Perspectives in Science (2016) **8**, 43—45

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Design of ANC filter using modified cuckoo search technique for ECG signal enhancement☆

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Received 5 January 2016; accepted 24 March 2016
Available online 2 April 2016

KEYWORDS
ANC;
MCS;
ECG;
SNR;
MSE;
ME;
HHT

Summary In this work, the design of an adaptive noise canceller (ANC) filter is presented using modified cuckoo search (MCS) optimization technique. The proposed scheme is applied for de-noising of ECG signals. Our simulation results reveal that the ANC filter based on MCS algorithm provides superior performance than other optimization techniques used to enhance the ECG signal. The performance of ANC filter is compared with other reported algorithms by evaluating the fidelity parameters such as the signal to noise ratio (SNR), maximum error (ME) and mean square error (MSE). The proposed ANC filter design with MCS scheme gives 18% improvement in output SNR, 87% decrease in ME, and 85% reduction in MSE over the recently reported Hilbert Huang Transform (HHT) technique.

Introduction

Electrocardiogram (ECG) signal is an electric signal generated in heart. It picks up electrical impulses generated by depolarization and polarization of the four chambers of heart. There are various types of noises in ECG signal like electrode contact noise, power line interference etc. In terms of frequency, noise can be divided into two categories. (1) High frequency noise caused by power line interference (Taralunga et al., 2015), electromyogram (EMG) generated from chest wall, and mechanical forces on electrodes. (2) Low frequency noise i.e. baseline wander caused by the

☆ This article belongs to the special issue on Engineering and Material Sciences.

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http://dx.doi.org/10.1016/j.pisc.2016.03.002
2213-0209/

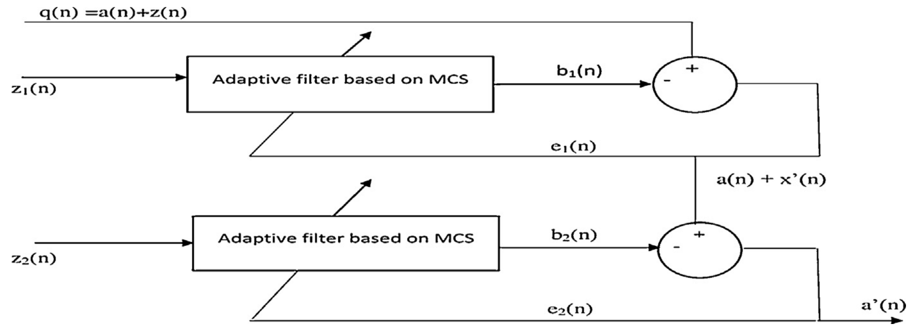

Figure 1 Noise cancellation based on MCS.

respiration or the movement of the patients or the instruments (Xin-She, 2010; Rahman, 2010). Noise in ECG signal is reduced by an adaptive filter (Diniz, 2008; Widrow et al., 1975) which act as adaptive noise canceller filter (ANC) due to its self-learning technique making it capable of altering its coefficient to minimize error. In Fig. 1, $z_1(n)$ and $z_2(n)$ are high and low frequency noise which are generated in MATLAB.

It may be noted that the $z_1(n)$ and $z_2(n)$ are correlated with $z(n)$ but uncorrelated with $a(n)$. The reference noise $z_1(n)$ and $z_2(n)$ are fed to ANC filter to produce output $b_1(n)$ and $b_2(n)$. The error signal $e_1(n)$ is computed as the difference of q(n) and $z_1(n)$, which is fed back to ANC filter in each iteration which will continue till $e_1(n)$ or the high frequency noise is minimized in first stage. The output signal, $a(n)+z'(n)$ containing low frequency noise is given to second stage of ANC filter where the error signal $e_2(n)$ is computed as the difference of $a(n)+z'(n)$ and $z_2(n)$. The final output signal ($a'(n)$) is nearly equal to $a(n)$.

