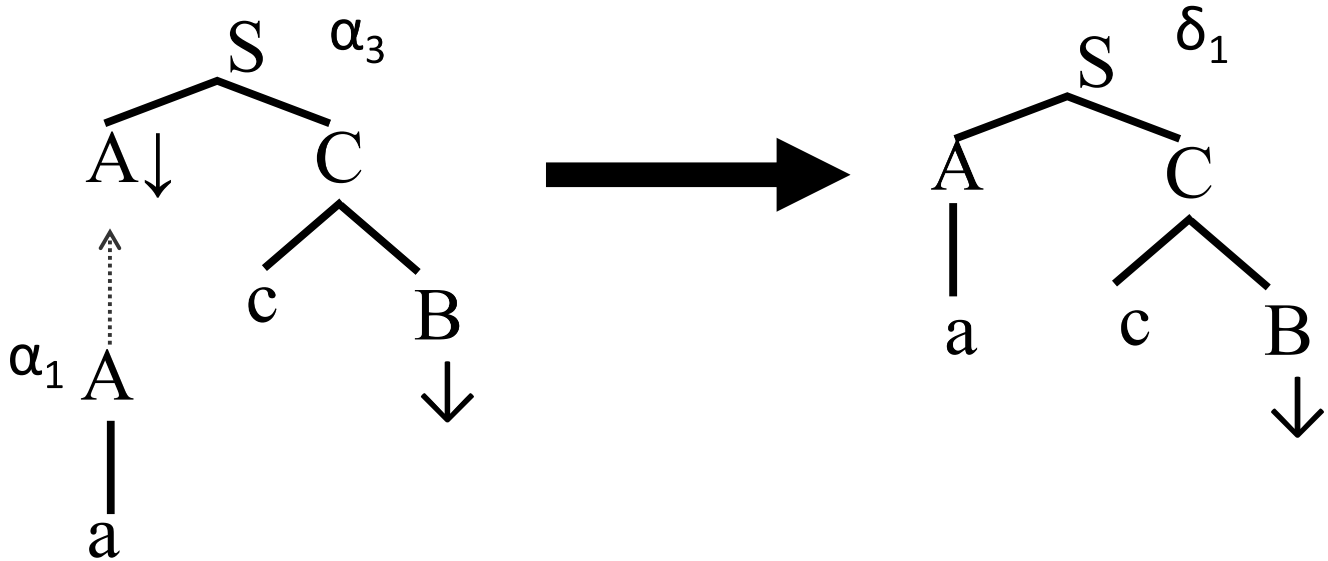
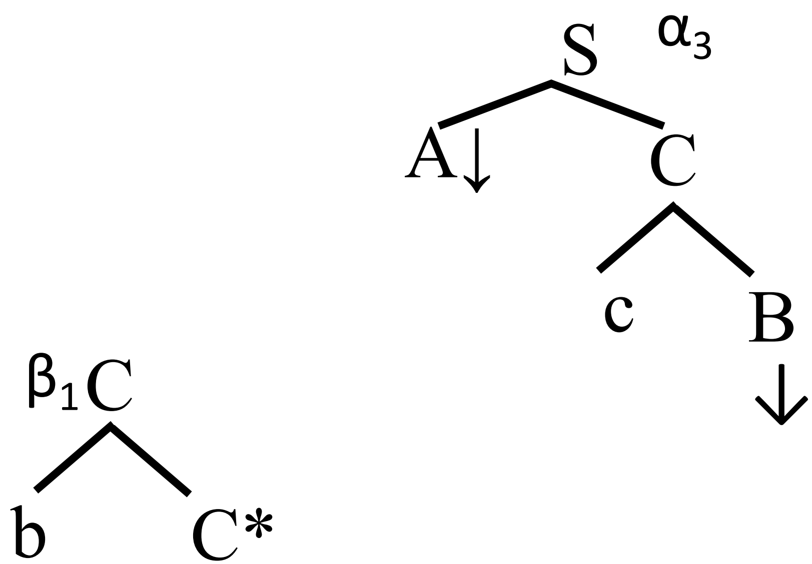


