Adaptive Distribution Strategies for Wireless Communication

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ABSTRACT:

Adaptive filter plays an important role in the field of digital signal processing and wireless communication. It incorporates LMS algorithm in real time environment because of its low computational complexity and simplicity. The LMS algorithm encompasses RLS (recursive least square), GN (Gaussian Newton), LMF (least mean fourth) and XE-NLMF algorithms, which provides faster convergence rate and low steady state error when compared to LMS. The adaptive distributed strategy is based on the incremental mode of co-operation between different nodes, which are distributed in the geographical area. These nodes perform local computation and share the result with the predefined nodes. The resulting algorithm is distributed, co-operative and able to respond to the real time change in environment.

By using incremental method, algorithms such as RLS,GN, DCT-LMS and DFT-LMS produces faster convergence and better steady state performance than that of the LMS when simulated in the presence of Gaussian noise. Higher Order error algorithm like LMF, XE-NLMF and variable XE-NLMF algorithm produce better convergence and steady state performance under Gaussian and non-Gaussian noise. A spatial-temporal energy conservation argument is used to evaluate the steady state performance of the entire network. A topology named as CLMS (convex LMS) was presented which combined the effect of both fast and accurate filtering at the same time. Initially CLMS have parallel independent connection, the proposed topology consists of series convex connection of adaptive filters, which achieves similar result with reduced time of operation. Computer simulations corroborate the results.

Keywords:

Incremental, Adaptive, CLMS,INC DCT-LMS,INC DFT-LMS, QWDILMS, XENLMF, LMF, LMS.

INTRODUCTION:

Wireless Sensor Networks (WSNs) is networks composed of tiny embedded devices. Each device is capable of sensing, processing and communicating the local information. The networks can be made up of hundreds or thousands of devices that work together to communicate the information that they obtain. In distributed signal processing Number of nodes are distributed in a geographical area, it collects the information or data which is present in the node. Each node assembles some noisy information related to a certain parameter of interest and performing local estimation, then share the data to the other nodes by some defined rule. The main object behind this is to reach the parameter of interest, which really outcomes from the node after share in the network. In traditional centralized solution the nodes collect the data then send it to the central processor for processing, the central processor process the data then finally again give back the estimated data to all the node.

For this a powerful central processor required and a huge amount of communication between node and central processor required. But in case of distributed solution, the nodes only depends on their immediate neighbor. Hence in case of distributed solution the amount of processing and communication reduced. Distributed solution has large number of application including tracking of target trajectory, monitoring concentration of chemical in air or water, also having application in agriculture, environment monitoring, disaster relief management, medical etc. There are three mode of cooperation namely incremental, diffusion and probabilistic diffusion will discuss. Here we use only the incremental mode of cooperation. This chapter describes about the central distributed algorithm, non-distributed algorithm and the advantage of distributed over non distributed solution. The comparison is done on the basis of convergence rate, steady state performance and computational complexity.

There are two type of algorithm used one is incremental steepest descent solution and other is incremental adaptive solution, comparing both on the basis convergence rate and steady state performance the adaptive solution perform better than steepest descent solution. The more explanation will found each case we consider the variance of noise is small i.e. Less than one, but sometime case arises where the noise 10 | P a g e variance is more than that of one, than a quality aware algorithm is used in the incremental method to maintain the steady state performance. The convergence performance of LMS (least mean square) algorithm depends on the correlation of the input data and the Eigen value spread of the covariance matrix of the regressor data. The smaller Eigen value of auto-correlation matrix results in slower convergence and larger Eigen value limit the range of the allowed step size and thereby limit the learning abilities of the filter.

Best convergence result when all the Eigen value equal i.e. having unit Eigen spread, this is possible only when auto correlation matrix is constant multiplication of identity matrix. This can be achieved by pre-whiten the data by passing it through pre-whiten filter which is practically not possible. Hence same thing will achieve by unitary transformation of data, such as DFT (discrete Fourier transform), and DCT (discrete cosine transform). Adaptive algorithms based on the higher order moments of the error signal found performs better than that of LMS algorithm in some important application. The practical use of such type application is not considerable because of its lack of accuracy in the model to predict the behavior. One of such type of algorithm is LMF (least mean fourth) algorithm, which minimize the mean fourth error.

