Using Output Strict Locality to Model and Learn Long-distance Processes

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Main objectives

- Define *Output Strict Locality*, a strong computational property that holds of the mapping from UR to SR.
- Show how the output-oriented nature of this property is needed to model spreading processes.
- Analyze various long-distance processes with a component of OSL spreading.

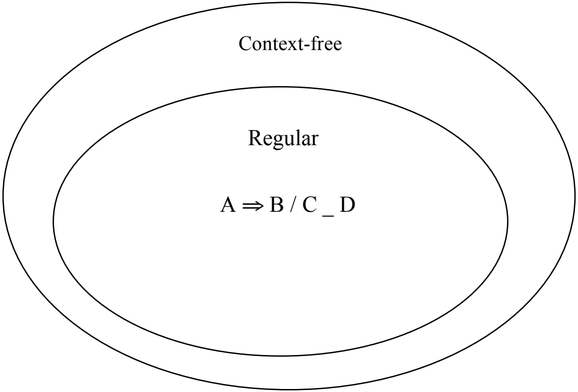
Computational properties

- Phonological processes are *maps* (i.e., functions) from an input (UR) to an output (SR).
- The nature of these maps helps us characterize possible phonological processes.

  (1) Tesar (2008, 2012, 2014) characterizes certain maps as *output-driven*.

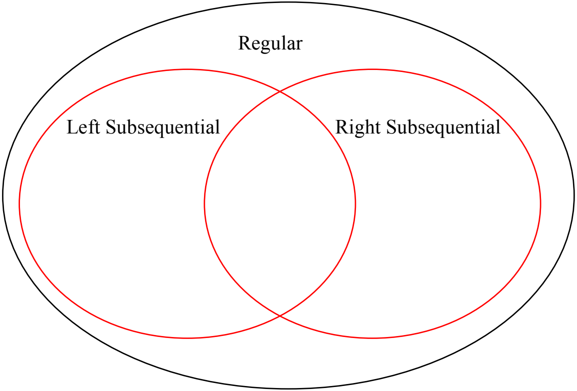
- Also aids in learning, when the learner can use the computational property as an inductive principle or bias.

Phonological maps are REGULAR



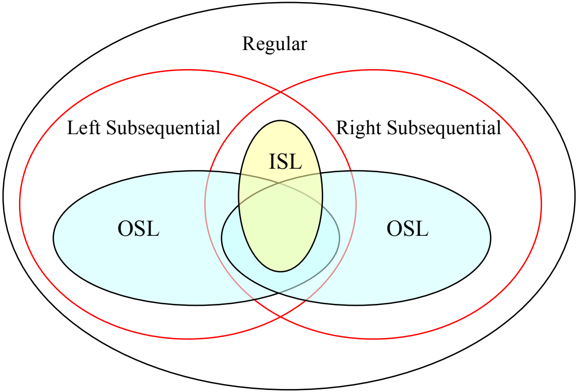
Johnson (1972); Kaplan and Kay (1994); Koskenniemi (1983)

Phonological maps are SUBSEQUENTIAL



Mohri (1997); Chandlee et al. (2012); Gainor et al. (2012); Heinz and Lai (2013); Jardine (2013); Luo (2013); Payne (2013); Chandlee and Heinz (2012)

Phonological maps are STRICTLY LOCAL



Chandlee (2014); Chandlee et al. (2014)

Tails

For any function $f : \Sigma^* \rightarrow \Gamma^*$ and $x \in \Sigma^*$, let the *tails* of x with respect to f be defined as

$$\texttt{tails}_f(x) = \left\{(y, v) \in \Sigma^* \times \Gamma^* \mid f(xy) = uv \wedge u = \texttt{lcp}(f(x\Sigma^*))\right\} .$$

Tails

Post-nasal obstruent voicing (Quechua, Orr (1962); Rice (1993); Pater (2010))

(2) f(kampa) = kamba

(3) $\texttt{tails}_f$(kam) = {(p,b),(m,m),(a,a),(k,k),(d,t)...}

Input Strict Locality

Definition (Input Strictly Local Function)

A function f is Input Strictly Local (ISL) if there is a k such that for all $u_1, u_2 \in \Sigma^*$, if $\texttt{Suff}^{k-1}(u_1) = \texttt{Suff}^{k-1}(u_2)$ then $\texttt{tails}_f(u_1) = \texttt{tails}_f(u_2)$.

