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Acoustic Investigation of Sindhi Consonants using Waveform and Spectrogram Techniques

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Abstract

Sindhi language has many accents and also contains a large variety of vowels, consonants and phonemes which can be extended at any place. The description and analysis of prosodic features are compulsory for various Speech Processing (SP) Applications. The accuracy of SP applications is not accurate due to the indistinct uniformity in consonants, which make similar sounds. In this paper, two of the prospective parameters of prosody; duration and pitch are used for extraction of features from the recorded sounds of both male and female speakers. To study these phonemes, twelve most frequently used consonant-phons are selected and distributed into six groups of experiments. The recorded sounds are subjected to a methodology that is also described and then applied in this work. The PRAAT speech analyzer tool is

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used to obtain the results of sound duration and pitch parameters. This study revealed that the sound duration and pitch of the female speakers are higher than the male speakers. The discussed pitch values proved that some of the identified consonants produce similar sounds and that others are quite different. The outcomes of this study will be of great benefit in the advancement of Sindhi SP applications

Introduction

Sindhi is spoken with many accents around the Sindh region [1]. Sindhi language has an extensible sound inventory in the form of vowels, consonants, phonemes and syllables [2]. Comparatively, the inventory of sounds of Sindhi is richer than the other Pakistani languages. The complications are observed with different homographic word sounds and consonant sounds. The performance accuracy of SP Applications is not accurate due to the obscure inconsistency in dialects, homographic sounds and consonants produce similar sounds. The accuracy of SP applications can be improved by study of phonological variations and linguistic characteristics. The sound duration and pitch should be computed in order for SP applications to run with maximum level of accuracy.

Less or more every language has its own orthographic mechanism, phonological mechanism, phonemic inventory and phonetic rules. The world wide advanced languages have been investigated with required precision but languages spoken in Pakistan like Sindhi are not studied at required level of precision. The software tools are developed to learn the acoustic phonetics for Sindhi consonants and vowels. Kerio [3] stated that the study of Sindhi vowel sounds is mainly focused by the researchers as compared to sounds of consonants. Furthermore, fifty two consonants, ten vocalic and forty six phoneme sounds are present in Sindhi language along with ten vowels and four implosive sounds [4] [5].

Many alphabetic letters are available in Sindhi which pronounced similar sounds such as ‘ھ} ‘hah} for ‘ح}. Wrong pronunciation of these alphabetic sounds creates problems in the development of SPA and natural language processing applications. The consonant sounds that produce similar sounds are not investigated so far for Sindhi. Eighteen consonants producing similar sounds are digitally investigated using waveform and spectrogram representations. A novel methodology is proposed in this paper and pitch and

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duration of recorded sounds are measured and presented. The PRAAT speech analyzer tool is used for examination for enhancing the accuracy of SPA. PRAAT provided some advanced level features pertaining to spectrographic information, intensity measurement and formant analysis. The sample image of recorded sound of a sentence is depicted in Figure 1.

