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A Study of Acoustic Characteristics, Prosodic and Distinctive Features of Dysarthric Speech

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***Abstract*—Speech can convey the information more than hundreds of signals, hence speech is one of the most information laid signal. Dysarthria is one of the speech pathology as a result of damage to the mind. Dysarthria can also originate at birth because of cerebral palsy or muscular dystrophy or may additionally arise later in life because of one of many numerous situations that involve the apprehensive gadget which includes stroke, brain injury, tumors, parkinson's disease and more than one sclerosis. This paper focuses on literature review in the analysis of motor speech disorder, work related to different types of Dysarthria , Speech characteristics like prosody Features, Acoustic Analysis, distinctive features of Dysarthric speech in estimating integillibility assessments. One of the demanding challenges in understanding speech motor disorders normally is to distinguish impairments of phonology from impairments of motor control.**

***Index Terms*— Dysarthria Types, Acoustic Features, Prosodic Features and Distinctive Feature.**

I. INTRODUCTION

Speech is the expressionofideas and thoughts by means of articulate vocal sounds and is the verbal means of communication. Speech includes articulation (how speech sounds are produced), Voice (Use of Vocal folds and breathing to produce sound) and fluency (rhythm of speech).When a person is not able to produce articulate sound properly, or has problems with vocalization, then the person is said to have speech disorder. Speech disorders may stem from various physical and / or mental ailments. On severalcases, the cause for speech disorder remains unknown. Some of the known causes for speech disorder include mental illness, brain injury, neurological speech disorder, alcohol abuse or drug abuse, genetic disorders, vocal abuse/misuse, hearing loss &Autism .
The major types of speech disorders identified by American Speech-Language-HearingAssociation (ASHA) are Spasmodic Dysphonia, Aphasia, Stuttering, Apraxia, Articulation Disorder, Speech Sound Disorders, Cluttering, Dysarthria, Lisps, Dysprosody, Expressive Language Disorder, Language Based Learning Disabilities, and Phonemic Disorders [2].

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Dysarthria is described as speech difficulty which can occur following an injury or ailment to the mind, cranial nerves or apprehensive machine.When a part of the brain that controls speech production is impaired, the transmission of motor signals from brain to the muscles associated with the production of speech gets affected. Speech characteristics associated with Dysarthric speech are specified in table I.

TABLE I: BASIC STUDY OF DYSARTHRIC SPEECH CHARACTERISTIC

Parameters	Speech characteristics
Syllable	Unit of organization for a sequence of speech sounds.Example:water is the word composed of wa and ter
Phoneme	Units of sound that distinguish one word from another in a particular language. The difference in meaning between the English words Kill and will is a result of exchange of the phoneme/k/ for the phoneme/w/.Two words that differ in meaning through a contrast of a single phoneme form a minimal pair.
Vocabulary	All words known and used by a particular person.
Respiration	Slow, restricted, weak, or uncoordinated muscles movement used in breathing may affect the speech.
Phonation	Process by which the vocal folds produce certain words through quasi periodic vibration.
Resonance	Selectively amplifying the sound by means of changing the shape, size, and wide variety of cavities through which it have to pass.
Articulation	Articulation is considered to be the movement of speech structures employed in generating the sounds of speech.
Prosody	Prosody varies stress, intonation, and rhythm throughout speech.

Classification System associated with dysarthrias is in particular primarily based at the common speech perceptual characteristics and location of lesion. The symptoms are slurred speech, slow or rapid rate of speech, strained voice quality, difficulty in moving the tongue, etc. The different types of dysarthrias include flaccid Dysarthria, ataxic Dysarthria, spastic Dysarthria, , Hypokinetic Dysarthria, Hyperkinetic Dysarthria and Mixed Dysarthria.

All types of dysarthria affect the articulation of consonants, causing the slurring of speech. In very severe cases, vowels may also be distorted. Depending on the extent of neurological damage, Intelligibility of speech differs from each types of dysarthria.

