Syllabification in ITB is QF

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Motivation

- Regular functions are those realized by transducers in Monadic Second Order Logic
- A subset of those correspond to transductions definable by First Order Logic
- A subset of those - Quantifier Free definable
- Many regular functions correspond to mappings which aren’t actually attested
- Both RBP and OT overgenerate

Basic facts on ITB syllabification

- Sonority Sequencing Principle:

  Sonority rises monotonically from a given segment to the sonority peak of its syllable

- Dell and Elmedlaoui (1985):

$$\text{vcl. stops} <_s \text{vcd. stops} <_s \text{vcl. fric} <_s \text{vcd. fric} <_s \text{nas} <_s \text{liq} <_s \text{HV} <_s [\text{a}]$$

Four other principles

- All non-initial syllables must have an onset
- Initial stops and final obstruent are forbidden from being nucleic
- Glide/vowel distinction among HVs: a nucleic HV is vocalic, a non-nucleic HV is a glide
- The SSP is violated in Glide Sonorant (GR) syllables:
    - /saulx/ → [sa.wLx]

Previous approaches (discussed in class before)

- Dell and Elmedlaoui (1985): ordered set of iterative rules to identify syllabic nuclei. Each refers to a natural class (e.g. voiceless stops)

- Prince and Smolensky (1993): OT account.
  - 2 main constraints penalize: onsetless non-initial syllables, syllables with not most sonorous nuclei
  - Additional constraints for the other principles

Previous approaches (discussed in class before)

- Scobbie (1993): a Declarative Phonology treatment.
  - constraints similar to Prince and Smolensky
  - BUT: inviolable, unranked and defined in FO logic

The Successor Model Theory

$$\mathfrak{M}^{\lhd} \stackrel{\text{def}}{=} \langle \mathfrak{D}; \{R_\sigma \mid \sigma \in \Sigma\}; \\ \{\mathtt{pred}(x), \mathtt{succ}(x)\}\rangle$$

- pred(x) and succ(x) pick out the immediate predecessor and successor of a given position.
- pred(0)=0 (the first position is its own predecessor)
- succ(n)=n (the final position is its own successor)

Successor Model for *ball*

$$\mathcal{M}^{\triangleleft}_{ball}$$

$$\mathcal{D} = \{0, 1, 2, 3\}$$

$$R_a = \{1\}$$

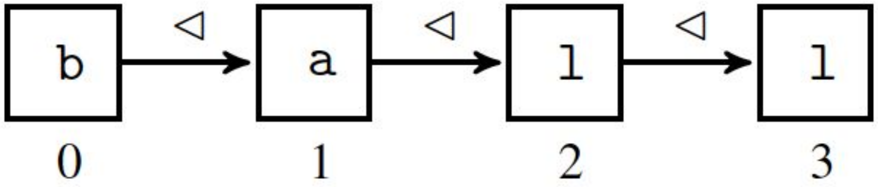
$$R_b = \{0\}$$

$$R_l = \{2, 3\}$$

$$\texttt{succ}(x) = \begin{cases} 1 & x = 0 \\ 2 & x = 1 \\ 3 & x = 2 \\ 4 & x \in \{3, 4\} \end{cases}$$

$$\texttt{pred}(x) = \begin{cases} 0 & x \in \{0, 1\} \\ 1 & x = 2 \\ 2 & x = 3 \\ 3 & x = 4 \end{cases}$$

Figure 1: A visual representation of $\mathcal{M}^{\triangleleft}_{ball}$.



The Modified Successor Model

- Strother-Garcia permits each position to have more than one label
- The alphabet:

$$\mathcal{F} \stackrel{\text{def}}{=} \{\texttt{voice}, \texttt{vocoid}, \texttt{high}, \texttt{lab}, \texttt{alv}, \texttt{post}, \texttt{pal}, \texttt{vel}, \texttt{uv}, \texttt{phar}, \texttt{glot}, \texttt{stop}, \texttt{fric}, \texttt{nas}, \texttt{approx}, \texttt{lat}\}$$