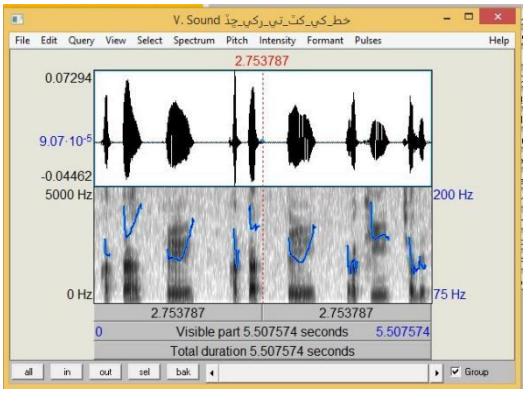

Figure 1 Recorded Sound of a Sentence

Literature Review

Since a decade, serious efforts have been taken by the researchers of Sindhi language regarding the acoustic analysis of vowels, consonants, phonemes and syllables. The acoustic signal processing problems faced by the students and researchers are discussed in [6]. For the task of prosody generation Mahar [1] digitally investigated the sound durations and pitches of the recorded sounds of Sindhi which are the main elements of acoustic. Various male and female students were selected for recording the sounds and results were measured and compared according to the formula of mean and standard deviation. Keerio [2] also analyzed the acoustic values of the liquid class of Sindhi consonants. The conducted study was purely based on the gathered voice samples from the local speakers. Keerio implemented the techniques of waveform and the spectrogram on the recorded sounds and observed the variation in trill and lateral consonants. In the same year, acoustic investigation is also performed on isolated utterances by Keerion [3] along with the ten vowels. The researchers also described the acoustic features of the vowels of Sindhi language. The acoustic based variations are investigated between the sounds of male and female speakers by using the approaches of formant one and formant two. The quality and height of the diphthongs and vowels were mainly focused in the conducted research study.

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Approximately, six dialects are observed in Sindh province. The formal communication and writing is followed by the people living in the central region. The dialects can be differentiated according to the phonology, morphology and syntax of the language. These parameters have a great impact on any language as discussed in Abbasi [7]. Shaikh [8] digitally investigated the Sindhi accents of the dialects such as Vicholi, Laarri and Lassi using the parameters of duration, pause, F0 peak, F0 contour, F0 excursion and the rise size of the sounds. The dialect Lasi was discussed and investigated by Amin [9] and proved that the speakers of Lasi follow the features of morphology and phonology and make language for easy communication. Remaining dialects of Sindhi are also discussed in the article. Furthermore, Abbasi [10] stated that the dialect Kachchi has a great importance in the dialects of Sindh. The researcher analyzed the acoustic understandings of the ten vowel sounds of Kachchi. The sounds of the native speakers were recorded and collected for experiments and investigations and revealed that F0, F1 and F2 values were high in between the male and female respondents. The F0, F1 and F2 parameters are also calculated by Abbasi [11] using the Sindhi sound units. The collected voice samples were acoustically examined for stressed and unstressed vowel sounds. The obtained results proved that significant variation is available pertaining to the short vowel and long vowel sounds.

Moreover, the core responsibility of pitch between stress and intonation in Sindhi was explored by Abbasi [12]. The researcher analyzed the F0 of vowel pitch contours as confirmation of the starting pitch rise varies to the position of stressed syllable. The empirical practice reveals that the stress is orthogonal to F0 contours. The pitch contour of various syllables in Sindhi is measured and presented by Mahar [13] along with the syllable patter. The study focused on the different positions of short and long vowels in Sindhi and found a clear difference particularly in rise size. Furthermore, Shahid [14] acoustically investigated the English vowel sounds spoken by the speakers of Sindhi language. The researchers stated that there is a difference between the vowels of Sindhi and English languages. For investigation, the PRAAT was used to analyze the duration and quality of the English vowels spoken by Sindhi speakers. Moreover, Khoso [15] discussed that due the huge number of alphabets in Sindhi the talking and writing difficulties are faced by the people.

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The development of the speech recognition system is one of the challenging tasks for Sindhi language. The Sphinx model was used and developed a robust system of speech to text recognition.

Research Methodology

The methodology outlines clear and specific research procedures for the analysis of Sindhi phonetics and phonology with regard to the structure, manner and characteristics of both vowels and consonants. In detailed study, work involves pitch, tone and height characteristics, to and from Sindhi sounds that provide and clarify the way auditory patterns and differentiation of Sindhi sounds. For this research, a Sindhi speech corpus is developed, containing information about the speakers including age, gender and dialect region in the Sindhi language. Speech data samples are collected based on certain standardized procedures, which entail a broader range of phonetic conditions to be covered, and produce a sufficiently representative set of speech samples. These recordings are filed under a structured database for easy retrieval and analysis of data.