TAG operations: 1) substitution

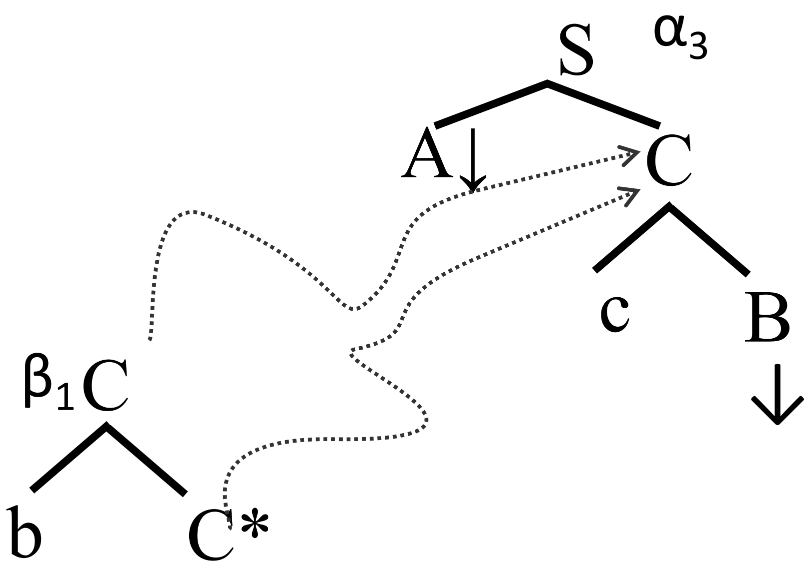
Tree Adjoining Grammars



merge di un albero dentro un altro

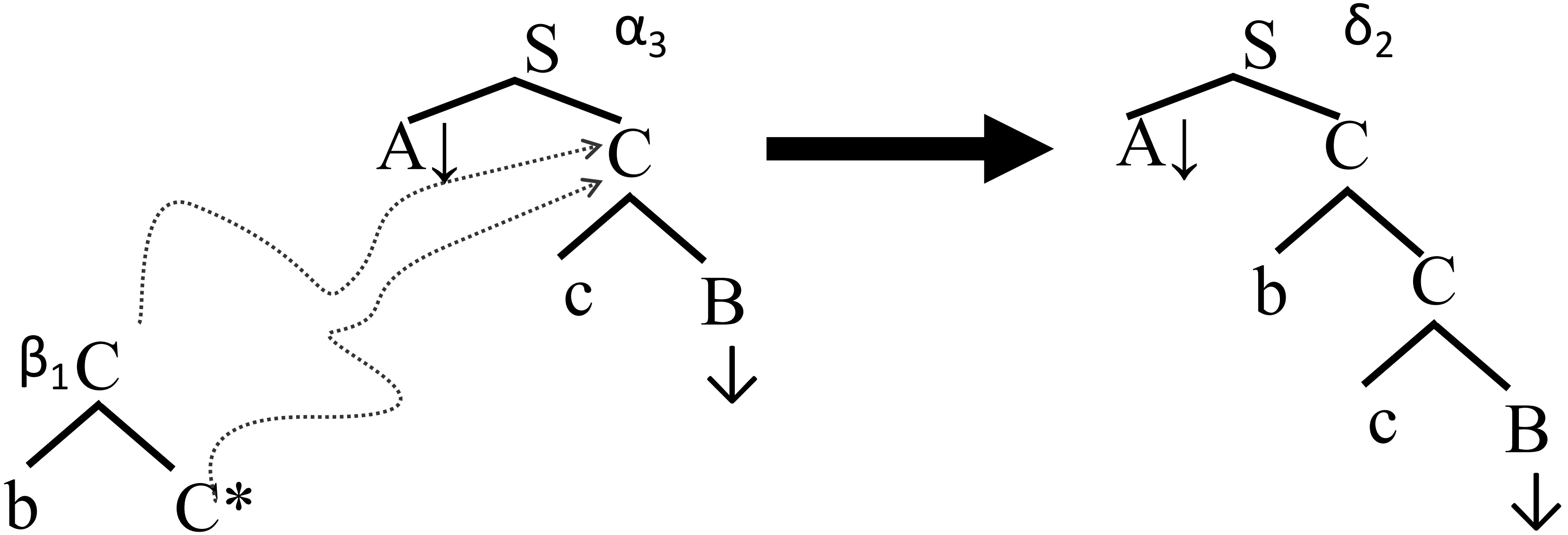
TAG operations: 2) adjoining

Tree Adjoining Grammars



TAG operations: 2) adjoining

Tree Adjoining Grammars



TAG operations: 2) adjoining

	CF standard	Tree Adjoining
struttura dati	stringhe	alberi
regola di riscrittura	sostituzione	sostituzione + joining

perché farlo?: PRO: riesco a modellare certi fenomeni linguistici
conoscente
in maniera molto + semplice

Tree Adjoining Grammars

TAG and MCSL

- TAG properly contains all context-free languages (finitely ambiguous). Theorem (Schabes 1990)
- TAG is polynomially parsable}: **$O(n^6)$**
  - Embedded Push Down Automata, CKY (Vijay-Shanker 1987)
  - Left-to-right parser (Schabes 1990)

TAG and MCSL

- TAG captures only certain types of dependencies
  - **Cross-serial dependencies**: verb-raised analisys (Kroch Santorini 1991)
  - No mix-languages
- TAG has the constant--growth property: (Weir 1988)

