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Assessment of Dysarthria Speech disorder through Lung Capacity Estimation

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Abstract

Dysarthria is a communication disorder resulting from acquired progressive neurological disorders such as Parkinson's disease, motor neuron disease, multiple sclerosis, and Huntington's disease. Speech is formed by the acoustic excitation of the vocal tract by an air stream resulting from the lungs and pulsed at a rate that is determined by the vibration of the speakers' vocal folds. EGG Signal of different dysarthria patients are gathered. Wavelet packet coefficient are analysed to extract the energy and entropy measures in different sub band.

Based on this, value clustering is done to group the similar wave sub bands with similar lung air flow. Here feature selection is performed by using kmeans clustering based Cuckoo search algorithm (Improved cuckoo search algorithm). In the modified algorithm, modification is performed on the grouping of the attributes using kmeans clustering. Due to clustering new combinations of feature subset are created, hence can select important features very easily in shorter time.Finally dysarthria diagnosis is performed by using (GA based layered recurrent neural network (LRNN)) GA is used to optimise the weight and bias. In this work, we have included lung capacity as one of the feature in identifying dysarthria disabled person. Splitting the breathing acoustic signal captured and then computing theaverage time duration and energy of the breathing cycleis proposed in this work to estimate the lung capacity.

Keywords: Dysarthria, Cuckoo search, Recurrent Neural Networks, Lung Capacity

Introduction

Dysarthria, a Neuro-motor speech disorder, is a common symptom of various neurological disorders with stroke, Parkinsonism, and traumatic brain injury [1]. Dysarthria can have an impact on the overall communication ability, speech intelligibility, and an individual's ability to join and interact in daily life situations.These disorders are linked to the disturbance of brain and nerve stimuli of the muscles involved in the production of speech. Finally they induce disturbances in the strength, speed, range, tone, steadiness, timing, or accuracy of activitiesneeded for prosodically normal, efficient and intelligible speech. Automatic speech recognition (ASR) is the process by which a computer can identify spoken language or utterances.

Fast advances in ASR technology have led to the pervasive use of ASR systems in various devices, such as smartphones and smart home devices, with a goal of providing an automated assistant system that can record spoken language as accurately as possible.

Moreover, ASR systems specialized for dysarthria have improved ASR performance. Several ASR models based on hidden Markov models (HMMs) or artificial neural networks have been utilized. In this work, the optimized or the best features will be fetched from voice samples. Cuckoo Search will reduce the number of these extracted features to get the best available features from this voice. Classification is performed by introducing the hybrid LRNN-GA algorithm. This classification is carried out on the selected features. Lung capacity is taken as one of the feature in identifying voices.

RELATED WORKS

Lowit et al [6] attempted to analyse the various factors that are involving around the dysarthria disorder. This analysis also focuses on the Parkinson disease and attempted to predict the structural variation between symptoms of different disordered people. This analysis has been done based on varying rhythm captured from the disordered people and made the final conclusion.

Vásquez-Correa et al [7] attempted to predict the varying kind of level in dysarthria over the Parkinson disordered people. This analysis provided the outcome of different level of disease which would occur on the disordered people. This is done extracting the different signal features and learning them using FDA scale procedure. This method ensures the accurate and automated prediction of dysarthria people without having need of medical observations.

WalidMohamedAly, HanyAtefKelleny et al [8] stated that K-means is one of the most popular unsupervised clustering algorithms, though the quality of its results relies heavily on the number of clusters chosen and the right selection of the initial cluster centroids. Cuckoo search is one of the most recent soft computing intelligent algorithms that can be chosen as an efficient search method in many optimization problems.

