Computational Phonology Workshop

Introduction & Tutorial

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Outline

1. The Subregular Enterprise
2. (Tier-Based) Strictly Local Phonotactics
3. Subregular Mappings for Phonology
4. (Tier-Based) Strictly Local Syntax

Computational View of Language

In formal language theory, string sets are classified according to their formal complexity.

regular $<$ context-free $<$ mildly context-sensitive $< \cdots$

Phonology

Morphology

Syntax

This allows predictions for

- typology
- learning
- cognitive architecture

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Kaplan and Kay (1994)

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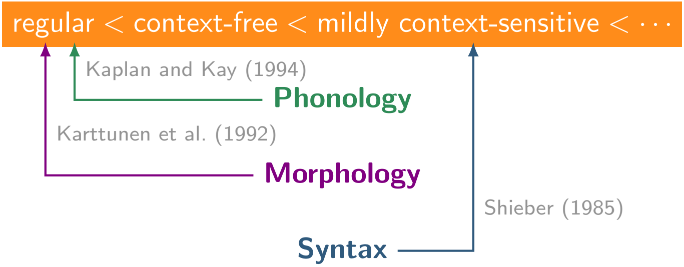

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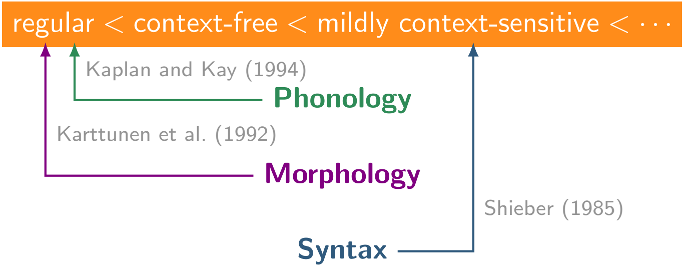

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Too Many Patterns are Regular

- **Problem**
  - All phonological and morphological patterns are regular.
  - But not all regular patterns occur in phonology.
- Regularity is **too loose an upper bound**.

Example

- First-last consonant harmony
- Every word with a plosive contains an open syllable
- Word with at least 3 suffixes must have exactly 5 prefixes

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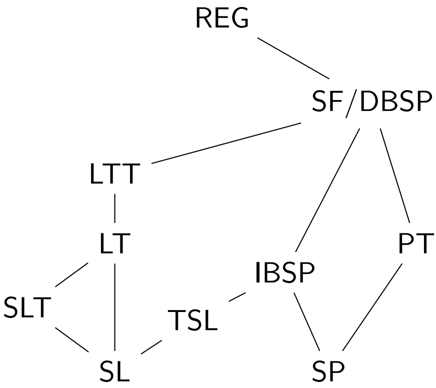
Subregular Languages

Often forgotten: hierarchy of **subregular languages** (McNaughton and Papert 1971; Rogers et al. 2010; Ruiz et al. 1998; Rogers and Pullum 2011; Heinz et al. 2011; Graf 2016)



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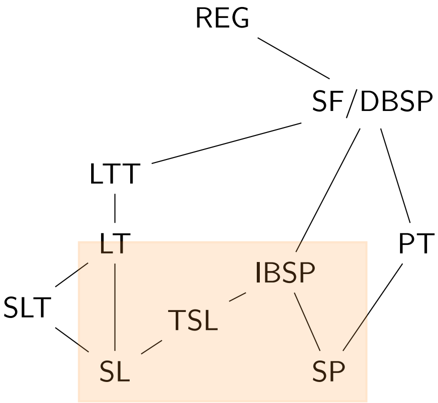

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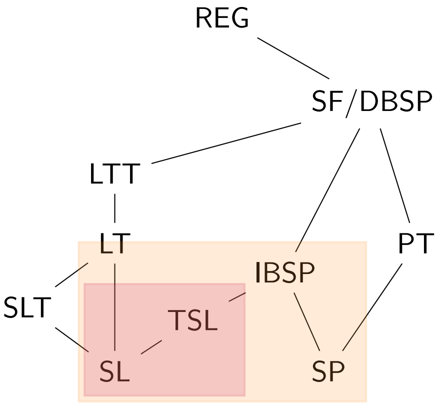

SL: Strictly Local

- SL formalizes **local dependencies**.
- SL grammars are collections of markedness constraints that are
  - hard/non-violable,
  - locally bounded.

