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Fractional Derivative based Echo Cancellation for Enhancement of Voice Quality

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ABSTRACT
Echo cancellation and echo suppression are the methods to improve the voice quality. For echo cancellation the right path of echo is necessary. When we transmit a sound signal it is severely effected by echo. In this research paper focus is given to fractional derivative based adaptive strategies for echo cancellation. Because the overall performance of fractional derivative based approach is better than other conventional methods of echo cancellation. Other conventional algorithms for echo cancellation are LMS (least mean square) , RLS (recursive least square), and NLMS (normalized least mean square). Where as FNMLS (fractional normalized least mean square) is fractional derivative based method. Therefore, we will exploit this method to improve the performance of echo cancelation algorithm. Various mathematical rule and methods used for fractional derivative based echo cancellation are Taylor series ,Grunawld letnikove method, Roy method , Matsuda method, Riemann Liouville formula and L hopital rule. In this research work I will concentrate on fractional derivative based approach for echo cancellation.

General Term
Echo cancellation , Fractional derivative based approach, Interlacing , Radwan procedure

Keywords
LMS, NLMS, RLS, FNLMS, ERLE, PDES

1. INTRODUCTION
Echo severely effect the transmitted signal. The two parameter on which echo depends are amplitude and time delay of reflected waves. In telecommunication echo is a big issue. Echo distort the transmitted signal. Echo cancellation and suppression are method use to improve the voice quality. Echo suppressor for the first time use for satellite communication. Various algorithms use for Echo cancellation are LMS, RLS, NLMS, FXLMS, FLMS, FXRLS, NRLS (Shah S. S., 2014), (Aslam, 2014), (Shah S. S., 2014). During the design of a system we must consider the problem of echo. We must include echo suppressor and echo cancellation circuit in our system.

The introduction of fractional term in fractional order polynomial increase stability. For cancellation of echo we use Kalman filter and other suppression and cancellation circuit (banesty, 2000), (Jones, 1997), (C.Paleologu, 2013). We reduce error to a minimum value. In case of LMS algorithm more number of iteration is required and system is less stable (S.Ciochin, 2013), (Enzner, 2012), (A.Stenger, 1999), (W.Zhu, 2006).

Least Mean Square have a wide range of application in fractional signal processing (F.Kuech, 2005), (D. Manolakis, 2005), (S.Grant, 2008). For better convergence and stability we will choose step size factor very small (S.Haykin, 1996), (Verges, 2010), (Kalman, 2006).For least mean square algorithm the rate of convergence depends on eigen value (S.Ciochina, 2013), (Gillorie, IEEE), (W.Kellermann, 2008).Echo is the sound of our own voice when we are talking in telephone. The echo is not problematic if its amplitude is small. If echo interval exceed 25 ms it becomes audible to the speaker. Echo can be extremely disruptive to conversation. It can degrade voice quality (P.Eneroth, 2001), (J.Benesty, 2010), (L.Chu, 2010), (Y. Jung . J. Lee, 2000), (D.Simon, 2000), (al S. e., IEEE).

Echo have some application in Radar and Sonar. When radar transmit a signal after transmission of signal it wait for echo. Acoustic echo produce when a sound signal reflected from a surface and it is hear when sound signal came to end. Echo degraded the quality of sound, to overcome echo we use echo canceller and echo suppressor (H.Michael, November 2003) , (N.Sven, 2005).

When two signal coupled together we will use acoustic echo compressor. Acoustic echo compressor technique are used for the removal of noise from signal and improve voice quality (P.Ahgren, 2005), (al S. e., 2006), (L.Fredric, 2007). In public switching telephone network hybrid echo is produce. Hybrid echo is also due to impendence mismatch or where the conversion from one type circuit to another type circuit (S.Gan), (Batalherio P. M., 2008), (Kim S.G, 2008). So to overcome echo we use various mathematical methods for example Couple burger partial differential equation(PDES) using mesh method, Galerkin method, Runwald letnikove method, Saputo, Collocation method and Riesez method (Batalherio P. M., 2004), (Abadi, 2009), (Duttweiler, 2000).

2. METHODS AND MATERIALS
Various methods use for Echo cancellation are LMS , NLMS , RLS and ERLS. We splitting actual and desired signal into small signals. The input and desired signal are first filter into sub band using analysis system. Echo cancellation is then performed on each small signal individually. After which the individual residual error of each sub band are reconstructed into a signal residual error signal using the synthesis system.

- Initially model for the cancellation of echo implemented using least mean square algorithm.
- Initially model for the cancellation of echo implemented using NLMS algorithm.
- Proposed FLMS algorithm will be implemented and comparison performed with LMS.
- A fractional NLMS and some variants will be developed and comparison will be performed with NLMS algorithm.
- Frequency domain and sub band algorithm implementation and comparison with proposed algorithms.

