Evaluation of the Quality of Synthesized Calls of Alexandrine Parakeet (Psittacula Eupatria)

Kamaljit Singh Arora, Randhir Singh, Parveen Lehana

Abstract— Speech synthesis is one of the interesting research areas now-a-days and it has been explored for various applications including man-machine interaction and telecommunications. Moreover, it can be significantly used as an aid for vocally and blindly handicapped persons, etc. Birds produce vocal calls for different meaningful purposes; for e.g. contact call is used for making a vocal coordination with the movement of flock members for the search of a particular type of vegetation, begging call is generally used by baby birds when they are hungry and thirsty, etc. Synthesis of vocal calls has many applications for e.g. synthesizing an alarm call may be used to protect the bird from any harmful situation, etc. LPC model has the ability to find out speech parameters for efficient speech synthesis. It has been used for speech coding applications because it has the property of low bit rate speech coding. Since the basic mechanism of vocal sound production mechanism in birds is almost similar to the human speech production mechanism in many aspects. LPC based synthesis may be used for the synthesis of the vocal calls of birds. In this paper, LPC based synthesis approach has been successfully used for the vocal calls of Alexandrine parakeet (Psittacula Eupatria) by estimating different speech parameters. The quality of synthesized speech output has been evaluated using visual analysis of spectrograms, subjective and objective assessment methods keeping in view different MOS and PESQ scores. In order to measure the quality of synthesized output, MOS and PESQ scores should be compared to identify the required quality level.

Index Terms— LPC synthesis, MOS scores, PESQ, Vocal calls.

I. INTRODUCTION

Speech synthesis is an interesting signal processing approach which requires computer simulation for the processing of speech signals using different models of speech generation and synthesis [1]. Speech synthesis can be used for a wide range of applications including man-machine interfacing, as a speech aid for blind and deaf handicapped persons, digital audio books, interactive games and may also used for automated handheld devices, etc [2], [3]. LPC is one of the most powerful and latest synthesis techniques utilized in signal processing for the need of spectral envelope information of speech signals in compact form [4].

Vocal cords are one of the most important speech organs located inside the human's neck and used for the excitation of the vocal tract, but these cords are not present in bird's species. Instead, they have a special interesting organ, known as syrinx and its location exists naturally in the intersection of the trachea. The sound production mechanism by different speech organs in humans is almost similar as compared to bird's in many aspects. The main function of syrinx is to produce different vocal sounds and it also gives information regarding the internal structure of different bird's species because different birds have different syringeal anatomy [5], [6].

There are different varieties of calls used for the vocal communication in psittacines (short vocalizations), and songs (complex vocalizations) which are used to convey some specific kind of information. There are more than 300 species of parrots found across the world. Parrots also found in various sizes i.e. varying from small size to extra large size; For example, the size of Pygmy parrot is only four inches or 10 cm long whereas Hyacinth Macaw parrot occupy the size of almost three feet or one m long. Parrots are also famous for their bright colors. Some parrots are red and blue; some are green and orange while some are also yellow in color. Moreover, some parrots are overall white in color. The parrot's species of birds have a frequency range from one KHz to four KHz for their hearing activities [7], [8].

The biological name of Alexandrine Parakeet is Psittacula Eupatria. They are larger versions of Indian Ringneck's (*Psittacula krameri manillensis*). They occupy a size of about 20 inches long. These species can be geographically distributed in Eastern Sri Lanka, India, Afghanistan and China, etc. They have different attracting appearances and they are usually recognized by their size and multiple colors. A black stripe is generally found under their neck and the neck is covered by a bright pink collar [9], [10].

The most important sound organs used for the speech production in parrot's vocal communication comprised of lungs, bronchi, tracheal syrinx, larynx, trachea, beak and mouth, as shown in Fig. 1. Different parts of syrinx can be used by different parrot's species to produce vocal calls and songs, and non homologous part of their brain can be used for controlling sound production mechanism. Tracheal type of syrinx is generally found in them. The parrot tracheal syrinx is mostly comprised of different varieties of muscles which include superficial syringeal muscle, stemotrachealis muscle and two lateral tympaniform membranes (LTM). Complex vocalizations are generally produced by them, it occurs due to the anatomical structure of their syrinx with two syringeal muscles. Their tongues can be twisted very easily. They have different syringeal muscles in their interiors [11], [12].