Strictly Local Grammars & Languages

SL$_n$ grammar finite set of forbidden n-grams

SL$_n$ language all strings except those with forbidden n-grams

Example: SL Constraints

Process	Constraint	Forbidden n-grams
Word-final devoicing	*[+voice]⋉	z⋉, v⋉, ...
Intervocalic voicing	*V[-voice]V	asa, asi, ..., isa, isi, ..., afa, afi, ..., ifa, ifi, ...,
CV template	*⋊V	⋊a, ⋊i, ...
	*CC	pp, pb, ... bp, bb, ...
	*VV	aa, ai, ..., ia, ii, ...
	*C⋉	p⋉, b⋉, ...

SL is Too Weak

- SL grammars only handle unbounded dependencies.
- But some processes in phonology are unbounded.

Samala Sibilant Harmony (Heinz 2015:16)

ʃtojonowonowaʃ

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Samala Sibilant Harmony (Heinz 2015:16)

ʃtojonowonowaʃ
*stojonowonowaʃ
*ʃtojonowonowas

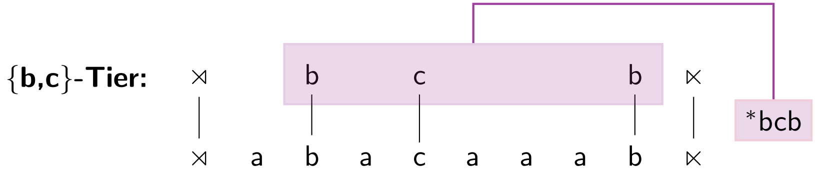
TSL: Tier-Based Strictly Local

We can make Samala SL-like if we **create new locality domains**.

Tier-Based Strictly Local Grammars & Languages

TSL$_n$ grammar finite set of forbidden n-grams + tier alphabet

TSL$_n$ language all strings except those with forbidden n-grams over tier



Example: Sibilant Harmony

Constraint	**Forbidden n-grams on sibilant tier**
$*[\alpha \text{ ant}] \cdots [-\alpha \text{ ant}]$	**ʃs**, **sʃ**

Tier: ⋊ ʃ **s** ⋉

Base: ⋊ e ʃ i s i ⋉

Tier: ⋊ ʃ ʃ ⋉

Base: ⋊ e ʃ i ʃ i ⋉

Example: Stress Assignment

Culminativity every word has exactly one primary stress

Tier contains segments with primary stress
n**-grams** śś and $\rtimes\ltimes$

$$\begin{array}{ccccc} \rtimes & & & & \ltimes \\ | & & & & | \\ \rtimes & \text{a} & \text{l} & \text{a} & \ltimes \end{array} \qquad \begin{array}{ccccc} \rtimes & \text{á} & & \text{á} & \ltimes \\ | & | & & | & | \\ \rtimes & \text{á} & \text{l} & \text{á} & \ltimes \end{array}$$

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What TSL Cannot do

Attested Patterns Beyond TSL?

A few other patterns may go beyond TSL.

- **Non-Final RHOL [Baek's talk]**
- **Multiple Harmony [Aksënova's talk]**

Complexity of Phonology

- All local phonological constraints are SL.
- All segmental long-distance constraints are TSL.
- Suprsegmental constraints (tone, stress) may go beyond TSL.
  (Graf 2010a,b; Jardine 2015)

Cognitive Implications

- SL and TSL languages are **learnable** from positive data. (Heinz et al. 2012; Jardine and Heinz 2016)
    - UG: specifies upper bound on size of n-grams
    - memorize which sequences have not been seen so far
    - induce tier (more complex)
    - learning input can be relatively small
- What cognitive resources are required?
    - Only memorization of the last n segments of a specific type
    - For most processes $n \leq 3$, and for all $n \leq 7$
    - Fits **within bounds of human working memory**

