Evaluation of Neurogenic Speech Disorder-Apraxia of Speech (AOS) with Special Focus on Normalized Pitch Variation Characteristics

Manasi Dixit[1] and Shaila Apte[2]

[1]Department of Electronics and Communication Engineering, K.I.T.'s College of Engineering, Kolhapur, 416234 Maharashtra, India.
[2]Department of Electronics and Communication Engineering, Rajarshi Shahu College of Engineering, Pune, Maharashtra, India.

ABSTRACT

In this work the speech disorder namely Apraxia of Speech is discussed. The basics of the disorder are described here. The speech parameters are identified which characterize the disorder and correction system is designed to improve the speech quality. The speech signal samples of people of age between five to eighty years are considered for the present study. These speech signals are digitized and enhanced and analyzed for the Speech Pause Index, Jitter, Shimmer, HNR, Pitch variations Tx graphs, Normalized Percentile f_0 characteristics and % Close Quotient EGG graphs using MATLAB, PRAAT, SFS and EXCEL platforms.

Introduction

Apraxia of Speech (AOS) is described as Motor or Neurogenic Speech Disorder. It is characterized by the damage to Broca's area in the cortex. Due to the damaged Broca's area the abilities to organize, plan, and execute the movement of speech muscles are affected. Apraxia of speech is categorized by the affected speech muscle groups. It may co-occur with other language impairments.

AOS is described as inability to group and sequence the relevant muscles with respect to each other. The disorder comprises of impairments of Planning/Programming leading to disrupted coordination of relevant muscles and muscle groups where as muscle physiology and movement is intact. The Apraxia of Speech (AOS) is Motor Planning /Programming Disorder. It is classified as follows.

Acquired AOS

It is described as inability to transform an intact linguistic representation into coordinated movements of the articulators. The main characteristics of the disease are disturbed phonological selection and sequencing of speech sounds and improper articulation.

The characteristics are slow speech, sound distortions, and prolonged durations of sounds, reduced prosody,[3] consistent errors within an utterance, difficulties in initiating speech, and repeated attempts of muscles to find the correct articulatory position, frequent articulation errors, awareness of errors done and self-correcting behaviors and variability in their abilities.

It affects the ability of muscles to organize, plan, and execute the movements for correct articulation and utterances. It is caused due to stroke, brain injuries, illness, and infections.

Childhood AOS

Salient characteristics of this disorder are the same as acquired AOS. There is considerable delay in speech production, limited sound inventory, and unintelligibility. Subjects are found to progress slowly in speech therapy. Causes are not well understood; some research points to hereditary component. Some cases are caused by stroke or traumatic brain injury.

Literature Review

Lawrence D. Shriberg has done Genetic Research in Childhood Apraxia of Speech (CAS). The author describes a conventional three-phase speech processing perspective and provides a sufficient framework of CAS.

He recommended Madison Speech Assessment Protocol (MSAP) an age-based protocol designed for Preschool, school-aged, adolescent and adult patients with speech disorders .The MSAP includes various tasks assessing speech, voice, and prosody parameters for detection and evaluation of speech disorders [1].

Justice has discussed that speech production is one of the most impressive and accurate motor skills in human body. Control of speech muscle movements get developed up to age 12 [4]. Justice discussed different motor units, the need of Motor Control regarding Planning, Programming, and Execution of motor movements and motor learning so as to maintain speed and fluency in speech production.

John-Paul Hosom et.al. have discussed automatic speech recognition (ASR) methods in childhood speech sound disorders [2]. The author has developed two diagnostic markers for suspected Apraxia of Speech (AOS) known as the Lexical Stress Ratio (LSR) and the Coefficient of Variation Ratio (CVR).

Tele:
E-mail addresses: manasidixit64@gmail.com

Assessment of Motor Speech Disorders

Assessment of motor speech disorders include measures of speech and non speech oral motor skills and isolate particular motor subsystems to determine impairment.

Measurement Methods

i) Perceptual measures – This method includes perceptual judgments of speech intelligibility, accuracy, and rate of speech production**.**

ii) Acoustic measures – This method includes spectrogram, formant analysis, Segmental Analysis and Supra segmental Analysis for detection of pathological speech and Classification of speech disorder as AOS etc.

Classification of Speech on the basis of Segmental and Supra segmental acoustic indices

The following parameters are extracted by using the developmental tool available as an open source software SFS and PRAAT from every speech data to classify whether the speech is Normal or Pathological. The Normal range and Pathological range of the parameter values are as below.

System Implemented for Confirmation of AOS Disorder

The present work attempts to find few parameters from pathological speech for confirmation of AOS. Researchers have used lot many parameters. We have tried to reduce the computational cost and reduce the number of parameters.

Database

The standard database is not available. The speech data of 10 AOS speakers comprising of above 100 words uttered by each subject are collected. The speech database consists of isolated words, connected words, fast uttered sentences and songs for e.g School-Prayer**,** National anthem and Pledge, Nursery Rhymes, famous film songs etc. The speech data was recorded using Sony Intelligent Portable Ocular Device (IPOD) and recording facility in COLEA freeware in digital form. The recording was carried out in a pleasant atmosphere and maintaining the children and other subjects in tension-stress free environment. The recorded signal is transformed into '.wav 'file by using GOLDWAVE software. The data was collected at Chetana Vikas Mandir, a special school established to educate Mentally Retarded children as well as children with various disorders. It is located at Kolhapur, India.