Manuscript Received on November, 2012.

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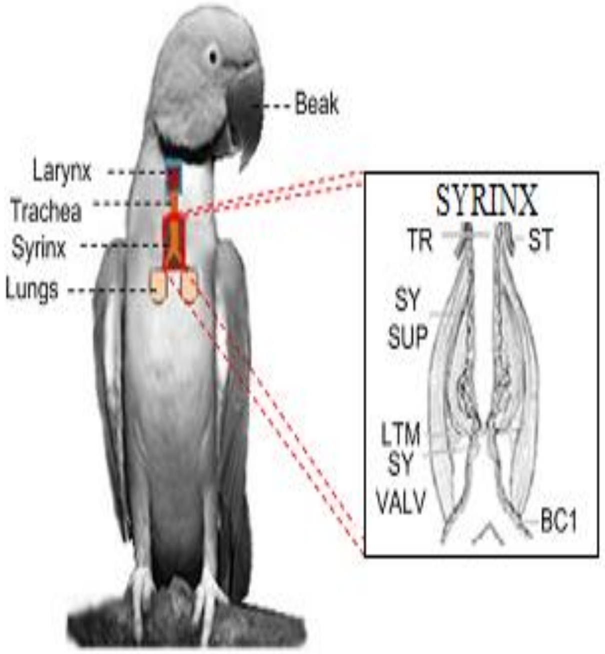

Fig.1. Sound Producing organs of Parrot, modified from [11], [13]

Table I. Parrot Syrinx composition [11]

Main parts	Explanation
TR	Trachea
ST	Stemotrachealis muscle
SY SUP	Superficial syringeal muscle
LTM	Lateral tympaniform membranes
SY VALV	Pneumatic valve
BC1	First Bronchial cartilage

The Parrot syrinx composition is shown in Table I. The sound which gives for a meaningful communicating purpose is known as a bird call. There are various categories of vocal calls produced by parrots for their vocal communication. Alarm call is one of the important calls produced by parrots and it is mostly produced when they feel any danger or unwanted physical activity around them. It is also produced to save other bird's species from danger situations. Pre-flight call is produced by them when they just started to fly and it is noticed as a harsh call. Begging call is a needy call and it is generally produced by young parrots when they feel hungry or thirsty. Distress call gives us an indication about the parrot emotional state Agonistic protest describes parrot anger or disturbed nature due to a particular type of behaviour like jealousy, weakness, etc. Parrots can also produce a special call which shows their sexual behavior, known as mating call. Contact call coordinates the movement of group members when they are flying in the sky for the search of particular vegetation and when it is loud, it can be mutually communicated with other species of flying birds. It is usually the loudest of all the vocal calls [14], [15], [16].

II. LPC BASED SYNTHESIS APPROACH

LPC model has the ability to estimate the parameters of a speech signal effectively for the analysis and synthesis of speech. This model has been used for low bit rate speech coding applications. The LPC model can be divided into two main sections, i.e. the analysis section and the synthesis section. The analysis section is used to analyze the speech signal for the estimation of error signal. It is also used to estimate the coefficients of LPC filter and the pitch, voiced (V) and unvoiced (UV) components for each speech frame. The synthesis section of the model can be used for generating synthesized speech by an input error signal [17], [18]. The LPC based analysis and synthesis is shown in Fig. 2. The first step of the LPC analysis is to filter (BPF) the input signal and pass it through an A-D converter. The output from the A-D is then passed to pre-emphasis filter. The pre-emphasis filter is a first order FIR filter, used for the flattening of speech spectrum. It is used to compensate the high frequency part of the speech signal that was suppressed during the sound production mechanism. Frame blocking is used for the division of frames sequences so that each frame can be analyzed independently and represented by a single feature vector. Window size is used for the reduction of discontinuities in the speech signal at the edges of each frame and hamming window is mostly used for LPC analysis. An interesting filter of LPC model is a linear predictive filter which is used for the prediction of next sample value using a linearly combination of previously sampled values. The mechanism of removing the effect of formants is known as inverse filtering, and the remaining speech signal left after subtracting the filtered signal is known as a residue signal. Voice detector is used to recognize whether the speech signal contains voiced or unvoiced components. Parameter coding is applied after the extraction of all the useful parameters. The pitch information can be obtained when the signal from the A-D is low pass filtered through an 800Hz Butterworth filter. The synthesis section includes decoding process, frame to pitch conversion, coefficient conversion, synthesis filter and De-emphasis filter, etc [19], [20], [21].

