

Computational Phonology

Interpretative Computing – Mapping to Phonetics

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Dafydd Gibbon

Bielefeld University
Jinan University, Guangzhou

Interpretative Computing – Mapping to Phonetics

Generative Phonologies

Optimality Theories

Finite State Phonologies: Two-Level, Cascaded

Linguistic and phonetic representations: a search space

- The search target:
 - A representation of a phonetic *type*
 - Judged by comparison with a phonetic *token*
 - by a speaker-hearer *directly*
 - uttered by a speaker-hearer and *measured*
- The two main search methods:
 - Generate a premise (Generative Phonology)
 - Change until the result matches the search target
 - Generate lots of premises (Optimality Theory)
 - Select smaller subsets until the best target match is found

Linguistic and phonetic representations: a search space

- The main deductive search methods:
 - 1) Generate a premise (logic, algebra)
 - Change with transformation rules until the outcome fits the intuitively determined search target
 - Generative Phonologies
 - Finite State Phonologies
 - 2) Generate all possible outcomes (set-theory)
 - Select smaller subsets with constraint rules until the outcome fits the intuitively determined search target
 - Optimality Theories
 - Preference Theories

Linguistic and phonetic representations: a search space

- The main inductive search methods:
 - 1) Supervised learning:
 - Measure properties of empirical inputs and classify them in terms of search targets
 - Measure new empirical inputs and statistically select most similar ('most probable') search target
 - 2) Unsupervised learning:
 - Measure properties of empirical inputs and classify them in terms of a hierarchy of similarities
- Both types of learning are used in
 - 1) Speech engineering (ASR, TTS, ...)
 - 2) Artificial Intelligence (person profiling)

Linguistic-Phonetic Mapping

either (Generative Phonologies)

- *generate* (lexicon, grammar) → underlying structure
- *interpret* (underlying structure) → *the* phonetic representation

or (Preference Theories, Markedness Theories, Default Theories)

- archiphoneme, phoneme and allophone relations
- define syntagmatic and paradigmatic markedness on the basis of frequency, ease of production/perception, e.g. for voicing

or (Optimality Theories)

- [LEXICON etc.: *make underlying structures* – in earlier theories]
- GEN: *generate* (something) → lots of phonetic representations for the underlying structures
- SEARCH:
 - CON: *define constraints* for filtering search space
 - EVAL: *filter* (lots of phonetic representations) → *best* representations

Deductive Search

***generate* (lexicon, grammar) → underlying structure**

***interpret* (underlying structure) → phonetic representation**

Deductive computing: grammar + lexicon → phonetics

- Generative Phonologies, rule properties:
 - Lexical rules
 - Lexical Phonology
 - Post-lexical rules
 - Phonological Cycle
- Optimality Theory, constraint properties:
 - Faith
 - Markedness
- Two-level Phonologies
 - OT style: Koskeniemi
 - GP style: Kay and Kaplan

Deductive computing: grammar + lexicon → phonetics

- The main deductive search methods:
 - Generate a premise
 - Change until it fits the search target
 - Generative Phonologies
 - Finite State Phonologies
 - Generate all possible premises
 - Select smaller subsets until the target is found
 - Optimality Theory
- The main inductive search methods:
 - Signal processing
 - Machine learning with Hidden Markov Models (HMMs):
 - Train – test – apply
 - Reduce ambiguity with top-down information:
 - Lexical
 - grammatical

