

# Acoustics Analysis of Bangla Consonant Phoneme Inventory

Firoj Alam

CRBLP, BRAC University, Dhaka, Bangladesh

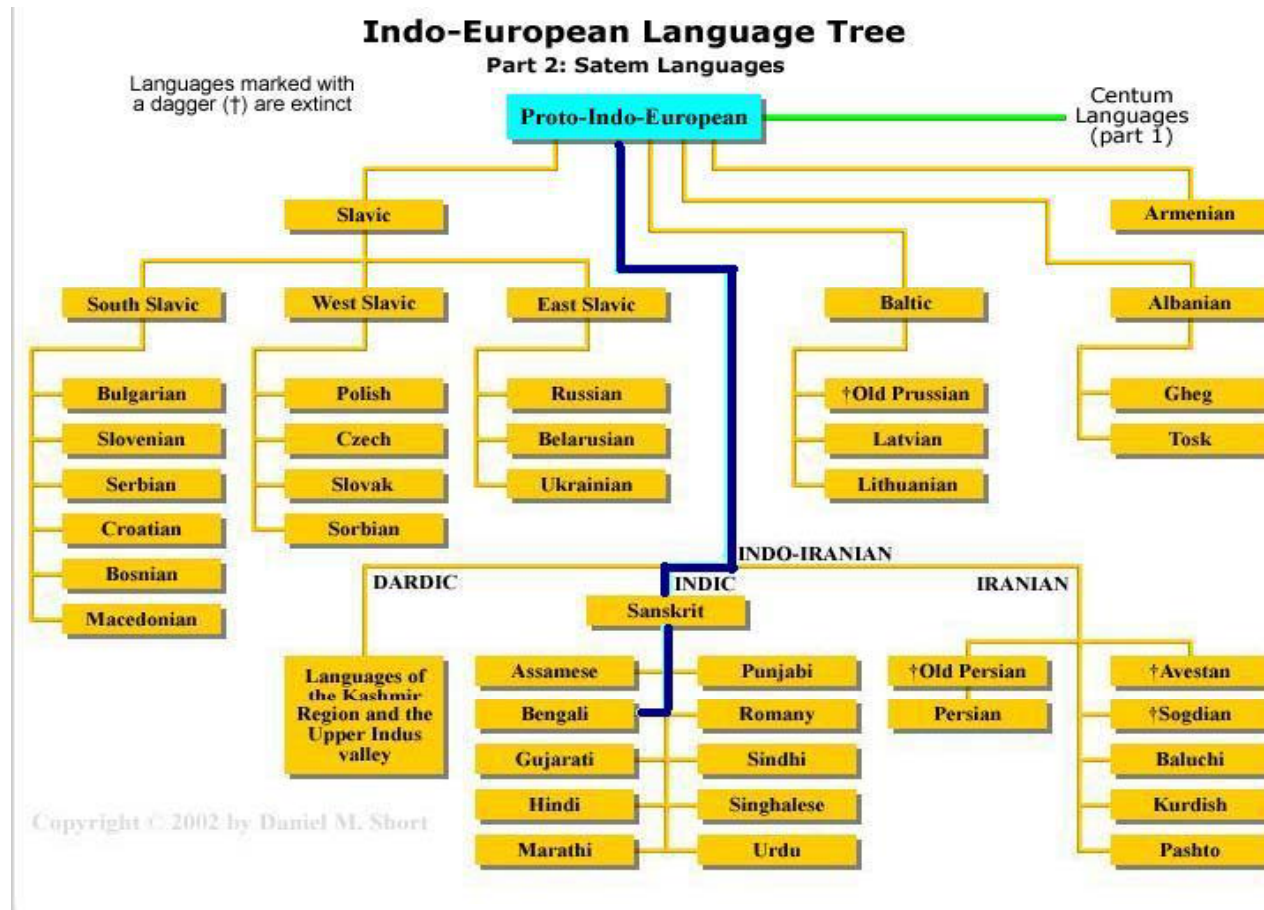
Center for Research on  
**CRBLP**  
Bangla Language Processing