Moreover, the extension of the experimental tasks to digital platforms is also aid in conducting acoustic analysis of Sindhi eighteen consonants with focus on duration, amplitude and frequency characteristics. This analysis is also considered differentiations as well as the relationship between consonant sounds within varying pitch and tone and kind of articulation. The research is also carried out a detailed formant analysis to classify the vowel sounds according to spectral density and formant frequencies learnt in the literature review section as well as investigate on the general acoustic characteristics of consonants to establish peculiar sound configuration and deviations. Specific samples of the similar consonant sounds from the acoustics' point of view are grouped together.

A comparison of consonants is made at the last to know the trend and characteristic features of the Sindhi language as well as the statistical terms for important phonetically or phonological phenomena. Everything uncovered is well recorded and mainly documented; in terms of audio recording, statistical analyses, and sound wave illustrations. Results are checked by their peers, experts in the Sindhi language phonetics, along with cross checking the results as per the recognized phonetic norms of Sindhi language. Such a planned methodology provided important findings on the acoustics of the Sindhi

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language sound through digital and acoustic approaches. The flow diagram of the methodology is depicted in Figure 2.

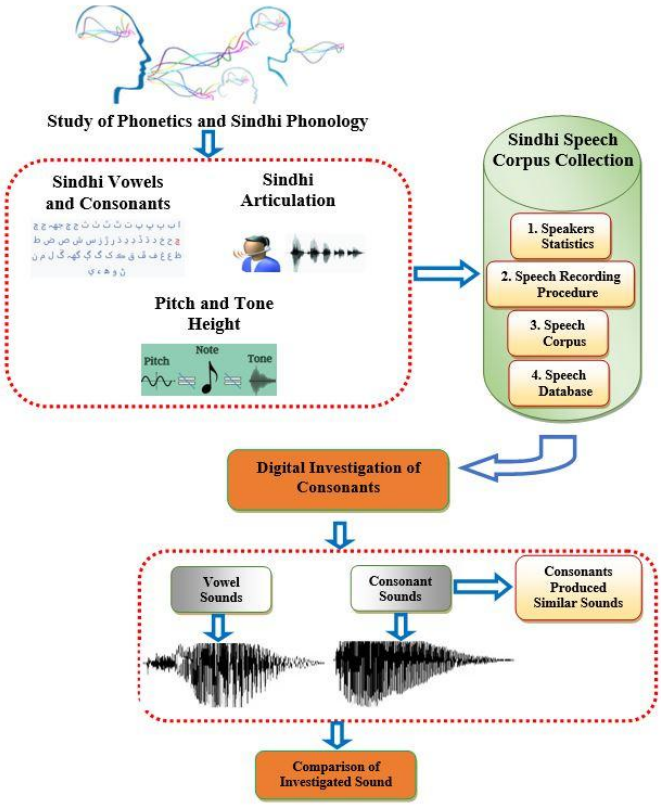

Figure 2 Flow Diagram of Research Methodology

Speech Corpus Collection

Various vowels and consonants produced similar types of sounds in Sindhi. People commonly pronounce these consonants with similar sounds but write differently because phonologically little difference is available between the consonants. Among the all, twelve letters were preferred and divided into six different classes for the purpose of experiments and investigation. Table 1 presents the list of classes and the classified letters.

Table 1: Eight Classes of Selected Consonants

Consonant Classes	Consonants Produce Similar Sound	SAMPA
Class-1	غ، گ	g', G’
Class-2	ق، ک	k', q’
Class-3	ڦ , ف	f'', p_h’
Class-4	ھ، ح	h', hh’

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Class-5	ک، خ	x', k_h’
Class-6	ط، ت	t', t’

Some specific persons are involved at all time for recording of their voices for analyzing the pitch and duration [16]. The students of Mehran Public High School Pano Akil were selected for sound recording. The students of 9th class to 12th class are selected. The selected students are separated in terms of class and gender. We choose the students on the basis of motivation pertaining to the acoustic analysis. The statistical information of selected male and female speakers is presented in Table 2. The total number of 49 male and 38 female students is selected for recording the sounds.

