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Preliminary Acoustic Analysis of Manipuri Vowels

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Abstract

Manipuri language is one of the low resourced languages of north eastern part of the India. The need of development of speech technology in the local language is of urgent demand, so as to improve the livelihood of the people. The pre-requisite of development of such speech technology requires the basic research on the acoustic phonetic of the phoneme together with the development of speech resources. Keeping the main objective in mind the current paper aims at preliminary study on acoustic characteristics of Manipuri vowels. The current study is conducted on the speech corpus of around 500 Phonetically Balanced Words (PBW) embedded in neutral carrier sentences spoken by ten informants (5 male and 5 female) in a reading mode. Moreover vowel segments which are in CVC context of the word are selected. The dialect chosen for the purpose of experiment is Imphal dialect of Manipuri language. After analyzing the data, vowel phoneme inventory of Manipuri language has been presented in this paper.

Index Terms: vowels, formants, acoustic analysis, Manipuri language, perceptual distance.

1. Introduction

Manipuri or Meitei is one of the low resourced languages of north eastern part of India whose exact classification still remains unclear but according to some linguists the language is a member of the Kuki-Chin sub-group of Tibeto-Burman languages, one of the co-ordinate members of the vast Sino-Tibetan language family. Manipuri is the official language of Manipur state since time immemorial and still continues to be the official language of the state even after Manipur joined the Indian Union on 15th Oct, 1949. Meitei is also spoken in the Indian states of Assam and Tripura, and in Bangladesh and Myanmar. According to 2001 census the language is spoken by 1.5 million people. It is currently classified as a vulnerable language by UNESCO [1]. The language has been recognized (under the name Manipuri) by the Indian Union and has been included in the list of scheduled languages of India. Manipuri has its own script called Meitei Mayek but Bengali script is also used for many purposes. Meitei contains various dialects. Among them Imphal dialect is treated as the standard one in the state of Manipur [2]. All the affairs of the state are conducted in this language and almost all the communication and medium of instructions in schools and colleges is made in this language.

Manipuri is described as having an inventory of six vowels. The six vowels of Manipuri are /u/, /o/, /ə/, /a/, /e/ and /i/. There is no evidence of length variation has been attested in the existing literature of Manipuri [3]. Moreover vowel nasalization is not phonemic in this language [3]. There have been a number of studies on the phonemic inventory of Manipuri language but most of the studies are based on perception. This study adds to the previous research in a way that it provides the first acoustic analysis of the vowels in Manipuri.

Rest of the paper is organized in a following way: After introduction methodology of investigation is described in section 2. Experimental findings are presented in section 3. Normalization of Meitei vowels are summarized in section 4. Finally references are given in section 5.

2. Methodology of Investigation

2.1. Recording material

For the current study the database consists of around five hundred isolated words. The wordset is prepared carefully taking into consideration of the fact that the wordset contains all the possible permitted combinations of the phonemes of the language. Moreover all the selected words for this study bear only one tone i.e. low tone to avoid the qualitative and quantitative aspects of the vowels which may be affected by tones. The distribution of the six Manipuri vowels in the current speech corpus taken for this study is given in Figure 1.

It is evident from figure 1 that the highest percentage of occurrence of vowel in Manipuri speech corpus is phoneme /a/, followed by phoneme /ə/, /e/, /i/, /u/ and /o/.

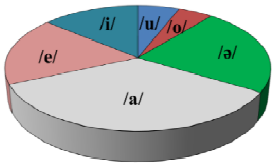

Figure 1: Distribution of Manipuri Vowels

The speech corpus is recorded by ten native Manipuri informants (5 male and 5 female) and their age ranges from 20 to 35 years.

2.2. Recording

The recording of speech data for all ten speakers is done in a studio environment and digitized at a sampling rate of 48,000 Hz with an accuracy of 16 bits/sample. The data is recorded using the Shure SM58 vocal microphone with the

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help of Cool Edit Pro Software. During the recording a constant distance from the microphone element and the speaker's mouth is maintained. After each recording, the moderator checks for any wrong pronunciation due to slip of tongue or any hesitation during the recording, and if the moderator finds so, the utterances are recorded again. For this study the vowel segments which are in CVC context of the word are selected. During the recording a movie of the informant's lips is also captured.