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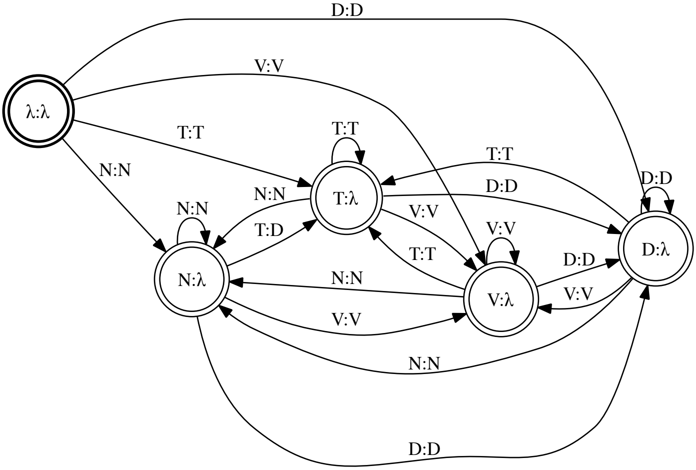
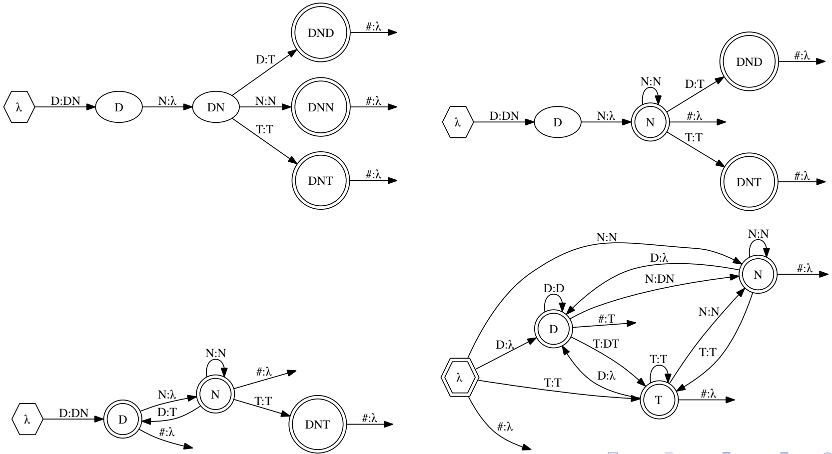
(4) $\texttt{tails}_f(\text{kam}) = \texttt{tails}_f(\text{tam}) = \texttt{tails}_f(\text{kamam}) = \texttt{tails}_f(\text{kamamam}) = \{(\text{p,b}),(\text{m,m}),(\text{a,a}),(\text{k,k}),(\text{d,t})...\}$

ISL FST characterization



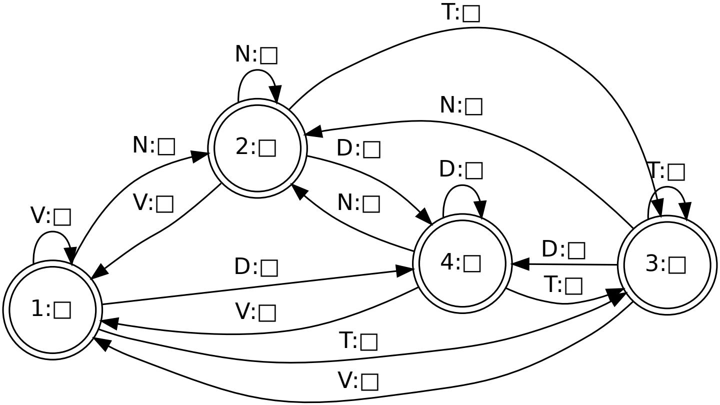
Learning ISL

ISLFLA: state merging algorithm (Chandlee 2014; Chandlee et al. 2014)



Learning ISL

SOSFIA (Jardine et al. 2014)



Empirical coverage of ISL

(5) A $\rightarrow$ B / C __ D

- If CAD is a finite language and the rule applies simultaneously, the mapping is ISL (see Kaplan and Kay, 1994; Hulden, 2009; Chandlee, 2014).
- This includes epenthesis, deletion, local substitution, metathesis, local partial reduplication, general affixation (approx. 94% of the processes in P-Base (v.1.95, Mielke (2004))).