Table 2: Statistical Information of Selected Male and Female Speakers

Student Class	**Gender**	
	Male	**Female**
Class-IX	6	2
Class-X	9	9
Class-XI	15	12
Class-XII	19	15
Total	**49**	**38**

The sound files are recorded at the FM 88 radio station, Sukkur with attached four components like adobe auditions, Computer System, Audio Console and a microphone. The first component is Adobe audition used for recordings and saving the audio files, the next one is a simple PC, third component is audio consol having the capability of modification, maintenance and delivering clear audio with the range of 100 decibels and fourth component is microphone that is responsible to maintain equipment having the capability of accepting 100 decibels appropriately.

The corpus of the sound units is developed for getting the features of acoustics from the available recorded sound of sentences. The sampling rate of 16-Khz and 16-bit encoding is fixed for receiving the authentic results. We have six classes of words having similar sounds of twelve consonants. We have composed three descriptive sentences of each letter so that we were prepared fifty four descriptive sentences. The class wise information of descriptive sentences is given in Table 3.

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Table 3: Information of Descriptive Sentences

Letter Classes	No. of Letters	No. of Descriptive Sentences	Total Number of Descriptive Sentences
Class-1	2	3	6
Class-2	2	3	6
Class-3	2	3	6
Class-4	2	3	6
Class-5	2	3	6
Class-6	2	3	6
Total	**12**	18	**36**

The composed and prepared sentences were share out among the selected students and basic prosodic knowledge was provided at the time of recordings. The total number of speakers are 87 among them 49 are male and 38 are female speakers. The sentences spoken by male speakers are 49x36 = 1,764 and the words spoken by females are 38x36 = 1,368 so that the total number of spoken words is 3,132. The recorded speech sentences were segmented into words using PRAAT. The segmented word sounds are further segmented into phonemes and separately stored in a speech database. The stored sound units are then used for the experiments and assessment for getting the knowledge of consonants that produced similar sounds.

Experiments and Results

The purpose of this study is to explore and investigate the hidden prosodic patterns of the sounds of Sindhi consonants. For this, we have recorded the sounds of male and female students using the PRAAT speech analyzer tool. The prepared fifty four descriptive sentences were given to the preferred speakers for recordings. We made a formation of each descriptive sentence in a way in which one or more selected consonants are present. From the recorded sentences, words are segmented and separately stored according to the selected twelve consonants which are further divided into six classes. The sample of recorded and experimented sentences is shown in Figure 1. The recorded sound of the word /GA: lj cॉo:/ is depicted in Figure 3. From the segmented sound of words, the twelve selected phoneme sounds are segmented and stored separately because we are investigating the consonant

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sounds of Sindhi produced similar sounds. The sample sound of phoneme غ/G'/ of class-1 is depicted in Figure 4.