2.3. Analysis Procedure

A total of 19985 vowel segments (5 male and 5 female Manipuri informants) are considered for the analysis of vowels.

From the literature survey it is evident that the articulatory position of the vowel can be determined from the acoustic formant measurement [4]. In general high first formants are associated with narrow tongue constriction near the glottis. Similarly the second formant frequency is increased as the constriction moves forward [5]. So for the determination of the articulatory position of Manipuri vowels, the two formant frequencies F1 and F2 are measured.

It is worth mentioning here that for the analysis of vowel duration, steady part along with two transitions is considered whereas measurement of formants frequency is done only from the steady part of the vowel segments itself. Initially the vowel phonemes within each word are labeled along with time stamp by the native Manipuri transcribers. In the next step the labeled vowel segments are cut automatically using the labeled files. The extraction of the steady state of the vowel is done by using simple amplitude tracking algorithm. The minimum length of the steady state vowel segment considered in the study for the extraction of formants is 40 ms. A Praat script [6] is used to automatically extract first and second formant corresponding to vowel segments. The parameter settings for the extraction of the formants using Praat are as follows:

- Analysis window length 0.025s
- Pre-emphasis factor 0.85
- Frame Interval 0.001s

The formant values of those vowel segments which are outside mean ± standard deviation are once again checked and if found erroneous these are corrected manually using spectrum section. The extracted formant frequency is then converted into Mel scale (as in equation 1) for further analysis.

$$m = 1127 \log_e (1 + f/700) \quad (1)$$

where m is frequency in Mel scale and f is the frequency in Hertz.

Figure 2: Height and width between the opening of the lip

To investigate the rounded/unrounded feature of the vowel, photographic evidence of the lip rounding during the articulation is used. Audio-visual data has been captured in course of the articulation of the vowel. A frame at the steady state of utterance of the vowel is selected for the analysis purpose. The degree of lip rounding is defined as a ratio of height and width of the area between the opening of the lips as shown in figure 2.

3. Experimental Findings

3.1. Analysis on vowel duration

Using Praat script, vowel duration has been derived from labeled files. For the quantitative analysis of Manipuri vowels frequency distribution of duration has been done. After getting the duration from the labeled file the frequency distribution of duration of each of the 6 Manipuri vowels has been derived. Finally the distribution of duration is being normalized by dividing the maximum number of occurrence in a duration interval of that individual vowel. It is evident from figure 3 that in Manipuri language there is no long short variation of vowels in Manipuri language as the frequency distribution of duration of each of the nucleus vowel exhibits single peak.

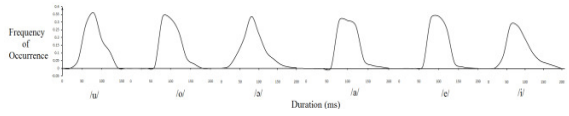

Figure 3: Frequency distribution of vowel duration

Figure 4 depicts the vowel duration of the six Manipuri vowels. It is evident from figure 4 that the duration of vowel /a/ is maximum and that of the vowel /u/ is lowest. In fact all the low vowels exhibit higher duration. This may be related to the jaw movement which has low position for these vowels.

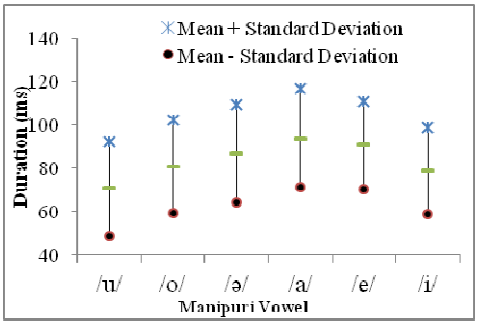

Figure 4: Intrinsic Vowel Duration

The low standard deviation indicates the average intrinsic vowel duration is meaningful.

3.2. Analysis on vowel formant

To obtain the acoustic features of vowels, formants were measured. Table 1 gives average (μ) and standard deviation (σ) of the values of first (F1) and second (F2) formant of all the Manipuri vowels with respect to male, female. It is

observed from Table 1 that there is a difference in mean of the formant frequency for both male and female.

