An Alternate View on Strong Lexicalization in TAG

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TAG+12

The Talk in a Nutshell

A well-known fact

Lexicalized Grammars are *good* for parsing algorithms

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Problem

TAGs not closed under strong lexicalization

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Idea

- generalize TAGs to multi-dimensional TAGs;
- lexicalization via increase in dimensionality:
  $\Rightarrow$ every d-TAG is strongly lexicalized by some (d+1)-TAG

Lexicalized Grammars

A grammar is lexicalized if the atoms from which compound structures are assembled each contain a pronounced lexical item.

Lexicalized grammars are *finitely ambiguous*:

- recognition is decidable;
- parsing is simplified [Schabes et al., 1988]

An Essential Distinction

weak lexicalization *vs* strong lexicalization

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TAGs and Lexicalization

Existing Results

- TAGs can be weakly lexicalized [Fujiyoshi, 2004]
- TAGs are not closed under strong lexicalization [Kuhlmann and Satta, 2012]
- TAGs are strongly lexicalized by context-free tree grammars of rank 2 [Maletti and Engelfriet, 2012]

Aim of this Paper

Derive lexicalization properties of TAGs by generalizing to multidimensional structures

- Every d-dimensional TAG is a $(d+1)$- dimensional TSG
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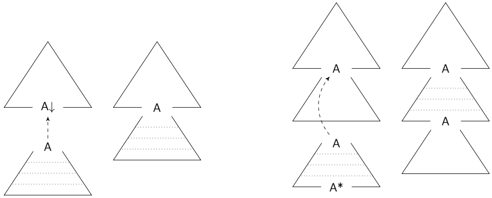
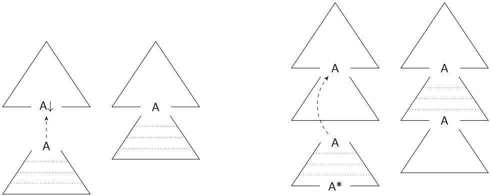


Substitution can be regarded as adjunction of a footless tree at a leaf node

Tree Substitution Grammar (TSG)

A restricted TAG where all licit instances of adjunction only rewrite leaf nodes



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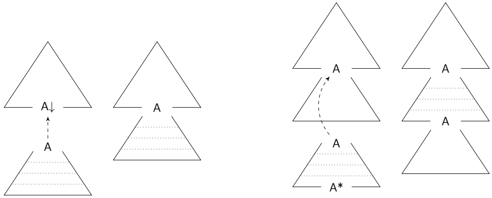

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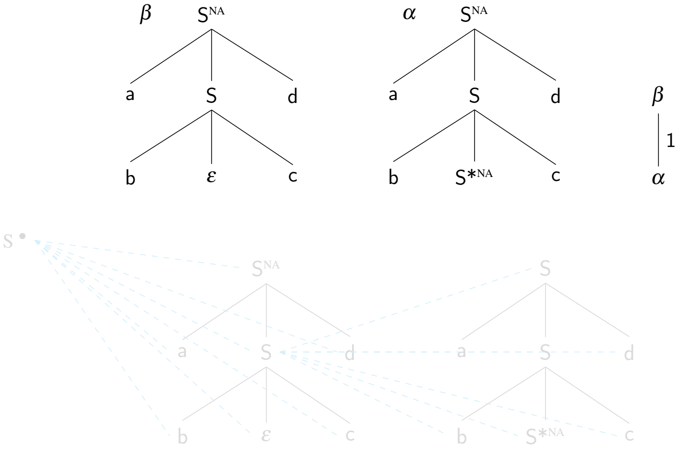

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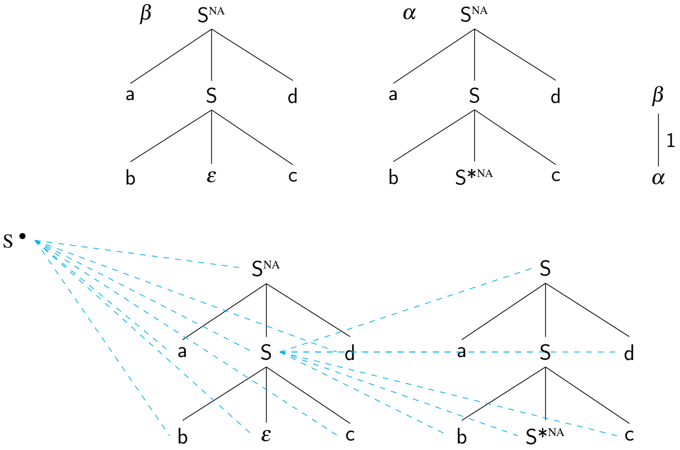
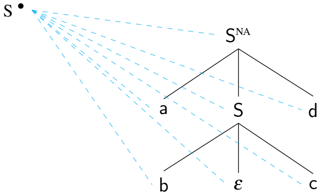


TAGs as multi-dimensional structures [Rogers, 2003]

We can increase the dimensionality of a grammar



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- d-dimensional mother
- yd^{d-1}: (d-1)-yield