Rahul Ghose ,Tiyasha Das ,AyoshnaSaha , Tejes Das , SoummyoPriyo, Chattopadhyayet al [9] describedCuckoo search is one of the recent optimization algorithms in the league of nature based algorithm whose results are better than the PSO and ACO optimization algorithms. The applications of Cuckoo includes optimizing weights of neural networks, parameters of Support vector machines and Radial basis function, job scheduling, finding optimal cluster head in wireless sensor networks, finding shortest path and clustering and is aimed to understand the breeding behaviour of the cuckoo bird

Kim, M., Cao, B., An, K., Wang, J et al [10] stated that Dysarthria is a motor speech disorder that impedes the physical production of speech. Speech in patients with dysarthria is generally characterized by poor articulation, breathy voice and monotonic intonation. Therefore, modeling the spectral and temporal characteristics of Dysarthric speech is critical for better performance in Dysarthric speech recognition. Convolutional long short-term memory recurrent neural networks (CLSTM-RNNs) have recently successfully been used in normal speech recognition, but have rarely been used in dysarthric speech recognition.

K-MEANS CLUSTERING BASED CUCKOO SEARCH ALGORITHM (IMPROVED CUCKOO SEARCH ALGORITHM)

Cuckoos are fascinating attractive birds not only they produce beautiful sound but also because of the aggressive reproductive strategy which proves to be combative in nature. They are referred to as brood parasites as they lay their eggs in the communal nests [4]. They remove the host's eggs and replace them by their own. If the host bird discovers the presence of 'alien' eggs then it will throw

away them or leave the nest. But there are some cuckoo birds which have this kind of specialization of mimicking the color and pattern of the egg so that it would create a delusion to the host bird. This results in increase of productivity [1].

Each cuckoo bird puts a single egg at a time which is discarded into anarbitrarily chosen nest. The optimum nest with greater quality eggs is approved over to the next generations. The number of host nests is constant and a host can find an alien egg with a probability (Pa) [0, 1], whose presence leads to either throwing away of the egg or abandoning the nest by the host bird [3]. One has to note that each egg in a nest signifies a solution and a cuckoo egg represents a new solution where the objective is to exchange the weaker fitness solution by a new solution.

The optimized or the best features will be fetched from voice samples. Cuckoo Search will reduce the number of these extracted features to get the best available features from this voice.

The best features are selected as per a Fitness Function. This Fitness Function is based on mean. From every voice the mean is calculated and it is subtracted from each value of that sample. This will fetch the required best values from each voice sample. The required features thus extracted are stored in the database and will be used for speaker recognition [2].

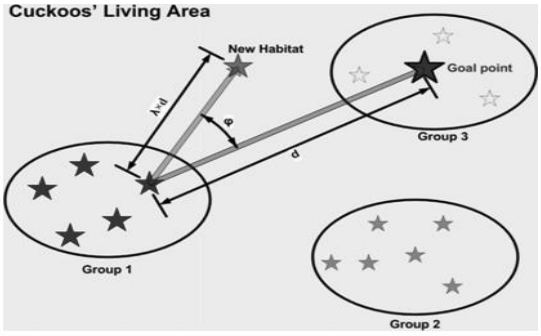

Fig 1: Cuckoo Living Area

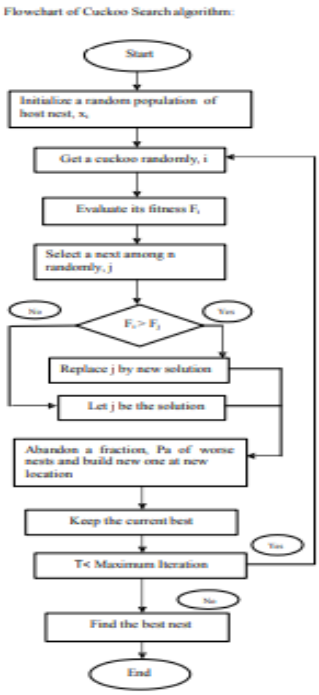

Fig 2: Flowchart of cuckoo Living Area

The algorithm for CSA is as shown which following steps:

(1) Introduce a random population of n host nests, Xi .
(2) Obtain a cuckoo randomly by Levy behavior, i.
(3) Calculate its fitness function, Fi
(4) Select a nest randomly among the host nests say j and calculate its fitness, Fj
(5) If Fi>Fj , then replace j by new solution else let j be the solution
(6) Leave a fraction of Pa of the worst nest by building new ones at new locations using Levy Flights.
(7) Keep the current optimum nest, Go to Step (2) if T (Current Iteration) < MI (Maximum Iteration)
(8) Find the optimum solution

Fitness Function is providing the required optimization.

