University of Sydney

Something Awesome Project Report-Using wavelet toolbox for denoising

HangYu Chen (490075948)

Table of Contents

1 Introduction

Write one paragraph about the overall understanding of the lab. In this report, some basic knowledge of wavelet will be introduced. Besides, the wavelet toolbox in MATLAB will be used for 1-D signal denoising and 2-D image denoising respectively. Finally, there is a self-reflection about this project.

2 Phase I: Basis of Wavelet

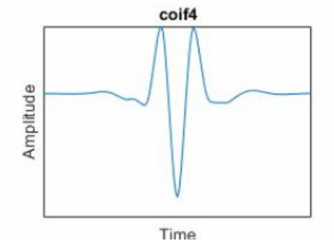
The signals in the real world are always changing slowly or oscillating suddenly with transients. Similarly, images which are considered as 2-D signals also have smooth regions interrupted by edges or abrupt changes in contract. The reason why we use wavelet is that although Fourier transform (which is made up of the sum of sine waves) is powerful for analyzing data, it cannot represent the sudden change efficiently.
In this case, we need wavelets which is a new function for us to deal with the abrupt changes for 1-D signals or 2-D images.

2.1 Different kind of wavelets

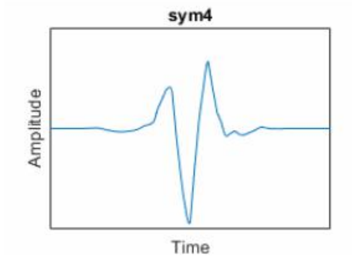
There are several kinds of wavelets. Because they have different shapes and features, we need to choose a proper one when we use them.

Some of them are shown below:

- **Coiflet**
  For Coiflet wavelet, the scaling function and wavelets have same number of vanishing moments.



- **Symlet**
  For Symlet wavelet, it has almost linear phase, but it is not asymmetric.



2.2 Two properties of wavelets

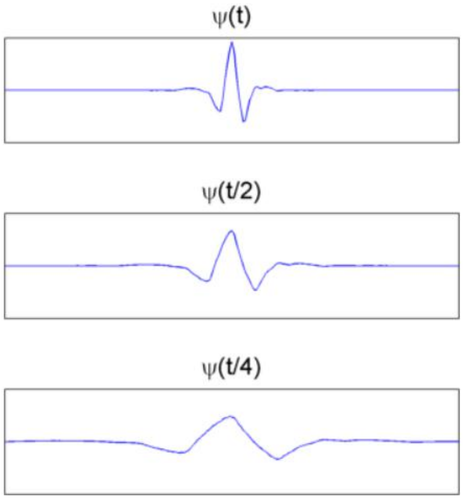
There are two different varying methods that we could apply on the wavelet which are scaling and shifting. Similar with what we do for continuous signals before, multiplying each coefficient by the appropriately scaled and shifted wavelet yields the constituent wavelets of the original signal.

2.2.1 Scaling

Scaling is similar with changing the frequency of the signal. For example, if we have a wavelet function φ, we could multiply the time domain with a factor s, where s>0. In this case, s is called scale.

$$\Psi\left(\frac{t}{s}\right) s>0$$

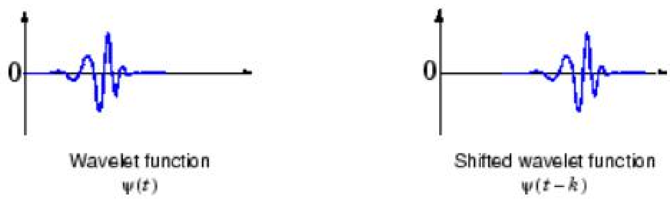
Scale represents how much we will scale the signal. And with different scale, we could change the shape of the wavelet.