Table 1: *Formant Frequency (in Mel) of male, female.*

Manipuri Vowel		**Male**		**Female**	
		F2	**F1**	**F2**	**F1**
/u/	**μ**	950	438	971	453
	σ	164	58	199	62
/o/	**μ**	934	590	965	601
	σ	100	79	91	90
/ə/	**μ**	1267	782	1308	858
	σ	110	103	96	85
/a/	**μ**	1250	914	1299	990
	σ	74	85	68	59
/e/	**μ**	1615	582	1668	606
	σ	79	107	83	35
/i/	**μ**	1691	412	1762	415
	σ	91	51	73	57

It is observed from Table 1 that there is a difference in mean of the formant frequency for both male and female. Student t-test was performed to find whether the difference between the mean of the formant frequencies between male and female is significantly different or not. Result of the t-test is tabulated in Table 2.

Table 2: *Significance of difference of formants with respect to sex of the informants*

Manipuri Phoneme	F2	F1
/u/	Significant at 0.05 level	Significant at 0.05 level
/o/	Significant at 0.05 level	Significant at 0.05 level
/ə/	Significant at 0.05 level	Significant at 0.05 level
/a/	Significant at 0.05 level	Significant at 0.05 level
/e/	Significant at 0.05 level	Significant at 0.05 level
/i/	Significant at 0.05 level	Not significant at any level

It is evident from Table 2 that there exists a significant difference in the formant value with respect to sex of the informants. It is interesting to note that there is no significant difference between the mean of the male and female informant's formant frequency F1 at any level for the vowel /i/.

The plot of F2 versus F1 (both in Mel scale) is shown in Figure 5. From Figure 5 it can be observed that front vowel /i/ and /e/ have been overlapped heavily. Similar is the case with vowels /a/ and /ə/, /u/ and /o/. The overlap region between vowel /u/ and /o/ and between /e/ and /i/ is less in comparison to the overlapping region between vowel /a/ and /ə/. Further second formant (F2) of vowel /ə/ and /a/ lies in same position in vowel space. It is interesting to note that F2 of vowel /u/ and /i/ have a larger spread than that of F1.

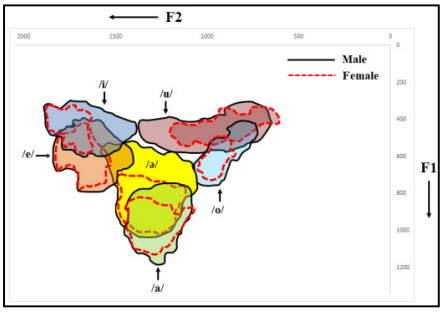

Figure 5: Plot of Raw F2 versus F1 (in Mel) vowels.

In order to objectively verify that whether the overlapped vowels are perceptually distinct from one another, a perceptual distance between the overlapped vowels has been measured using Eq. (2).

$$D_{ij} = \sqrt{\left((M1_i - M1_j)^2 + (M2_i - M2_j)^2\right)} \qquad (2)$$

where Dij is the Euclidean distance between two vowel (i,j) points and M1 and M2 are the frequency of F1 and F2 expressed in Mel [5]. A higher Dij value confirms that the two vowels i and j are highly distinct, for example in case of English, it has been noted that the average Dij value is about 70.2 Mel [7].

Table 3 presents the perceptual distance between overlapping vowel pairs.

Table 3: *Perceptual Distance between overlapping vowel pairs*

	u	o	ə	a	e	i
u	0	151	482	580	688	753
o		0	394	468	685	786
ə			0	133	412	581
a				0	503	685
e					0	192
i						0

From Table 3 it can be observed that vowel /i/ and /o/ maintains the highest perceptual distance. Though perceptual distance between vowels /u/ and /o/, / ə/ and /a/, /e/ and /i/ are less in comparison with other vowels, they are much distinct in comparison with perceptual difference scores obtained for English [7].

