Language and Computation

week 10, Thursday, April 03

Tamás Biró
Yale University
tamas.biro@yale.edu
http://www.birot.hu/courses/2014-LC/

Practical matters

- **Post-reading:** JM 11
- **Pre-reading:** JM 17.1-2, 18.1, 19.1, 20.1
- `http://birot.hu/courses/2014-LC/readings.txt`
- Assignment 4 posted, due: 04/10.
- (To come(?): Viterbi and Forward-Backward – an example)
- Midterm returned.

Today

- Finite State phonology
- Optimality Theory: general definition
- Implementations of OT

Next week: learning OT; computational semantics.

Finite-state phonology

Regular relation (recap)

Relation $\mathcal{R} \subseteq \Sigma^* \times \Delta^*$

is a **regular relation** iff

- accepted by a *Finite State Transducer* over Σ and Δ, that is,
- matched by a *regular expression* over $(\Sigma \cup \{\epsilon\}) \times (\Delta \cup \{\epsilon\})$.

Phonology: mapping UR $\mapsto$ SR

Is it a regular relation?

- Non-cyclic SPE-rules are finite-state (Johnson 1972; Kaplan and Kay, 1981/1994):
  - SPE based on context-sensitive rules (Chomsky and Halle 1968): $A \rightarrow B/C\_\ D$, that is, $C\ A\ D \rightarrow C\ B\ D$.
  - But, they are not applied recursively!
  - `/.* (C:C) (A:B) (D:D) .*/`, equivalent to some FST.
  - Cascade of SPE rewrite rules $\rightarrow$ cascade of FSTs.

Phonology: mapping UR $\mapsto$ SR

Is it a regular relation?

- Kimmo Koskenniemi (1983): **two-level morphology** with *declarative constraints*

Rule Type	**Interpretation**
`a:b` $\Leftarrow$ c ___ d	*a* is **always** realized as *b* in the context *c* ___ *d*
`a:b` $\Rightarrow$ c ___ d	*a* may be realized as *b* **only** in the context *c* ___ *d*
`a:b` $\Leftrightarrow$ c ___ d	*a* must be realized as *b* in context *c* ___ *d* and nowhere else
`a:b` $/\!\!\Leftarrow$ c ___ d	*a* is **never** realized as *b* in the context *c* ___ *d*

Example: allomorphs of English plural morpheme

Morphology:		<fax> + Plural
Phonology:	UF	/f a: k s + z /
Phonology:	SF	[f a: k s i z]

Solution with **rules** in SPE-style phonology (early generative phonology):

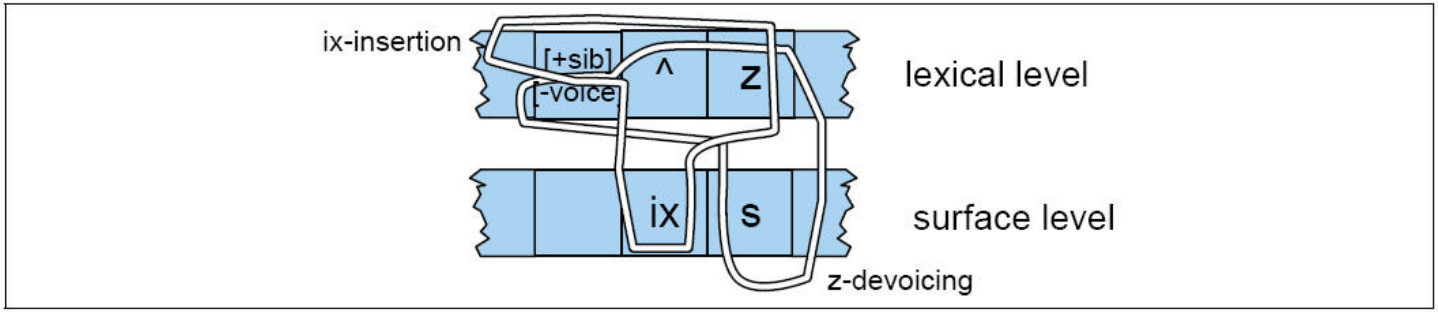
$$\emptyset \rightarrow \text{i} \;/\; [+\ \text{sibilant}] + \_\ \text{z}\ \#$$

$$\text{z} \rightarrow \text{s} \;/\; [-\ \text{voice}] + \_\ \#$$

Example: allomorphs of English plural morpheme

Morphology:		<fax> + Plural
Phonology:	UF	/f a: k s + z /
Phonology:	SF	[f a: k s i z]

Solution **with constraints** in two-level morphology:



Example: allomorphs of English plural morpheme

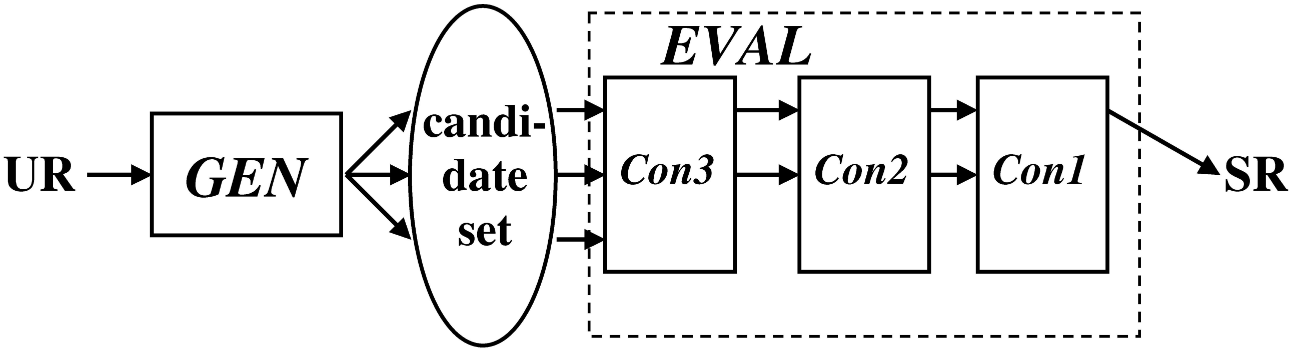
Morphology:	<fax> + Plural
Phonology: UF	/f a: k s + z /
Phonology: SF	[f a: k s i z]

Solution **with soft constraints** in Optimality Theory:

/f a: k s + z/	*sz e.g., voice assim	*ss e.g., OCP	Faithfulness
[f a: k s z]	*!		
[f a: k s s]		*!	*
☞ [f a: k s i z]			*
[f a: k s i s]			*!*

Architectures for phonology

- Overall architectures: Optimality Theory



Phonology: mapping UR $\mapsto$ SR

Is it a regular relation?

- Optimality Theory is finite-state under some assumptions Frank and Satta (1998), Karttunen (1998), Gerdemann and van Noord (2000).
  `Gen oo Constr_1 oo Constr_2 oo .. oo Constr_n`

- Non-finite state constraints: Eisner (1997), Bíró (2003)

- OT as weighted FST: Ellison (1994), Eisner (1997, etc.)

Optimality Theory: the basic idea

Optimality Theory

Simplified language **typology**:

- Stress on first syllable
- Stress on last syllable
- Stress on penultimate syllable
- No language with stress on second syllable as a rule

Optimality Theory

Simplified language **typology**:

- EARLY: stress as early as possible
- LATE: stress as late as possible
- NONFINAL: stress not on last syllable.

Optimality Theory

	$/\sigma\sigma\sigma\sigma/$	EARLY	LATE	NONFINAL
☞	[s u u u]	0	3	0
	[u s u u]	1!	2	0
	[u u s u]	2!	1	0
	[u u u s]	3!	0	1

Optimality Theory

/σσσσ/	NonFinal	Late	Late
[s u u u]	0	3!	0
[u s u u]	0	2!	1
☞ [u u s u]	0	1	2
[u u u s]	1!	0	3

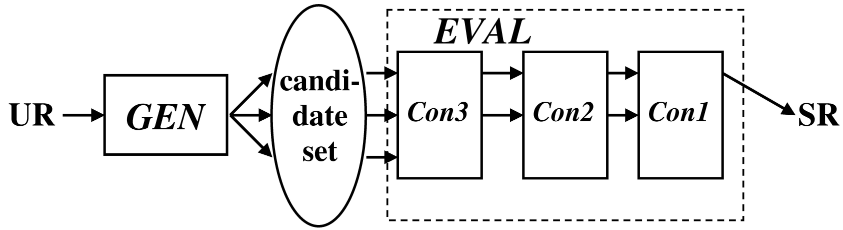
Optimality Theory

OT **accounts for** this simplified language typology:

- Stress on first syllable: Early ≫ Late, NonFinal,
  NonFinal ≫ Early ≫ Late
- Stress on last syllable Late ≫ Early, NonFinal
- Stress on penultimate syllable
  NonFinal ≫ Late ≫ Early
- No language with stress on second syllable as a rule:
  No such hierarchy.

Basic ideas of Optimality Theory

- Gen and Eval



- Gen and constraints are universal.

- Constraints ranked into **strict domination hierarchy**

- Language typology due to differences in hierarchy
  $\rightarrow$ learning: find the correct hierarchy.

Optimality Theory at a disciplinary crossroads

Theoretical linguistics	$\rightarrow$	constraints
Computer science		
	$\rightarrow$	optimization
Cognitive science		

OT: optimize some target function,
motivated by linguistic research.

Optimization in linguistics

$$\mathrm{SF}(u) \;=\; \underset{c \in \mathrm{Gen}(u)}{\arg\,\mathrm{opt}}\; H(c)$$

Harmony Grammar: $H(c) = \sum_{i=1}^{n} w_i \cdot C_i(c)$

Optimality Theory: $H(c) = (C_1(c), C_2(c), \ldots, C_n(c))$

Principles and Parameters: $H(c) = \bigvee_{i=1}^{n} (w_i \wedge C_i(c))$

Implementations of Optimality Theory

How to find the most harmonic element of $\mathrm{Gen}(u)$?

- Exhaustive search
- Finite state representations
- Dynamic programming / chart parsing
- Genetic algorithms
- Simulated annealing

See you next week!