The following formula is used:

$$(FF) = a_i - (\sum N_i = a_{i/N}) \quad \text{--- (1)}$$

Where FF = Fitness Function, a = Voice Signal

The matched voice will have a high correlation otherwise a low value below the threshold is neglected

GA BASED LAYERED RECURRENT NEURAL NETWORK (LRNN)

Layer recurrent neural networks are comparable to feed forward networks, except that each layer has a recurrent connection with a tap delay related with it. This permits the network to have an infinite dynamic response to time series input data. This network is related to the time delay (timedelaynet) and distributed delay (distdelaynet) neural networks, which have finite input responses.

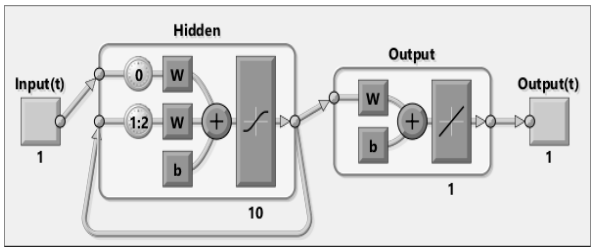

Fig 3: Layered Recurrent Neural Network

LRNN with GA

In this, classification is performed by introducing the hybrid LRNN-GA algorithm. This classification is carried out on the selected features. LRNN has several disadvantages such as long training time, unwanted convergence to local instead of global optimal solution, and large number of parameters and layers; therefore, there have been attempts to remedy some of these disadvantages by combining LRNN with another algorithm that can take care of a specific problem. An algorithm that has frequently been hybridized with LRNN is Genetic Algorithm.

Step 1 (initialization of population). Generate an initial population of chromosomes which are bit strings of randomly generated binary values. The chromosome and population sizes that we used were 44 and 10, respectively.

Step 2 (decoding). Decode chromosomes (bit strings) to find which input variables will be selected.

Step 3 (LRNN).Run LRNN model to make prediction. The parameters in the model that we used were the same as those reported by Inthachot et al.

Step 4 (fitness evaluation). Take the prediction error rate of each chromosome from LRNN as its fitness value for GA.

Step 5 (stopping criterion). Determine whether to continue or exit the loop. The stopping criterion was not more than 10 generations.

Step 6 (selection). Select chromosomes to cross over using tournament selection technique. A tournament selection involves running several tournaments on a few chromosomes chosen at random from the population. The winner of each tournament is selected for crossover.

Step 7 (crossover). Apply an arithmetic crossover operator that defines a linear combination of two chromosomes.

Step 8 (mutation). Inject new genes into the population with uniform mutation operator and generate a random slot number of the crossed-over chromosome as well as flip the binary value in that slot.

Step 9 (replacement). Replace old chromosomes with two best offspring chromosomes for the next generation.

Step 10 (loop). Go to Step 2.

LUNG CAPACITY ESTIMATION

Lung volumes and lung measurements denotes the volume of air in the lungs at unlike phases of the respiratory cycle. The average total lung capacity of an adult human male is around 6 litres of air.

We propose a methodology using the microphone to capture the acoustic signal of respiration and process the signal using voice segmentation and signal energy computation to estimate the speech accuracy of dysarthria disordered people.

Lung capacity refers to the amount of air inhaling to or exhaling from the lung and is measured by L (liters) as a volume measurement unit. The total volume of air voluntarily moved in one's breath from full inspiration to maximum expiration represents the vital capacity (VC) or more precisely, forced vital capacity (FVC) [11]. FVC usually ranges between 4-5L in healthy young men and between 3-4L in young women. Forced Vital Capacity (FVC) is defined as the maximum volume expired after maximum inspiration or the total volume of air exhaled during the expiratory phase, as shown in the following equation:

Estimated Lung Capacity:

$$FVCm = \frac{15e}{100}(0.1524h - 0.0214a - 4.65)\ t \quad \text{---- (2)}$$

FVCf = $\frac{15e}{100}$ (0.1247h – 0.0216a – 3.59) t ---- (3)