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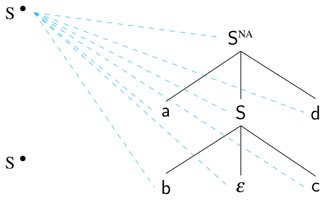

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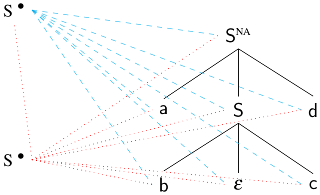

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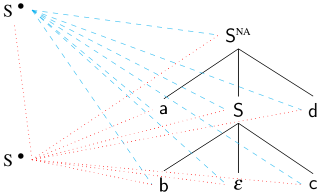

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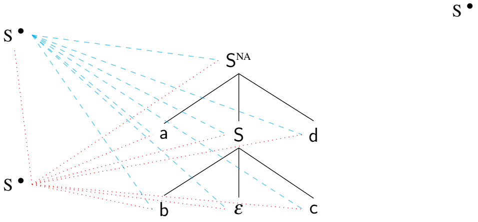

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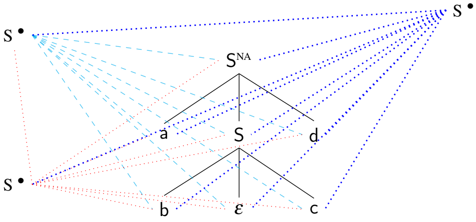

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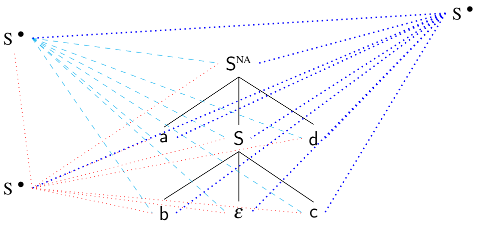

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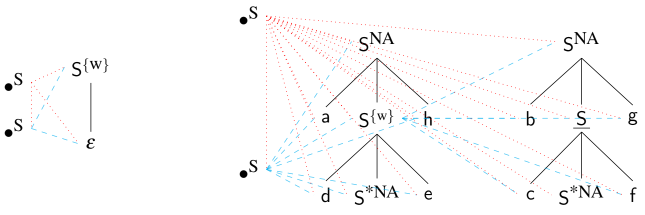

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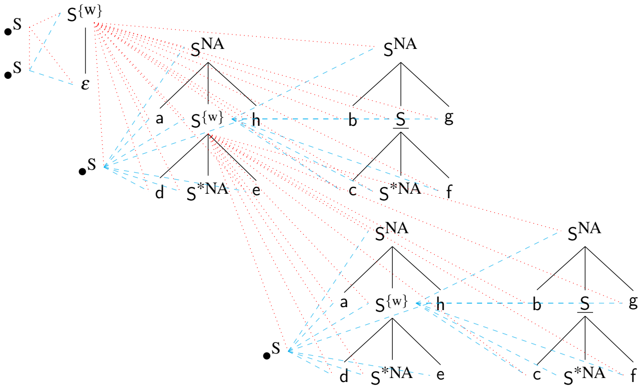
The 4-d structure



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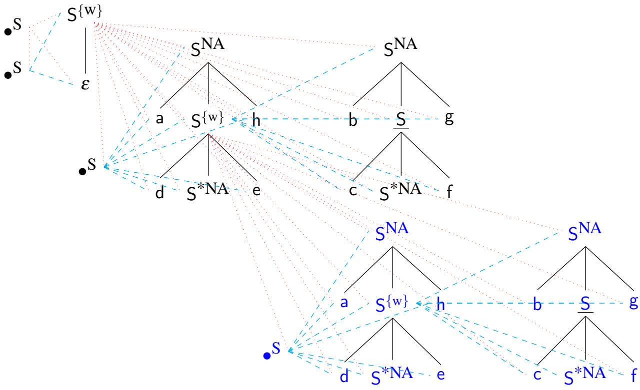

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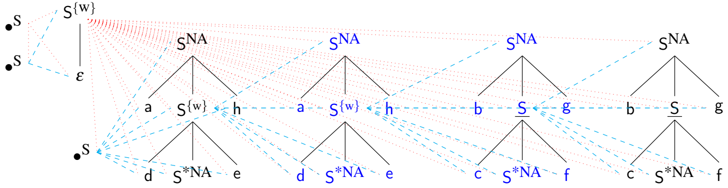
S
S
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ε
S
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h
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S*NA
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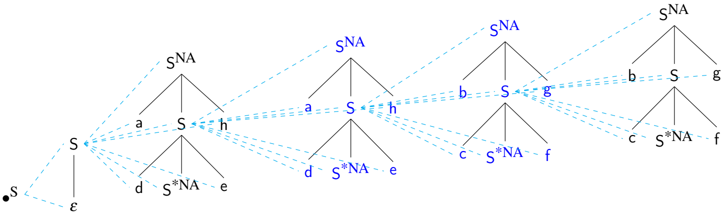