Interim Summary: Phonotactics

- Natural languages have **TSL phonotactics**.
- gives tighter bound on typology
- solves poverty of stimulus by greatly simplifying learning
- reduces cognitive resource requirements

Next

- phonological mappings
- SL & TSL syntax

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Phonological Mappings

- So far we have only considered phonotactics.
- But mappings from underlying representations to surface forms can be studied, too.
- Regular mappings are enough.
  (Kaplan and Kay 1994)
- What about subregular mappings?

Input Strictly Local Mappings

Input Strictly Local (ISL)

- Move through string from left to right.
- Rewrite x as y based on previous n symbols in input string.
- Output is **not considered**!

A Note on TSL

Every TSL_n grammar can be decomposed into

1. an **ISL_1** function (the tier projection), and
2. an SL_n grammar.

An Interesting Puzzle

- What happens if we use an ISL_k function for tier projection?
- Addressed in **Aniello De Santo**'s talk

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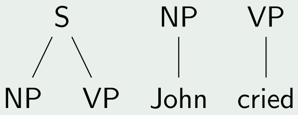
(Tier-Based) Strictly Local Syntax

- SL tree grammars are common in computational linguistics: **context-free grammars**
- By adding tier projection, we get TSL tree grammars.

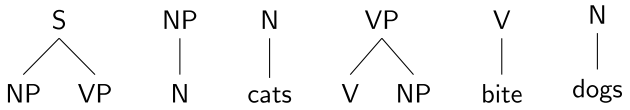
Example: CFGs as SL_2 Tree Grammars

$$\begin{aligned} S &\rightarrow \text{NP VP} \\ \text{NP} &\rightarrow \text{John} \\ \text{VP} &\rightarrow \text{cried} \end{aligned}$$

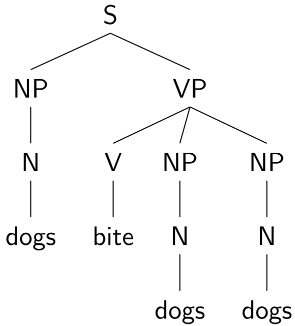


Example: An Illicit Tree

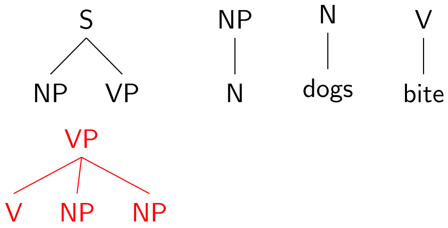
SL_2 Tree Grammar



Example Tree

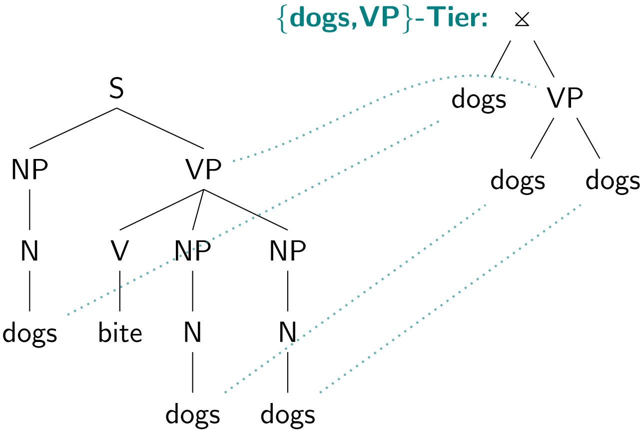


Tree Bigrams of Example Tree



Tier Projection for Trees

Just as for strings, we can project tiers for trees.
(Graf and Heinz 2016)



Towards TSL-Syntax

While TSL-Syntax is still young, it holds promise:

- movement dependencies are TSL (Graf and Heinz 2016)
- Mandarin negation in **Hongchen Wu's talk**
- scope ambiguities in **Lei Liu's blitz talk**

Conclusion

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