# Contents

- Bangla Language
- Why/Motivation
- How:
  - Literature review
  - Data collection
  - Speaker selection
  - Recording
  - Analysis
- Results



# Bangla/Bengali in Language Tree



# Motivation

- This research goal started from the development of TTS (Text to Speech) and SR (Speech Recognition).
- The plan is to develop TTS using diphone and unit selection technique.
- Basics of G2P/LTS, pronunciation dictionary, syllabification and other phases of Linguistic.
- This research is fully linguistic, but important for the development of TTS and SR.
- Phonetically balanced corpus

# Literature review

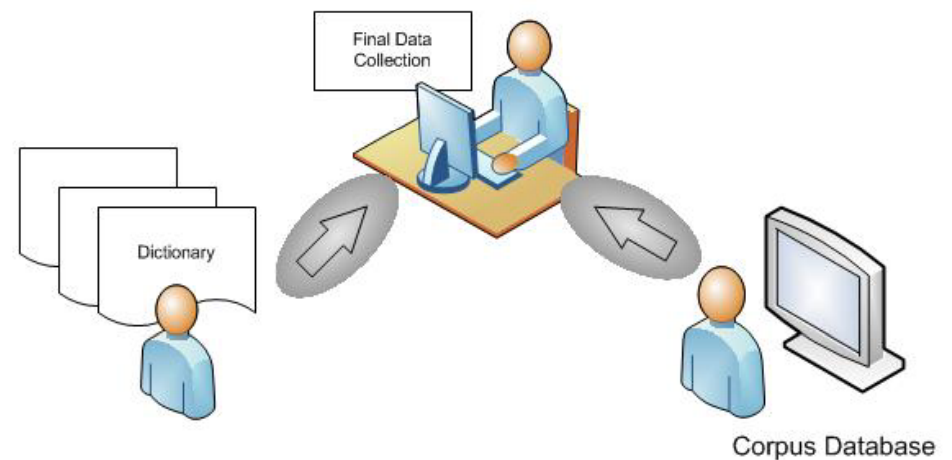
- Abdul Hai. *Dhvani Vijnan O Bangla Dhvani-Tattwa*, 10<sup>th</sup> Reprint, 2007, Mullick Brothers, Dhaka, pp-12-35, 1967.
- Daniul Huq. *Bhasha Bigganer Katha (Facts about Linguistics)*, Mowla Brothers, Dhaka, pp-81-93, 2002.
- Hossain A., Nahid N., Khan N. N., Gomes D. C., Mugab S. M.. *Automatic Silence / Unvoiced / Voiced Classification of Bangla Velar Phonemes: New Approach*. 8<sup>th</sup> ICCIT, Dhaka, 2005.
- Ladefoged P. *A course in phonetics*. 4<sup>th</sup> edition 2002, Thomson Asia Pte Ltd. Singapore. pp-161-170. 191-196, 2002
- Mahbulul Haque. *Bangla Bhashar Bekaron and Rachonariti (Grammar and Essay of Bangla Language)*, 10<sup>th</sup> reprint 2007, Boi Prokashony, Dhaka, pp-231-233, 6<sup>th</sup> Edition 2004.
- Manzur Morshed. *Adhunik Bhasatatto (Modern Linguistics)*, Mowla Brothers, Dhaka, pp-219-237, 3<sup>rd</sup> Edition 2001.
- Pickett, J.M. *Acoustics of Speech Communication, The: Fundamentals, Speech Perception Theory, and Technology*, Allyn & Bacon, 1998.
- Scarborough R. *Segmentation and Segment Durations*.  
[http://www.stanford.edu/class/linguist205/index\\_files/Handout%203%20-%20Segmentation.pdf](http://www.stanford.edu/class/linguist205/index_files/Handout%203%20-%20Segmentation.pdf), last accessed December 26' 2007.
- Wikipedia, *Bengali phonology* [http://en.wikipedia.org/wiki/Bengali\\_phonolog](http://en.wikipedia.org/wiki/Bengali_phonolog), last accessed December 26' 2007.
- Zeenat Intiaz Ali. *Dhanibijnaner Bhumika (Introduction to Linguistics)*, Mowla Brothers, Dhaka, 2001.