III. SPEECH QUALITY MEASUREMENT METHODS

The exact and accurate evaluation of speech quality is an interesting research area that has attracted attention in the field of speech synthesis now-a-days. Basically, there are two main methods employed in the evaluation of speech quality i.e. subjective and objective speech quality assessment methods [22], as shown in Fig.3.

Subjective evaluation is a method in which a group of listeners perform repetitive listening tests carefully so as to give scores for several processed or synthesized speech signals in order to recognize the perceived call quality. In this method, opinionated scores are mathematically averaged to

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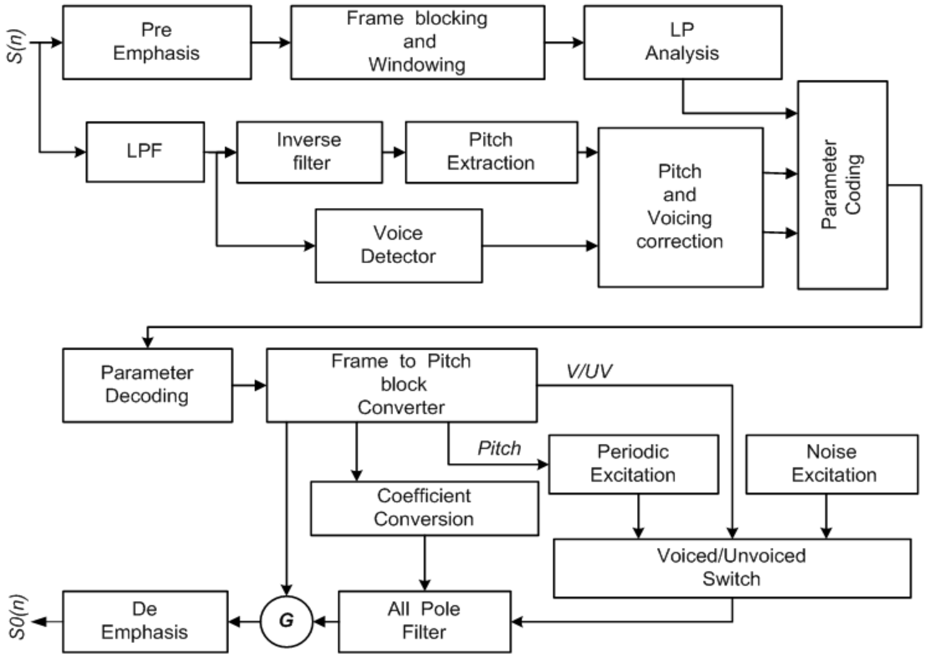

Fig.2. LPC based Synthesis approach, modified from [21]

