

Detection of heart anomalies by use of adaptive LMS filters in ECG signals*

*Note: Sub-titles are not captured in Xplore and should not be used

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Abstract—An implementation of a heart anomaly detector for non-paced rhythms using different adaptive filter structures is proposed.

The detection algorithm uses an Adaptive Recursive Filter (ARF), for which the impulse input is previously determined via a peak localization and time shift estimation algorithm.

The detection of each anomaly by itself is product of the direct observation of the magnitude of the ARF output. The design and testing of the detector was based on the MIT-BIH Arrhythmia Database with almost none false-negative and few false-positive results.

Index Terms—ECG analysis, heart anomaly detection, Adaptive Filtering, LMS filters

I. INTRODUCTION

A. Electrocardiogram signals

An Electrocardiogram (ECG) signal is a non invasive recording (electrodes are placed on the patient's skin) of the electrical activity of a heart. There are several places where the signals may be recorded, and usually as many as ten electrodes are used to perform an ECG, where the polarization and repolarization of the heart muscles are recorded.

An ECG portrays an incredibly large amount of information from the patient, such as the rate and rhythm of heartbeats, the size and position of the heart chambers, the presence of any damage to the heart's muscle cells or conduction system, the effects of heart drugs, and the function of implanted pacemakers.

These polarization cycles form the main three components of a heart signal, which are listed as follows:

- **P-wave** : Depolarization of the atria. This component is frequently the one with the lowest amplitude.
- **QRS complex**: Depolarization of the ventricles. In the QRS complex a peak of high frequency and the highest amplitude is detected.
- **T-wave**: Repolarization of the ventricles.

These components were enumerated in their usual order of appearance. However, some patients with heart abnormalities exhibit a P-wave that superposes over the QRS complex, so the techniques developed below should take into account this

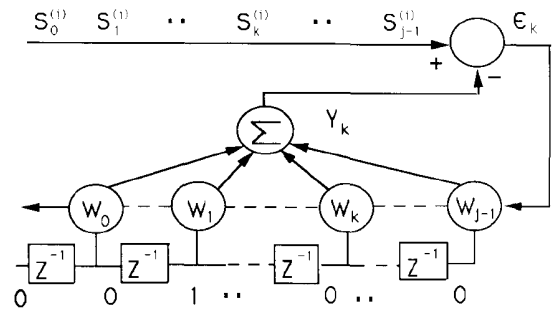


Fig. 1. Basic diagram of an ARF

factor when analysing the ECG signal even with no previous knowledge of the abnormality. Adaptive filters have been proven efficient in such cases.

B. Adaptive Recursive Filters

An Adaptive Recursive Filter (ARF) is an adaptive filter whose coefficients change so that when it is adapted, its impulse response converges to a single pseudo-period of an ideally periodic signal. The ARF is therefore applied to signals that are known to have periodic behaviour with considerably small changes through time in both its pseudo-periods and its fundamental period.

The signal in question may be then considered to be stationary between time intervals of a given length.

A diagram of the ARF, taken from [1] is shown below:

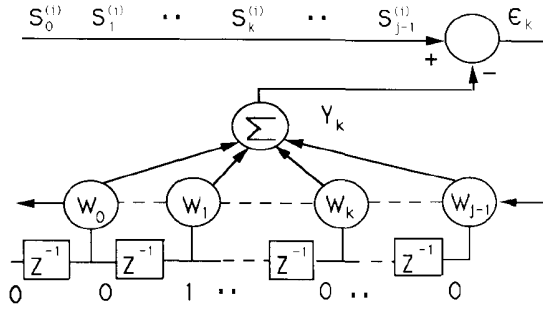


Fig. 2. Basic diagram of an ARF

II. LMS PREDICTION

The first approach taken was the implementation of an adaptive predictor based on the following diagram:

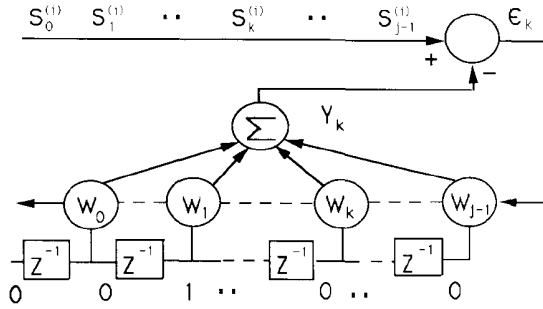


Fig. 3. Basic diagram of an ARF

The implementation achieved its desired purpose of predicting the signal, as shown in the following figure:

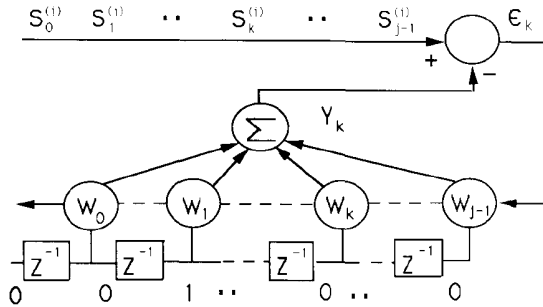


Fig. 4. Signal 202 of the MIT-BIH Arrhythmia Database, minute , and the predictor's response.

The magnitude of the error signal was afterwards processed in order to get its peaks, which were considered anomalies when its amplitude exceeded a designated value. This method of anomaly detection did not manage to achieve acceptable results as the predictor error tends to raise when the ECG signal has high frequency changes, and so the peaks of the QRS complex were also taken as anomalies.

Although this problem disqualified the method, if the QRS complex is detected via a previous analysis of the signal,

discarding the false positives that appear with its peaks may be a path to be followed in future investigations.

III. DETECTION

The detection of each anomaly consists of applying the detection algorithm to the entire ECG signal or a portion of it. The steps of this algorithm are in line with the arrhythmia detection method stated by [1]:

- 1) Find the peaks of each QRS complex.
- 2) Generate an impulse signal in which each impulse coincides with the beginning of the QRS complex.
- 3) Feed the ARF with both the new impulse signal and the ECG.
- 4) Get the error signal of the ARF after processing the inputs.
- 5) Identify the peaks of the absolute error signal and select those points in which these peaks may signify an anomaly.

Choosing to generate an impulse at the start of the QRS complex and not at the start of the P-wave is the solution for the possibility of an abnormality in the P-wave that may provoke it to overlap with other components of the signal. The ARF will make its impulse response copy by default the QRS complex and the T-wave, and in such case that no overlapping occurs, the P-wave will also be shown in the impulse response of the filter.

A. Detection of the QRS complex

The localization of the QRS complex is based on the detection of high amplitude peaks. This may be done by assuming signal stationarity for some interval of time. Fifteen pseudo-periods of the signal has been proven an effective amount of time. The period has been estimated with the a priori knowledge of an ECG: The period of a heart signal is of approximately 1 beat per second. Taking this into account and the fact that the sample rate of the MIT-BIH Database is 360 Hz, a number of 350 samples was the estimated length of a heart beat.

After defining the stationary interval, the signal is then converted to its energy signal by simply squaring each value. Converting the signal to its energy signal for peak detection has two advantages:

- 1) All values of the energy signal will be non negative.
- 2) Greater values will be weighed as more important and significant than smaller values as pondered by the square function.

A peak will be detected each time a sample of the energy signal has a value that is at least 0.55 times the maximum value of the interval.

B. Generation of the impulse signal

As each peak of the QRS complex corresponds to the R component of the signal, a time shift should be applied so that the generated impulse signal will have its impulse assigned to the beginning of the QRS complex. This time shift should also be estimated in a proportion of the estimated pseudo-period time.

IV. ACCURACY OF THE METHOD

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Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \quad (1)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

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- Do not confuse “imply” and “infer”.
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- There is no period after the “et” in the Latin abbreviation “et al.”.
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TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
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^aSample of a Table footnote.



Fig. 5. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [?].

REFERENCES

[1] Nitish V. Thakor and Yi-Sheng Zhu, “Applications of Adaptive Filtering to ECG Analysis : Noise Cancellation and Arrhythmia Detection”, IEEE Transactions On Biomedical Engineering. Vol. 18. No 8. August 1991.

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