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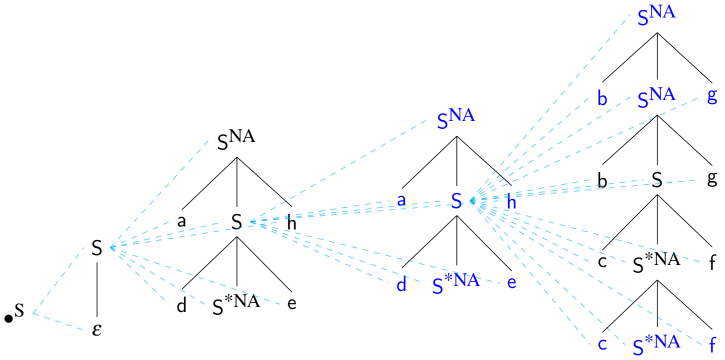

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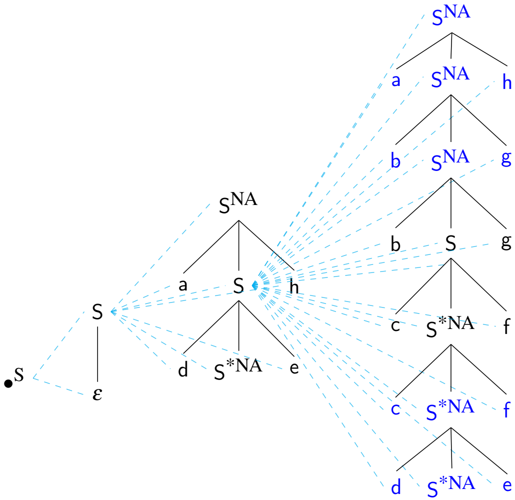

The 8-language: a derivation

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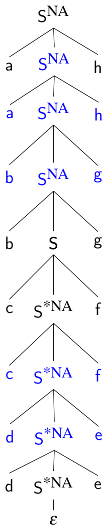

Interim Summary

The Road so far

- Substitution as Adjunction
- TAGs as natural 3-d structures
- the generalization to higher dimensions is easy

An Important Concept

d-dimensional Local Structure:

- d-dimensional mother;
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Next Steps

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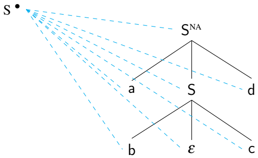

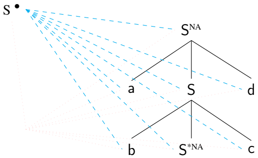

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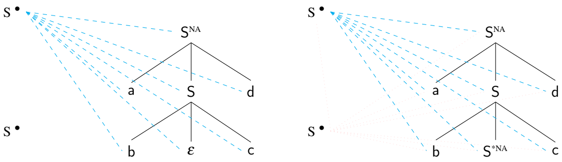

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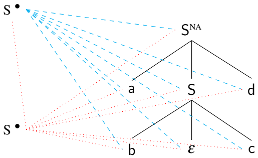

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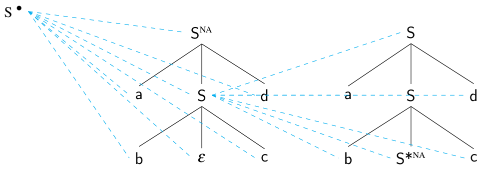

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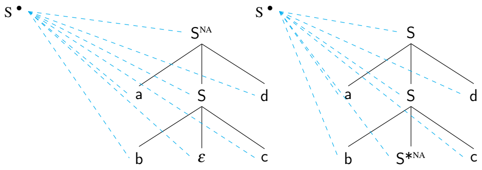

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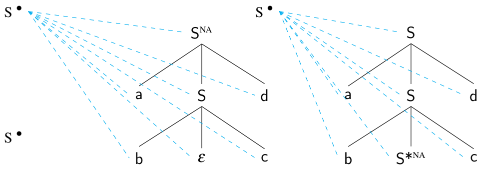

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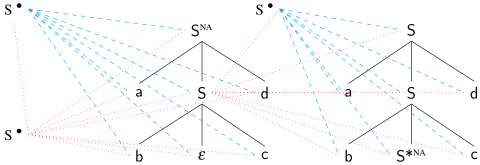

Adjunction in 3d / Substitution in 4d

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[Schabes, 1990]

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A Lexicalization Procedure

Consider a TSG G:

1. Divide G in recursive and non-recursive;
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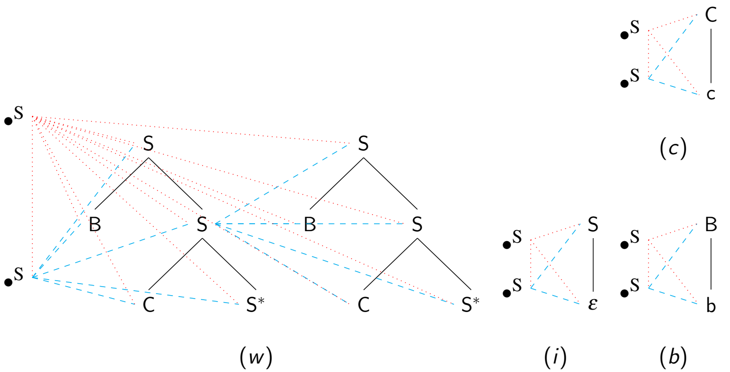