The data is also collected from the patients under the treatment of speech therapists and ENT specialists in Kolhapur city. We got the database labelled by consulting the doctors as AOS speech data. The speech data of normal subjects/children and pathological subjects/children of the same age group between 3 to 10 years is collected. The children were trained to utter similar words before recording. The speech data of normal adult male and female subjects and pathological adult male and female subjects of the same age group between 20 to 56 years is collected.

To identify the parameters for AOS confirmation, the ready to use open source software such as PRAAT and SFS are used as development tools. The following features were extracted and tested for confirmation of AOS. PRAAT is used to extract f0 variations, Voice Regularity parameters.

The parameters extracted using PRAAT are used as verification procedure to confirm the results obtained by adopting the MATLAB code developed by us. SFS is used for extraction of Laryngograph % CQ and % Tx parameters. Percentile Glottal signal frequency graphs are drawn in Percentile Domain after adopting Normalization Procedure. The Microsoft Excel Software is used here as it is convenient for data handling and graphical representations.

System Block Schematic

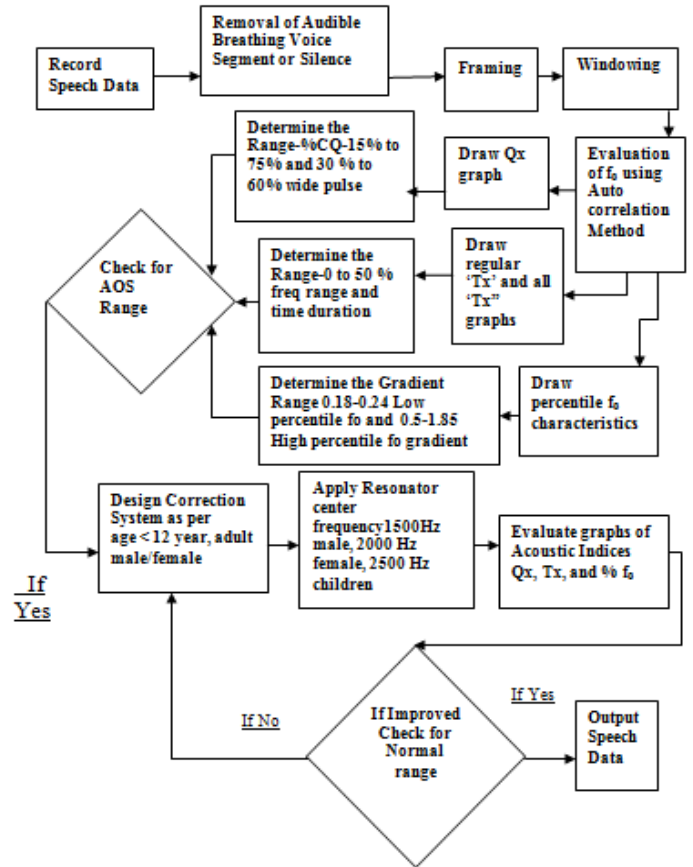The diagram of the system implemented for evaluation of AOS is as shown in Figure 1 below.

Figure 1. Block Diagram for Evaluation of AOS

System Development

The system developed operates in two modes training mode and testing mode.

Training Mode- In training mode 50 speech samples are used to train the system. The following parameters namely (Laryngograph) Closed Quotient, Tx variation graph and Glottal Frequency fo variations are used as the Diagnostic Markers. The procedure to extract these parameters is discussed in detail as follows.

Procedure: - Percentile Glottal signal frequency graphs

The Speech sample data file under consideration is divided into frames of short time duration in time domain. The Hamming/Hanning window is selected at preprocessing. The glottal signal frequency is evaluated in each frame. The average value (denoted as 'mean') of glottal signal frequency is considered as the pitch or fundamental frequency for the subject. The maximum value (denoted as 'max'), the minimum value (denoted as 'min') are also evaluated for calculation of the % percentile value. The entire glottal signal frequency data for every subject is transformed or mapped into Percentile form. Percentile factor 'k' lies in the range 0 to 1 with both limits included $(0 \leq k \leq 1)$.

$$k = \frac{x - \min}{\max - \min}$$

Where 'x' represents the instantaneous glottal signal frequency. After mapping the glottal signal frequency data into percentile domain 'k' is plotted on X axis and the corresponding glottal signal frequency is plotted on Y axis. This Percentile domain conversion is considered as normalization procedure.

It is found that plotting the glottal signal frequency variations in terms of Percentile data is a perfect tool useful in the classification of normal speech and various types of disordered speech. By analyzing the properties of the graph for example linearity/nonlinearity/curved nature, slope (gradient) and useful range following inferences can be drawn.

- Pitch or fundamental frequency of the person
- Age -adult male/female, children or elderly male/female
- If the above data is confirmed then whether the person is having normal speech OR disordered speech.

Procedure: - All Tx and Regular Tx graphs

The Speech sample data file under consideration is divided into frames of short time duration in time domain. The Hamming/Hanning window is selected at preprocessing. The glottal signal frequency is evaluated in each frame.

The glottal signal frequency data is sorted out with respect to minimum value to maximum value attained. Then it is checked for how many glottal cycles (time periods) a particular frequency outcome is available. Then a graph is plotted with glottal signal frequency on X axis and the number of glottal cycles (time periods) on Y axis. This graph is denoted as 'All Tx 'graph. All 'Tx' graph indicates histogram of all pitch cycles for the total time duration of speech samples. Regular 'Tx' graph indicates the histogram of the regular pitch periods which vary within +/- 10% with respect to the adjacent pitch periods.

