Real Time Acoustic Sensor Elephant Direction of Arrival Estimation

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***Abstract*— :** In this paper, we implement real time specific target acoustic fingerprint for estimating Direction of Arrival (DOA) and Error Analysis at two different atmospheric conditions. The proposed DOA estimation method comprises of partial hyperbolic circular array for specific target generated random signal generation. The proposed sensor network consists of four nodes arranged in a circular array and all the nodes are Omni directional in nature. We test out proposed system for about circularly covered around 3 Kms with two different forests for specific target (elephants) situated in India. DOA estimation is obtained by pre processing the random signal generated at forest using hyperbolic circular differentiation. In addition to DOA estimation, we are estimating the error analysis factors affecting outdoor propagation of sound in forests with different constraints.

***Keywords*—** acoustic fingerprint, sensor network, Omni directional, error analysis, random signal.

I. INTRODUCTION

Sensor Networking in forest for estimating Direction of Arrival Estimation for specific acoustic source is emerging area in network application in forest[1]-[5]. Sensor nodes are arranged in a circular array with 3kms maximum coverage and their positions are arranged as (Top,Bottom,Left,Right or East/West/North/South). Due to battery power efficiency sensor's are active mode if they detects the signal otherwise all the nodes are sleep mode[12][15]. As soon as sensor detects the signal, acoustic fingerprint is designed and signal pre processing (A/D conversion, Filtering and Compression) are processed [6]-[9]. Using the pre processed signal SPIN routing protocol is designed. If two sensor's store a similar signal in exactly the same SPIN routing protocol is designed to eliminate the signal redundancy occurred in sensor. In order to use the battery energy efficient the sensor network operation used here is synchronous protocol [11]. After estimating the DOA arrival we are identified and work some of the few external factors affecting outdoor propagation in forest [13][15]. The external factors are (i) attenuation from geometrical divergence (distance between source and sensor far away / nearby) (ii) temperature changing the speed of sound profile (iii) wind changing the speed of sound profile[10].

The organization of the paper is structured as follows. Chapter 2 explains the proposed methodology for finding the Direction of Arrival. Chapter 3 demonstrates the simulation results for DOA estimation. Chapter 4 reveals the Error Analysis for external factor affecting outdoor propagation in forest. Chapter 5 outlines the Results and Discussion. Finally, Chapter 6 concludes the paper.

II. METHODOLOGY

Problem Statement: Let us consider an circular omnidirectional array of n sensor which sense the random signal generated at least one target coverage etc, from the specific target around 3 km's with the unknown location or Direction of Arrival (DOA), w be the direction of sensor located in the forest, L be the life time of a sensor, dc be the set of directions that cover a target[6].

Signal model and Assumptions :

The prototype for all Hyperbolic Partial Differential equations of one-way wave equations.

$$u_t + a u_x = 0 \quad (1)$$

where a is a constant, t represents time, and x represents the spatial variable.

III. SIMULATION RESULTS FOR DOA ESTIMATION

Initially we are identifying few outdoor external factors affecting the source localization error in forest. In our real time implementation the acoustic source sound was recorded in three types of forest under different atmospheric condition. Initially the sound was recorded and then signal pre-processing(A/D conversion, compression, filtering) was done[14][3]. In figure 1: shows the original and compressed wave form for 3 elephants. In figure 2 & 3 shows the localization error of running and stand alone elephant with different wind speed.

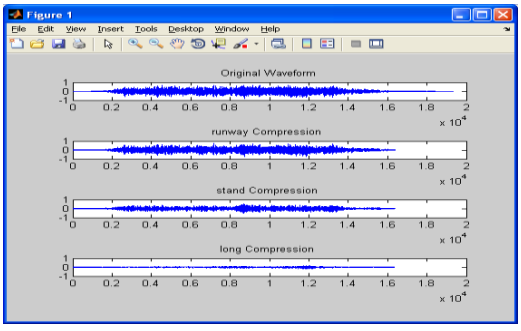
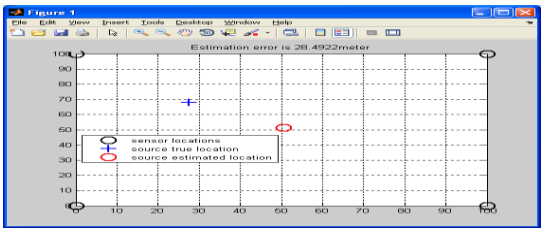
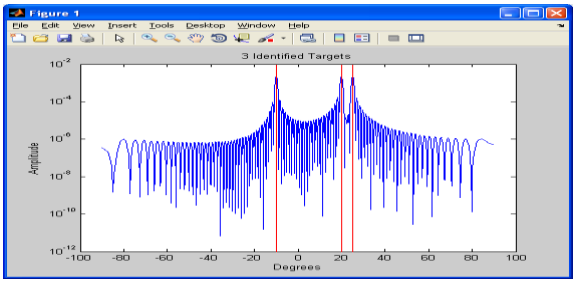