A non lexicalized d-TSG: a derivation

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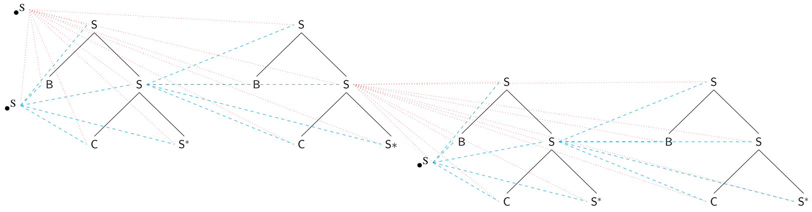

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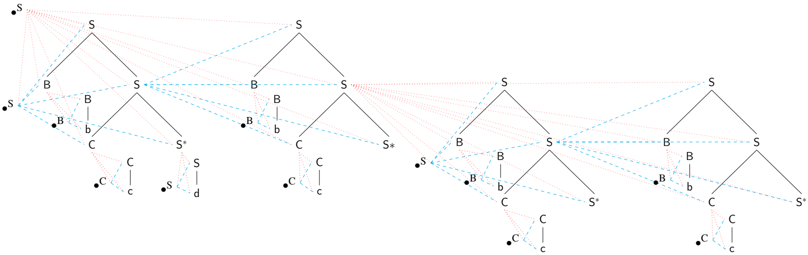

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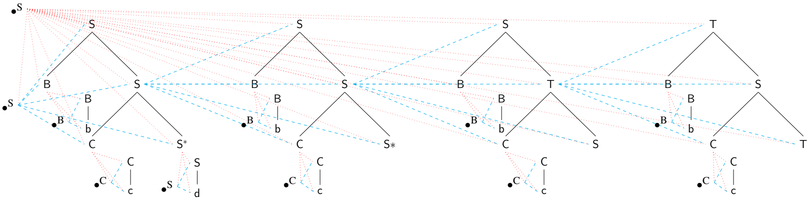

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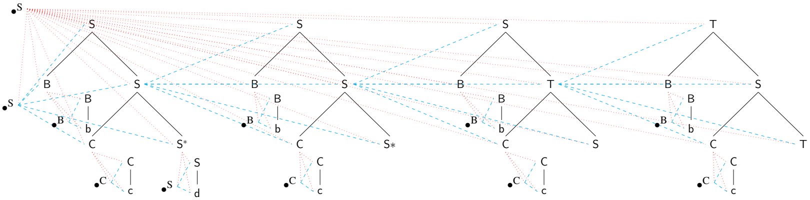

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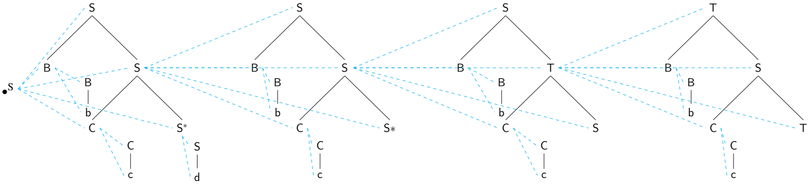

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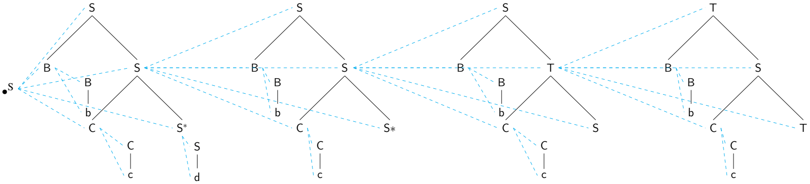

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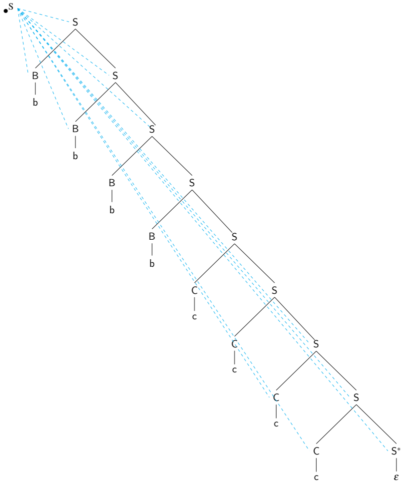

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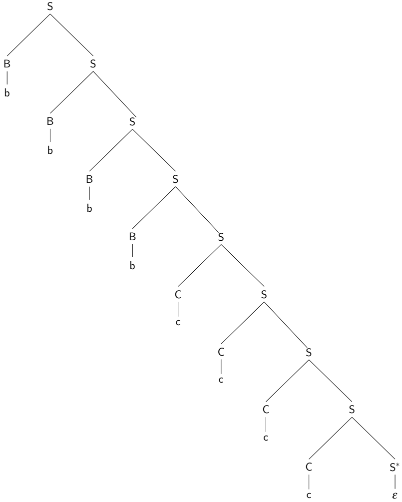