TABLE II. DYSARTHRIA TYPES AND ITS CHARACTERISTICS

Dysarthria Types	Site of Lesion	Neuromuscular Symptom	Perceptual Characteristics
Flaccid Dysarthria	Peripheral nervous or lower motor neuron system	Weakness Lack of regular muscle tone	Hyper nasality Imprecise consonant productions Breathiness of voice Nasal emission
Spastic Dysarthria	Pyramidal and extrapyramidal systems	Muscular weakness Greater than regular muscular tone	Imprecise consonants Harsh voice quality Hyper nasality Strained voice quality
Ataxic	Cerebellum	Inaccuracy of movement and Slowness of movement	Imprecise consonants abnormal articulatory breakdowns Prolonged phonemes & periods Slow rate
Hypokinetic	Subcortical Structures concerning Basal Ganglia	Slow movements limited range of movement	Articulatory mechanism - Impaired because of reduced variety of movement involving the lips, tongue, and jaw. Disturbance may also range from mildly obscure to overall unintelligibility.
Hyperkinetic	Subcortical Structures which involves Basal Ganglia	brief, unsustained, involuntary movements	Emission of grunts as a end result spontaneous contractions of the respiration and phonatory muscular tissues, Barking noises,
Mixed	Revolutionary degeneration of the upper & lower neuron device. Most cases seem to occur without reason.	Impairs the feature of all of the muscle tissues utilized in speech production	Shortness of word, Imprecision of consonants,Hypernasality,Harshness

II. Related Work

A. Significant work carried out with respect to dysarthria types

Flaccid Dysarthria

B J M de Swart et al. have proposed that Myotonia and weak point are the maximum critical additives of dysarthric speech in myotonic dystrophy. To specify and quantify possible defects in speech execution in patients with grownup onset myotonic dystrophy.they have taken into consideration 30 mildly affected patients with myotonic dystrophy. special attention turned into paid to myotonia. because muscle interest can result in a decrease of myotonia, speech characteristics have been measured before and after heat up. The opportunity that warming up reasons accelerated weak point changed into additionally assessed[4].

Spastic Dysarthria

Heejin Kim et al. provided a quantitative evaluation of acoustic cues to lexical stress in people with spastic dysarthria. The outcomes suggest that speakers with Celebral Palsy associated dysarthria can convey lexical stress via prosodic modulations as visible in increased depth, pitch and length values on stressed syllables in comparison to unstressed syllables[6].

Milton SarriaPaja and Tiago H. Falk have proposed computerized dysarthria severity classification is explored as a device to improve objective intelligibility prediction of spastic dysarthricspeech . A Mahalanobis distance-primarily based discriminant evaluation classifier is developed based totally on a set of acoustic capabilities formerly proposed for the assessment of intelligibility and voice pathology. severity classification and intelligibility prediction tasks were carried out in this work to select and extract features of disordered speech samples.The effects of type errors on intelligibility accuracy also are explored and proven to be insignificant[7].

Mark Hasegawa-Johnson et. al. haveproposed his work on HMM based and SVM-based recognition of the speech of the subjects affected with Spastic dysarthria. In this work they have studied about the speech of three subjects with spastic dysarthria caused by cerebral palsy. All three subjects proportion the symptom of low intelligibility,but the root cause of the dysarthria may differ. Two algorithms were used to develop automatic isolated digit recognition systems for these subjects. HMM-primarily based recognition was successful for two subjects, but failed for the subject who deletes all consonants. The digit recognition experiments assuming a fixed word length the use of SVMs had been a success for 2 subjects, however failed for the problem with the stuttering [8].

Ataxic Dysarthria

Kristie A. Spencer and Ashley A. France, Their study has yielded initial proof that speakers with ataxic dysarthria may represent with speech characteristics that cluster toward a pattern of instability, inflexibility, or a mixture of the two subgroup profiles. Experienced speech–language pathologists were able to identify some of the perceptual characteristics with enough reliability to differentiate these subgroups. A better understanding of the speech profiles of this various population would facilitate differential diagnosis and advance our knowledge in the area of ataxic dysarthria[21].

ImedLaaridh, et al.have investigated the specific behavior of an automatic cell phone-based anomaly detection system implemented on read and spontaneous French dysarthric speech. The conduct of the automatic tool reveals some of the interesting inter-pathology differences across speech patterns[22].

Hypokinetic Dysarthria

Kaitlin L. et. al. proposed a cognitive-perceptual method for conceptualizing speech intelligibility deficits and remediation effects in hypokinetic dysarthria. Hypokinetic dysarthria is one of the most common manifestation of Parkinson's disease, which negatively impacts on the quality of life. In this proposed work, they have addeda novel framework for clinical practitioners to conceptualize and justify the objectives in the production of speech. The most common targeted deficits are speaking rate and loudness of the vocal tract might be supported by this method [14].

