Phonetics & Phonology
An Introduction

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Levels of Linguistic Analysis

Pragmatics
Semantics
Syntax
Morphology
Phonology
Phonetics
Overview

- Phonetics
- Phonology
- Computational Phonology
Phonetics
What is Phonetics?

- Study of human speech as a physical phenomenon
  - Articulation
  - Acoustics
  - Perception
Articulatory Phonetics

- Study of how speech sounds are produced by human vocal apparatus
  - Anatomy of vocal organs
  - Air stream Mechanism
  - Voicing
  - Articulation
Anatomy of Vocal Organs
Air-stream Mechanisms

- Pulmonic
- Glottic
- Velaric
Pulmonic Sounds

- Air flow is directed outwards towards the oral cavity
- Pressure built by compression of lungs
  - English [p], [n], [s], [l], [e]
Glottic Egressive Sounds

- Air flow is directed outwards towards the oral cavity
- Pressure built by pushing up closed glottis
  - Georgian [p’], [t’], [k’]
Glottic Ingressive Sounds

- Air flow is directed inwards from the oral cavity
- Pressure reduced by pulling down closed glottis
- Hausa, Sindhi [ɓ,ɠ]
Velaric Sounds

- Air flow is directed inwards from the oral cavity
- Pressure reduced by forming velaric and alveolar closure and pulling down tongue
  - clicks
Articulatory Phonetics

- Study of how speech sounds are produced by human vocal apparatus
  - Anatomy of vocal organs
  - Air stream Mechanism
  - Voicing
  - Articulation
Bernoulli Effect

- Air pumped from the lungs applies pressure on closed glottis
- High pressure opens vocal cords
- High velocity air flow creates low pressure region pulling vocal cords together again
- Process is repeated, producing vibrations in the vocal cords
Voicing

<table>
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<tr>
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Articulation

- Manners of Articulation

- Places of Articulation
# Consonants – Manners of Articulation

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<tr>
<th>Category</th>
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Places of Articulation

- Labial
- Labio-dental
- Dental
- Alveolar
- Palatal
- Dental
- Alveolar Ridge
- Velar
- Uvular
- Pharyngeal
- Laryngeal
- Nasal Cavity
- Oral Cavity
- Hard Palate
- Velum (Soft Palate)
- Uvula
- Epiglottis
- Larynx
- Vocal Folds
- Glottis
Consonants – Places of Articulation

Labial

Dental

Velar

Nasal cavity

Tongue

Teeth

Lips

[9]
## Consonants – Places of Articulation

<table>
<thead>
<tr>
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<th>Consonant</th>
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<td>$\ddot{y}$</td>
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<td>Multiple Places of Articulation</td>
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[4]
# Consonantal Sounds

## Consonants (Pulmonic)

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<td>s</td>
<td>z</td>
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Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.
Vowel – Features

- Low / High
- Back / Front
- Round
- Nasal
- Long
Vowel – Minimal Pairs

Bag  Big  (English)
/bæɡ/  /bɪɡ/

Beat  bit
/bit/  /bɪt/

Boot  bait
/but/  /bet/
/a/ Vocal Tract Outline
## Vocalic Inventory

<table>
<thead>
<tr>
<th></th>
<th>Front</th>
<th>Central</th>
<th>Back</th>
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<td>Rounded</td>
<td>Unrounded</td>
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<td>i</td>
<td>y=ü</td>
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<td>Ì</td>
<td>ɿ</td>
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<td>Mean-mid</td>
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<td>θ</td>
<td>ə</td>
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<tr>
<td>Lower-mid</td>
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<tr>
<td>Higher-low</td>
<td>æ</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>a</td>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>
Vocalic Quadrilateral

- **high**
  - close
  - open
- **mid**
  - close
  - open
- **low**
  - close
  - open

**front**
- i
- ü
- u

**central**
- i
- u
- ü

**back**
- i
- u

- blue = unrounded
- red = rounded

[12]
Diphthongs

- Combination of two vocalic sounds
  - English: [aj] I, eye [aj]
    [aw] cow [kaw]
Gemination of Consonants

- Double/long consonants
  - English: "misspell", "unknown"
  - Urdu: "نااک", "گنتی"
What is Phonetics?

- Study of human speech as a physical phenomenon
  - Articulation
  - Acoustics
  - Perception
Periodic Sine Wave

- **Period**
  Time to complete one cycle (sec)

- **Frequency**
  Number of cycles per second (Hertz)

- **Amplitude**
  Maximum displacement of a periodic wave (dB)
Complex Periodic Waves

- Sinewaves contain a single frequency
- Complex waves contain multiple frequency waves added together
- Complex periodic waves contain only Sine waves at base (fundamental) frequency (F0) and integral multiples of F0 (Fourier’s Theorem)
Response of a system is not constant for signals at all frequencies. The frequency which gives largest response is called Resonance (frequency).
Sound Wave

- Sound waves are formed by longitudinal movement of particles creating high and low pressure regions called compressions and rarefactions.

- Graph of pressure at each point in time
Acoustic Phonetics

- Source-Filter Model

Source

Filter
Source-Filter Theory: Filter

- Response curve with tongue in neutral position
- Resonances are called *Formants* (F1, F2, F3, …)
Source-Filter Theory: Source

- Waveform and spectrum of the glottal pulse
Source-Filter Theory

- Combining the two results in results in spectrum of short vowel ‘ə’ (schwa)
Spectrogram

A spectrogram is a time-frequency-amplitude graph representing sound.

“a bab” “a dad” “a gag”
Spectrogram
What is Phonetics?