The Search Problem

ORIGINAL LARGE SEARCH SPACE

REDUCE THE SIZE OF THE SEARCH SPACE
STEP BY STEP, BY ELIMINATION OF
SUBSPACES

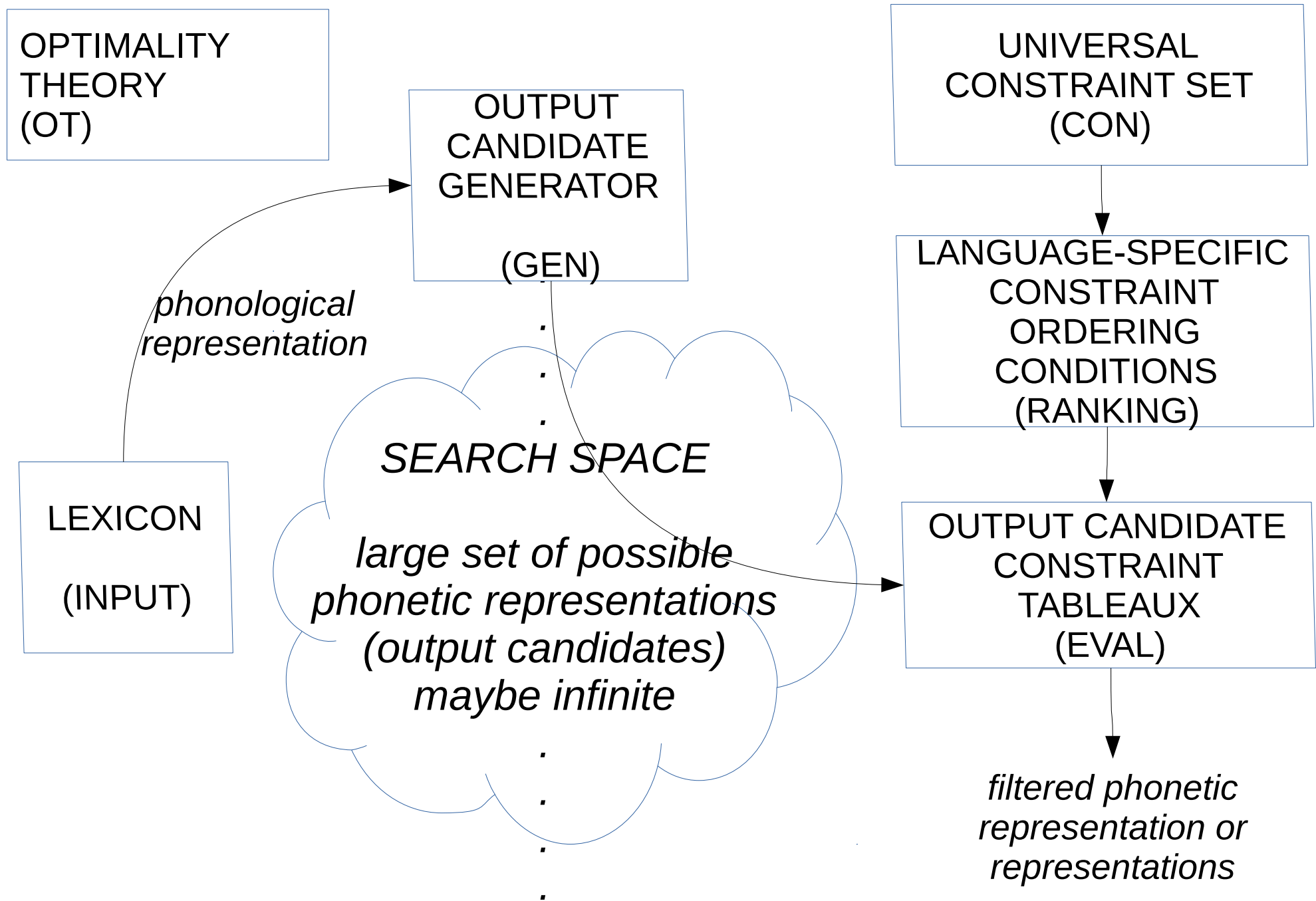
CONSTRAINT #1

CONSTRAINT #2

CONSTRAINT #3
THE
WINNE
R(S)

Imagine you can't find your keys.
They could be anywhere.
Eliminate upstairs.
Eliminate the living room.
Bingo: *IN THE FRIDGE* !!!!

Phonetic Interpretation as a Search Problem



GEN maps input to (mis)matching candidates

- Transduction constraints apply to segments, features, prosody:
 - Faithful
 - Feature differences
 - Order differences
 - Number of elements differences
 - No similarities at all
 - Possibly an infinite number of candidates
- Archangeli:
 - “in practice, linguists try to select the candidates that are closest to the winner and to show how these are eliminated by EVAL”
 - This appears to mean a strong subjective element
 - How to avoid this: use objective computational methods.

Types of OT constraint

- Classic types:
 - Faithfulness: similarity to lexical representation
 - Markedness: phonetic modifications

- Prosodic type:
 - alignment

- Later types:
 - antifaithfulness
 - local conjunction
 - ...

Specific types of constraint
in different linguistic domains
and different linguistic models
(sources: all over the internet)

General
Morphological
Syntactic
Antihomophony
Phonetic
Perceptual
Segmental
Phonotactic
featural
Autosegmental
Prosodic
Metrical
Accentual
Tonal
Intonational
Antialignment

Examples of OT phonotactic constraints


- Every CV syllable has
 - ONSET
 - syllable onset
 - PEAK
 - syllable nucleus
 - NOCODA
 - no syllable-final consonant
 - COMPLEX
 - syllable margins contain at most 1 consonant

Examples of OT faithfulness constraints

- Correspondence (transduction) constraints apply to segments, features, prosody:
 - MAX: input properties correspond to output properties
 - cf. Chomsky's Biuniqueness Condition on taxonomic phonologies
 - DEP: output depends on input
 - Both collapsed together as FAITH
 - CONTIGUITY
 - ALIGNMENT


OT example: final devoicing in German

- Constraints:
 - Markedness:
 - ~~VOP: All voiced obstruents forbidden!~~
 - *VF: Final voiced obstruents forbidden! *[+voiced]#
 - Faithfulness:
 - IDENTV: Don't change voicing! IDENT[voiced]

Input: tu:gend	*[+voiced]#	IDENT [voiced]
 a. tu:gent		*
b. du:gent		**!
c. tu:gend	*!	
d. du:gend	*!	*

OT example: final devoicing in German

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 - Faithfulness:
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bed	*VF	IDENTV	VOP
 bet		*	*
pet		**!	
bed	*!		**
ped	*!	*	*

OT constraints in phonetic interpretation

- Constraints
 - are universal
(not necessarily innate)
 - are either
 - phonologically grounded (FAITHFULNESS)
 - phonetically grounded (MARKEDNESS)
- Constraint ordering / ranking
 - is variable across languages
 - is language-specific
 - Discussion:
 - MARKEDNESS before FAITHFULNESS?

OT constraints in phonetic interpretation

- Each constraint is equivalent to an inference rule:
 - FOR each candidate:
 - IF match(candidate:constraint)
THEN candidate → candidate+asterisk
- The constraint PARSE implies that the Input has
 - a phonotactic structure which may be a *tree*
 - segments with features like [+ voice], [-voice]
- Each Constraint can refer to a component of an input structure, such as
 - Feature: NO FINAL VOICING ≡ *[+voice]#
 - Category: NOCODA ≡ *_{Coda}) Syllable)

Problems

- Where does the input come from?
- How does OT relate to the lexicon?
- How do the constraints fit into an overall picture language architecture?
- What are the computational properties of OT in terms of time and space complexity?
- How to contain the combinatorial explosion of candidates, most of which are irrelevant?
- Maybe just generate candidates by using the constraints as rules in reverse?

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Good luck – and thanks for your attention!

To be continued ...