Hyperkinetic Dysarthria

Jan Rusz, et. al. have worked on automatic detection of speech rhythm instability and basal ganglia dysfunction. Speech rhythm abnormalities are normally found in patients with different neurodegenerative disorders. The study intended to design a robust signal processing technique to detect spectrally distinctive nuclei of syllable vocalizations and speech features. In this work, speech features are rhythm instability (RI) and rhythm acceleration (RA). Speech samples primarily based on repetition of the syllable /pa/ at a self-determined steady pace have been received from 109 subjects. Subsequently, a set of rules for the automated detection of syllables in addition to features representing RI and RA were designed. The proposed algorithm was able to identify correct syllables and able to remove erroneous detections during excessive inspiration with an accuracy of 99.6% [18].

Mixed Dysarthria

Jan Rusz, et, al. have worked on a distinct variations of mixed dysarthria. A distinctive alteration of speech has been found in patients who are suffering from ephedrone-induced parkinsonism. For this study, they have considered 28 young Caucasian men samples. The exact and correct differential analysis of dysarthria subtypes changed into primarily based on the quantitative acoustic analyses of 15 speech samples dimension. they have found out a distinct features of mixed dysarthria representing the altered motor programming of dystonia and bradykinesia in ephedrone-triggered parkinsonism with a mixture of hyperkinetic and hypokinetic components. According to analyses of acoustic features, all patients presented as a minimum one affected speech sample dimensions, while dysarthria turned into moderate in 43% and severe in 36% of patients. Further calibrations indicated relationships between dystonia, bradykinesia and speech additives of loudness ,articulation and timing[11].

III. Prosodic Features of Dysarthric Speech

Speech is primarily meant to transmit a message via sequence of sound devices in a language. Prosody is described as a branch of linguistics devoted to represent speech elements. Prosodic features of Dysarthric speech include intonation, stress and rhythm. Each of them is a complicated perceptual entity, expressed using three acoustic parameters: pitch, period and energy [7].
A neurological damage in dysarthria, affects the nerves that manipulate the articulatory muscle system involved in speech production which causes weakness, slowness and incoordination of tongue and larynx. This disturbance impacts the prosody relying on the severity level of dysarthria.
The extraction of a fairly restrained, informative and significant set of features is an crucial step towards the automatic dysarthria severity classification. To select prosodic features, they have adapted discriminant analysis with Wilk's lambda method in classification.
The process used in the speech utterance at the sentence level considers seven features as follows:

A. Mean pitch

The mean pitch is defined as the Averaging fundamental frequency (*F0*) for one sentence using the autocorrelation approach. This can also be calibrated by the vibration rate of the vocal folds during speech production. The intonation is described as ensemble of pitch variations for the duration of an utterance. Mean pitch value in dysarthric speech can assist to detect abnormality in glottic signals[19].

B. Jitter

Jitter represents the fundamental frequency variations within the time evolution of an utterance. It shows the variability in the time period *(T0)* across different cycles of oscillation. Jitter could be affected by a vocal fold vibration .The threshold is 1.04% given through Multi-Dimensional Voice Processing Program (MDVP) designed with the aid of Kay ElemetricsCompany[13] . The two types of jitter are raw jitter and the normalized jitter which are defined by:

$$Jitter(Seconds) = \sum |T_i \overset{N-1}{\underset{i=1}{-}} T_{i+1}| / N - 1 \qquad (1)$$

$$Jitter(^0/_0) = Jitter(Seconds) / \frac{1}{N}\sum_{i=1}^{N} T_i \qquad (2)$$

Where T represents period and the N represents number of periods.

C. Shimmer

Shimmer is defined as perturbation or variability in the amplitude of the speech samples. It is associated with the variations of the vocal emission intensity. Estimation of Shimmer is similar to jitter, but calibration is based on amplitude parameter[9].

D. Articulation rate

The articulation rate describes the severity level of dysarthria by estimating the number of syllables pronounced per second excluding the pauses [12].

E. Proportion of the vocalic duration

Proportion of the vocalic duration (%V) is the fraction of utterance length which consists of vocalic intervals. The problem that continues voicing over a sustained vowel can be considered as a sign of pathology [14].

F. HNR

Harmonics to Noise Ratio (HNR) describes the degree of acoustic periodicity. Harmonicity is measured in dB, calculated by means of the ratio of the strength of the periodic part associated with the noise energy. Harmonics to noise ratio can be used as a measure of voice quality. For example, a healthy speaker can utter a sustained "a" with HNR around 20dB [16]. HNR is defined by:

$$HNR(dB) = 10\log(\frac{E_P}{E_N}) \quad (3)$$

Where Ep is the periodic energy and En is thenoise energy.