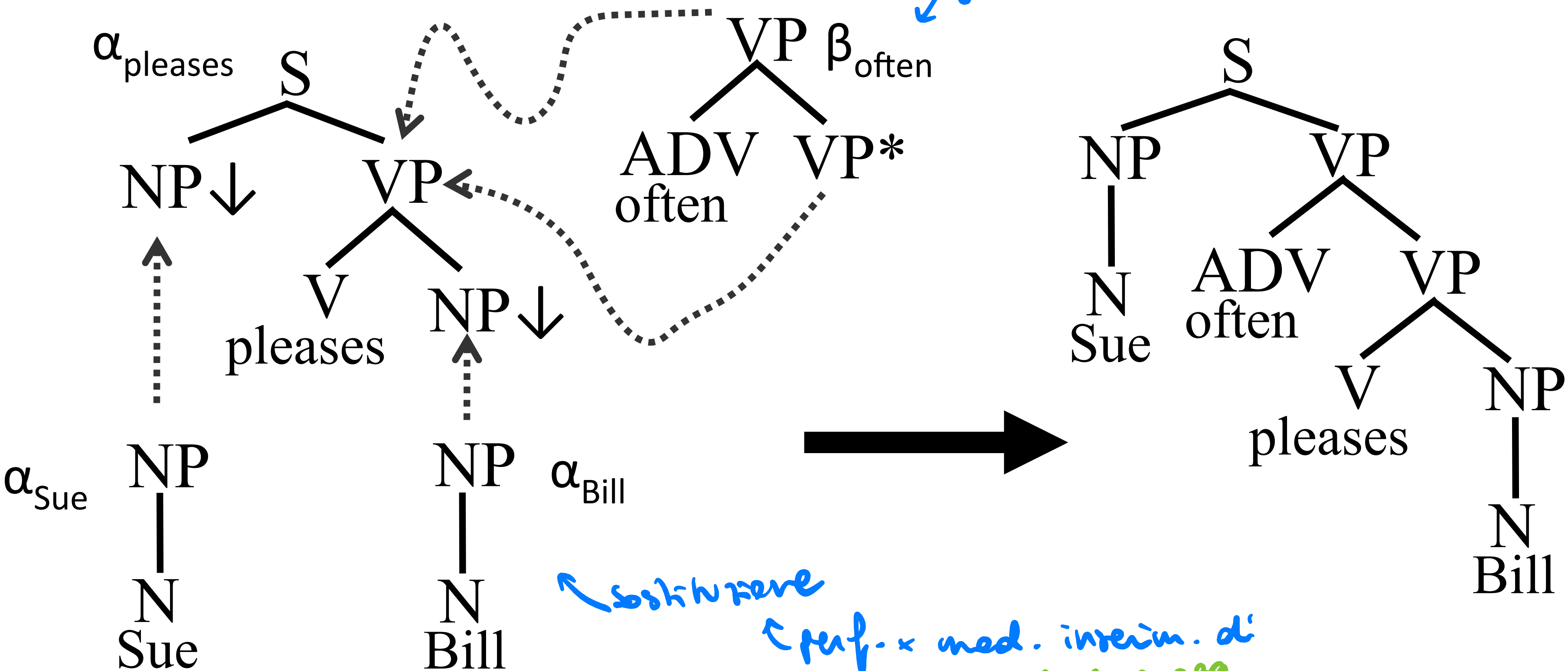
Lexicalized Tree Adjoining Grammars

- Extended domain of locality
- Recursion Factorization by adjoining operation
- Lexicalization

LTAG

perfetto x modellare l'inserim. di modificatori , es: avverbi

join



sostituzione

perf. x mod. inserim. di argom. , sogg e c.ogg.

- structures = multilevel trees

modellare proprietà verbi transitivi

- operations = substitution, adjoining

fatte al volo

sono anch'esse mildly bla-ble

Combinatory Categorial Grammar

- Generative -> top-down
- Categoriali ->bottom-up

The Syntactic Process, *Mark Steedman*

Categories, Lexicon, Rules

Combinatory Categorial Grammar

- Generative -> top-down

- Categoriali ->bottom-up

è la struttura dati

Category

-> $A \subseteq C$, where A is a given set of atomic elements