Then a graph is plotted with regular glottal signal frequency on X axis and the number of glottal cycles (time periods) on Y axis. This graph is denoted as 'Regular Tx 'graph. The similarity between the two graphs and the mean f_o value of the person are important parameters.

Procedure: - % CQ   Laryngeal Quality Analysis

Analysis of the relationship between the Electroglottograpgh (EGG) measures and the physical movements of the vocal folds are expressed as ratios between the temporal measures of one particular phase of vocal fold movement with another phase and also between different phases of movement with the full glottal period. (Open phase and closed phase) Open quotient (OQ) is defined as the ratio of the time period for which the vocal folds are open (open phase) to the full glottal period. EGG duty cycle is defined as the ratio between the open phase and the full glottal period measured from crossings at the 40% baseline.

A greater EGG duty cycle suggests longer vocal fold open time and thus less vocal fold contact. EGG duty cycle is greater in elderly males than in younger males where as in contrast, elderly females have smaller duty cycles (greater vocal fold contact) than younger females. A greater EGG duty cycle indicates rise in fundamental frequency f_0.

The SFS software provides % CQ close quotient with respect to time periods. % Close Quotient (CQ) graph simulates the Laryngograph and indicates the close phase of Glottis pulse signal or vocal folds vibration cycle. The mean CQ, range of variation of CQ and CQ variations with respect to total time duration of speech sample are important parameters .

Generally the graph is symmetrical about mean value 40% to 50 % .The spread of the graph i.e. % CQ range increases with increase in the age of the subjects as well as in disordered conditions.

The observations for CQ are as follows

1. % CQ is a time periods with respect to CQ graph. It indicates that the CQ values are in the range of 15 % to 75 % for AOS speakers.

2. For normal speech, CQ variation is found to lie from 10 % to 60 %.

Graphs of some of the Diagnostic Markers-AOS

Sample three %CQ graphs with respect to time are given below which confirm the above observations. Figure 2 to 4 show variation of CQ for AOS speakers. Figure 5 shows % CQ variation with respect to time for a normal person.
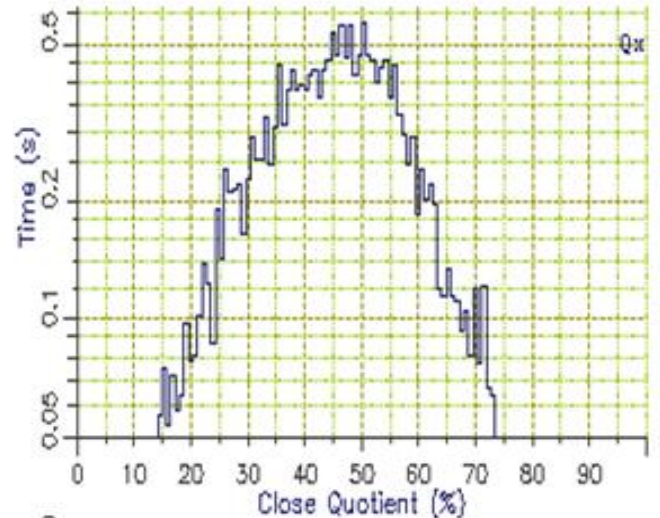

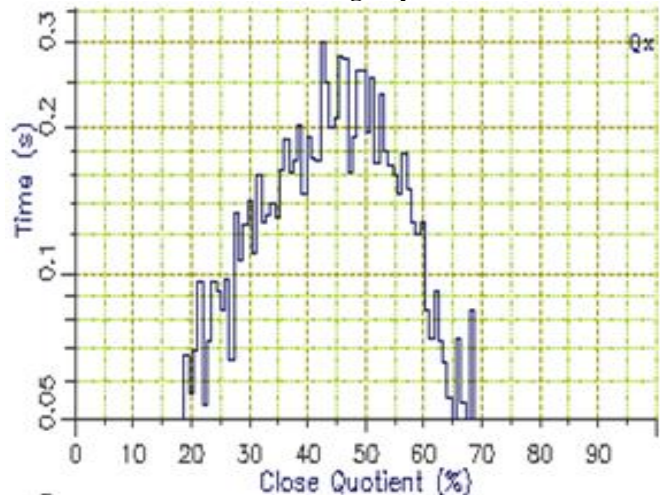**Figure 2. % Close Quotient wrt Time for AOS speaker named Aginkya**

Figure 3. %CQ wrt time graph for AOS speaker named Kiran Rokde
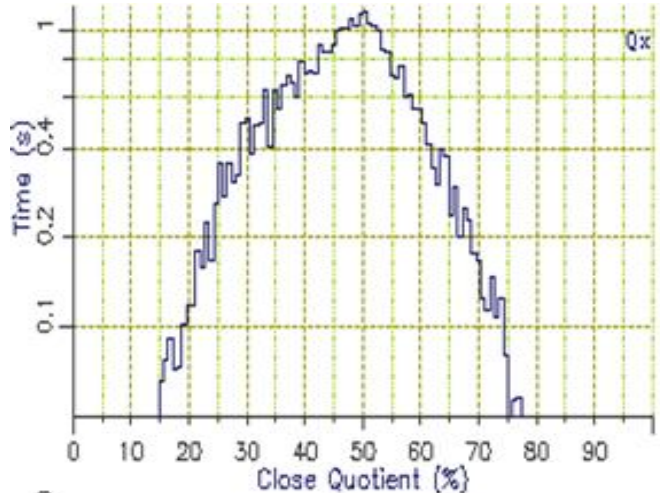