G. Degree of voice breaks

degree of voice breaks is described as the full duration of the breaks over the signal divided by the whole duration except for silence at the start and the end of the sentence. A voice damage can occur with sudden stoppage of the air flow due to a transient deficiency in the manipulate of the phonation mechanism [7].

IV. Acoustic Characteristics of Dysarthric Speech

Acoustic research of dysarthria are each challenging and informative. The assignment arises because the dysarthrias can be complex disorders with capability disruptions occurring at some stage in the speech production system. some disruptions can also mask others, and the acoustic sign can be substantially faded within the contrasts that are needed for specific measurements. Acoustic evaluation may be informative as it provides quantitative analyses that deliver capacity for subsystem description and for determining the correlates of perceptual judgments of intelligibility, quality, and dysarthria type. consequently, acoustic analysis can be a valuable complement to perceptual assessment.

Acoustic studies can be extensively categorized as time-domain, frequency-domain, and time-frequency domain analyses. A typical example of a time-domain analysis includes waveform and energy envelope of speech. The frequency-domain analyses consists of Fast Fourier Transform (FFT) spectra, Linear Predictive Coding (LPC) spectra, and the cepstrum. The standard waveform of time-frequency domain analysis is the spectrogram, but waterfall spectral shows are also used for this purpose. Essentially, the time-frequency analysis is a running spectrum, that is, a series of spectra received during selected time intervals. Fundamental frequency can also be determined by suitable algorithms that work in either the time or frequency domain[6].

The errors in the speech production includes articulatory and pronunciation. The errors appear to be repeatable within individual speakers, which verify existing clinical work. It should be therefore possible to construct lexicons specific to individual dysarthric speakers given their particular erroneous pronunciation patterns. The observed features within the utterances of the six dysarthric subjects are grouped into the subsequent classes:

• **Final consonant deletion:** Omission of final consonants needs more control over articulation of a word. Examples include stops and fricatives like feed→ [f iy], beat→ [b iy], clings→ [k l ihng], tried → [t r ay], etc.

• **Consonant cluster reduction:** Omission of a greater tough consonant in a consonant cluster is determined within the speech. Examples are bright→ [b ay t], explore→ [ih p l ao r], slip →[s ih p] and many others.

• **Initial /s/ deletion:** When /s/ is followed through a stop in a phrase preliminary syllable. Example consists of spark →[p ae r k], storm → [t ao r m],spit → [p ih t], snow→[n ow] and so forth.

• **Initial /h/ deletion:** The voiceless glottal fricative sound /h/ is commonly deleted when it takes at the beginning of utterances of the target word. E.g.:hair→ [eh r], hitting→ [ih t ihng], hate→[ey t], house→ [aw z] and so on.

• **Devoicing:** The voiceless counterpart of a voiced target produced within the utterances. E.g.:league→[l iy k], bag→ [b ae k],deer →[t ih r], ride → [r ay t] and so on.

• **Prevocalic voicing:** Voicing of initial unvoiced target consonants is determined.Examples include toe →[d ow], peer→ [b ih r],kitten →[g ih d ah n] and many others.
• **Fronting:** Consonants which can be typically produced in the back of the alveolar ridge are substituted by way of consonants that are produced at or in front of the alveolar ridge.Examples are ship→ [s ih p], share→ [s eh r], ring→ [r iy n], etc.
• **Backing:** In a few cases, /s/ that is produced further ahead on the palate by /sh/ which is produced at the back of the palate. E.g.: spark →[sh p ae r k], sip → [shih p], suit→ [shuw t] and many others.
• **Vocalization:** Liquids (/l/ and /r/) are once in a while produced as vowels once they occur in word-final positions. this is predominantly located within the speech. E.g.: table→ [t ey b ow], trouble→[t r ah b ow], better→[b eh r ah] , etc.
• **Stopping:** Substitution of a stop consonant for a fricative is discovered within the utterances.Examples are farm → [p aa r m], thorn→ [t ao r n], though→[d ow] and so on.
• **Insertion** of a brief vowel in consonant clusters is likewise located in the speech. Examples are slip → [s ih l ih p], blow→ [b ih l ao w], bright→[b ih r ay t] and many others.
From these above classes of the study helps speech pathlogists and research scholars in describing the predominant types of acoustic analysis and specify the components needed for a contemporary speech evaluation laboratory, which include equipment's for recording and evaluation.