2.2.2 Shifting

Shifting means delaying or advancing, we could move forward or backward the wavelet in time domain.

$$\phi(t-k)$$



2.3 Two wavelets Transforms

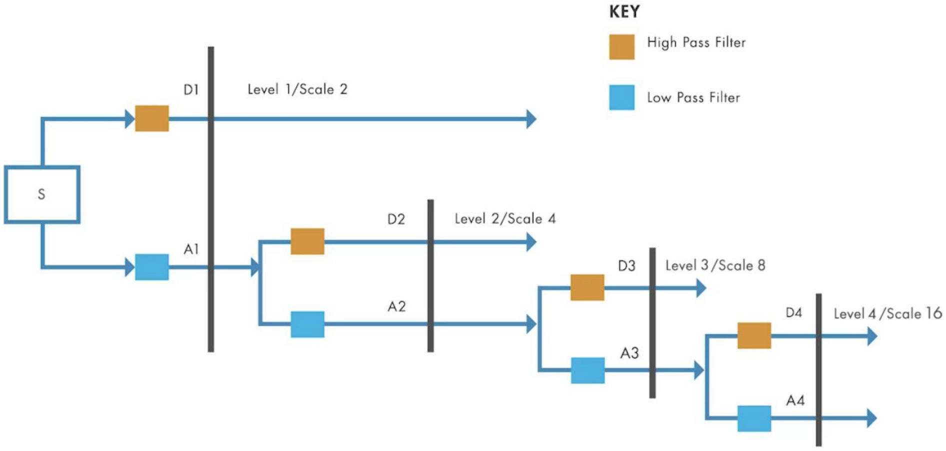
There are two types of wavelets, which are continous wavelet transform (CWT) and discrete wavelet transform (DWT) respectively. The CWT is normally used for filtering and DWT is used for denoising and compressing. In our project, we will mainly use DWT for signal and image denoising.

2.4 Wavelet Denoising Methods

There are three steps for wavelet denoising. Firstly, we need to perform a multilevel wavelet decomposition. Secondly, we need to identify a thresholding technique. Finally, we could define the threshold value and then reconstruct the signal.

2.4.1 Multilevel wavelet Decomposition

The aim of decomposition is to divide the approximation sub-band at multiple levels or scales for a fine scale analysis. We divided the signal into high-pass sub-band (detail level) and low-pass sub-band (approximation level).



2.4.2 Threshold

As we know that, the noise always exists in the high frequency part. However, because the high frequency components are consisted by the sudden change of signals, they have some valuable information. In this case, we want to keep that information during denoising, we need to scale the detail coefficients by a threshold.
There are several thresholding techniques:

- The Universal Threshold
- SureShrink method
- Heursure method

3 Phase II: Denoising for 1-D signals

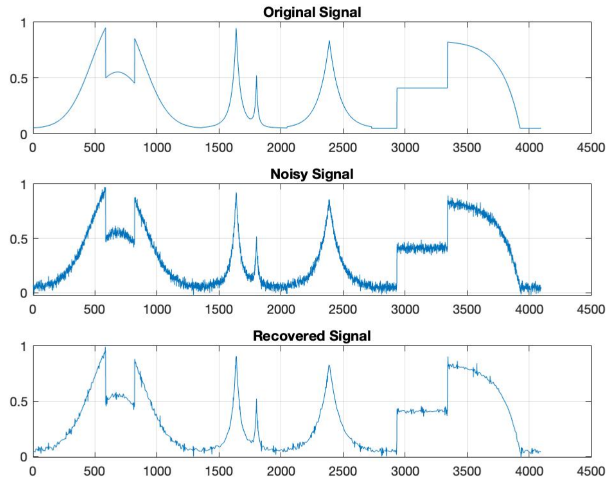
I used SureShrink method for thresholding and Symlet6 wavelet.
There are also two different functions for applying the threshold, which are soft thresholding and hard thresholding. The main difference between these two is how to deal with the coefficients that are greater in magnitude than the threshold. (Hadhami, 2012)

3.1 Symlet Denoising

I used sym6 as wavelet and soft thresholding. The detailed code is shown in the MATLAB file with explanations.