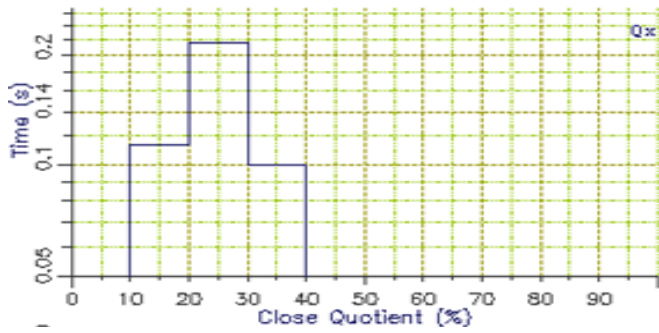**Figure 4. %CQ wrt time graph for AOS speaker named Sudesh**

Figure 5. % CQ variation with respect to time for a normal speaker

ii) Comparison of histograms of all 'Tx' which is all pitch periods with respect to regular 'Tx' pitch periods are plotted for these 50 speech samples to confirm AOS characteristics. The observations for Tx are as follows.

1. In case of normal persons, regular Tx graph matches with all Tx graph**.**

2. For AOS persons, regular Tx graph exists for maximum 50 % of frequency range and for maximum 50 % of time periods as compared to all Tx.

Figure 6 to 8 show All Tx and regular Tx graphs with respect to time periods for AOS speakers and Figure 9 shows All Tx and regular Tx graphs for a normal speaker. These graphs confirm the above observations.
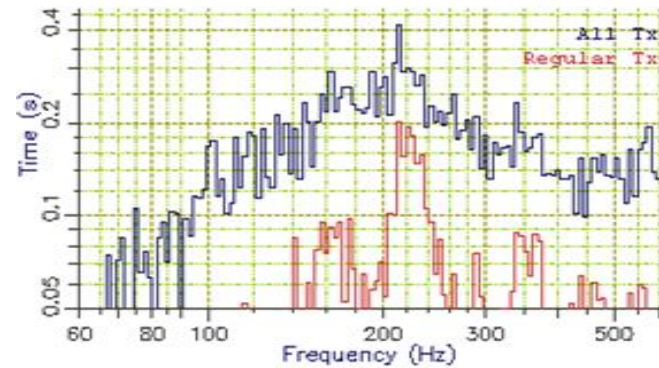

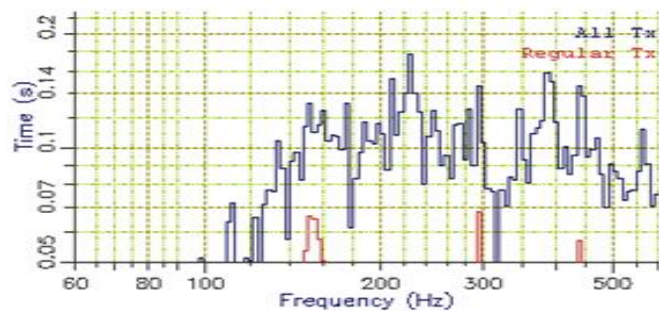**Figure 6. Tx graph for AOS speaker named Ajinkya**

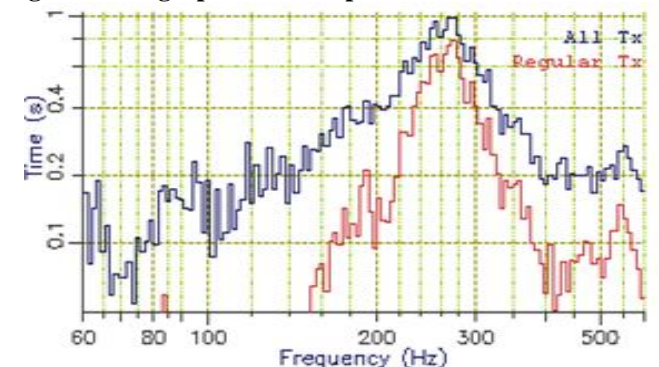**Figure 7 . Tx graph for AOS speaker named Kiran Rokade**

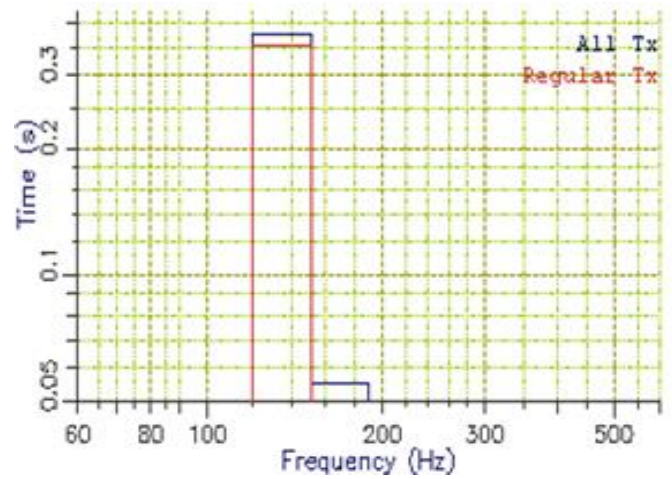**Figure 8. Tx graph for AOS speaker named Sudesh**

Figure 9. Tx graph for normal speaker named Ashwathama

iii) Glottal Frequency f_o variation is found for normal as well as pathological speech. It is evaluated in transformed percentile domain. The f_o values for a speech data file are calculated by using Framing and Windowing Algorithm in MATLAB. Then the Normalization routine is developed in Microsoft Excel. The algorithm for evaluation of Normalized f_o Variation in Percentile Domain is as follows**.**

1. The percentile value of f_0 maximum level is considered to be 100 percentile and f_o minimum level is considered to be 0 percentile.

