Fuzzy multiwavelet denoising on an ECG signal

Charlotte Yuk-Fan Ho, Bingo Wing-Kuen Ling, Thomas Pak-Lin Wong, Albert Yick-Po Chan, and Peter Kwong-Shun Tam

ABSTRACT

Since different multiwavelets, pre- and post-filters have different impulse and frequency responses characteristics, different multiwavelets, pre- and post-filters should be selected, integrated and applied at different noise levels if a signal is corrupted by an additive white Gaussian noise (AWGN). In this letter, some fuzzy rules on selecting and integrating different multiwavelets, pre- and post-filters together are proposed. These fuzzy rules are setup based on the training results of the denoising performances of applying different multiwavelets, pre- and post-filters at different noise levels. When a new electrocardiogram (ECG) signal is applied, the appropriate multiwavelets, pre- and post-filters are selected and integrated based on fuzzy rules and the noise level of the signal. A hard thresholding is applied on the multiwavelet coefficients. According to an extensive simulation, we found that our proposed fuzzy rule-based multiwavelet denoising algorithm achieves 30% improvement compared to the traditional multiwavelet denoising algorithms.

I. INTRODUCTION

The multiwavelet theory has already proved its efficiency for the signal denoising problem. However, what multiwavelets, pre- and post-filters should be used? Do the selections depend on the noise levels? The aim of this letter is to propose a method to select and integrate different multiwavelets, pre- and post-filters together to obtain sub-optimal results for the ECG denoising problem.

II. Proposed multiwavelet fuzzy denoising algorithm

The block diagram of our proposed multiwavelet fuzzy denoising system comprises with six blocks as in Figure 1. Since two types of Chui Lian (CL) multiwavelets [1, p.289, p.295] and Qingtnag Jiang (QJ) multiwavelet [2] are the most widely used in the signal processing area, we choose these three multiwavelets. Besides, thirty-five commonly used pre- and post-filters, including symlets, coiflets, Daubenchies and biorthogonal filters, are also used, as listed in Table 1.

The fuzzy rules are established based on the following methods: A set of input-output relations that describes the denoising performances of applying different multiwavelets, pre- and post-filters at different noise levels are obtained based on training samples in the database [3], where the denoising performances are calculated based on the mean square error (MSE) criterion. A TS fuzzy model is established based on trapezoidal fuzzy membership functions described in Figures 2 and 3. The fuzzy rules are summarized in Table 2.

A hard thresholding based on the Donoho approach is applied on the multiwavelet coefficients [4].

III. Experimental results

The ECG signals used in the experiment are from the Beth Israel Deaconess Medical Center at Boston [3]. In order to demonstrate the sub-optimality of different multiwavelets, pre- and post-filters, computer simulations were performed to recover signals of 1000 points embedded in the zero mean AWGN at various noise levels.

Figure 4 shows the average of the MSE of signals in [3] for the fuzzy and non-fuzzy methods. The non-fuzzy method is described as univariate soft thresholding in GHM multiwavelet domain [5]. Compared the result of two methods, the fuzzy systems do provide better denoising performances as expected with consistently about 30% MSE improvement.

IV. Conclusions

This letter proposes an intelligent based method for selecting and integrating different multiwavelets, pre- and post-filters together at different noise levels for the ECG signal denoising problem. According to our extensive simulations, we found that our proposed fuzzy system gives an excellent performance.