Grünwald Letnikove method to reduce the error between exact and approximate solution
The definition of Grünwald letnikove order derivative is

$${}_{a}^{G}D_{t}^{v}s(z) = lim_{h\to 0}\, z_h^v = lim_{h\to 0}\, h^{-v} \sum_{u=0}^{m} \begin{bmatrix} -v \\ u \end{bmatrix} z(z-uh) \text{ .... (Eq.1)}$$

$$\{\binom{u-a}{m} \sum_{u=0}^{m} \frac{\Gamma(u-v)}{u(u+1)}\}$$

Where $\begin{bmatrix} -m \\ r \end{bmatrix} = -m(-m+1) \ldots\ldots (-m+r-1)$.

$$n_x = \begin{bmatrix} x_2 - x_1 \\ h \end{bmatrix} \text{ and } n_y = \begin{bmatrix} y_2 - y_1 \\ h \end{bmatrix}$$

$$d^v s(g,h) \approx s(g,h) + (-u)s(g-1,h) + \frac{(-u)(-u+1)}{2} s(g-2,h) +$$

$$+ + \cdots + \frac{\Gamma(-u+1)s(a-n,b)}{n!\Gamma(-u+n+1)} \text{ .... (Eq.2)}$$

$$d^m = s(g,h) + (-u)s(g,h-1) + \frac{(-u)(-u+1)}{2} s(g,h-2) +$$

$$((-m)(-m+1))(-m+2) + s\frac{g}{n!(-n+1)} + +\Gamma(-m+1)s(g,h-n) \text{ .... (Eq.3)}$$

The solution of required equation is given below

$$\begin{Bmatrix} c_0 = 1 \\ c_1 = -m \\ c_n = \dfrac{\Gamma(-m+1)}{n!\,(-m+n+1)} \end{Bmatrix}$$

Where Γ(.)is equal to (n-1)!

Riemann Liouville equation is an integral function.

Riemann equation is widely used in fractional derivative based adaptive strategies for echo cancellation. In Riemann equation α is a complex number. The modified form of Riemann equation is given in equation no 4. The upper and lower limit of Riemann equation are u and x.

$$D_x^u F(x) \frac{d}{dx} = b I_x^{m-u-1} F(\tau)\, dt \text{ .... (Eq.4)}$$

Riemann equation in summarized form in equation no 5 is given

$$D_x^v f(x) = \sum_{k=0}^{m-1} \frac{(x-a)^{k-v}}{\Gamma(k-v+1)} f^{(k)a} + \int_a^x \frac{f^{(n)(t)}}{(x-t^{v-n+1})} d\tau \text{ .... (Eq.5)}$$

Analysis of fractional order polynomial for stability of echo cancellation

A fractional order polynomial P(s) is given. Using different formula and rule we find out the even and odd roots of the given polynomial.

$$P(s) = s^{9.2} + 11\, s^{8} + 52s^{7.1} + 145s^{6} + 266s^{5} + 331s^{4} + 230s^{3} + 155s^{2} + 49s + 6$$

$$\begin{bmatrix} -.30904118.1346145331-155 \\ -.30904118.1346145331-155 \\ -.30904118.1346145331-155 \\ -.30904118.1346145331-155 \\ -.30904118.1346145331-155 \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \end{bmatrix}$$

For stability the following two condition are necessary.

a) Leading coefficient of even and odd part of polynomial having same sign

b) Even and odd part parts are in below pattern

$\omega_{1e} < \omega_{1o} < \omega_{2e} < \omega_{2o} \ldots\ldots\ldots\ldots < m_e < m_o$

Where ω_{1e} and ω_{1o} are the roots of fractional order polynomial. We can also prove stability by Radwan methods. Positive real root of even and odd parts of polynomial are determined.

A table (a) of frequency is shown which obey interlacing property.

Table (a)

ω_{1e} = .2061	ω_{6e} = 1.6234	ω_{1o} =.4676
ω_{2e} = .2061	ω_{7e} = 2.8584	ω_{2o} =.4744
ω_{3e} =.7509	ω_{8e} = 4.2520	ω_{3o} =.8336
ω_{4e}.=7678	ω_{9e} = 18.0620	ω_{4o} =1.666
ω_{5e} =1.3403	$\omega_{10e=}$19.9033	ω_{5o} = 1.971

For proper echo cancellation the stability of fractional order polynomial is very necessary.

3. CONCLUSION

Echo cancellation have many significance for robust transmission of acoustic signal. Acoustic echo cancellation is capable of the eliminating of acoustic echo in difficult conditions such as unbalanced speech levels, close speaker to mic proximity, background noise, indoor/outdoor environment, reflective room surface, double talk and echo path changes. For acoustic echo cancellation we use fractional derivative based adaptive strategies. Echo path detection is also very important for radar and sonar communication. For under water communication echo is also very important. To reduce the error we use various algorithm for example LMS algorithm , RLS algorithm, NLMS algorithm and FNLMS algorithms. The overall performance of FNLMS algorithm is better than other conventional methods of echo cancellation.

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