Lexicalization of a d-TSG: Step 1

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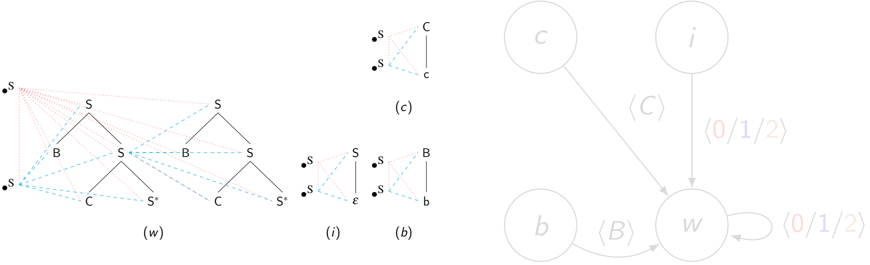

(c)

(w) (i) (b)

The TSG is Partitioned in Two Sets

$NR = \{b, c, i\}$

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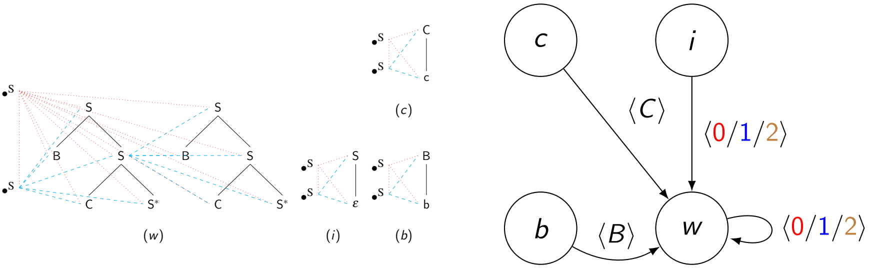

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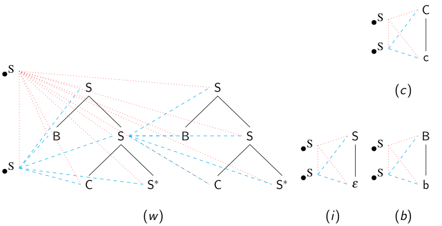

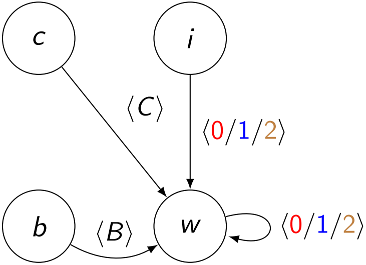

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Step 2: Determine the set I_{lex}.

- $T(NR)$: the closure of NR under adjunction

I_{lex}

is the maximal subset of $T(NR)$ that only contains d-trees whose root is labeled by the start category S.

$$I_{lex} = \{i\}$$

Lexicalization of a d-TSG: Step 2

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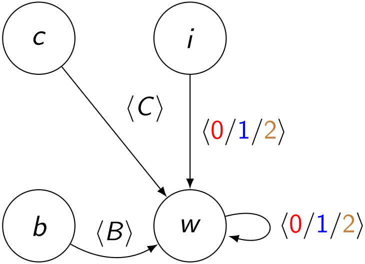

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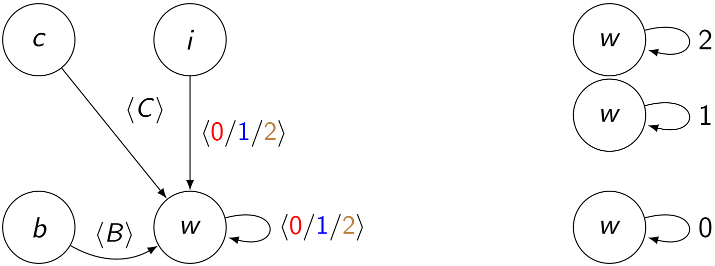

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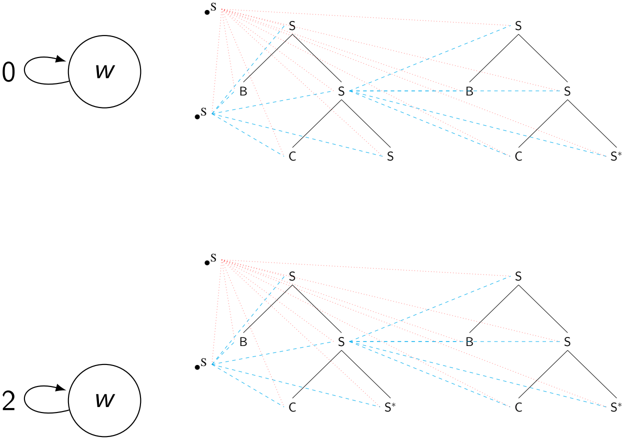
Step 4: Determine A_{lex}