Where:m – Male, f– Female, h – Height (in inches), a – Age (in years)

Here, we extract the voice (speech) segments of the breathing cycles and compute the time duration the patient inhales or exhales air.

$$LC_m = \sum_{i=1}^{n}(0.15 * SS_i) * (4.65 * Time) \quad ---(4)$$

$$LC_f = \sum_{i=1}^{n}(0.12 * SS_i) * (3.59 * Time) \quad -- (5)$$

From the above equation (4) and (5) the lung capacity 'LC' is obtained based on the speech signals considered for simulation 'SS_i' and the time duration 'Time' of patient inhaling or exhaling the air. The two factors height 'h' and age 'a' are eliminated as it does not provide any significant changes in the output values.

RESULTS AND DISCUSSION

Here speech data from different people are examined with different algorithms. Speech data is first analysed with Naïve Bayes Algorithm. It is tested with the parameters like accuracy, precision, Recall, fmeasure, RMSE. Then the same data is tested with K-Nearest Neighbor algorithm. Then it is tested with our own Noise and Echo aware Dysarthria recognition Model (NE-DSRM). Finally it is tested with our proposed GA based Layered Recurrent Neural Networks with Improved Cuckoo search optimization algorithm (GALRNN – ICSO). Our proposed system get the maximum accuracy, precision etc. Them the error rate also very less compared with other three algorithms.

Table 1: Comparison of Proposed system with existing algorithm

Metrics	Methods			
	NB-DRM	KNN-DSRM	NE-DSRM	Proposed GALRNN-ICSO
Accuracy	87.95	92.77	93.97	97.03
Precision	77.5	47.23	64.21	96.56
Recall	54.4	49.04	54.918	97.51
Fmeasure	55.08	48.6	56.77	97.52
RMSE	9.25	7.89	4.86	2.815

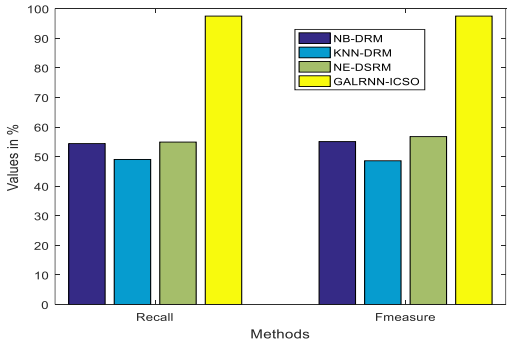

Fig 4: Comparison of Proposed systemwith recall and fmeasure values.

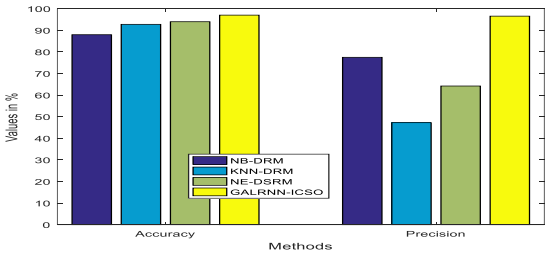

Fig 5: Comparison of Proposed system with Accuracy and precisionvalues

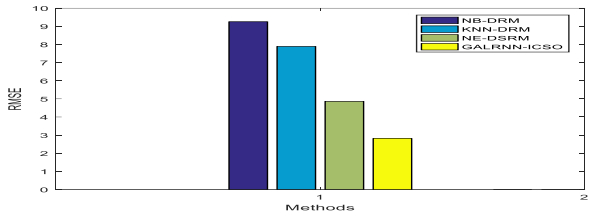

Fig6: Comparison Values with RMSE Values

Conclusion:

In this proposed work, identification of dysarthria disabled people is done using Improved Cuckoo Search Optimization (ICSO) algorithm and GA based Layered Recurrent Neural Networks (GA-LRNN). This work includes lung capacity as an additional feature. Speech is recorded from different set of people and analysed with three existing algorithms and with our proposed algorithm. Our Proposed algorithm shows better accuracy. This system will helps to automatically assess the intelligibility measures of Dysarthria disabled people in a better manner.

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