2. Hence according to the data values of f_0 variations as per the speech sample 0-5-10-15- - - --95-100 percentile values of every speech sample are calculated.

3. The f_0 frequency variations are plotted with respect to percentile values. This graph provides a very good measure of fundamental frequency analysis to differentiate between normal speech and pathological speech. It also confirms AOS.

Observations for f_o track variations are as follows.

1. For AOS speech, it was observed that the percentile f_0 track graphs indicate linear response with very low gradient levels in the range 0.18 to 0.24 initially up to 50 percentile range and then high gradient in the range 0.5 to 1.85.

2. For normal speech percentile fo track graphs are linear from 5 to 95 range with very low gradient 0.05 to 0.3.

Figure 10 to 12 show fo track variation for AOS speakers and Figure 13 shows variation of fo track for a normal speaker which confirms the above observations.

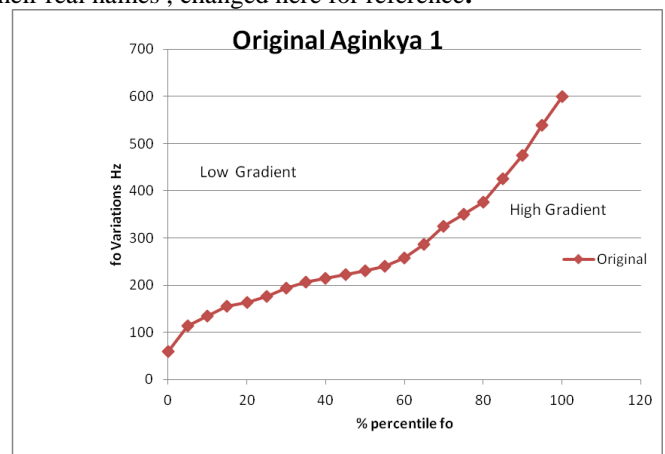*Note : The names of subjects i.e. people under study are not their real names , changed here for reference**.**

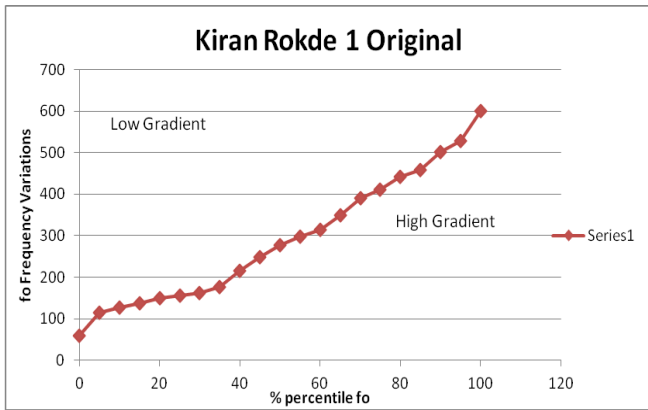**Figure 10. Percentile fo track variation for AOS speaker named Ajinkya**

Figure 11. Percentile fo variation for AOS speaker named Kiran Rokade
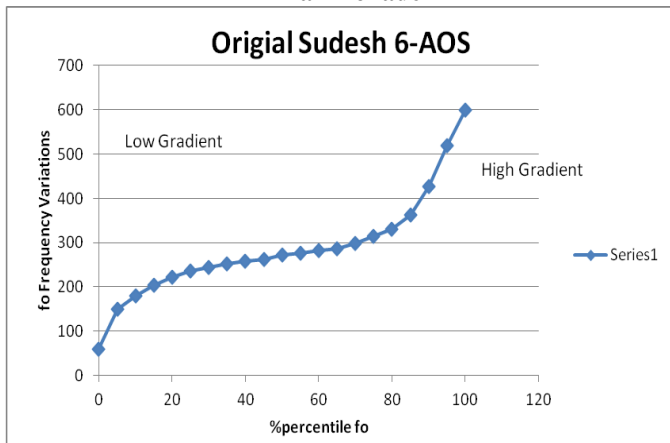

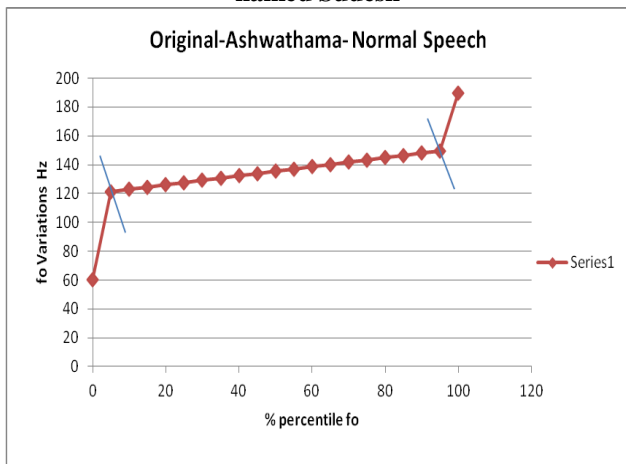**Figure 12. Percentile fo track variation for AOS speaker named Sudesh**

Figure 13. Percentile fo track variation for a normal speaker

Testing Mode- In testing mode remaining 50 speech samples are used for confirmation of AOS disorder. The testing mode checks the Laryngograph characteristics, CQ graph and f_0 track to confirm AOS disorder. The following observations are made.