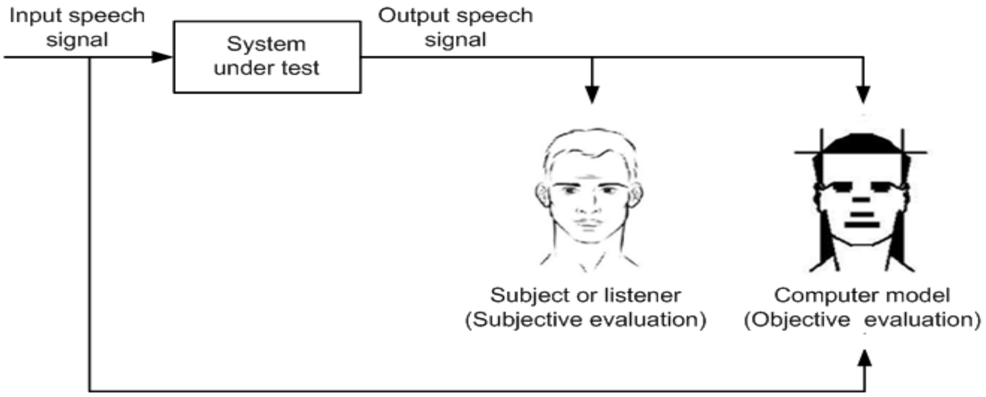

Fig.3. Speech quality assessment methods [23]

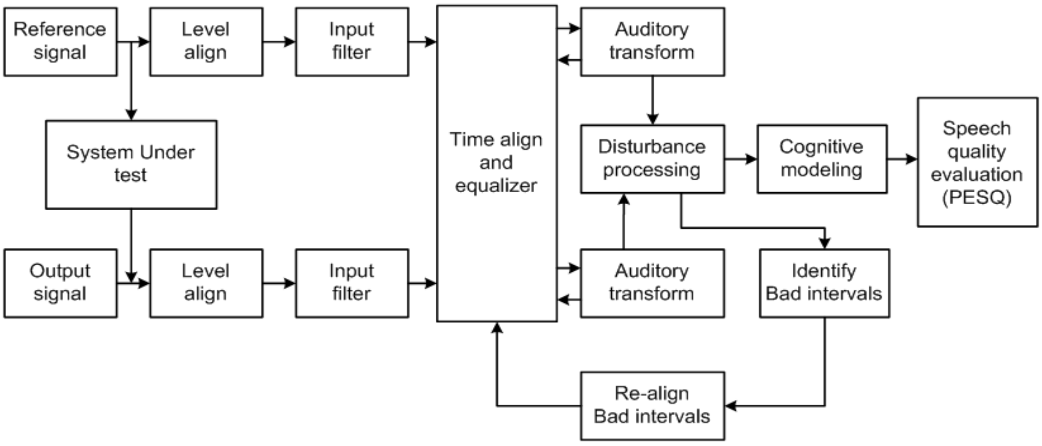

Fig.4. Block diagram of Perceptual evaluation of speech quality (PESQ) [24]

provide a quality level for the speech signals [25].

This method is generally more accurate and robust, but it is time consuming and costly also. Mean opinion score is mostly used as a scoring technique which provides a numerical value for the quality of synthetic speech. It is defined as the arithmetic mean of all the individual ratings that have values in the range from 1 to 5 [26]. The MOS score and their corresponding quality level is shown in Table II

Table II. Mean opinion scores (MOS)

MOS	Perceived quality level
5	Excellent (Imperceptible)
4	Good (Perceptible but not annoying)
3	Fair (Slightly annoying)
2	Poor (Annoying)
1	Bad (Very annoying)

On the other hand, one of the interesting objective evaluation methods, known as Perceptual evaluation of speech quality (PESQ). PESQ estimates MOS scores by comparing processed or synthetic speech signals that have been communicated through the system with the original recorded speech signal that were used as an input to the system. This method has some advantages also i.e. it is less expensive, saves time, money and human resources. It is not interrupted by human errors and provides consistent results [27], [28]. The subjective and objective quality evaluation methods are shown in Fig. 3. The block diagram of PESQ is shown in Fig.4 and has the following main composition:

A. Time alignment

In this section, the delay is assumed as a piecewise constant. The signals are divided into different parts, known as utterances. It provides delay estimate for each utterance and frame by frame delay can be identified for the auditory transform stage.