- Study of human speech as a physical phenomenon
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  - Acoustics
  - Perception
Speech Perception

- Acoustic signal is highly variable but perception is very stable (invariant)
- How do map physical variance to perceptual invariance?
  - Intrinsic vs. extrinsic normalization
  - Categorical perception
  - Articulatory Invariance - recreation of articulatory gestures
  - Acoustic Invariance - stable regions in speech within articulatory variability
  - …?
Phonology
What is Phonology?

- Study of how sounds interact in various languages (phonetics $\rightarrow$ conceptual representation)
  - Segmental phenomena
    - Phonemic Inventory and Allophony
    - Sound-change rules and ordering
  - Supra-segmental phenomena
    - Syllabification
    - Prominence
    - Tones
    - Intonation
Phoneme?

- Mental concept representing a physical sound
- Many to many mapping between phoneme and a phone within a language
- English /t/
  - aspirated in “tunafish”
  - unaspirated in “starfish”
  - dental before labio-dental
  - flapped in “buttercup”
Phonological Features

- Phoneme = set of features that are true at a given time for a particular phonemic unit (phonological features) (Auto-segmental theory)

- Values of features can be unary or binary ( +/- for present/absent)
Phonological Features

- **Contrastive function:**
  Each phoneme differs from others in at least one feature

- **Descriptive function:**
  Accurately describes phonetic nature of a sound (may include redundant, non-contrastive features)

- **Classificatory function:**
  Explains and allows generalizations and common phonological processes
# English Consonant Features

| Feature          | m | n | ɲ | p | t | k | b | d | g | f | θ | s | ʃ | x | m | h | v | ɬ | z | ʒ | l | r | w | j |
| **Consonantal**  | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - |
| **Sonorant**     | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + |
| **Continuant**   | - | - | - | - | - | - | - | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| **Anterior**     | + | + | - | + | + | - | + | + | - | + | + | - | + | - | + | - | + | - | + | + | + | + | - | - | - |
| **Coronal**      | - | + | - | + | - | - | + | + | - | + | + | + | + | + | + | + | - | - | + | + | + | + | - | - | - |
| **Strident**     | - | - | - | - | - | - | - | - | - | + | + | - | - | + | + | - | + | - | + | + | + | + | - | - | - |
| **Round**        | - | - | - | - | - | - | - | - | - | + | + | - | - | + | + | - | + | - | + | + | + | + | - | - | - |
| **High**         | - | - | + | - | - | + | - | + | + | - | - | + | - | + | + | - | + | - | + | + | + | + | - | - | - |
| **Low**          | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Back**         | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Tense**        | - | - | + | + | - | - | + | + | - | + | + | - | + | + | + | - | + | - | + | + | + | + | - | - | - |
| **Voice**        | + | + | + | + | - | - | + | + | - | + | + | + | + | + | + | - | + | - | + | + | + | + | - | - | - |
| **Nasal**        | + | + | + | + | - | - | + | + | - | + | + | + | + | + | + | - | + | - | + | + | + | + | - | - | - |
| **Lateral**      | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
## English Vowel Features

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Phonological Rules

- Humans are lazy so compromise articulation to reduce effort
- Compromise in Articulation changes the sound
- Constituents of a phonological rules are
  - Phonemes to be modified due to a rule
  - Conditioning context in which the rule has to be fired
  - Change that occurs in a sound after the rule has been fired
- Rules are sometimes ordered in a language
Types of Phonological Rules

- **Assimilation**
  - Addition of features due to neighboring phonemes
  
  \[
  \text{phone book} /fonbuk/ \Rightarrow [fombuk] \\
  n \rightarrow [+bilabial] / \_ [+bilabial, +voiced, +stop]
  \]

- **Dissimilation**
  - Deletion of features due to neighboring phonemes
  
  \[
  \text{fifths:} /fifθs/ \Rightarrow [fifts]
  \]
Types of Phonological Rules

- **Insertion / Deletion**
  - Addition or deletion of an entire phone
    
    \[ \text{warmth}: /wərmθ/ \Rightarrow [wərmpθ] \]

- **Metathesis**
  - Change order of phonemes
    
    prescribe \Rightarrow \text{perscribe}
    
    ask \Rightarrow \text{aks}
A syllable is a unit of sound composed of

- A central peak of sonority (usually a vowel), and
- Consonants that cluster around this central peak
Syllable Structure

Syllable structure of Urdu word پاکستان /pakistan/
Syllabification

- Syllabification is the process of dividing words into syllables
  - Nuclear Projection
    - Maximal Onset Principle
    - Sonority Sequencing Principle
  - Template based Matching
    - Templates: V, CV, CVC, CVCC
    - Direction of largest template application: RTL, LTR
Prominence

- Syllable(s) in a word may be more prominent than others
- Prominence can change meaning
  - Spanish:
    - término, 'end' (noun), terminó, 'I'm finishing'
    - terminó, 'she/he finished'
  - English
    - ‘ob.ject, ob.’ject
    - ‘con.tent, con.’tent
- Syllable vs. stress timed languages
  - Final heavy syllable is stressed, no secondary stress
  - Sensitive to segmental “quantity” or moras
  - Every odd syllable is stress, First has primary stress
Intonation

- You are going!
- You are going.
- You are going?

- Intonation carries linguistic meaning, e.g. emotion, intention, etc.
- Realized primarily through variation of F0 over a sentence
- Multiple theories of how intonation is computed and realized, e.g. Pierrehumbert (TOBI), IPO, Fujisaki, etc.
Computational Phonology

- Letter-to-sound rules (?
  - Regular, heuristic, statistical
- Sound change rules
  - FST
  - Rule base
- Syllabification algorithm
  - Template or sonority based algorithm
- Stress-assignment algorithm
  - Stress-assignment algorithm
- Intonation assignment algorithm
  - Rule-based algorithm – based on syntactic parse (?)
  - Corpus based (Machine Learning) algorithm
  - Other corpus based approaches
Thank you
References

References

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