A Real-time DSP-Based Ringing Detection and Advanced Warning System

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Abstract

Epilepsy in itself is a brain disorder, in which the normal pattern of neuron electrical activity becomes disturbed, causing abnormal problems to the patients. This paper explains the DSP-based real time system for a patient who suffers from these types of recurrent bouts with sound induced epileptic seizures. Specifically, sounds that are produced by telephone (rotary, cellular) rings and pagers. It should be noted, however, that this patient has the ability to block the effect of the trigger by merely being aware that the ring is about to occur.

The basic idea behind this real-time DSP based system is that, it could receive the sounds heard by the patient mentioned above with a microphone and deliver a visual signal or on vibrator worn by him, providing an advanced warning of an incoming ring.

Index Terms

ALP Adaptive line predictor
ALED Adaptive line enhancer and detector
LMS least mean square block
Chebyshev filter bank

I. INTRODUCTION

EPILEPSY is a neurological condition in which the electrical activity of groups of nerve cells or neurons in the brain becomes disturbed. In the extreme of cases, this abnormal activity causes convulsions, muscle spasms, and loss of consciousness in the patient. There are several factors that contribute to the triggering of an epileptic seizure. Among these factors are external stimuli such as flashing lights or sudden changes from dark to light, loud noises or monotonous sounds, or even certain musical notes.

This Application focuses on the development of a real-time DSP-based system that will assist a patient that suffers from epileptic attacks that are specifically triggered by Seizure Inducing (SI) stimuli consisting of loud and sudden sounds from telephone ringing and pagers. It has been observed, however, that if the patient is forewarned of the impending occurrence of these sounds he is able to prepare himself for the event and avoid a seizure. The system developed in this project provides the kind of advanced warning needed by the patient.

The system will integrate a parallel Adaptive Line Enhancer structure that will divide the available input spectrum into individual frequency bands that will be analyzed separately. An Adaptive Line Enhancer and Detector (ALED) will evaluate each frequency band for the purposes of extracting any periodic component present in the incoming input audio signal. This paper examines the performance of this structure in terms of how accurately it will detect any signal whose spectral content varies with time and how fast it can provide a timely warning signal to the patient that this seizure inducing sound is about to occur.

II. MOTIVATION

The statistics about epilepsy speak for themselves. More than 2 million people in the U.S. and some 50 million people worldwide have epilepsy. It is estimated that 12.5 billion dollar per year is spent on expenses such as treatment and research. In the United States, about 316,000 children under the age of 14 have epilepsy, in addition to 1.4 million young adults and 550,000 people over 65 years of age.

For centuries, epilepsy was considered a curse of the gods, a contagious disease, or a type of insanity. As a result, people with epilepsy and their families have suffered unfairly because of the ignorance of others. In fact, coping with the reaction of society can be the most difficult part of having epilepsy.

Living successfully with epilepsy requires a positive outlook, a supportive environment, and good medical care. Some types of epilepsy are harder to control, depending on severity of the seizures, the effects of medications, and associated disorders. For the
vast majority of people with epilepsy, seizures and their treatment should not be a barrier to a fulfilling life. So, in this world of advanced technology some technique must be thought of to help this types of patients where sometimes medicines cannot show its effect.

III. System Specifications

1. Sends information of the impending ring 1 second before the time.
2. Advance system with dsp technique compared with its older version.
3. 6th order Chebyshev filters with bandwidth 500Hz.

IV. Working

![Block diagram of the real-time adaptive system](image)

Figure 1. DSP based Ring Detector

The block diagram of the real-time adaptive system is shown in Figure 1. The system receives an input, delays it just enough to allow the system hardware to perform the numerical calculations and then signal if at any time there is an impending ringing. Since the focus is mainly on detection, the system will give advanced warning of any incoming ringing by way of a visual indicator, such as a Light Emitting Diode (LED). As soon as any ringing or strong periodic component is detected in an incoming input audio signal, the LED would turn on and remain on for as long as that periodic interference is present.
V. THEORY BEHIND THE APPLICATION

This project pursues the design of a real-time DSP system that could receive the sounds heard by the patient mentioned above with a microphone and deliver a processed audio signal to headphones worn by him, while:

1. Providing an advanced warning of an incoming ring
2. Attenuating the ring in the signal delivered to the headphones at least to a point where it will not trigger a seizure.

As such, the project pursues the design and implementation of the following Blocks:

ADAPTIVE RING DETECTOR:

This block of the system will track and detect any strong periodic component in an incoming audio signal and warn the patient of the impending ring with about 1 second ahead of time.

RING SUPPRESSION OR CANCELLATION:

The block will track, detect and attenuate these strong periodic components in the incoming audio signal. At this stage, attenuation rates of at least 25dB are being sought.

Subsequently, one of these two implementations will be used in the development of a stand alone real-time system that will utilize a dedicated DSP processor, such as the TMS320C31 or a TMS320C6201. The choice of which of the implementations will be used will ultimately be the decision of the patient.

We are currently favoring the implementation of the advance warning system, relying on the ability of the patient to block the negative effects of the ring, if he has advance notice of its impending occurrence.