V. Distinctive Features of Dysarthric Speech

Distinctive features are used to classify phone segments in more economical way and these features are used in analyzing and understanding the variations of phone segments. every phone may be classified by way of a completely unique set of binary valued (either positive (+) or negative (-)) distinctive features. It is broadly classified in to two categories, articulator free and articulator bound.
An articulator free(manner) feature is an important parameter in phonological structure that encodes a perceptually salient features of speech production. The primarily concerned five manner features are silence, continuant, sonorant, syllabic, consonantal. These manner features describes whether a voiced sound created by the human vocal apparatus [-silence] or silence or noise [+silence].In Manner features, phone segments are categoried broadly into vowels, glides, nasals, stops, fricatives, and many others.
An articulator bound (place) feature is a another important parameter which describes a physical, articulator-dependent aspects of human speech production. These Place features is defined only for a phone which are manner dependent and detects that different manner classes will have different place features.
Nasals can be characterized via the capabilities alvelar, labial and velar. Alvelar sounds are the ones that are made with the aid of pressing the tongue blade to the again of the alvelar ridge, as within the nasal/n/. Labial sounds are created via by pressing the lips together. The sound /m/ is the labial nasal. sooner or later, velar sounds are made the usage of the velum, the membrane that separates the mouth and the nostril. The velar nasal is /ng/.
Stops also are characterized via the functions alvelar (/t/, /d/), labial (/p/, /b/), velar (/k/, /g/). further, stops are also categorised via the feature voice. Voiced sounds (+voice) are those which can be made with the vibration of the vocal folds. The sounds /p/,/t/ and /k/ are unvoiced while /b/, /d/ and /g/ are voiced.
Fricatives can be defined by means of the features consisting of anterior, dental, labial, strident and voice. Anterior fricatives which include /s/ are created in the paleto-alvelar region of the mouth,. A phone with the characteristic dental is found out the use of the teeth. The phone /th/ is an instance of a dental fricative. Strident fricatives are those in which obstacleis located in front of the constriction in the vocal tract, as inside the phone /z/. fricatives are +continuant, +consonantal. An example of a labial frictive is the sound /f/ and an instance of a voiced fricative would be the sound /zh/.
The glides, /h/, /l/, /r/, /w/, and /y/ are unique in nature and each articulated with a different region of the oral cavity.Therefore the place features for glides are h, l, r, w and y.
Vowels are described through the functions superior tongue root, front, excessive , low, reduced, round and tense. these features describe the tongue tip function during production of the vowel.A vowel with the feature superior tongue root is produced with a widened pharynx (ey vs. ih). if there is lip rounding at some point of vowel production is referred as round vowel. Example consists of Vowel /uw/ is +round. tense vowels, like /aa/, are generally longer in duration, have a higher pitch and better tongue position than lax vowels, consisting of /uh/. Vowels which can be reduced are usually unstressed, inclusive of the schwa /ax/.

VI. CONCLUSION

Speech is the most essential mode of communication among humans. Dysarthric speech is a speech disorder that is affecting hundreds of thousands of people. The literature review is carried out in assessment of motor speech disorder, different types of Dysarthria , prosody Features of Dysarthric speech, Acoustic features of Dysarthric speech, Distinctive Features of Dysarthric speech in estimating integillibility assessments. From the evaluation carried out , it is intended that the basic features which are tabulated in Table III will be useful for analysis and synthesis of any type of dysarthric speech. This analysis features of Dysarthric speech helps in identifying and describing the best feature useful for carrying out research in Dysarthria.

TABLE III. SUMMARIZATION OF PROSODIC, ACOUSTIC AND DISTINCTIVE FEATURES OF DYSARTHRIC SPEECH

Features	Description
Manner(M)	High Level Categorization of speech sound approximant, fricative, nasal, retroflex, silence, stop, vowel.
Place (PI)	Location of primary construction alveolar, bilabial, dental, labiodental, velar, silence, nil.
High/Low (HL)	Ventral position of the tongue high, mid, low, silence, nil
Front/back (FB)	Anterior position of the tongue front, central, back, nil
Voice(V)	Presence/absence of glottal vibration voiced, unvoiced.
Round(R)	Circularity of the lips round, non-round, nil
Static(S)	Movement of articulators (e.g. diphthong), static, dynamic.

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