ACKNOWLEDGEMENT

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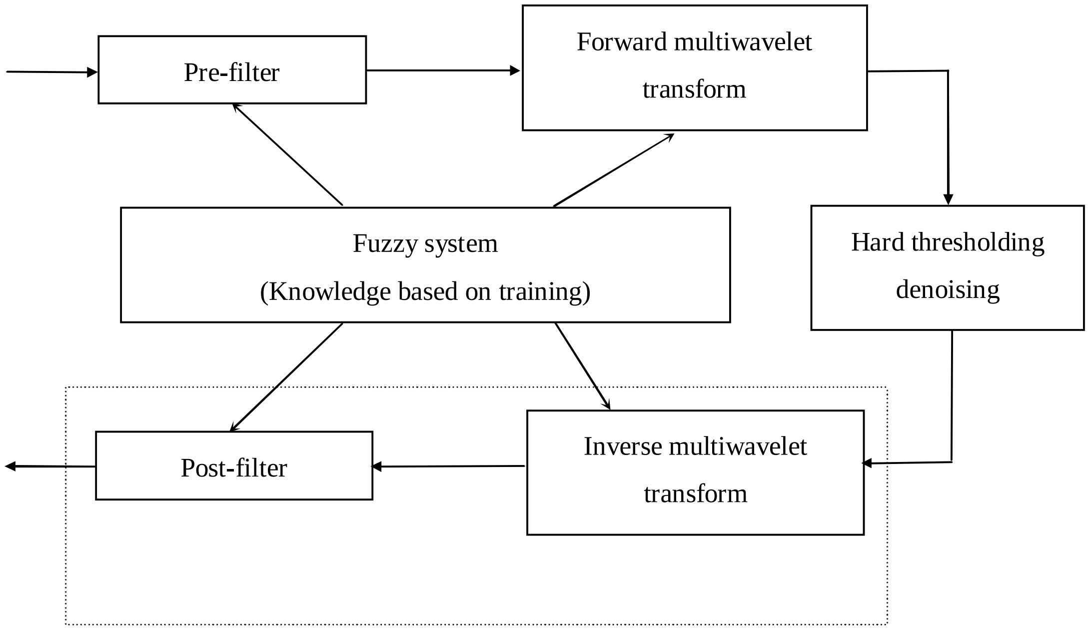

Figure 1: Block diagram of multiwavelet fuzzy denoising system

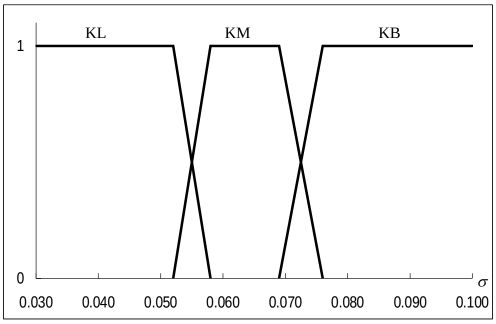

Figure 2: Membership functions of multiwavelet kernels

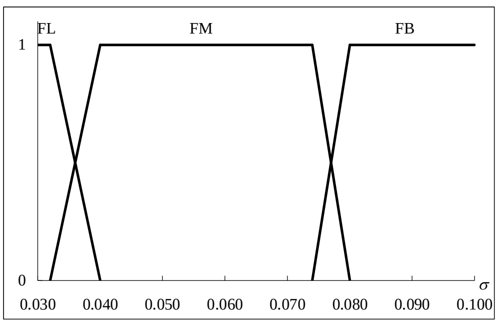

Figure 3: Membership functions of pre- and post-filters

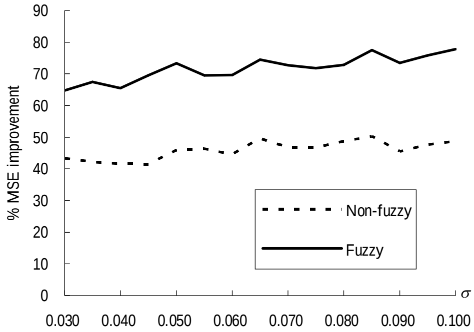

Figure 4: Comparison of denoising performance

	Name	
Multiwavelet kernels	Chiu Lian [1, p.289, p.295]	
	Qingtang Jiang [2]	
Pre- and post-filters	Symlets	2 to 8
	Coiflets	1 to 5
	Daubenchies	1 to 8
	Biorthogonal	1.1, 1.3, 1.5, 2.2, 2.4, 2.6, 2.8, 3.1, 3.3, 3.5, 3.7, 3.9, 4.4, 5.5 and 6.8

Table 1: Multiwavelet kernels, pre- and post-filters

Rules	Kernels
If KL,	then CL2 or QJ.
If KM,	then CL2.
If KB,	then QJ.
Rules	Filters
If FL,	then Symlets 2.
If FM,	then Biorthogonal 3.3.
If FB,	then Biorthogonal 3.1.

Table 2: Sets of fuzzy rules