# Literature review

- Different counts of phoneme in different literature
- Represented according to articulatory investigation
- Controversy on couple of phoneme
- Consonants:
  - Total 35 phoneme (union of all literature)
  - ন/n/ - ণ/n/
- Vowel: 14 vowels including 7 nasals
- Diphthong: 38 diphthongs

# Data Collection

- One of the difficult challenges
- Written/text corpus is important.
- Pattern of data collection
  - Consonants: iCi and aCa
  - Vowel:
    - cV.Cv.cvc
    - cV.v.cvc -> v.v.cv.cvc
    - cV?V.Cvc



# Data Collection

- Consonants:  $35 \times 2 = 70$  words
- Vowels:
  - Pattern:
    - $cV.Cv.cvc$ :  $14 \times 4 = 56$  words
    - $cV.v.cvc \rightarrow v.v.cv.cvc = 2$  words
    - $cV?V.Cvc \rightarrow 38 \times 4 = 152$  words
- All are combined with carrier words to form sentences

Consonants	Vowel
আমরা কাজ পাই $\rightarrow$ ক	এখন গবেষক বলো
amra kaʃ pai $\rightarrow$ /k/	ek <sup>h</sup> on gobesʃok bɔlo
1 <sup>st</sup> P.Pl work get.pres	Now researcher say.pres
[We get work.]	[Say researcher now]

# Speaker selection

- Both male and female
- Professional and non-professional
- Age limit
  - 25-30 (non-professional)
  - 52 to 54 (professional)

# Recording environment

- Professional studio
- Some high quality equipment:
  - TM-D4000 Digital-Mixer
  - Noise free Audiotechnica microphone
  - .....
- Digitized at 44100 Hz at 24-bit resolution and stored as wave format (**.wav**)
- Any wrong pronunciation during recording were checked by moderator
- Affected utterances were re-recorded

# Analysis

- By praat:
  - Used standard praat settings
  - **Script** was used to calculate Duration and formants

Praat. [www.fon.hum.uva.nl/praat/](http://www.fon.hum.uva.nl/praat/). Version - 4.6.27.

# Analysis: Consonants

- Duration calculation (Closure, VOT), formant measurement
- Comparison of formants among controversial phoneme
- Place and manner features of consonants by looking formants