- Set of relations labelling positions with features: $\mathcal{R}_f \stackrel{\text{def}}{=} \{R_f \mid f \in \mathcal{F}\}$
- Binary sonority relations: $\mathcal{R}_s \stackrel{\text{def}}{=} \{<_s, =_s, \leq_s\}$
- Modified model:

$$\mathfrak{M} \stackrel{\text{def}}{=} \langle \mathfrak{D}; \{\mathcal{R}_f \cup \mathcal{R}_s\}; \{\mathtt{pred}(x), \mathtt{succ}(x)\}\rangle$$

Graph transductions

- e.g. transduction that changes all bs to as

$$R_a^{\omega}(x) \overset{\text{def}}{=} R_a(x) \vee R_b(x)$$

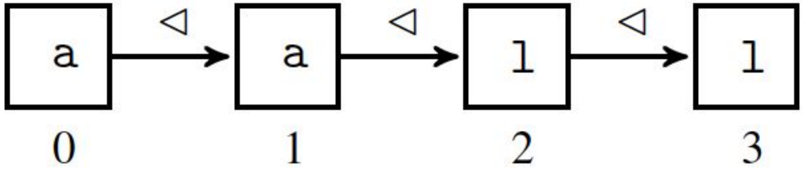
$$R_b^{\omega}(x) \overset{\text{def}}{=} \texttt{FALSE}$$

$$R_l^{\omega}(x) \overset{\text{def}}{=} R_l(x)$$

$$\texttt{succ}^{\omega}(x) \overset{\text{def}}{=} \texttt{succ}(x)$$

$$\texttt{pred}^{\omega}(x) \overset{\text{def}}{=} \texttt{pred}(x)$$

Figure 2: A visual representation of $\Gamma_{ba}(\mathcal{M}_{ball}^{\triangleleft})$.



Logics and Locality

- Logics:

$$\text{closed}(X) \stackrel{\text{def}}{=} (\forall x, y)(x \in X \wedge x \triangleleft y) \Rightarrow y \in X \tag{15}$$

$$x \prec y \stackrel{\text{def}}{=} (\forall X)(x \in X \wedge \text{closed}(X)) \Rightarrow y \in X \tag{16}$$

- (16): MSO
- (15): FO

- Locality:

$$R_a^{\omega\prime}(x) \stackrel{\text{def}}{=} R_a(x) \vee (\exists y)[R_b(y)] \tag{17}$$

$$R_a^{\omega}(x) \stackrel{\text{def}}{=} R_a(x) \vee R_b(x) \tag{18}$$

- (17) vs (18): in (17) x will be labeled a if the input position is an a or if there's b somewhere in the input

Syllabification Transduction

$\mathfrak{M}$ (Input)

Domain	Set of segment positions
Relations	voice, vocoid, high, lab, alv, post, pal, vel, uv, phar, glot, stop, fric, nas, approx, lat, $<_s$, $=_s$, $\leq_s$
Functions	pred(x), succ(x)

$\xrightarrow{\Gamma}$

$\mathfrak{M}'$ (Output)

Domain	Set of segment positions
Relations	voice, vocoid, high, lab, alv, post, pal, vel, uv, phar, glot, stop, fric, nas, approx, lat, $<_s$, $=_s$, $\leq_s$, ons, nuc, coda
Functions	pred(x), succ(x)

Recall: ITB Syllable Structure

- Sonority rises monotonically to the sonority peak of each syllable
  - EXCEPT in glide-sonorant (GR) syllables, which will occur when high vocoids follow another vowel. In this case, the high vocoid is realized as a glide, and becomes the onset for a nucleic sonorant. This prevents hiatus.
- All non-initial syllables must have an onset
- Initial stops and final obstruents cannot be nuclei
- If there is a sonority plateau, the leftmost segment takes prominence

How it Works

- **Find the sonority peaks**: any segment whose predecessor and successor are either a word boundary or of lower sonority
- **Rule out marked segments:** word-initial stops and word-final obstruents can never be nuclei
- **Find GR nuclei:** Any sonorant segment which follows a V(HV) pair will be a GR nucleus
- **Find the onsets:** Any segment which precedes a nucleus is an onset
- **Find the codas:** Any segment which is not an onset or nucleus is a coda