- expand base cycles;
- relabel $3d$ foot node;
- exhaustive substitution;



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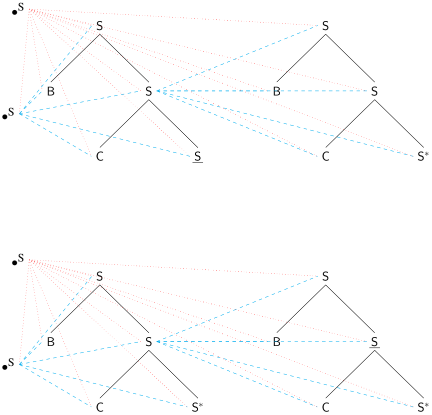

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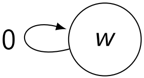
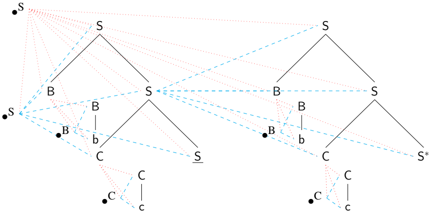
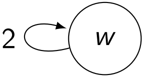
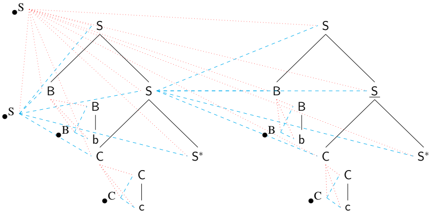
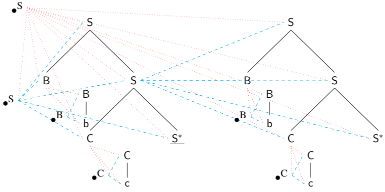




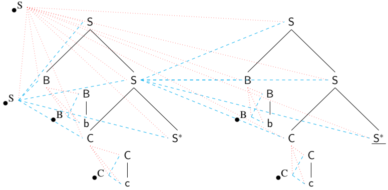




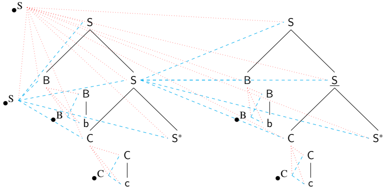
The lexicalized d-TAG



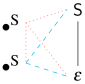
(w_2)



(w_3)

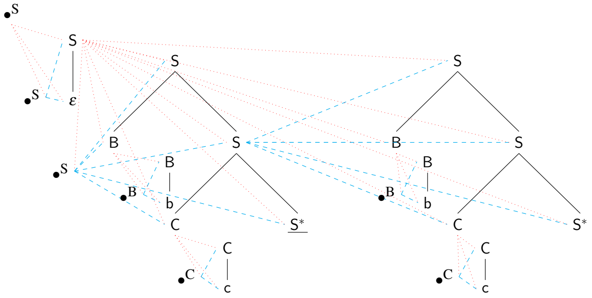


(w_1)



(i)

The lexicalized d-TAG: a derivation



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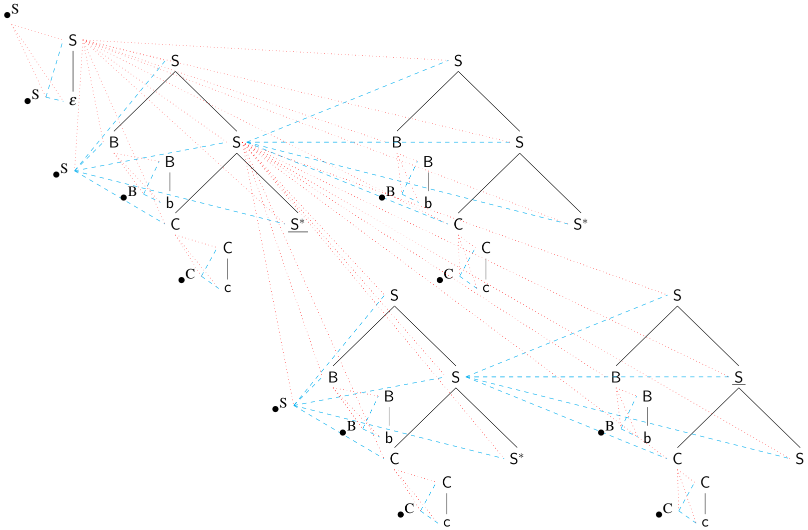
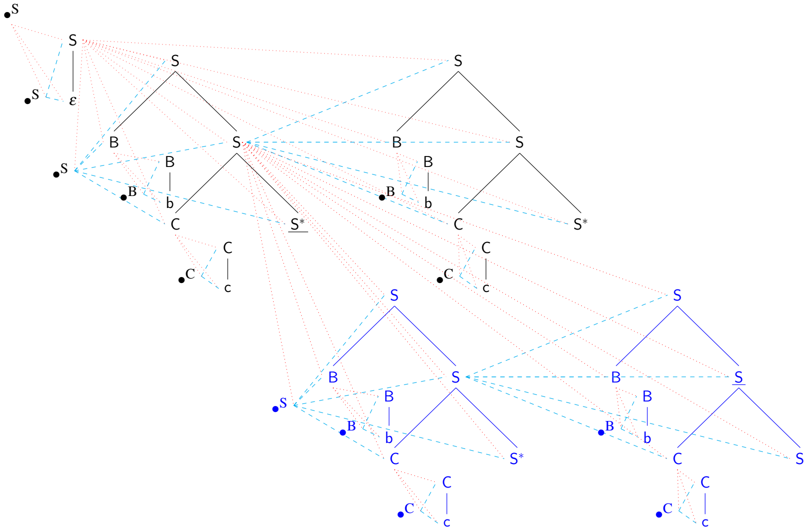
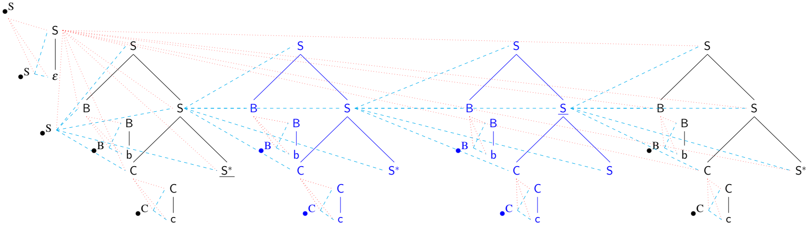