3.2 Results

We also used SNR to show the denoising result.




```
sprintf('Noisy Signal SNR:  %0.2f dB',-20*log10(norm(abs(f0-f))/norm(f0)))
```

```
ans = 'Noisy Signal SNR:  24.44 dB'
```

```
sprintf('Denoised Signal SNR:  %0.2f dB',-20*log10(norm(abs(f0-fd))/norm(f0)))
```

```
ans = 'Denoised Signal SNR:  30.73 dB'
```

We could find that the SNR increased by 6dB after denoising, which means the quality of signal increased.

4 Phase III: Denoising for 2-D images

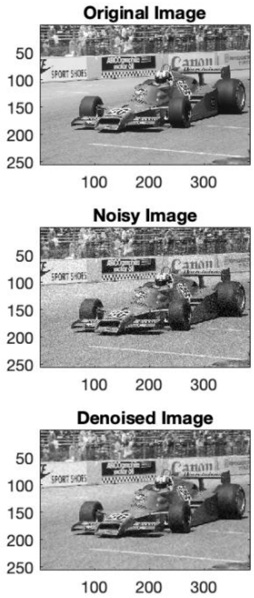
Similarly, we used wavelet denoising for images. In this part, I used Coiflet wavelet and decompose 2 levels. However, the difference between 1-D is that we could deal with the threshold three times, which are horizontal, vertical, and diagonal respectively. The code is included in the MATLAB file, so only some results is shown below.

4.1 Thresholding three times

The thresholding is used for keep some valuable information in the image during the denoising. In order to make the result more accurate, I used horizontal, vertical, and diagonal thresholding respectively.

```
nc = wthcoef2('h',c,l,n,p,'s');
X1 = waverec2(nc,l,'coif2');
% image(X1)
mc = wthcoef2('v',nc,l,n,p,'s');
X2 = waverec2(mc,l,'coif2');
% image(X2)
tc = wthcoef2('d',mc,l,n,p,'s');
X3 = waverec2(tc,l,'coif2');
% image(X3)
```

4.2 Result




```
sprintf('Noisy Signal SNR:  %0.2f dB',-20*log10(norm(abs(myImage-myImageN1))/norm(myImage)))
```

```
ans = 'Noisy Signal SNR:  20.35 dB'
```

```
sprintf('Recovered Signal SNR:  %0.2f dB',-20*log10(norm(abs(myImage-X3))/norm(myImage)))
```

```
ans = 'Recovered Signal SNR:  23.21 dB'
```

We could find that the SNR increased by 3dB after denoising, which means the quality of the image increased after denoising.

5 Self Reflection

Making a reflection is a good habit for us to improve ourselves in the future especially as an engineer.

Because I have no background knowledge about wavelet, so I had to search for some materials online. During the project, I found there are some useful materials on MathWorks website, so I follow the tutorials from MathWorks at beginning.
After I finished the project, I found that although I made a Gantt Chart at beginning which is aim to push me to make the project in time, I still did not follow that scheduler to finish my project step by step. I think it is because I did not think about the "risks" that I might meet. For example, I have other units and other projects/exam to do, which would affect my progress.

In this case, I will try to leave room for the scheduler in the next project. Besides, as I am interested in the signal processing and I found the deep learning is also a useful method for denoising, so I will try to find more materials about deep learning in the future.

6 Reference

- Hadhami Issaoui, Aicha Bouzid .et.al (2012), Comparison between soft and hard Thresholding on selected intrinsic mode selection. Retired from: https://ieeexplore.ieee.org/document/6482001
- Kirthi Devleker, MathWorks, Understanding Wavelets, Retired from: https://au.mathworks.com/videos/understanding-wavelets-part-3-an-example-application-of-the-discrete-wavelet-transform-121284.html?s_tid=vid_pers_recs