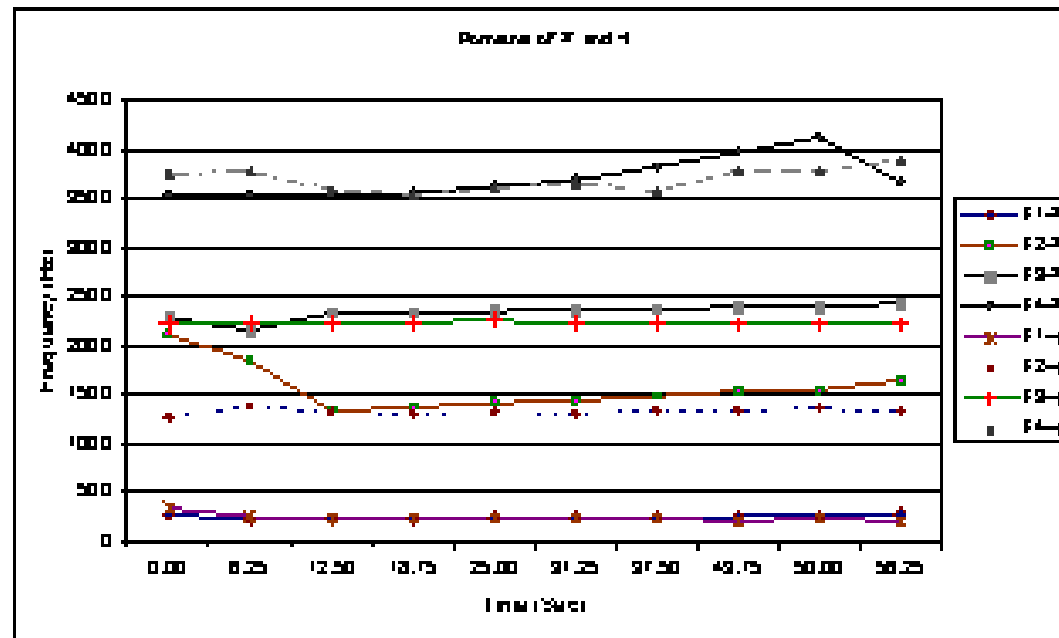


Figure 1: Comparison of sound produced by the letter ʃ and ɳ

# Results

- Finally we concluded in a phoneme inventory with their duration, manner and place features.
  - 30 consonants

Place		Bilabial		Dental		Alveolar		Post- Alveolar		Palatal	Velar		Glottal
Manner													
Stops	voiceless	প/p/	ফ/p <sup>h</sup> /	ত/t/	থ/t <sup>h</sup> /	ট/t/	ঠ /t <sup>h</sup> /	চ/c/	ছ/c <sup>h</sup> /		ক/k/	খ/k <sup>h</sup> /	
	voiced	ব/b/	ভ/b <sup>h</sup> /	দ/d/	ধ/d <sup>h</sup> /	ড/d/	ঢ /d <sup>h</sup> /	য, জ/ɟ/	ঝ/ɟ <sup>h</sup> /		গ/g/	ঘ/g <sup>h</sup> /	
Nasals		ম/m/				ন, ণ/n/					ঙ, ঞ/ŋ/		
Trill						র/r/							
Flap						ড়, ঢ/r̩/							
Fricatives						শ, স/s/				ষ, ষ/sʃ/			হ, ঃ/h/
Lateral						ল/l/							
Approximant										য়/j/			

# Results

- 30 consonants: average duration

Phoneme	Total (Average both male and female)			
	Closure (Avg)	VOT (Avg)	Closure (std)	VOT (std)
ক /k/	107.32	32.26	57.55	8.62
খ /k <sup>h</sup> /	84.93	96.87	21.48	23.72
গ /g/	83.71	28.31	22.45	8.07
ঘ /g <sup>h</sup> /	76.31	113.72	23.93	40.94
চ /c/	85.93	63.33	20.91	20.29
ছ /c <sup>h</sup> /	71.61	118.63	12.50	49.84
য,জ /j/	67.80	44.58	16.64	26.75
ঝ /j <sup>h</sup> /	61.00	121.31	9.81	46.18
ট /t/	113.39	14.24	28.38	5.57
ঠ /t <sup>h</sup> /	93.15	77.35	17.64	25.01
ড /d/	86.03	14.24	12.29	6.49
ঢ /d <sup>h</sup> /	78.98	89.45	19.72	44.62
ত /t̪/	126.05	16.52	38.48	7.21
থ /t̪ <sup>h</sup> /	114.54	90.75	54.19	23.66
দ /d̪/	93.41	11.46	19.38	6.00
ধ /d̪ <sup>h</sup> /	82.57	83.00	23.68	40.71
প /p/	114.14	14.36	29.59	8.90
ফ /p <sup>h</sup> /	96.03	74.24	34.77	42.16
ব /b/	91.81	10.72	13.39	4.20
ভ /b <sup>h</sup> /	79.23	77.02	14.47	41.86

Phoneme	Total (Avg)	Total (Std)
শ,ষ,স/j/	175.14	48.59
শ,স/s/	147.26	26.52
ম /m/	100.52	19.34
ং,ং /ŋ/	98.71	34.60
ণ, ন /n/	69.07	30.49
র /r/	64.71	11.09
ল /l/	100.70	16.66
ড়, ঢ় /r̥/	49.57	18.80
য় /j/	75.70	24.71
হ্,ঃ/h/	120.80	55.29

# Question