B. Auditory Transform

It is a transform which maps a speech signal in a form of perceived loudness representing in time and frequency. The auditory transform provides psychoacoustic models for perceptual evaluation of speech signals. It has different stages including bark spectrum, frequency equalization, gain variation equalization and loudness mapping. Gain equalization is needed so that the change in audible power of the two signals i.e. reference and degraded signals do match with respect to each other.

C. Disturbance processing

Disturbance or auditory error is defined as the absolute difference between the reference and test signals. It is processed by different meaningful steps including deletion, masking and asymmetry before a non linear average of time and frequency is measured.

D. Aggregation of Disturbance in frequency and time

PESQ integrates audible error over various time and frequency scales using a method which is designed to measure optimal distribution of error in time and amplitude. The auditory error or disturbance values are calculated using a norm known as '*Lp* norm'.

E. Realignment of Bad Intervals

In some cases, the time alignment block may be failed to estimate a more change in delay which results in large amount of errors corresponding to incorrect delay. These can be identified and labeled as bad frames whose symmetric disturbance is more than 45. Bad sections are realigned and the disturbances are calculated again. A new delay estimate can be calculated using cross-correlation. Finally, all these measurements are used for calculating the MOS scores [24], [27], [29].

IV. RESEARCH METHODOLOGY

The Research methodology can be divided into three sub-parts: Material recording, Visual analysis of spectrograms, Subjective evaluation and Perceptual evaluation of speech quality. The flow chart for research methodology is shown in Fig. 5.

A. Material Recording

Investigations were carried out by recording six different vocal calls of Alexandrine parakeet (*Psittacula Eupatria*) including alarm call, flight call, contact call, mating call, agonistic protest and begging call at different locations. The recording was done in an acoustically protected and noiseless environment with a high quality Sony digital recorder version ICD-UX513F. The digital recorder is a 4GB digital voice recorder having expandable memory capabilities and provides high quality voice recording. The number of bits and sampling frequency used for quantization of vocal calls were 16 bits and 16 KHz respectively. After that, recorded vocal calls were processed, labeled and stored in wav format.

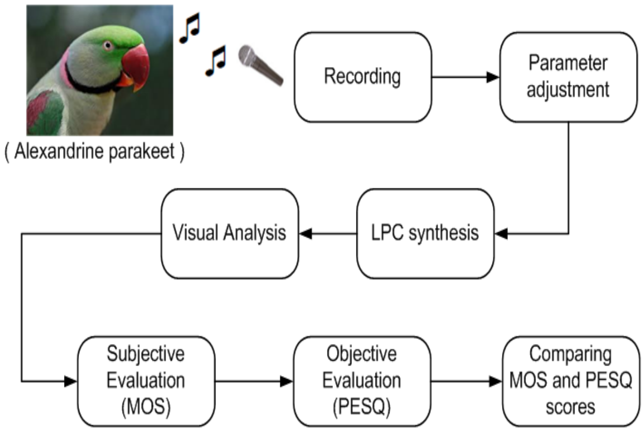

Fig.5. Overview of Research Methodology

B. Visual Analysis of Spectrograms

LPC based analysis and synthesis have been used for the vocal calls of Alexandrine Parakeet. Since LPC parameters exhibit significant effect on the output call quality. So, the recorded calls were analyzed for different parameters of speech.

Speech parameters including size of time frame (*fr*), in ms, size of window (*fs*), in ms and order of LPC (*L*) were adjusted manually at different values in order to make efficient speech synthesis. The spectrogram is basically a machine generated plot which shows different frequencies present in a speech signal at each instant of time. The spectrograms of recorded and synthesized vocal calls of Alexandrine parakeet were analyzed for making a visual comparison between original and synthesized call quality keeping in view several factors like formants, bandwidths and amplitudes, frequencies, duration, etc.

C. Subjective Evaluation

For subjective evaluation, the listener must have excellent hearing sense and expert in differentiating the synthesized signal from any sort of distortion or background noise in comparison to natural signal. The listeners should perform quality evaluation in a quiet room and the noise level of the room must be less than 30 dB. The listening test was performed using high quality Sony headphones version MDR-XD200. After listening, each listener score a synthesized call quality by considering Mean opinion scores (MOS) in the range from 1 to 5. The synthesized calls were evaluated by each listener randomly. Each listener scored at least four times a call. So, mean and standard deviation values of calls corresponding to different listeners were calculated. The overall mean value was also calculated for overall estimation of the synthesized quality.