Non-ISL processes

Because ISL functions only pay attention to the input, the trigger of the process must be present underlyingly.

Nasal spreading

(6) Johore Malay (Onn 1980)

a. [-nasal] $\rightarrow$ [+nasal] / [+nasal] __

b. pəŋawasan $\mapsto$ pəŋãw̃ãsan, ‘supervision’

Nasal spreading

(7) f(pəŋawasan) = pəŋãw̃ãsan

(8) a. pəŋaw ↦ pəŋãw̃

b. paw ↦ paw

(9) a. $\mathtt{tails}_f$(pəŋaw) = {(p,p),(a,ã),(w,w̃),...}

b. $\mathtt{tails}_f$(paw) = {(p,p),(a,a),(w,w), ...}

Output Strict Locality

Definition (Output Strictly Local Function)

A function f is Output Strictly Local (OSL) if there is a k such that for all $u_1, u_2 \in \Sigma^*$, if $\texttt{Suff}^{k-1}(f(u_1)) = \texttt{Suff}^{k-1}(f(u_2))$ then $\texttt{tails}_f(u_1) = \texttt{tails}_f(u_2)$.

Output Strict Locality

(10) a. pəŋa ↦ pəŋã
b. pəŋawa ↦ pəŋãw̃ã
c. papa ↦ papa

(11) $\texttt{tails}_f$(pəŋa) = $\texttt{tails}_f$(pəŋawa) = {(p,p),(a,ã),(w,w̃),...}

(12) $\texttt{tails}_f$(papa) = {(p,p),(a,a),(w,w),...}

Output Strict Locality

$$\text{OSL} = \text{transitive closure of ISL} \circ \text{ISL}$$

Output Strict Locality

- Conjecture: the ISL functions of interest to phonology are also OSL.

(13) Final devoicing: bad $\mapsto$ bat

(14) Place assimilation: inpossible $\mapsto$ impossible

- Some processes are *only* OSL.

Schwa deletion

(15) French (Dell 1973, 1980, Noske 1993)

a. $ə \rightarrow \emptyset$ / VC__CV

(16) tu devenais, ‘you became’

a. ty dəvənɛ $\mapsto$ ty dvənɛ

b. ty dəvənɛ $\mapsto$ ty dəvnɛ

c. ty dəvənɛ $\mapsto$ *ty dvnɛ

Long Distance Processes

Spreading: trigger arbitrarily far from target, but iteration makes the process local.

Long Distance Processes

Harmony: spreading but with certain segments skipped.

Harmony

Vowel harmony without transparent vowels.

(17) $\mathsf{V} \rightarrow [+\alpha] \; / \; \mathsf{V}_{+\alpha}\mathsf{C}_0^{k-2}\_\_$

k = length of maximum coda + maximum onset + 2

Harmony

Vowel harmony *with* transparent vowels.

There is no k such that the target and trigger vowel will form a contiguous substring bounded by k.

Harmony

Vowel harmony with transparent vowels:

1) spread harmonizing feature to all vowels ✓ OSL

2) remove feature from transparent vowels ✓ OSL

(Clements 1977; Vago 1980)

Vowel transparency

(18) Khalkha Mongolian rounding harmony, [i] transparent (Svantesson et al. 2005; Gafos and Dye 2011)

a. poor-ig-o, ‘kidney.ACC.RFL’

b. teeʒ-ig-ɔ, ‘food.ACC.RFL’

(1) V $\rightarrow$ [+round] / $V_{[+round]}$ C_0^{k-2} __
(2) y $\rightarrow$ i

poor-ig-O $\mapsto_1$ poor-yg-o $\mapsto_2$ poor-ig-o

LD assimilation

(19) Kikongo nasal assimilation (Rose and Walker 2004)

a. /tu-kun-idi/ $\mapsto$ [tukunini] 'we planted'

b. /tu-nik-idi/ $\mapsto$ [tunikini] 'we ground'