Design of adaptive noise cancellation using MCS technique

ANC is usually implemented using two types of gradient based algorithms: Least Mean-Square (LMS) (Hong et al., 2006; Rahman, 2010) and Recursive Least-square (RLS) (Rani et al., 2012). We formulate the ANC problem as an optimization work so that the probability of encountering the global optimum is maximized. In comparison to other optimization algorithms, the MCS provides advantages of faster convergence rate, simplicity, strong global search, few adjustable parameters, and ease of implementation (Valian et al., 2011; Walton et al., 2011). At each iteration, we have to find the MSE for each particle as:

$$\mathrm{MSE} = \frac{1}{M}\sum_{j=1}^{M}(ejk(m))^2 \quad (1)$$

where $e_{jk}(m)$ is kth error of jth particle and M is the total number of samples of applied input.

It may be observed that the MCS gives a range of possible solutions in a single iteration cycle. The design procedure of the ANC filter is as follows:

Step 1: Set the number of nest. Nest is different solutions. Here it is 20. The probability is set with discovery rate. Set stopping criteria, which is either fixed number of iteration or the tolerance value which is already predefined. Set number of dimension as 3.

Step 2: Generate n different nests for obtaining n different solutions randomly.

Step 3: Find best nest corresponding to minimum value of suitability.

Step 4: Start iteration, generate new nest by Lèvy flight (Fister et al., 2014; Roy and Chaudhari, 2013) but keep the current best. A Lèvy flight is performed by the equation:

$$x_i(t+1) = x_i(t) + \alpha * \text{Lè vy}(\lambda) \quad (2)$$

where α is the step size and is linked to the size of optimization problem, * is entry wise multiplication, and Lèvy (λ) is Lèvy flight distribution. Lèvy flight distribution is defined as

$$\text{Lé vy} \approx u = t^{-\lambda} \quad 1 \le \lambda \le 3 \quad (3)$$

For large-scale search space, Lèvy flights are better than Brownian random walks because the variance (σ^2) parameter of Lèvy flights increases at higher rate than Brownian random walks case. Variance of Lèvy flight distribution is given by:

$$\sigma^2 \approx t^{3-\beta} \quad 1 \le \beta \le 2 \quad (4)$$

where β is scale factor, controlling deviation of other solution of search space from cuckoo egg.

Step 5: Compare the old suitability with the new suitability and replace old suitability if new fitness is better than the old one. Update the best nest correlating to fitness.

Step 6: Repeat the above process until some stopping condition is achieved giving the best fitness and corresponding best nest.

Controlling parameters for CS are NS, Max. number of iterations (NOI), α and p_{a1}. In order to reduce the MSE of ANC filter, the values of NS and $pa1$ are taken as 25 and 0.25, for the CS technique (Fister et al., 2014; Kamat and Karegowda, 2014). The value of NOI is taken as 100 with $\alpha = 1$ in our simulations.

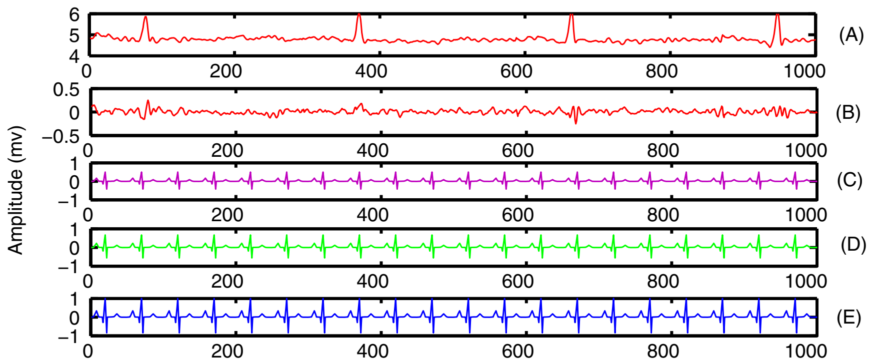

Figure 2 (a) Corrupted ECG signal, (b) motion artefacts, (c) signal filtered through LMS, (d) signal filtered through HHT, (e) signal filtered through MCS.

Table 1 Fidelity parameters calculated for LMS, HHT and MCS.