D. Perceptual Evaluation of speech quality (PESQ)

After the subjective evaluation of synthesized calls, an objective speech quality measure, known as PESQ was carried out. This was done to reduce the possibility of human errors and to identify the exact value of quality using computer based model. Different PESQ scores were calculated for six different vocal calls in the range 0.5 to 4.5. The original and synthesized calls were compared using PESQ simulation model and quality scores were calculated for different calls. The average mean value was also calculated for overall estimation of call quality.

V. RESULTS AND DISCUSSIONS

Investigations were carried out for determining the validity of LPC model for the analysis and synthesis of the vocal calls of Alexandrine parakeet (*Psittacula Eupatria*). The speech parameters were adjusted manually of the values as '*fs'* = 30 ms, '*fr*' = 20 ms and '*L'* = 21 so to make the synthesized speech acceptable. From the visual analysis of speech through spectrograms, it has been found out that the recorded and synthesized calls are almost similar with respect to various frequencies or formants, amplitudes and duration, etc. Spectrograms for different vocal calls have been analyzed. But, for example, the spectrograms of flight calls, begging calls, contact calls and alarm calls are shown in Fig.6, Fig.7, Fig.8 and Fig.9 respectively.   .

Subjective evaluation has been carried out for six different vocal calls i.e. C1 to C6 by six different listeners ranging from L1 to L5. Mean opinion score (MOS) was scored by the five different listeners in the range from 1(bad) to 5(excellent). MOS scores for the six different vocal calls are shown in Table III and their corresponding block plot is shown in Fig.10. The overall average MOS score was calculated as 4.36.

An objective speech quality measure, known as PESQ (perceptual quality of speech measurement) have been carried out for six different vocal calls of Alexandrine parakeet. The PESQ scores for six different calls are shown in Table III and their corresponding block plot is shown in Fig.11. The overall average PESQ score was calculated as 4.29.   .

Hence, from the estimated parameters, visual analysis of spectrograms, subjective evaluation (MOS scores and their corresponding block plot), Perceptual evaluation of speech quality (PESQ scores and their corresponding block plot), it can be seen in results that the quality of the synthesized output is excellent as the overall mean of MOS scores in case of subjective evaluation is 4.36 and the overall mean of PESQ scores in case of objective evaluation is 4.29. Hence, both the scores (PESQ and MOS) found out to be greater than value 4.