(1) [+voice] $\rightarrow$ [+nasal] / [+voice] T_0^{k-1} __

(2) [-cons] $\rightarrow$ [-nasal]

$$\text{tu-nik-idi} \mapsto_1 \text{tu-n}\tilde{\text{i}}\text{k-}\tilde{\text{i}}\text{n}\tilde{\text{i}} \mapsto_2 \text{tu-nik-ini}$$

LD displacement

(20) Colville (Mattina 1979)

a. pˤáw 'he ran down'

b. pw-ən-cˤát-əlx 'they make noise running down'

pˤáw-ən-cat-əlx ↦ pˤaˤwˤ-əˤnˤ-cˤát-əlx ↦ paw-ən-cˤát-əlx

OSL composition

OSL functions are not closed under composition!

OSL composition

Theorem (Elgot and Mezei 1965)

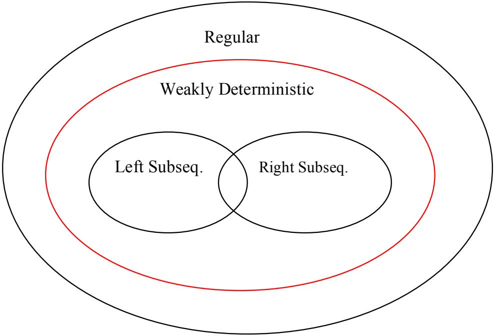
A function $f : X^* \mapsto Y^*$ is a regular relation iff there exists a left subsequential function $g : X^* \mapsto Z^*$ and a right subsequential function $h : Z^* \mapsto Y^*$, with $X \subseteq Z$, such that $f = g \circ h$.

Weakly Deterministic Function

Definition (Weakly Deterministic Function, (Heinz and Lai 2013))

A regular function f is weakly deterministic iff there exists a left subsequential function $g : X^* \mapsto X^*$ and a right subsequential function $h : X^* \mapsto X^*$ such that g is not length-increasing and $f = g \circ h$.

Weakly Deterministic Function



(Heinz and Lai 2013)

How much markup?

Will constraints on markup likewise restrict the power of $OSL \circ OSL$? If so, what are those constraints?

Two options for LD processes

Option 1

- One computational property, OSL, characterizes both local and long-distance processes.
- Like ISL, the OSL property can also be used to learn these maps (stay tuned!).

Two options for LD processes

Option 2

- Local processes are characterized as those OSL maps that *are* closed under composition (i.e., Structure Preservation, Kiparsky 1985)).
- Long distance processes require a distinct, to-be-defined property (e.g., Strictly Piecewise, Tier-Based Strictly Local).

Acknowledgments

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Optimization

Nonregular mappings can be obtained through the interaction of simple markedness constraints and standard faithfulness constraints (Riggle 2004; Gerdemann and Hulden 2012).

Optimization

$\textsc{Ident}, \textsc{Dep} \gg *ab \gg \textsc{Max}$

Non-regular relation:

$a^n b^m \mapsto a^n$, if $m < n$

$a^n b^m \mapsto b^m$, if $n < m$

Strict Locality

- A *Strictly k-Local formal language* is one for which the following property holds:

Theorem (Suffix Substitution Closure)

(Rogers and Pullum 2011) $\mathcal{L}$ *is Strictly Local iff for all strings* u_1, v_1, u_2, v_2, *there exists* $k \in \mathbb{N}$ *such that for any string* x *of length* $k-1$, *if* $u_1 x v_1, u_2 x v_2 \in \mathcal{L}$, *then* $u_1 x v_2 \in \mathcal{L}$.

Strict Locality

Post-nasal obstruent voicing

(21) Quechua (Orr 1962; Rice 1993; Pater 2010)

a. sinik-pa ‘porcupine’s’

b. kam-ba ‘yours’

Strict Locality

Post-nasal obstruent voicing: Valid surface strings are a SL-2 language.

TVNDV in the language.
NVNTV in the language.

TVNTV *necessarily* in the language.

Strict Locality

- Surface constraints expressible with a contiguous substring of bounded length can be are Strictly *k*-Local, where *k* is the length of the illicit substring (**?**).
- For *processes* (i.e., UR $\mapsto$ SR), we need *functions*.