It is found that the LMF algorithm outperforms than the LMS algorithm in non Gaussian noise case. We will find the family of LMF algorithm and its performance in both Gaussian and non Gaussian noise case in the chapter 4. Generally fast filter gives higher convergence rate and accurate filter gives better steady state performance. An algorithm developed named CLMS (convex LMS) algorithm which consists of two adaptive filters connected parallel. The CLMS algorithm track initially the faster convergence respond, then followed the accurate response. It has advantage that it achieve both at the same time.

It is very difficult to develop a filter which provides both at same time. Hence this algorithm has number of application in the distributed signal processing.

Incremental Adaptive Strategies over Distributed Network:

In Distributed processing number of nodes are distributed in a geographical area, it extract the information from data collected at nodes. For example nodes distributed in a geographical area collects some noisy information related to a certain parameter, than share it with their neighbor by some defined network topology, the aim is to reach the required parameter of interest. The objective is to reach the exact parameter of interest and it should same as it outcome from the nodes estimation in the geographical area. In a comparison Distributed solution is better than that of centralized solution because in centralized solution a central processor is required, nodes collect noisy information than send it to the central processor for process, central processor process the data than send back to all nodes. Hence for this a heavy communication between node and central processor required and a powerful central processor also required, but in distributed solution, the nodes only depends upon their local data and an interaction with the immediate neighbors. Distributed solution reduces the amount of processing and communication.

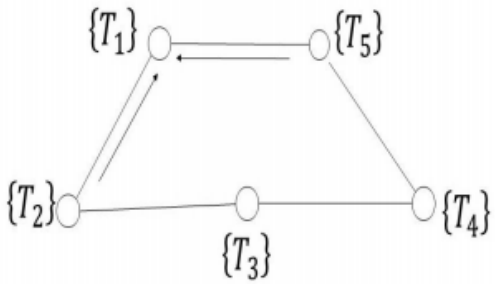

Fig. 1 Distributed network

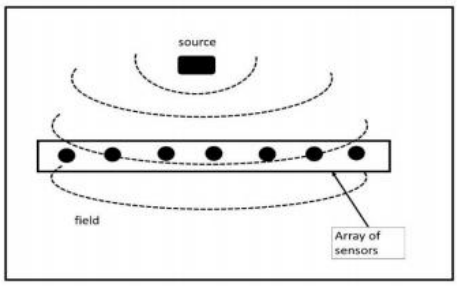

Fig. 2 monitoring a diffusion phenomenon by a network of sensors

Applications:

Consider there are N number of nodes are distributed in a geographical area as shown in Fig.1. Each node collect some noisy temperature measurements . The main goal is to give all the node information about the average temperature $\bar{T}$. This can be possible by using the distributed solution known as consensus implementation, which states that one node measurement combines with the measurement of the immediate neighbor node and the outcome become the nodes new measurement.i.e. For node 1 we can write that

$$x_1(i) \leftarrow \alpha_1 x_1(i-1) + \alpha_2 x_2(i-1) + \alpha_5 x_5(i-1)(node\ 1)$$

Where $x1$ (i) update measurement for node 1and α's are appropriately chosen coefficients. Similarly we can apply the same update process to other nodes and repeat the process. By suitably choosing α and network topology all the node finally converge to desired average temperature $\bar{T}$. Another Application is it is also very useful to monitor the concentration of a chemical in air or water by collecting the measurements in time and space by number of sensors as shown in Fig.2. The measurements collected from number of sensors used to estimate the parameter $\{\theta 1, \theta 2, \theta 3\}$ that calculate the concentration of chemical in the environment by some diffusion equation with some boundary condition. e.g.,

$$\frac{\partial c(x,t)}{\partial t} = \theta_1 \frac{\partial^2 c(x,t)}{\partial x^2} + \theta_2 \frac{\partial c(x,t)}{\partial x} + \theta_3 c(x,t) + u(x,t)$$

Where c(x,t) indicates the concentration at location x at time t. Another Application of distributed processing is to monitoring the moving target by collecting the signal from different sensors, with the help of the sensors we can find the presence of the target and we can also track its trajectory. Distributed network links to pc, laptop, cell phones and sensors forms backbone for future data communication and Network.