PRELIMINARY SOLUTION:

Our initial hypothesis modeled the ringing disturbance in the incoming signal as just a fixed periodic fundamental tone with its corresponding harmonics that was potentially superimposed on speech, or other audio components. According to this simple model of the targeted interference, an adaptive filter or ALP (Adaptive Line Predictor) could be applied to solve this problem. The ALP would be able to separate the periodic and speech components from the incoming signal. The output of this filter would then consist of a relatively undistorted speech signal.

However, spectral analysis of a couple of types of this particular disturbance (cellular phone and office phone ringing sounds) brought about the notion that this disturbance is not just one strong fundamental tone, but rather a combination of more than one strong fundamental frequencies, all with their associated harmonics.

In addition, spectrogram of these rings shows that the spectral composition of these signals varies with time. Using a recorded waveform that contained speech and the ringing of an office telephone, an ALP was used to test the initial hypothesis. The ALP was able to remove some of the ringing, however, the power of this interference was still quite high, not to mention that severe degradation to the speech in the recording that also took place.

ADAPTIVE RING DETECTOR:

This method will work around the shortcomings of the ALP in regard to its inability to deal with more than one strong, switching periodic component. In this method, the incoming signal spectrum will be broken down into several bands for subsequent processing by a set of ALP filters. Each filter will process its assigned band to determine if there is any strong frequency component present in that band.
By reducing the number of strong frequency components at the input of each adaptive filter this approach will enhance the performance of the ALP filters in terms of quickly detecting any strong periodic component that is present in the incoming speech signal.

FILTER BANK:

The first block of the adaptive system consists of bank of eight IIR band pass filters, each having a bandwidth of 500Hz and covering a range from DC to approximately 10Khz. The upper limit of this range was decided upon based on knowledge of the
hearing range for a normal human being. This is range is usually between 16 Hz to 16Khz, the upper limit falls off with increasing age. A bandwidth including up to 10KHz will satisfy speech intelligibility requirements. Each filter is a 6th order Chebyshev band pass IIR filter. The choice for this type of filter was made on the basis of the filter’s sharp cutoff frequency response. The output of each filter will isolate any significant strong spectral component that might be associated with the ringing or that could also be associated with any other type of input (i.e. sirens, beepers) or even speech.

ADAPTIVE LINE ENHANCER AND DETECTOR:

Once the input signal has been partitioned into different spectral bands, each band is processed by its corresponding Adaptive Line Enhancer and Detector. The ALED can be thought of as consisting of two parts; an Adaptive Line Enhancer, and a modified spectral peak detector. An adaptive line enhancer aims to pass the narrowband components in observed data with unity gain while reducing broadband components. The only assumption required for operation of the ALE is that the signals of interest are narrowband. And the ring signal have strong periodic components concentrated at particular frequencies. The ALE filter will extract any strong periodic component(s) from its given spectral band. The idea here is that a periodic component of ring signal is much more concentrated (larger power density) about a certain frequency than any portion of speech over the frequency spectrum in that assigned band.

The output of the filter is then compared with the input portion of the signal. The comparison is made on the basis of their RMS power measured over a small interval of time. Using the ratio of the filter output power over the error power, we can determine if there is a periodic component present by comparing it to a fixed threshold level. If the filter fails to detect any strong periodic component this ratio will be small, however in the event that the filter does detect some periodicity in the spectral band the ratio will be considerably larger. The boundary that separates these two events is set as a threshold value (Theta). If detection has taken place, a small pulse will be triggered in that assigned spectral band.
RING OUTPUT DETECTOR:

Given the fact that speech is quasi-periodic, there will be sections of speech that may contain a periodic component of considerable strength. However, we would like to prevent this speech periodicity from triggering a false alarm in the system. To address this problem, all the triggering pulses from the individual single-band ALEDs are fed into the Ring output detector, which will determine if there is ringing present. Since speech, at the most can only trigger a detect signal in two frequency bands, while a ring could trigger them in as many as four, all of the detect pulses are added up and the result is compared to a threshold value \( \Theta_2 \). This value can be set to 2.1, and as such if the combined result of all the bands (detection pulse) add up to more than 2, then we can say that a ring has been detected.
Figure 6. Advance warning outputs generated by the system, from a typical audio segment containing both speech and a telephone ringing.

The simulation of this project can easily be done with the matlab software. First we have to store the composite signal of ring with the speech as a file. Now from matlab we can read that file using function "wavread". The output of the function will be an array. We can now find its fast fourier transform using the function "fft" and can find the strong periodic component from the spectrum and also whether the ring signal is present among the composite signal or not.
VI. USE OF APPLICATION IN REAL LIFE.

Our application is itself a real life application.

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REFERENCES


BIBLIOGRAPHY

Chebyschev filter:

In the chebyschev filter the passband is monotonic and the stopband is equiripple. The main advantage of the chebyschev filter is that for the same order of the filter roll off will be sharper. Order of the filter is the number of single stage of the filter cascaded with one another. As the order of the filter increases the response approaches to the ideal one but the complexity of the filter will increase. In our case we want sharp cutoff so we are using a higher order chebyschev filter in order to block any other component to pass through it and will get 8 non overlapping passbands.