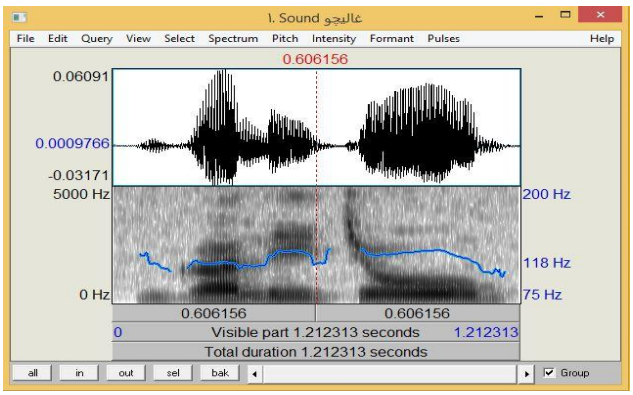

Figure 3 Recorded Sound of Word /GA: lj cō:/

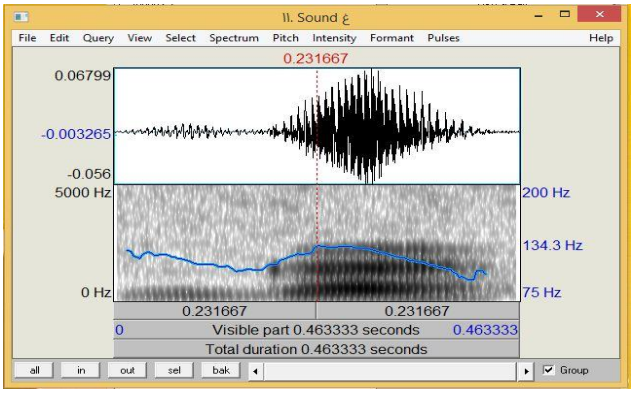

Figure 4 Recorded Sound of Phoneme غ

The sound duration and pitch is calculated separately and then investigated with twelve consonants. These consonants are further divided into eight classes. We have calculated and presented the results of consonants according to their respective classes.

Letters of Class-1

We have calculated the sound duration and pitch of recorded sounds which start with the phoneme ﮔ. Table 4 presents the measured average duration and pitch of sounds class-1 and letter ﮔ. We have measured the average duration of 0.3828 from male speakers and 0.3923 from the female speakers. The sound pitch of 166.32 and 241.55 are calculated from the recorded sounds of male and female students respectively. From the class-1, we have calculated the pitch and duration of the recorded sounds of غ. The average duration of 0.2770 and 0.2963 is calculated with the male and female sounds. The average pitch of 166.56 and 241.46 is measured with the recorded sounds.

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The measured average duration and pitch of sounds class-1 and letter غ is presented in Table 5.

Table 4: Measured Average Duration and Pitch of Sounds Class-1 and Letter گ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-1,	Class-IX	8	0.3826	0.3891	166.07	241.51
Letter	Class-X	18	0.3828	0.3911	166.24	241.65
'گ'	Class-XI	27	0.3828	0.3958	166.37	241.49
	Class-XII	34	0.3830	0.3934	166.59	241.55
Cumulative Results			0.3828	0.3923	166.32	241.55

Table 5: Measured Average Duration and Pitch of Sounds Class-1 and Letter غ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-1,	Class-IX	8	0.2788	0.2932	166.49	241.41
Letter ' غ'	Class-X	18	0.2767	0.2976	166.58	241.59
	Class-XI	27	0.2722	0.2993	166.57	241.43
	Class-XII	34	0.2801	0.2952	166.61	241.39
Cumulative Results			0.2770	0.2963	166.56	241.46

Letters of Class-2

Being a Sindhi, it is observed that most of the people pronounced the sound of phoneme ق and ڪ. After investigation of sound duration and pitches it is found that the sound duration of male is closely identical whereas difference is present in the duration of sounds pronounced by female speakers. On the other hand, pitch values of male and female are nearly the same. The measure average duration and pitch of phoneme sounds of ڪ and ق are presented in Table 6 and Table 7.

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Table 6: Measured Average Duration and Pitch of Sounds Class-3 and Letter ق

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-3,	Class-IX	8	0.4241	0.4366	166.91	167.44
Letter 'ق'	Class-X	18	0.4251	0.4329	166.82	167.48
	Class-XI	27	0.4274	0.4341	166.45	167.43
	Class-XII	34	0.4288	0.4363	166.62	167.44
Cumulative Results			0.4263	0.4350	166.70	167.45

Table 7: Measured Average Duration and Pitch of Sounds Class-3 and Letter ک

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-3,	Class-IX	8	0.4242	0.4359	166.83	167.44
Letter	Class-X	18	0.4256	0.4332	166.82	167.49
'ک'	Class-XI	27	0.4277	0.4333	166.49	167.43
	Class-XII	34	0.4288	0.4301	166.62	167.46
Cumulative Results			0.4266	0.4331	166.69	167.46

Letters of Class-3

We have extracted the prosodic features of duration and pitch from the recorded sounds of two phonemes produced similar sound one is ڤ and other one is ف. The extracted features are investigated and results are presented in Table 8 and Table 9. The obtained results proved that selected speakers similarly pronounced the sounds of both phonemes as the sound duration of both phonemes is 0.2565 and pitch of both phonemes is 123.75. However, a small difference is found between the cumulative average of sound duration of female and pitch of male speakers.