1. Fundamental Frequency f_o mean is in the range 120 Hz to 440 Hz as per the categories like adult male, female, children or elderly speakers.

2. It is observed that Laryngograph comprising of regular Tx pulses contains less than 20 % or even negligible of the frequency spectrum as compared to all Tx.

3. Time Vs closed quotient graph indicates closed quotient range more than 50 % wide with mean %CQ within 42% to 48%.

4. f_o track has Two linear Sections with variation in gradients**.**

System Designed for Correction of AOS Disorder

The ready to use software is used for system development. COLEA, Adobe Audition and SFS E-system are used as

development tools. After designing the system using a development system, the system is designed using MATLAB.

Band Pass Filter- The lower cut off frequency is in the range 10 Hz to 100 Hz and the upper cut off frequency selected should be such that the second formant frequency f_2 should lie in the pass band. Hence it is selected as either 1500 Hz, 2000 Hz or 2500 Hz as per if the speaker is a male, female or children based on pitch frequency range.

Resonator - The resonating center frequency selected should be such that the second formant frequency f_2 should lie in the pass band. Hence it is selected as either 1500 Hz, 2000 Hz or 2500 Hz as per if the speaker is a male, female or children based on pitch frequency range.

Vocal Tract Filter – It is realized as a cascaded combination of three resonators acting as per three formant frequencies. The standard adult male formant frequencies are 500 Hz, 1500Hz and 2500Hz. The first formant frequency is amplified by 20 dB. The second formant frequency is amplified by 10 dB and the third formant frequency is maintained at 0 dB. Hence this filter boosts up the input speech signal spectrum as per the formant frequencies. In case of pathological speech the amplitudes of upper formants are degraded. Hence the VTF is the better solution to lift up the second formant spectrum.

System Applied for Correction of AOS disorder

The performance of the AOS speech after applying Band Pass Filter, Resonator and vocal tract filter with specifications as stated above is tested for fo track variations as it gives 100 % confirmation results. Figure 18 shows the f_o track variations modified using above 3 correcting methods. It is observed that the resonator correction system extends the linear range of the f_o track as compared to other methods. Hence Resonator System is applied as Correction System. After applying the Resonator system to AOS speech the following observations are made. It is observed that Laryngograph comprising of regular Tx pulses graph shows improvement and contains less than 50 % of the frequency spectrum as compared to all Tx. It more closely approaches the all Tx.

5. Time Vs closed quotient graph indicates closed quotient range more than 50 % wide with mean % CQ within 42% to 48%.

6. Glottal frequency fo variations graph exhibits two sections

• Linear Initial Section—10 to 65 percentile range with a low gradient in the range 0.17 to 0.2

• Linear Later Section in 65 to 100 percentile range with a high gradient in the range 0.55 to 1.94

Improvement in the diagnostic markers due to application of Resonator Filter is indicated below with the help of Regular Tx graph, % Close Quotient (CQ) graph and percentile fo track graphs as shown in Figure 14 to Figure 17
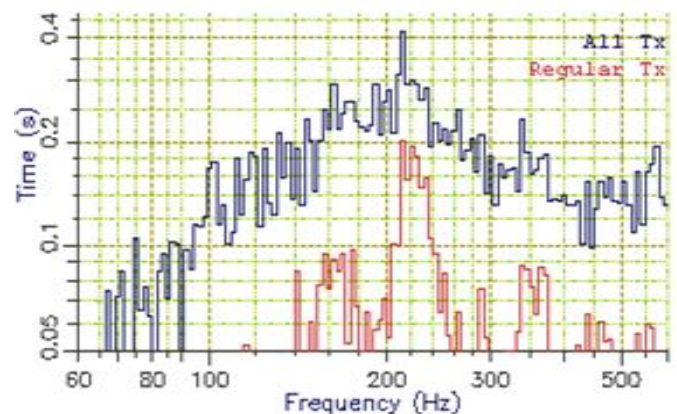

Figure 14. Tx graph for AOS speaker named Ajinkya

Table 1. Range of Segmental and Supra segmental Acoustic Indices for Classification of Normal Speech and Pathological Speech

Parameter	Normal Speech Range			Pathological Speech Range
Fundamental Frequency-Pitch	Children	Adult Male	Adult Female	for VPD* 300 -550 Hz otherwise same as Normal Speech
	208-440 Hz	85-196 Hz	155-334Hz	
Jitter (mean)	Range 0.0 % to 18%			Range 14% to 45%
Shimmer (mean)	Range 0.0 % to 5 %			Range 0.0% to15%
HNR (mean)	Range 12 dB to 45 dB			Range 5dB to 11 dB
Voice Regularity	Range 50% to 95 %			Range 5 % to 45%
Audible Breathing Voice Segment	Not Present			Always Present

*VPD : Velopharyngeal dysfunction or Resonance disorders are observed in patients with a history of cleft palate or cleft lips.

Table 2. Range of diagnostic markers for 50 % of AOS speech sample and 50 % of normal speech

Diagnostic marker	Range of values for AOS speakers	Range of values for normal speech
Time Vs % CQ	15 % to 75 %	10 % to 60 %
Time Vs frequency TX graph	Regular Tx has less than 50 % frequency range as compared to all Tx graph with intermittent pulses	Regular Tx matches with all Tx for more than 90%.
Percentile fo Characteristics	Linear Characteristics with Two Sections – Initial Section with very low gradient in the range 0.18 to 0.24 from 0% to 50 % percentile range . Later Section with high gradient in the range 0.5 to 1.85 from 50% to 100 % percentile range.	Linear Characteristics with very low gradient for almost 90% range.