Fig 1: original and compressed wave form for 3 elephants(run away, stand alone and walk)

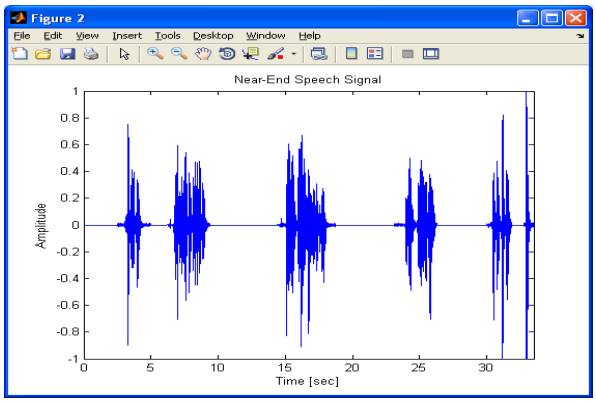


(Fig 2: DOA estimation for run away elephant,when the wind speed is about 2 miles/hour and temp about 72 ^{o}F and 22^{o} C at Mudumalai Forest)

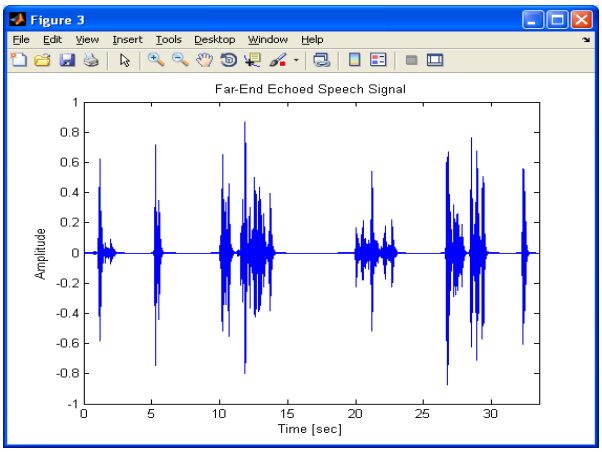
IV. SIMULATION RESULTS FOR ERROR ANALYIS



(Fig 4: Angle fluctuations when elephant is walking around temp 78^{o} F and 87^{o}C and wind direction about 54^{O}NE)



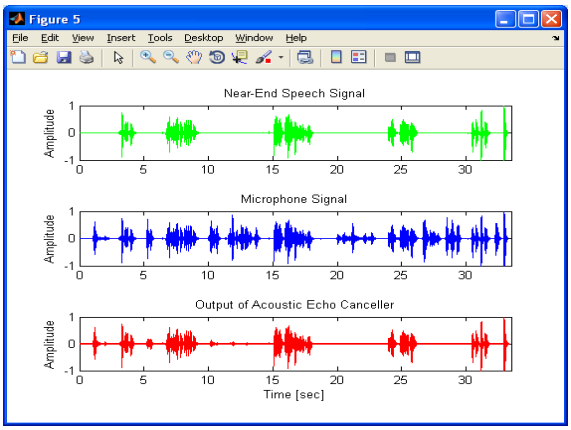
(Fig 5: DOA estimation error when object is near to sensor about 10ft and humidity about 57% at Kodaikanal forest).



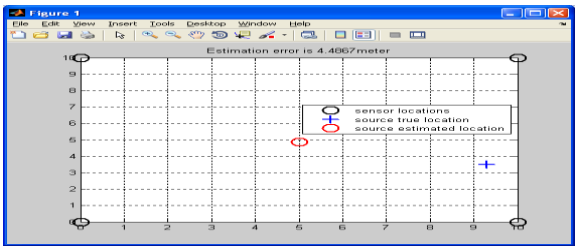
(Fig 6: DOA estimation error when object is far away from sensor about 35ft wind direction about 100^{o}E)

V. RESULTS AND DISCUSSIONS

Our proposed results show that due to some external factors the direction of arrival estimation or source localization error are affected. Due to different position of sensor and source with in nearby (10ft) sensor field the source localization achieves high accuracy. Otherwise source and sensor far away from sensor field, temperature variation and reverberation in forest (echo) affects the localization error.



(Fig 7: DOA estimation error under variation of echo when object is far away from sensor about 75ft and wind speed about 5miles/hour at Palamalai)



(Fig 3: DOA estimation for stand alone elephant,when the wind speed is about 5miles/hour at Palamalai)

VI. CONCLUSION AND FUTURE SCOPE

This paper, we proposed a methodology for estimating direction of arrival and error analysis for outdoor atmospheric conditions using hyperbolic partial circular array. Our DOA estimation results are very encouraging about using limited battery power and minimum number of sensor nodes. In future our work enhances in two directions (i) identifying more external factors (wind direction, humidity, reflection scattering)affecting direction of arrival. (ii) simultaneously monitor and estimating the direction of arrival for more than one source.

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