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Table 8: Measured Average Duration and Pitch of Sounds Class-4 and Letter ڦ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-4,	Class-IX	8	0.2565	0.2584	123.19	123.76
Letter	Class-X	18	0.2567	0.2587	123.27	123.77
'ڦ'	Class-XI	27	0.2565	0.2583	123.27	123.76
	Class-XII	34	0.2564	0.2587	123.25	123.71
Cumulative Results			0.2565	0.2585	123.25	123.75

Table 9: Measured Average Duration and Pitch of Sounds Class-4 and Letter ف

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-4,	Class-IX	8	0.2564	0.2571	123.09	123.75
Letter	Class-X	18	0.2567	0.2575	123.21	123.77
'ف'	Class-XI	27	0.2565	0.2572	123.26	123.75
	Class-XII	34	0.2562	0.2572	123.27	123.73
Cumulative Results			0.2565	0.2572	123.21	123.75

Letters of Class-4

In Sindhi, some consonants are pronounced incorrectly but write within correct alphabets. Some consonants are also available which are pronounced incorrectly and people make mistakes when they write with these consonants. Among them, two consonants are ھ and ح. The word sounds using these consonants are also recorded and investigated. The measured average duration and pitch of sounds class-5 and letter ھ is presented in Table 10. The cumulative average duration of male speakers is 0.4554 and cumulative duration of female sounds is 0.4616. We have also calculated the pitches of recorded sounds both mentioned consonants. The average pitch of male and female sounds is 177.84 and 245.54 respectively. Table 11 presents the cumulative average duration and pitch of sounds class-5 and letter ح. The average sound duration of male and female is calculated which are 0.4552 and

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0.4616 respectively. The average sound pitches of male and female speakers are 177.84 and 245.49 respectively. The obtained outcomes proved that selected speakers are wrongly pronounced these both consonants.

Table 10: Measured Average Duration and Pitch of Sounds Class-5 and Letter ھ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-5,	Class-IX	8	0.4551	0.4617	177.81	245.22
Letter 'ھ'	Class-X	18	0.4551	0.4611	177.67	245.66
	Class-XI	27	0.4556	0.4618	177.93	245.65
	Class-XII	34	0.4559	0.4618	177.96	245.66
Cumulative Results			0.4554	0.4616	177.84	245.54

Table 11 Measured Average Duration and Pitch of Sounds Class-5 and Letter ڃ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-5,	Class-IX	8	0.4552	0.4616	177.81	245.20
Letter 'ڃ'	Class-X	18	0.4551	0.4611	177.68	245.51
	Class-XI	27	0.4553	0.4619	177.96	245.61
	Class-XII	34	0.4554	0.4619	177.91	245.64
Cumulative Results			0.4552	0.4616	177.84	245.49

Letters of Class-5

Two letters ک and څ are included in class-7. Many word sounds starting with these consonants were recorded and inspected. The cumulative results of sound duration and pitch are presented in Table 12. The sound duration of male speakers is recorded with the value of 0.4734 and with the female speakers the value of 0.4810 is calculated. The pitch values of 167.63 and 196.90 are measured with the sounds of male and female speakers respectively. We have also calculated the sound duration and pitch values from the recorded sounds of consonant څ. The cumulative average of 0.4733 and 0.4813 is measured as the sound duration of male and female respectively.

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The pitch value of 167.68 is received with the sounds of male speakers and the pitch value of 196.84 is calculated with the sounds of male speakers. The calculated results of consonant خ are presented in Table 13. The obtained results show that a tiny difference is available between the sound duration and average of both consonants.