Parameters	LMS	HHT MCS	MCS
Input SNR (dB)	12	12	12
Output SNR	20.21	21.64	26.43
ME	4.46×10^{-2}	3.34×10^{-4}	4.32×10^{-5}
MSE	4.32×10^{-3}	2.6×10^{-4}	3.76×10^{-5}

Simulation results

Let us calculate the performance parameters of ANC utilizing MCS technique.

$$\text{SNR (dB) at input}: \quad \text{SNR}_{\text{dB}} = 10\log_{10}\frac{(S_{pure})^2}{(S_{noisy}-S_{pure})^2} \tag{5}$$

$$\text{SNR (dB) at output}: \quad \text{SNR}_{\text{dB}} = 10\log_{10}\frac{(S_{pure})^2}{(S_{filtered}-S_{pure})^2} \tag{6}$$

$$\text{Mean square error}: \quad \text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(S_{filtered}-S_{pure})^2 \tag{7}$$

$$\text{Maximum error}: \quad ME = |(S_{filtered}-S_{pure})^2| \tag{8}$$

where S_{pure} is the pure ECG signal, and S_{noisy} is the noisy ECG signal which are combined to get $S_{filtered}$ as the filtered ECG signal at output terminal. The various fidelity parameters evaluated for the HHT (Song et al., 2011; Soorma and Singh, 2014) and MCS is given in Table 1. The proposed algorithm achieves 18% higher output SNR, 87% decrease in ME, and 85% reduction in MSE HHT technique. Therefore, the proposed technique gives appreciable improvement (Fig. 2).

Conclusion

In this work, we have designed ANC filter using MCS technique to reduce the noise present in ECG signal. The simulation results illustrate the superiority of the given method in terms of improved values of fidelity parameters like SNR, ME, and MSE. A comparative study of the MCS algorithm has been made with that of the HHT method for ECG noise reduction. From our simulation results, it is evident that the given filtering of ECG signal using MCS scheme can be a superior alternative approach for ECG enhancement process.

References

Diniz, P.S.R., 2008. Adaptive Filtering: Algorithms & Practical Implementation. Springer, pp. 54—58.

Fister Jr., I., Yang, X.S., Fister, D., Fister, I., 2014. Cuckoo search: a brief literature review. Stud. Comput. Intell. 516, 49—62.

Hong, W., Rongshen, F., Li, S., 2006. The elimination of 50 Hz power line interference from ECG using variable step size LMS adaptive filtering algorithm. Life Sci. J., 90—93.

Kamat, S., Karegowda, A.G., 2014. A brief survey on cuckoo search applications. Int. J. Adv. Res. Comput. Commun. Eng. — IJARCCE 2, 7—14.

Rahman, M.Z.U., 2010. Baseline wander and Power line interference elimination from Cardiac signals using Error Nonlinearity LMS algorithm. In: ICSMB, pp. 217—220.

Rani, R., Kumar, D., Singh, N., 2012. Design of ANC using RLS filter: a review. Int. J. Adv. Res. Comput. Sci. Softw. Eng. — IJARCSE 2, 430—433.

Roy, S., Chaudhari, S.S., 2013. Cuckoo search algorithm using Lèvy Flight: a review. Modern Educ. Comput. Sci. 12, 10—15.

Song, J., Lin, S., Zhao, C., Liu, H., 2011. Decomposition of seismic signal based on Hilbert Huang Transform. BMES 1, 813—816.

Soorma, N., Singh, J., 2014. Feature extraction of ECG signal using HHT algorithm. Int. J. Eng. Trends Technol. — IJETT 8, 454—460.

Taralunga, D.D., Gussi, I., Strungaru, R., 2015. Fetal ECG enhancement: adaptive power line interference cancellation based on Hilbert Huang Transform. In: IEEE International Conference on Neural Network, pp. 77—79.

Valian, E., Mohanna, S., Tavakoli, S., 2011. Improved cuckoo search algorithm for feed forward neural network training. Int. J. Artif. Intell. Appl. (IJAIA), 210—214.

Walton, S., Hassan, O., Morgan, K., Brown, M., 2011. Modified cuckoo search: a new gradient free optimization algorithm chaos solitons fractals. Int. J. Math. Model. Numer. Optim., 710—718.

Widrow, B., et al., 1975. Adaptive noise cancellation: principles and applications. Proc. IEEE 1, 692—716.

Xin-She, Y., 2010. An introduction with metaheuristic applications. Eng. Optim. 1, 1—5.