4. Normalization of Manipuri Vowels

It is evident from Fig. 4 that there is heavy overlapping among Manipuri vowels in F2-F1 plane. To reduce the inter speaker variability within a particular vowel intrinsic-cum-extrinsic normalization [8] procedure has been adopted. The reason behind adopting this procedure is two-fold. In

this procedure individual vowels are well separated by reducing the overlapping between them, on the other hand data of both the sexes are concentrated to form separate cluster for a particular vowel. The above said normalization procedure is effective in the sense that it is, in one hand, useful in acoustic phonetic study of vowels and on the other this procedure of vowel normalization preserves the relative position of vowels in vowel space as the raw formant data does. Fig. 6 represents the intrinsic-cum-extrinsic normalized value of first and second formant (henceforth DF1 and DF2) in mel scale.

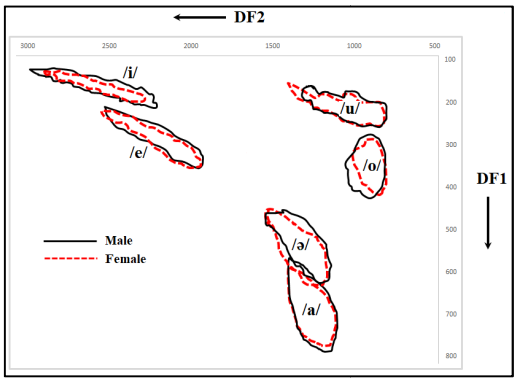

Figure 6: *Plot of DF1 and DF2 in mel scale*

It can be observed from the above figure that almost all the vowels form well separated clusters by reducing the spread due to talkers except vowel /ə/ and /a/. The spread is more along the DF1 axis which is also reflected in raw formant plot.

5. Lip Rounding of Manipuri Vowels

The degree of lip rounding is measured by the ratio of height and width of the area between the opening of the lips. The measurement has been taken when the opening of the lips was maximum. Table 4 presents the height-width ratio of lip opening.

Table 4: *Ratio of height and width of Vowel*

Phoneme	Ratio between height and width
/u/	0.96
/o/	0.93
/ə/	0.73
/a/	0.53
/e/	0.45
/i/	0.45

It is interesting to note that there is a clear distinction in the values of ratio between the rounded and unrounded vowels. The rounded vowels have ratio closer to one whereas the ratio for unrounded vowel is less than 0.6. It is quite evident from Table 4 that value of the ratio for the phoneme /ə/ lies in the range 0.6 to 0.9, as the phoneme /ə/ is a central vowel and hence the spread of the lips is less than the rounded vowel but more than the unrounded vowel.

Figure 7 shows the photographical evidence of lip rounding for six Manipuri vowels.

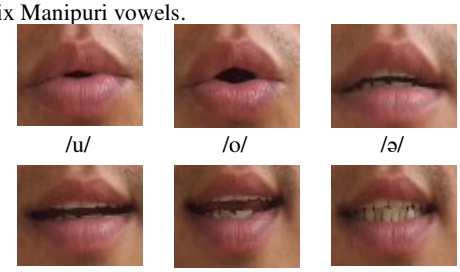

Figure 7: *Lip rounding of six Manipuri vowels*

6. Conclusion

Based on the experimental findings following conclusions for Manipuri vowels can be drawn

- There is no long and short variation of vowel in Manipuri language
- There is significant difference in the value of both F1 and F2 of male and female speakers.
- As per the experimental findings Manipuri has 2 rounded and 3 unrounded vowels.
- Incase of /ə/ lip is neither rounded nor spread.
- Though some vowels are overlapped in the acoustic vowel space they are distinct in perceptual domain.

Keeping in mind the findings of Manipuri vowels the following is summarized in Table 5 along with existing description of the Manipur vowel in the literature.

Table 5: *Articulatory description of Manipuri Vowel*

Phoneme	Description as per literature	Description as per experimental findings
/u/	Closed back rounded	Closed centralized rounded
/o/	Closed mid back rounded	Closed centralized rounded
/ə/	Mid central unrounded	Mid low central unrounded
/a/	Open front unrounded	Open front unrounded
/e/	Closed mid front unrounded	Closed mid front unrounded
/i/	Closed front unrounded	Closed front unrounded

7. Acknowledgement

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