Helpers

$$\mathsf{obs}(x) \stackrel{\text{def}}{=} \mathtt{stop}(x) \vee \mathtt{fric}(x) \tag{21}$$

$$\mathsf{son}(x) \stackrel{\text{def}}{=} \neg\mathsf{obs}(x) \tag{22}$$

$$\mathsf{init}(x) \stackrel{\text{def}}{=} \mathtt{pred}(x) = x \tag{23}$$

$$\mathsf{fin}(x) \stackrel{\text{def}}{=} \mathtt{succ}(x) = x \tag{24}$$

$$\mathsf{med}(x) \stackrel{\text{def}}{=} \neg(\mathsf{init}(x) \vee \mathsf{fin}(x)) \tag{25}$$

Finding Sonority Peaks

$$\mathsf{med\_pk}(x) \stackrel{\text{def}}{=} \mathsf{med}(x) \wedge \mathtt{pred}(x) <_s x \wedge \mathtt{succ}(x) <_s x \tag{26}$$

$$\mathsf{init\_pk}(x) \stackrel{\text{def}}{=} \mathsf{init}(x) \wedge \mathtt{succ}(x) <_s x \tag{27}$$

$$\mathsf{fin\_pk}(x) \stackrel{\text{def}}{=} \mathsf{fin}(x) \wedge \mathtt{pred}(x) <_s x \tag{28}$$

$$\mathsf{son\_pk}(x) \stackrel{\text{def}}{=} \mathsf{med\_pk}(x) \vee \mathsf{init\_pk}(x) \vee \mathsf{fin\_pk}(x) \tag{29}$$

Sonority vs Prominence peaks

- Recall that if two adjacent segments are equal in sonority, the leftmost of the two will be more prominent
- When assigning nuclei, we actually care about **all** the peaks in prominence, including those that are part of a plateau

$$\mathsf{left\_prom}(x) \stackrel{\text{def}}{=} x =_s \mathsf{succ}(x) \wedge \mathsf{med}(x) \qquad (30)$$

$$\mathsf{prom\_pk}(x) \stackrel{\text{def}}{=} \mathsf{son\_pk}(x) \vee \mathsf{left\_prom}(x) \qquad (31)$$

Handling Exceptions

$$\mathsf{mrkd}(x) \stackrel{\text{def}}{=} \mathsf{init\_stop}(x) \vee \mathsf{fin\_obs}(x) \tag{32}$$

$$\begin{aligned} \mathsf{GR\_nuc}(x) \stackrel{\text{def}}{=} & \ \mathtt{vocoid}(\mathtt{pred}(x)) \wedge \mathsf{son}(x) \\ & \wedge \mathsf{prom\_pk}(\mathtt{pred}(\mathtt{pred}(x))) \end{aligned} \tag{33}$$

Assigning Syllable Constituency

$$\mathsf{nuc}(x) \stackrel{\text{def}}{=} (\mathsf{prom\_pk}(x) \wedge \neg \mathsf{mrkd}(x)) \vee \mathsf{GR\_nuc}(x) \tag{34}$$

$$\mathsf{ons}_1(x) \stackrel{\text{def}}{=} \neg \mathsf{nuc}(x) \wedge \mathsf{nuc}(\mathtt{succ}(x)) \tag{35}$$

$$\mathsf{ons}_2(x) \stackrel{\text{def}}{=} \mathsf{init\_obs} \wedge \mathsf{ons}_1(\mathtt{succ}(x)) \tag{36}$$

$$\mathsf{ons}(x) \stackrel{\text{def}}{=} \mathsf{ons}_1(x) \vee \mathsf{ons}_2(x) \tag{37}$$

$$\mathsf{cod}(x) \stackrel{\text{def}}{=} \neg \mathsf{nuc}(x) \wedge \neg \mathsf{ons}(x) \tag{38}$$

The Transduction

$\mathfrak{M}$ (Input)

Domain	Set of segment positions
Relations	voice, vocoid, high, lab, alv, post, pal, vel, uv, phar, glot, stop, fric, nas, approx, lat, $<_s$, $=_s$, $\leq_s$
Functions	pred(x), succ(x)

Γ

$$\text{nuc}^{\omega}(x) \stackrel{\text{def}}{=} \text{nuc}(x)$$

$$\text{ons}^{\omega}(x) \stackrel{\text{def}}{=} \text{ons}(x)$$

$$\text{cod}^{\omega}(x) \stackrel{\text{def}}{=} \text{cod}(x)$$

$\mathfrak{M}$' (Output)