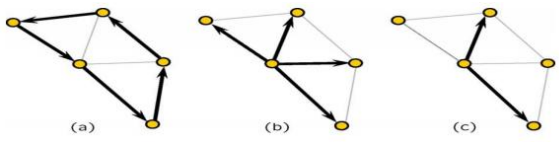

Fig. 3 three mode of cooperation (a) incremental (b) diffusion (c) probabilistic diffusion

Modes of Cooperation:

The successes of any Distributed Network depends upon the mode of cooperation that used among the nodes. There are three mode of cooperation as shown in Fig.3. In an incremental mode of cooperation the information flows in one direction from one node to adjacent node. Incremental mode of cooperation follows a cyclic pattern among the nodes, and it requires least amount of power and communication. In diffusion mode of communication the information flows to all the nodes connected to that node where information starts to communicate, it requires more power and communication than that of Incremental mode of cooperation. It is complex than that of incremental mode of cooperation.

In case of incremental mode of cooperation if one node is failed than we cannot get the information that is the network fails to transmit the information, which is one of the disadvantage of incremental mode of cooperation but this problem can be solved in diffusion mode of cooperation because if one node failed than we can collect information from any of its connected node, since the information flows to all the connected node in case of diffusion mode of cooperation. But the design of Diffusion mode of cooperation is more complex than that of incremental mode of cooperation and also it requires more power and communication than that of incremental mode of cooperation. In case probabilistic mode of cooperation the information flows to subset of number of nodes that is connected to a particular node .It also require more power and communication than that of incremental mode of cooperation. Here I used Incremental mode of cooperation for all my work.

Consensus Strategy:

The temperature example explain in section 2.2 represents the consensus strategy. Consensus strategy states that first every node collects noisy information and update itself to reach an individual decision about a parameter of interest. During updating period each node act as an individual agent i.e. there is no interaction with the other node, then according to consensus strategy all the node combines their estimates to converge asymptotically to the desired global parameter of interest. Let consider another example to understand the consensus strategy properly. Let each node has a data vector yk and a data matrixHk. For some unknown vector w 0 the noisy and distorted measurement yk is given by

$$y_k = H_k w^0 + v_k$$

Each node estimate for w 0 by using its local data $\{yk,$ $\}$ .for estimate, the node should evaluate the local cross correlation vector $\theta k = Hk*yk$ and its autocorrelation matrix$Rk = Hk*Hk$. Then, the local estimate for w 0 can be found from $\hat{wk} = Rk - 1\ \theta k$ .similarly each node should estimate its local estimation, then a consensus iteration apply to all node to calculate $\hat{R}$ and $\hat{\theta}$ defined by as follows

$$\hat{R} = \frac{1}{N}\sum_{k=1}^{N} R_k \quad \text{And} \quad \hat{\theta} = \frac{1}{N}\sum_{k=1}^{N} \theta_k$$

A global estimate of w 0 is given by$\hat{w} = \hat{R}-1\hat{\theta}$. For all practical proposes, a least square implementation is an offline or non-recursive solution. A difficulty is come when one particular node collect one more data and updating for the optimal solution w 0 without repeating the prior process and iteration. The offline averaging limits the consensus solution, especially when the network having limited communication resources.

RESULTS:

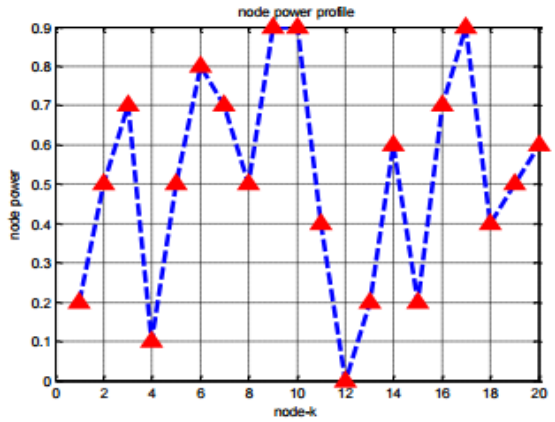

Fig.Regressor power profile

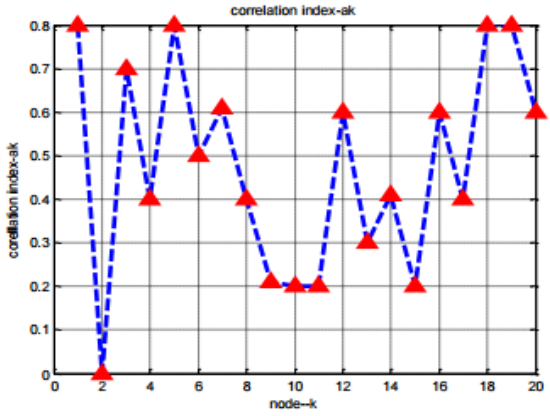

Fig. Correlation index per node

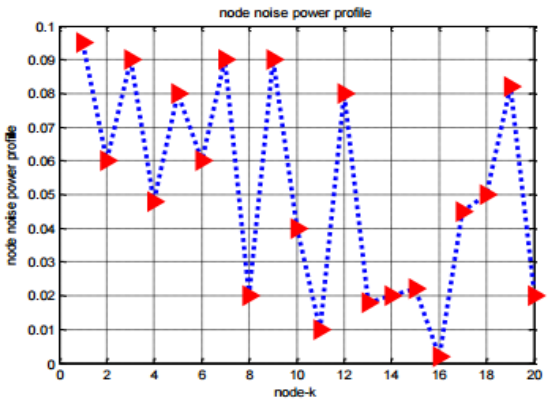

Fig. Noise power profile

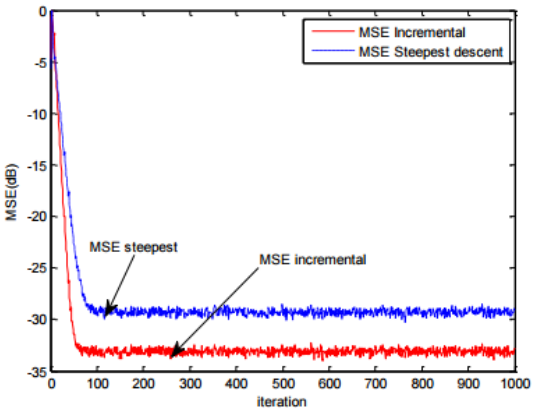

Fig. Transient MSE performance at node 1for both incremental adaptive solution and stochastic steepest descent solution

CONCLUSION:

Distributed signal processing has wide number of application in the field of signal processing. Day to day number of algorithms are developed to improve the convergence rate, steady state performance and to reduce the computational complexity. Here in this thesis number of algorithms like incremental steepest descent algorithm, incremental adaptive solution, INC RLS, INC GN, INC LMF, INC XE-NLMF, INC variable XE-NLMF, INC CLMS, QWDILMS, INC DCT-LMS, INC DFT-LMS algorithms are tested to achieve the same. In case of INC RLS, INC-GN algorithm it achieve the goal but the computational complexity is more than that of previous. The algorithms are tested under different noise condition and at different SNR case it is found that the lower order error algorithms like INC RLS,INC GN,INC DCT-LMS,INC GN and INC DFT-LMS perform better than that of LMS algorithm under Gaussian noise case, but it fails to achieve the same under non Gaussian noise case like under binary noise , sinusoidal noise and uniform noise.

By experiment it is found that the higher order noise algorithm like LMF algorithm, XE-NLMF and variable XE-NLMF algorithm performs better than that of LMS algorithm under non Gaussian noise case. In all case we consider the SNR is uniform i.e. the variance of noise in all the node present in the network is less than that of one. But it not happens always practically. It is found that in number practical application the SNR of one or more node is less than that of other on that case the algorithms are fails to give better performance by using incremental adaptive strategies. To improve the performance the algorithms like QWDILMS developed which improves the steady state performance under noisy node condition by assigning special weights to each node. But the disadvantage of this algorithm is it only improves the steady state performance but not effects on the convergence rate. But by proper design the convergence rate of the QWDILMS algorithm also will improve.

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