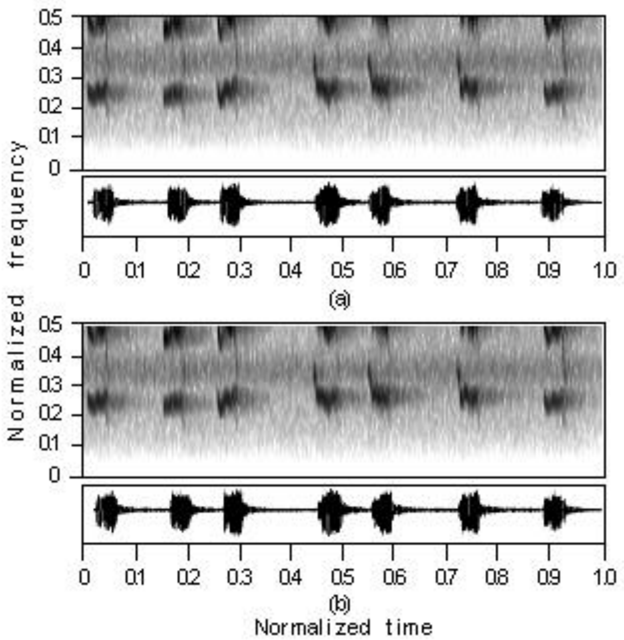

Fig.6. Spectrograms of Flight calls
(a) Recorded call (b) Synthesized call

Fig.7. Spectrograms of Begging calls
(a) Recorded call (b) Synthesized call

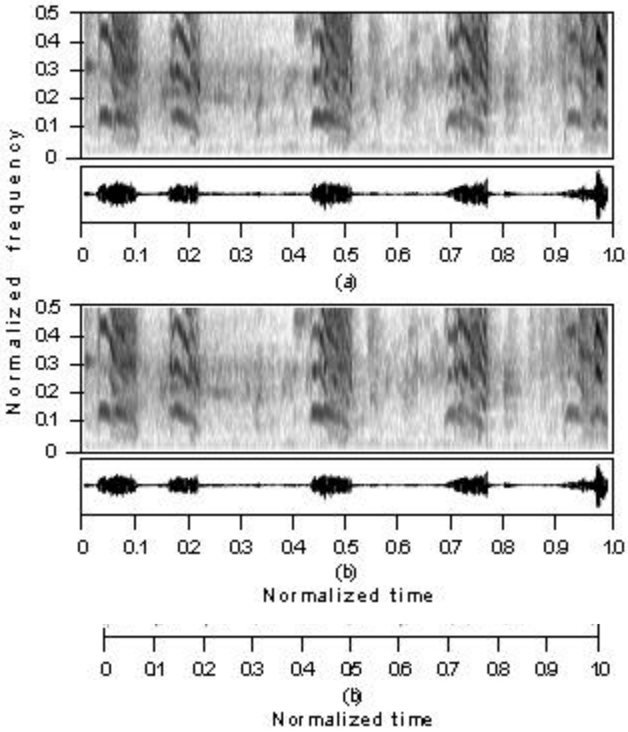

Fig.8. Spectrograms of Contact calls
(a) Recorded call (b) Synthesized call

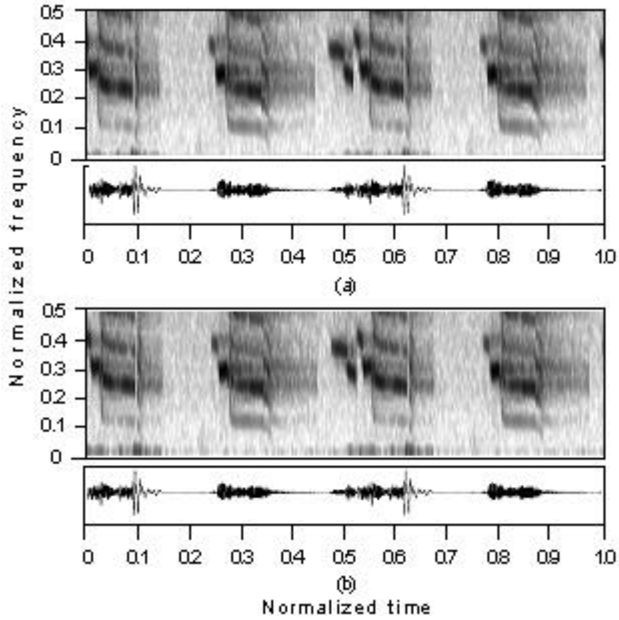

Fig.9. Spectrograms of Alarm calls
(a) Recorded call (b) Synthesized call

Table III. Subjective and Objective Quality Evaluation of synthesized calls

Vocal calls	Listener L1	Listener L2	Listener L3	Listener L4	Listener L5	Subjective Evaluaton (MOS scores)	Objective Evaluation (PESQ scores)
C1	4.5	4.25	3.75	4.5	4	4.20	4.36
C2	4.75	4.25	4.5	4.5	4. 5	4.50	4.22
C3	4.75	4.5	4.5	4.25	4.25	4.35	4.44
C4	4	4	4.5	4.25	4.25	4.20	4.06
C5	4.5	4.75	4	4.5	3.5	4.25	4.21
C6	4.75	4.5	5	4.5	4.75	4.70	4.48