Table 12: Measured Average Duration and Pitch of Sounds Class-7 and Letter ک

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-7,	Class-IX	8	0.4722	0.4775	167.55	196.88
Letter	Class-X	18	0.4738	0.4822	167.87	196.78
'ک'	Class-XI	27	0.4728	0.4823	167.52	196.91
	Class-XII	34	0.4746	0.4820	167.63	196.90
Cumulative Results			0.4734	0.4810	167.64	196.87

Table 13: Measured Average Duration and Pitch of Sounds Class-7 and Letter خ

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-7,	Class-IX	8	0.4723	0.4776	167.55	196.88
Letter 'خ'	Class-X	18	0.4738	0.4822	167.89	196.74
	Class-XI	27	0.4723	0.4827	167.52	196.83
	Class-XII	34	0.4747	0.4828	167.74	196.90
Cumulative Results			0.4733	0.4813	167.68	196.84

Letters of Class-6

With the help of selected speakers we have recorded many sounds of consonants ط and ت. The prosodic features with the sounds of these both consonants were extracted and investigated. Table 14 presents the calculated cumulative average duration and pitch of sounds of consonant ط. The sound duration of 0.3561 is calculated with the sounds of male speakers and sound duration of 0.3620 is calculated from the recorded sounds of female speakers. The cumulative results of male and female pitches are 143.92 and 224.48

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respectively. Furthermore, using the sounds of consonant ت we have extracted two prosodic features. The calculated information in terms of sound duration and pitch is presented in Table 15. The sound duration of male speakers is calculated with the value of 0.3254 and with the female sounds we have received the sound duration of 0.3304. The pitch of male and female speakers with this consonant is also calculated and investigated. The cumulative average pitch of 144.07 and 224.52 is achieved from the recorded sounds of male and female speakers.

Table 14: Measured Average Duration and Pitch of Sounds Class-8 and Letter ط

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-8,	Class-IX	8	0.3566	0.3531	143.63	224.36
Letter	Class-X	18	0.3523	0.3643	143.90	224.61
‘ ط’	Class-XI	27	0.3582	0.3633	144.23	224.42
	Class-XII	34	0.3571	0.3674	143.95	224.54
Cumulative Results			0.3561	0.3620	143.92	224.48

Table 15: Measured Average Duration and Pitch of Sounds Class-8 and Letter ت

Letter Class	Student Class	n	μ Duration in ms (Male)	μ Duration in ms (Female)	μ Pitch in Hz (Male)	μ Pitch in Hz (Female)
Class-8,	Class-IX	8	0.3232	0.3273	143.78	224.37
Letter	Class-X	18	0.3279	0.3294	143.78	224.67
‘ت’	Class-XI	27	0.3255	0.3356	144.83	224.54
	Class-XII	34	0.3251	0.3296	143.89	224.51
Cumulative Results			0.3254	0.3304	144.07	224.52

Cumulative Results and Discussion

In this paper, two prosodic features i.e., duration and pitch are selected for experiments and investigation. We have created six classes of those consonants that produced similar sounds. The cumulative results of sound durations with twelve selected consonants are presented in Figure 5. The

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cumulative mean duration of male and female is 0.3828 and 0.3923 which is recorded with the sounds consonant گ. With the consonant غ, we have calculated the cumulative mean duration of 0.277 and 0.2963 from the sounds of male and female speakers. A clear difference is found between the consonants of class-1. We have received the cumulative results of 0.4263 and 0.4266 using the male consonant sounds of ق and ڪ. Small difference is present between the received results however a clear difference is available in female recorded sounds. In class-3, the consonants ڦ and ف are included. The sound duration of 0.2565 is measured which is identical in recorded sounds of male speakers. After that we have selected the sounds of consonants ھ and ح and then calculated the sound durations. Similar results are collected with the sounds recorded by the male and female speakers. The consonants ک and خ are included in Class-5. We have also calculated the cumulative sound durations of these both consonants and found very close results with the recorded sounds of male and female speakers. In terms of sound duration, variation in investigated results is observed with the consonants of class-6.