Results for testing of remaining 50 % samples are shown in Table 3 as % samples confirmed for AOS or normal.

Table 3. % confirmation for 50 % of AOS and normal speech samples

Parameter used	% samples confirmed for AOS speech	% samples confirmed for normal speech
Time Vs frequency TX graph	94 %	100 %
Percentile F0 track variation	100 %	100 %
All 3 parameters % CQ, Tx, F0	92 %	100%

Note : Some of the speech samples of Geriatric or elderly speakers have shown nature of Percentile Glottal frequency fo characteristics similar to AOS speakers but on the basis of All Tx-Regular Tx histogram and % CQ graphs it is confirmed as elderly speech and not confirmed as AOS disordered speech.

Table 4. Results of correction for AOS speech after applying correction using resonator

| Diagnostic marker	Range of values for AOS speakers	Range of values for AOS after applying correction using Resonator
Time Vs % CQ	15 % to 75 %	15 % to 75 % graph is more smooth
Time Vs Frequency TX graph	Regular Tx graph --- < 50 % frequency range All Tx graph --- intermittent pulses in entire frequency range	Regular Tx graph matches with All Tx graph for more than 60 %. No intermittent pulses, graph is smooth and present for all time
Percentile Glottal Frequency fo variation	First Section – 5 to 50 percentile range --very low gradient levels with range 0.18 to 0.24 Second Section—from 50 to 95 percentile range-- high gradient levels in the range 0.55 to 1.94 Values vary for every subject	First Section— 5 to 65 percentile range – gradient is 0.17 to 0.2 Second Section--- 65 to 100 percentile range – gradient is 0.5 to 1.80 Initial Low Gradient range is improved -i.e. extended and Gradient values are improved-i.e. reduced
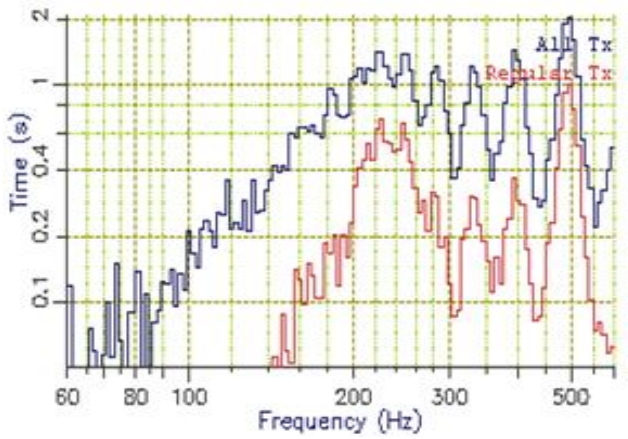
Figure 15. Tx graph for AOS speaker named Ajinkya after applying resonator

Note: Regular Tx graph is improved for frequency range and time periods of existance**.**

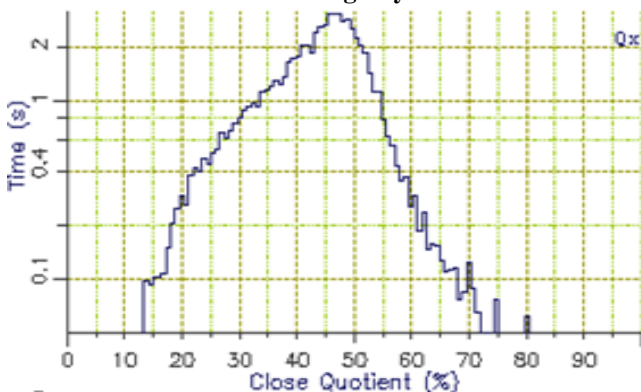**Figure 16. % Close Quotient wrt Time for AOS speaker named Aginkya**

Figure 17. Graph of CQ after applying resonator.
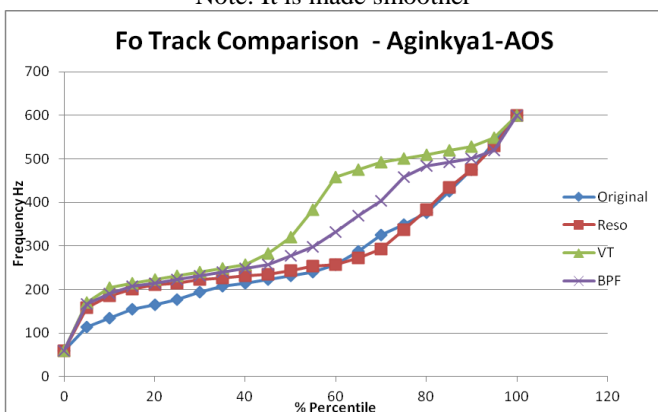
Note: It is made smoother

Figure 18. Comparative Response of the Correction System of AOS Disorder

Note: Resonator Correction system extends the linear range of Characteristics with comparatively low gradient.

Segmental and Supra segmental Acoustic indices Analysis

The analysis of segmental and supra segmental acoustic indices was carried out for particular isolated words and continuous speech data. The isolated word data above 100 words uttered by each of 25 normal subjects and 12 AOS disabled subjects were analyzed and reference /threshold level was considered for each isolated word. Various Misarticulation cases were studied and analyzed in case of pathological subjects. In case of fast uttered words or continuous sentences complex pronunciation errors occur and the speech intelligibility is very poor. Considering the observations for % CQ variation, Tx variation and fo track variation observations the system is designed for confirmation of AOS. Results for training system are shown in Table 2.