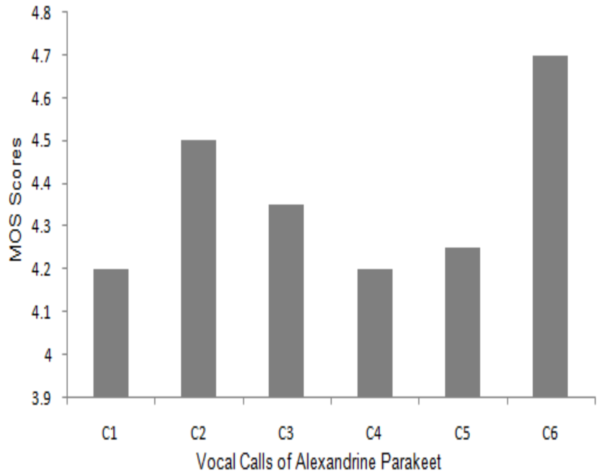

Fig.10. Block plot for MOS scores

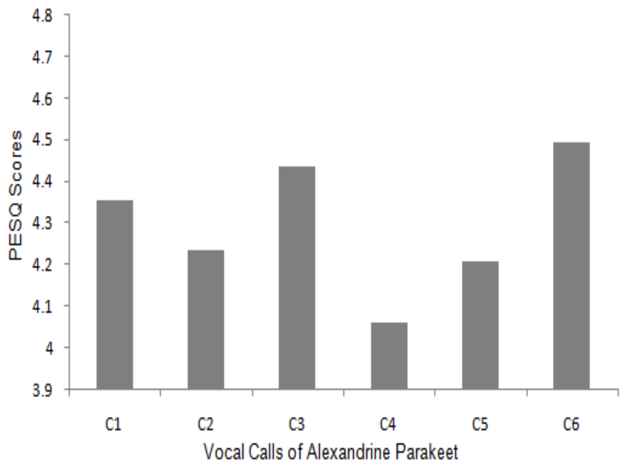

Fig.11. Block plot for PESQ scores

VI. CONCLUSIONS AND FUTURE SCOPE

Birds produce vocal calls for the need of their survival requirements like food, water, nesting, protection from any danger and other useful tasks, etc. For example, alarm call gives an indication for any threat or danger near them. Alexandrine parakeets are the larger version of Indian Ringnecks which can produce complex vocalizations. Also, they are fast learners and mimic human speech very well. They have excellent color recognizing and counting abilities. Six different vocal calls of Alexandrine Parakeet were processed using LPC model. The speech parameters were estimated as L = 21, fs = 30ms and fr = 20 ms and all the spectrograms were analyzed carefully. The quality of the synthesized calls is evaluated by subjective and objective quality assessment methods. By comparing the subjective and objective evaluation (PESQ) methods, we observed that average value of both MOS and PESQ scores were greater than value 4. So, the synthesized vocal calls found out to be of 'quality level - excellent' while applying LPC synthesis and quality assessment methods. Also, there is almost no degradation found in synthesized call quality. So, LPC based analysis synthesis approach has been validated and efficiently used for the analysis and synthesis of the vocal calls of Psittacula Eupatria. Researches can be extended for other species of birds also and comparison can be analyzed between different speech models in the future. Synthesized calls by different models have a lot of future applications like vocal aid, feeding medicine to particular variety of bird to prevent bird's flu, avoiding aeroplane crashes with many bird's species, use of birds for defense related activities, behaviour study of different bird's species, etc.

ACKNOWLEDGEMENT

First and above all, I would like to praise God, the Almighty for providing me this opportunity and granting me the hardworking capabilities to proceed successfully. I would like to pay a special thanks to my parents for everything they have done for me because without them everything wouldn't be possible. It is honour to express my heartfelt gratitude to those who contributed towards the preparation on this research. I am indebted to my guides Prof. P.K Lehana and Prof. Randhir Singh whose invaluable guidance and timely suggestions inspired me to complete the research work in the present form. And last but not the least; I am very much thankful to IJSCE team members for providing us this esteemed platform.

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