-> (X/Y) , $(X\backslash Y) \in C$, if $X, Y \in C$

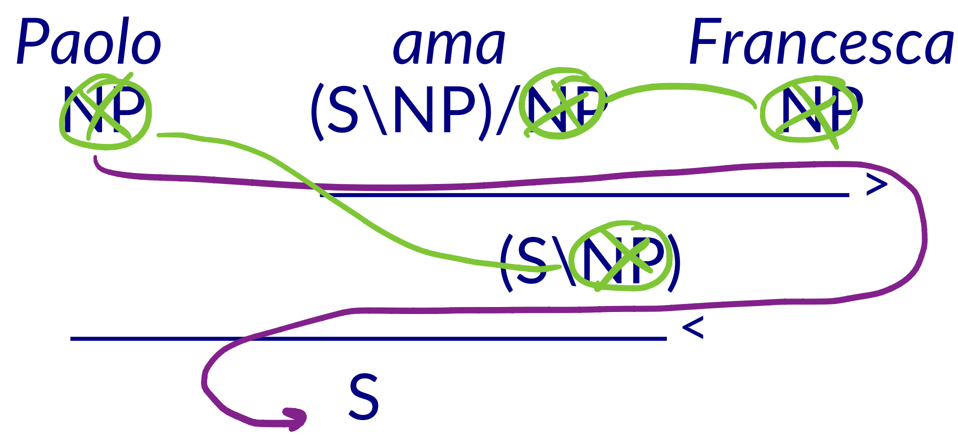
CCG

invece delle reg. di riscrittura, ho regole di combinazione

- Lexicon
  - Paolo : NP
  - Francesca : NP
  - amare : (S\NP)/NP
- Rules
  - X/Y Y ⇒ X
    ->
  - Y X\Y ⇒ X
    -<
  - …

CCG

- Lexicon
  - Paolo : NP
  - Francesca : NP
  - amare : (S\NP)/NP
- Rules
  - X/Y Y ⇒ X ->
  - Y X\Y ⇒ X -<
  - …



CCG

sono utili in casi particolari

- Coordinazione: X CONJ X ⇒ X

We	*flew*	*to*	*Geneva*	*and*	*drove*	*to*	*Chamonix*
NP	(S\NP)/PP	PP/NP	NP	CONJ	(S\NP)/PP	PP/NP	NP
		PP (>)				PP (>)	
	S\NP (>)				S\NP (>)		
	S\NP (<Φ>)						
S (<)							

R ⇓

noi scegliamo questa

ho 2 strade: 1. il NL ≅ CF (xké la diff. è poca)

2. usare una TAG o una CCG o altro x modellare una mildly blabla
(e non fare l'approssimazione NL ≅ CF)