The lexicalized d-TAG: a derivation

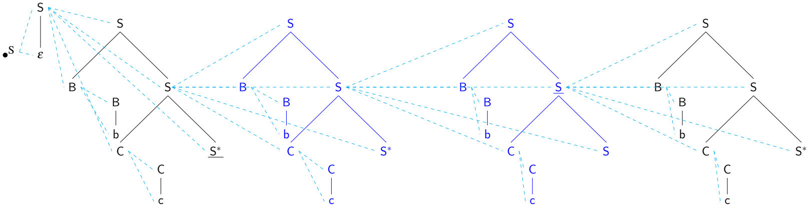


The lexicalized d-TAG: a derivation

The 3d yield ...

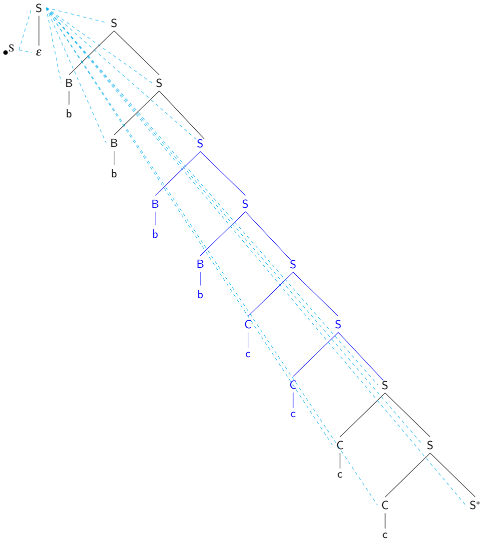


The 3d yield!

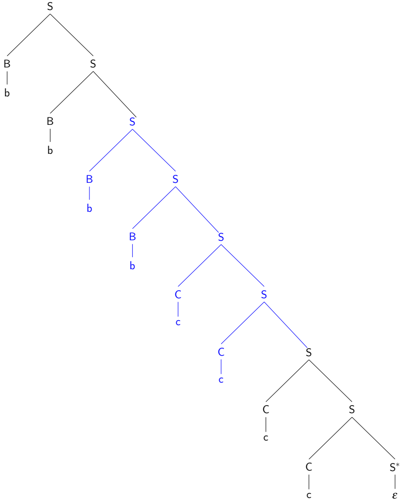


The lexicalized d-TAG: a derivation

The 2d yield ...



The 2d yield!



Strong Lexicalization of d-TAGs

Proposition

For each finitely ambiguous d-dimensional TSG that does not generate the empty string and contains only useful trees, there is a strongly equivalent d-dimensional Lexicalized TAG.

but

d-TSGs are equivalent to (d - 1)-TAGs.

Proposition

$(d+1)$-TAGs strongly lexicalize d-TAGs

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(d+1)-TAGs strongly lexicalize d-TAGs

- TAGs can be generalized to higher dimensional trees [Rogers, 2003]
- TAGs strongly lexicalize CFGs/TSGs [Schabes, 1990]

⇒ (d+1)-TAGs strongly lexicalize d-TAGs

TAGs as higher dimensional-trees

- lifting of existing results is straightforward
- increase in generative power
- what about parsing?

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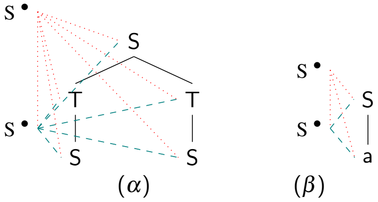
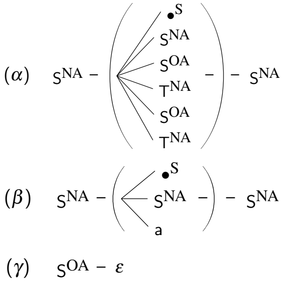
One final question

Are *d*-dimensional TAGs closed under strong lexicalization?