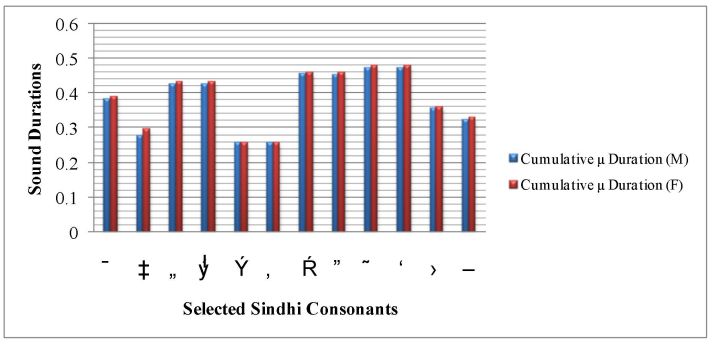

Figure 5 Cumulative Results of Recorded Sounds Duration

The pitch values of male and female sounds are also investigated according to the selected Sindhi consonants produced similar sounds. The calculated cumulative mean results are presented in Figure 6. Here we can see the clear different between the pitch values of male and female recorded sounds when they pronounce the words having use of گ and غ. The cumulative mean pitch of 166.7 and 167.45 is calculated with ق sounds of male and female respectively. The consonant ڪ is present in same class therefore we compared the pitch related results and found small difference. The cumulative mean of sound pitch of female is 123.75 in consonants ڦ and ف. However the pitches of male sounds are 123.25 and 123.21 are calculated.

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On the contrary, same pitch value of 177.84 is received with the consonants ھ and ڄ. But the difference is observed with the female recorded sounds. Calculated pitch based results of consonants of class-5 ک and خ and consonants of class-6 ط and ت proved that people correctly pronounced the words starting with these consonants.

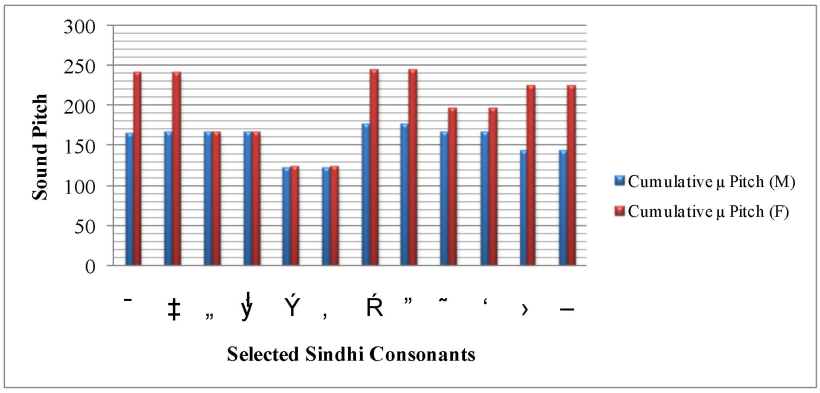

Figure 6 Cumulative Results of Recorded Sounds Pitch

The experimented results mentioned above demonstrate that the phonological difference is available in selected twelve consonants but people pronounced these consonants in incorrect way while they are communicated with each other. But in writing people are correctly used these consonants.

Conclusion

Sindhi language is spoken with many accents and has an extensible sound inventory in the form of vowels, consonants and phonemes. The study and investigation of prosodic features are mandatory for different Speech Processing (SP) Applications. The accuracy of SP applications is not accurate due to the obscure inconsistency in consonants that produce similar sounds. In this paper, two prosodic parameters i.e., duration and pitch are selected for extraction of feature from the recorded sounds of male and female speakers. Twelve commonly spoken consonants are selected and divided into six classes for experiments. A methodology is proposed and implemented on the recorded sounds. The PRAAT speech analyzer tool is used to get the values of sound duration and pitch. The study proved that the sound duration and pitch of the female speakers is high as compared to male speakers. The investigated pitch values showed that the sounds of some consonants are identically pronounced and some have clear differences. The outcome of this study will be beneficial for the development of Sindhi SP applications.

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