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Canceling donor interference in heart transplantation using adaptive signal processing techniques

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ABSTRACT

Heart Attack and other cardiac diseases have shooted up the death rate in the world in recent years. So they have to be given more importance. Though the Heart transplantation techniques has originated in 1960's it gained popularity only in 1980's, after the invention of Anti Rejection Medicine. Now the advancement is such that, the patient's old heart ECG can alone be monitored by suppressing the interference arising from the new heart, which ease the job of the surgeon, which can be achieved using Adaptive Noise Cancellation Technique. The algorithms such as LMS and RLS were implemented using MATLAB 6.5 and simulated and synthesized using Modelsim and Leonardo spectrum VLSI tools. In future the design will be fused into a chip and dedicated to mankind.

Introduction

Among all organs, Heart is the major part of the body. There are some peculiar cases in which cardiac diseases cannot be cured. Hence for Heart Transplantation which is a highly risky procedure and 5 year mortality rate is about 60%. The life of the patient may vary from days to years. Texas Heart Institute in United States has reported that, 4000 patients are waiting for heart transplantation per year. But only 2300 Donors are available per year[3]. After transplantation, for research purposes, one would like to determine the firing rate of old heart. While observing the ECG of old heart, the donor heart ECG interferes with it and hence to cancel this we go for adaptive noise cancellation Techniques.

Heart transplantation:

The procedure developed by Norman Shumway of Stanford university consists of removal of portion of recipient's heart leaving the posterior walls of atria and aorta and pulmonary arteries. It involves suturing of new heart to a portion of remnant old heart. Scar tissue formed at suture line electrically isolates the small remnant of old heart(Containing only the Sino Atrial Node) from the new heart which contains both Sino Atrial node and Atrio Ventricular Node[1]. Unlike old heart, sinoatrial node of new heart is not connected to central nervous system, but it beats at a separate self pacing rate. The fig:1 shows the procedure for Heart Transplantation.

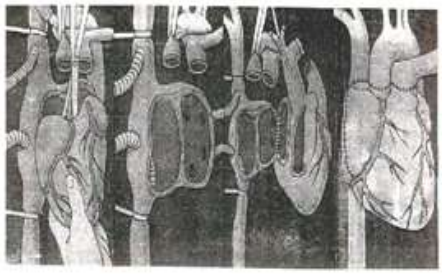

Fig:1Heart Transplantation Procedure

How the donor heart ECG interferes:

For Research purposes, we need to monitor the ECG of old heart. Since conventional methods are not applicable, a catheter consisting of small coaxial cable is threaded through the left brachial vein and the venecava to position of atrium of old heart[1]. But the catheter receives cardiac electric signals of both donor and old heart. This is due to the possibility of sino atrial nodes of both hearts close to each other [1].

Thus the donor heart ECG interferes, which needs to be suppressed. For that, we go for Adaptive noise cancellation techniques.

Adaptive filters:

An adaptive filter is essentially a digital filter with self adjusting characteristics. We generally go for adaptive filters when there is a spectral overlap between the signal and noise and band occupied by noise is unknown or varies with time[2]. Basically an adaptive filter can be modeled as an noise canceller. Let us assume that the signal Sk is contaminated by a noise Nk.

Yk = Sk + Nk----------(1)

Let us assume that the signal and the noise are uncorrelated with each other. The desired signal estimate is found out by,

S1k = Yk - N1k---------- (2)

S1k = Sk + (Nk – N1k)----------(3)

The estimate of Nk is N1k and is found out by,

$$N1k = \sum_{i=0}^{N-1} Wk(i)\ Xk\text{-}i \text{----------(4)}$$

Xk be the correlated noise.

Wk(i) are the adjustable filter coefficients.

Canceling donor heart interference using adaptive noise cancellation technique:

The Block Diagram for the technique is shown in the fig:2. The Primary input taken from catheter lead refers the combination of both old and new heart ECG signal. Reference input taken from the chest leads refer to new heart ECG signal. This reference input is given as input to Adaptive Filter.

Thus the desired old heart ECG signal is obtained by subtracting the estimate of new heart ECG signal from the primary input signal.

Desired old heart ECG = Primary Input – Estimate of Reference Input.

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Adaptive algorithms used for noise cancellation:

Adaptive algorithms are used to adjust the coefficients of the digital filter such that the noise is minimized. The algorithms widely used are

1. Least Mean Square (LMS) Algorithm.
2. Recursive Least Square (RLS) Algorithm.

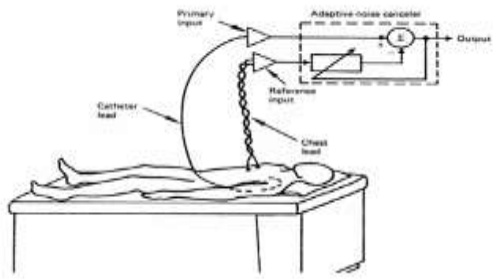

Fig: 2: Block Diagram For Canceling Donor Heart ECG

Least mean square (LMS) algorithm:

The Computational procedure for LMS algorithm is summarized below[2].

1. Initially set the weights Wk(i), i=0,1,2,3….N-1 to an arbitrary fixed value such as Zero. For each subsequent sampling instant k=1,2,3… carry out the steps 2 to 4.
2. Compute the filter output:

N1k = $\sum_{i=0}^{N-1}$ Wk(i) Xk-i (Simillar to equation(4)).