Observations

The existing speech enhancement algorithms like spectral subtraction do not help in enhancement of pathological speech . The pathological speech due to AOS disorder suffers from following conditions**.**

• Breathing voice segments are audible in speech because the subjects are under stress when they speak .When the speakers are supposed to take pause in between utterances of two successive words generally the breathing voice segment is heard.

• The minimum intensity level does not drop much as there is no silence region due to the presence of breathing voice segments.

• The speakers have to put more efforts for the motor movements of articulators. Hence the utterances of different words are not appropriate.

• Due to low HNR levels below the pathological threshold of 12 dB the speech indicates harshness.

Our Contribution to present work

The AOS disordered speech database is not available.

• We got the database labeled by the doctors.

• We have evaluated and analyzed the speech of the AOS disorder people with the help of few segmental an supra segmental acoustic indice**s** like fo mean, Percentile glottal frequency fo track Characteristics, Laryngeal Quality represented by % Close Quotient characteristics , All 'Tx'- Regular 'Tx' time-frequency Histogram   and % voice Regularity**.**

• Evaluation and confirmation of AOS disordered speech using the present theory is done for the first time by us and it is not done by any one before.

Concluding Remarks

The Apraxia of Speech (AOS) disorder is identified by evaluation of speech of 25 normal and 12 pathological AOS subjects consisting of more than 100 samples for AOS and more than 50 normal speech samples. The following conclusions can be drawn from the experimental results obtained**.**

• CQ values are in the range of 15 % to 75 % for AOS speakers. For normal speech, CQ variation is found to lie from 10 % to 60 %**.**

• In case of normal persons, regular Tx graph matches with all Tx graph. For AOS persons, regular Tx contains maximum 50 % of frequency range as compared to all Tx.

• For AOS speech, it was observed that the percentile Glottal Outcome f_0 graphs indicate two linear Sections. Initial section with very low gradient in the range 0.18 to 0.24 from 5 to 50 percentile range. Later section with high gradient in the range 0.5 to 1.85 from 55 to 95 percentile range. Whereas for normal

speech percentile fo track graphs are linear from 5 to 95 range with very low gradient 0.05 to 0.3

• The testing of the system indicates 97% samples confirmed for AOS using all parameters. The testing of the system indicates 100% samples confirmed for normal speech using each parameter.

• After applying resonator, CQ graph becomes smooth. Regular Tx matches with all Tx for more than 60 %. No intermittent pulses, graph is smooth and from 150Hz to 600 Hz present for all time. f_0 track variation graph has low slope for 5 to 65 percentile range after applying a resonator.

Acknowledgments

References

[1] Lawrence D. Shriberg "Studies of Childhood Apraxia of Speech in Complex Neurodevelopment Disorders" Conference on Motor Speech: Motor Speech Disorders Monterey, California March 6-9, 2008

[2] John-Paul Hosom, Lawrence Shriberg, Jordan R. Green "Diagnostic Assessment of Childhood Apraxia of Speech Using Automatic Speech Recognition (ASR) Methods" J Med Speech Lang Pathol. 2004 December; 12(4): 167–171. PMC 2006 October 25. PMCID: PMC1622919 NIHMSID: NIHMS2560 Lincoln Viewcontent.pdf

[3] L.R.Rabiner, R.W.Schafer-Digital Processing of Speech Signals-Pearson Education-2006

[4] Justice "Communication Sciences and Disorders: An Introduction Motor Speech Disorders: Apraxia and Dysarthria" Pearson "Speech Communications Human and Machine" University Press Second Year 2001

Biography

[1] Dr.Mrs. Manasi Dixit is working as Associate Professor in KIT's College of Engineering, Kolhapur. Her teaching experience is 30 years. Her main fields of interest are Digital Signal Processing, Speech Processing, Image Processing and Microwave Engineering. 28 PG students have completed their research work and have been awarded M.E.(E&TC) degree under her guidance. She has published 18 papers in reputed international journals. She has worked in the capacity of the SENATE member Shivaji University, Kolhapur and BOS-Board of Studies Member for Electronics and Telecommunication Engineering, Shivaji University, Kolhapur.

[2] Prof. Dr. Shaila Dinkar Apte is currently working as a professor on PG side in Rajarshi Shahu College of Engineering, Pune and as reviewer for the International Journal of Speech Technology by Springer Publication, International Journal of Digital Signal Processing, Elsevier Publication. She is currently guiding 8 Ph.D. candidates. Five candidates have completed their Ph.D. under her guidance. About 54 candidates completed their M.E. dissertations under her guidance. Almost all dissertations are in the area of signal processing. She has a vast teaching experience of 37 years in electronics engineering, and enjoys great popularity amongst students. She has been teaching Digital Signal Processing and Advanced Digital Signal Processing since last 18 years. Her previous designations include being an Assistant Professor in Walchand College of Engineering, Sangli, for 27 years; a member of board of studies for Shivaji University and a principle investigator for a research project sponsored by ARDE, New Delhi. She has published 32 papers in reputed international journals, more than 40 papers in international conferences and about 15 papers in national conferences. She has a patent published to her credit related to generation of mother wavelet from speech signal. Her books titled "Digital Signal Processing" and "Speech and Audio Processing" are published by Wiley India. A second reprint of second edition of the first book is in the market. The book titled "Advanced Digital Signal Processing" is published in June 2013 by Wiley publishers.