[Kuhlmann and Satta, 2012]

TAGs are not closed under strong lexicalization





Excess

measures the distance between a root node and a terminal node

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[Kuhlmann and Satta, 2012]

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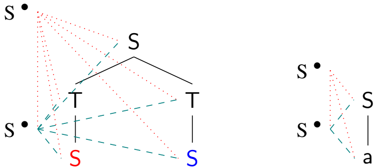
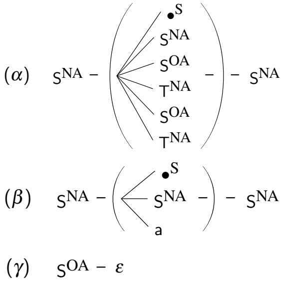


(α) (β)



Excess

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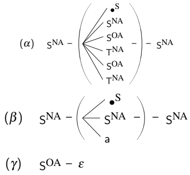
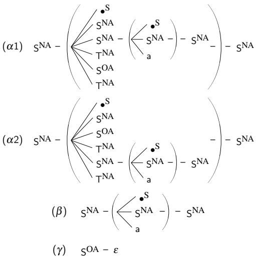
Non Lexicalized

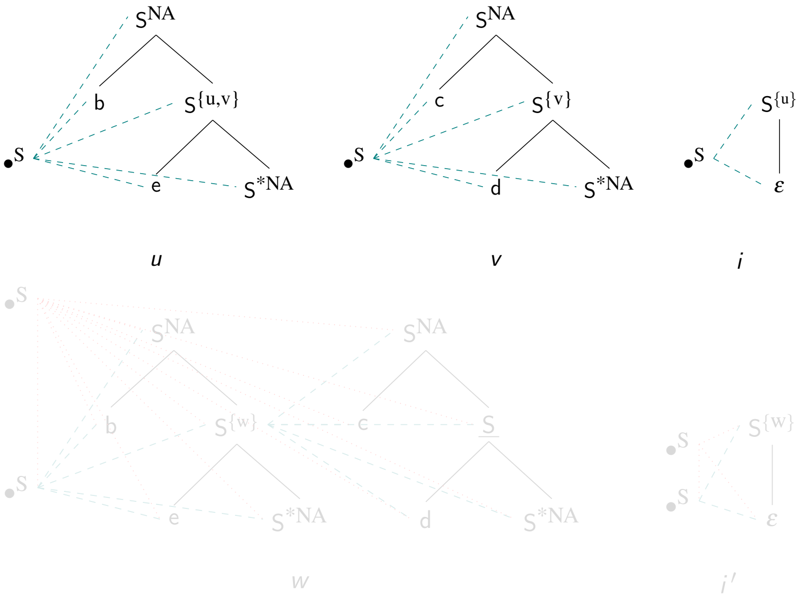


Lexicalized

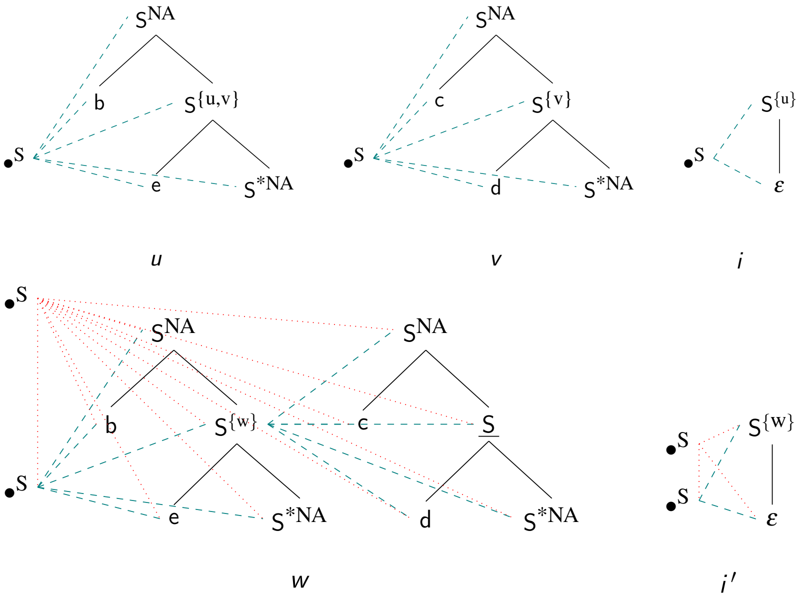


max. excess of node *a* is unbounded

max excess of node *a* is 2


S
S^NA
b
S^{u,v}
e
S^*NA
u
S
S^NA
c
S^{v}
d
S^*NA
v
S
S^{u}
ε
i
S
S
S^NA
b
S^{w}
e
S^*NA
S^NA
c
S
d
S^*NA
w
S
S
S^{w}
ε
i'

Increasing the power by increasing the dimensionality: Ex. 2



Map of Existing Results