3. Compute the error estimate:

ek = S1k = Yk – N1k (Simillar to equation (2)).

4. Update the next filter coefficients:

Wk(i+1) = Wk(i) + 2uekXk-i.---------- (5)

where u refers to Adaption Step Size.

Recursive least square (RLS) algorithm:

To reduce the number of iterations we go for RLS algorithm. The steps involved in the RLS algorithm is given below[2].

1. Initially set each weight Wk(i), i=0,1,2,3….and set the cross correlation matrix Po.
2. Find the Gain Factor Gk:

$$G_k = \frac{P_{k-1}x(k)}{\partial_k} \text{----------} \quad (6)$$

where $\partial_k = r + x^T(k)P_{k-1}x(k)$ ---------- (7)

3. Find the cross correlation matrix Pk:

$$P_k = \frac{[P_{k-1} - G_k x^T(k)P_{k-1}]}{r} \text{----------} \quad (8)$$

where r is the forgetting factor and $0.98 \le r \le 1$.

4. Compute the error estimate:

$$e_k = y_k - x^T(k)w_{k-1} \text{----------} \quad (9)$$

5. Update the filter coefficients:

$$w_k = w_{k-1} + G_k e_k \text{----------} \quad (10)$$

Simulation using Matlab:

The Adaptive algorithms such as LMS and RLS were simulated using MATLAB 6.5. The Real time ECG samples were taken for simulation. The ECG signal of Old Heart is shown in Fig:3 and the ECG of New heart is shown in the Fig:4.

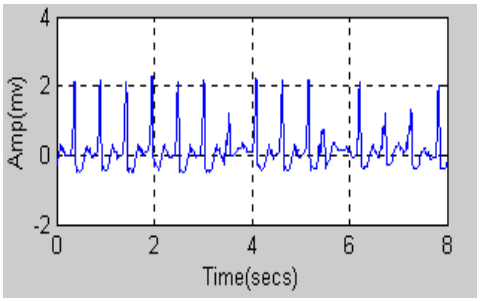

Fig: 3: Old heart ECG signal

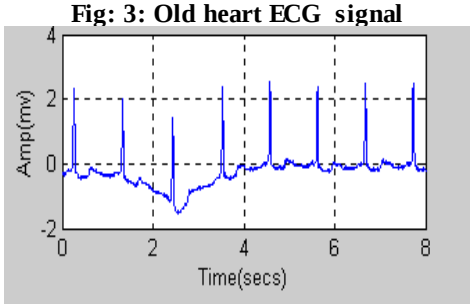

Fig: 4: New heart ECG signal.(reference input)

The output of the catheter lead is shown in the Fig:5.

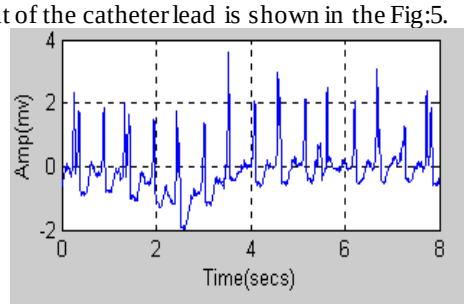

Fig:5: Output of the catheter (old + new heart ECG)

The LMS output is shown in the Fig 6. The LMS output shows the Old heart ECG Signal, from which is cancelled the New heart ECG. The Computational complexity involved in the LMS algorithm is less and hence it is easy to implement. But the number of iterations taken is more.

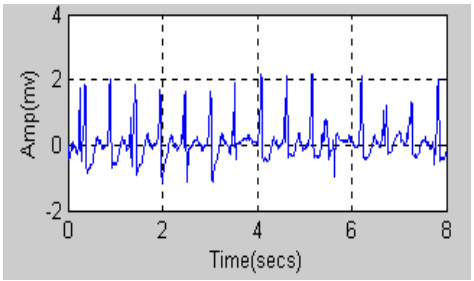

Fig: 5: LMS output (old heart ECG)

The RLS output is shown in the Fig:7. The RLS output shows the old heart ECG signal, from which is cancelled the new heart ECG. The computational complexity involved in the RLS algorithm is more and hence it takes less number of iterations and it begins the adaption at an earlier stage.

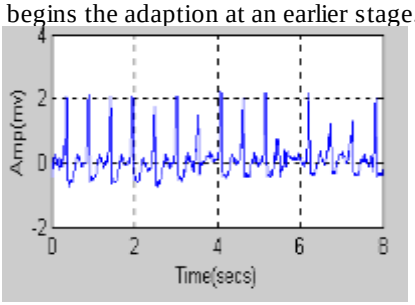

Fig: 6 RLS Output (Old Heart ECG)

Conclusion:

The Heart Transplantation is a research area in medical field. The old heart ECG signal after the transplantation is important for the post operative treatment to check whether the surgery is successfully done or not. The adaptive algorithms can be realized using VLSI Techniques.

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Authors Biography

N.J.R.Muniraj is presently working as a Principal of Tejaa Shakthi Institute of Technology, Coimbatore. He has more than 22 years of teaching and five years of industrial experience. He has presented more than 40 National and International papers and published fifteen international journal papers. His research area includes VLSI Signal Processing, Neural Networks, Image Processing and MEMS. He is also heading the Tejaa Shakthi Innovation centre. He expresses his sincere thanks to his chairman Mr.T.N.P.Muthu Natarajan and the secretary Ms.A.Tharalakshmi for their support and encouragement.