Domain	Set of segment positions
Relations	voice, vocoid, high, lab, alv, post, pal, vel, uv, phar, glot, stop, fric, nas, approx, lat, $<_s$, $=_s$, $\leq_s$, ons, nuc, coda
Functions	pred(x), succ(x)

Example

/salx/ → [s**a**.w**I**x]

x	0	1	2	3	4
s(x)	✓	.	.	.	.
a(x)	.	✓	.	.	.
u(x)	.	.	✓	.	.
l(x)	.	.	.	✓	.
x(x)	.	.	.	.	✓
$x <_s$ succ(x)	✓	.	.	.	.
$x =_s$ succ(x)	.	.	.	.	.
son_pk(x)	.	✓	.	.	.
left_prom(x)	.	.	.	.	.
prom_pk(x)	.	✓	.	.	.
fin_obs(x)	.	.	.	.	✓
mrkd(x)	.	.	.	.	✓
GR_nuc(x)	.	.	.	✓	.
nuc(x)	.	✓	.	✓	.
ons$_1$(x)	✓	.	✓	.	.
ons(x)	✓	.	✓	.	.
cod(x)	.	.	.	.	✓

Conclusion

- ITB Syllabification is a QF process
  - Ie strictly local
- OT or rule-based phonology are both capable of more complex processes, but this suggests they may be *too* powerful

Consequences of the Model: "Maximize Coda"

Recall:

$$\mathsf{ons}_1(x) \stackrel{\text{def}}{=} \neg\mathsf{nuc}(x) \wedge \mathsf{nuc}(\mathsf{succ}(x)) \quad (35)$$

$$\mathsf{ons}_2(x) \stackrel{\text{def}}{=} \mathsf{init\_obs} \wedge \mathsf{ons}_1(\mathsf{succ}(x)) \quad (36)$$

$$\mathsf{ons}(x) \stackrel{\text{def}}{=} \mathsf{ons}_1(x) \vee \mathsf{ons}_2(x) \quad (37)$$

$$\mathsf{cod}(x) \stackrel{\text{def}}{=} \neg\mathsf{nuc}(x) \wedge \neg\mathsf{ons}(x) \quad (38)$$

/satgsznra/ → [s**a**tgszn.r**a**]

- Default is to stick leftover segments into the coda
- This is sort of the opposite of "maximize onset", which we see most places
- May need constraints on the **underlying representation** to prevent this kind of thing

Other Edge Cases: Initial Obstruent Peak

/zta/ → [**z??**.ta]

Recall:

$$\mathsf{ons}_1(x) \stackrel{\text{def}}{=} \neg\mathsf{nuc}(x) \wedge \mathsf{nuc}(\mathtt{succ}(x)) \qquad (35)$$

$$\mathsf{ons}_2(x) \stackrel{\text{def}}{=} \mathsf{init\_obs} \wedge \mathsf{ons}_1(\mathtt{succ}(x)) \qquad (36)$$

$$\mathsf{ons}(x) \stackrel{\text{def}}{=} \mathsf{ons}_1(x) \vee \mathsf{ons}_2(x) \qquad (37)$$

$$\mathsf{cod}(x) \stackrel{\text{def}}{=} \neg\mathsf{nuc}(x) \wedge \neg\mathsf{ons}(x) \qquad (38)$$

	z	t	a
Prom peak	✔	.	✔
mrkd	.	.	.
nuc	✔	.	✔
ons_1	.	✔	.
ons_2	✔	.	.

Initial Vowel Plateau

Recall:

$$\text{left\_prom}(x) \stackrel{\text{def}}{=} x =_s \text{succ}(x) \wedge \text{med}(x) \quad (30)$$

$$\text{prom\_pk}(x) \stackrel{\text{def}}{=} \text{son\_pk}(x) \vee \text{left\_prom}(x) \quad (31)$$

/aark/ → [aark]

	a	a	r	k
Prom peak	.	.	.	.
GR nuc	.	.	.	.
nuc	.	.	.	.
ons	.	.	.	.
cod	✔	✔	✔	✔