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NOAA Satellite signal analysis and Denoising using wavelet based technique

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Abstract

For more than five decades, the National Oceanic and Atmospheric Administration (NOAA) environmental satellites have been an important key to life-saving weather and climate forecasts in the world. NOAA monitor Earth every day. It gathers data about the earth, oceans, air, space, and the sun .These data are used in weather warnings and prediction; oceanographic forecasts; climate monitoring, assessments, and prediction; detecting environmental hazards; and environmental research. NOAA satellite send its signal from long distance ,the signal is simply a tone that are exposed to different level of noise during travelling this long distance. This paper study and analyze the denoising of NOOA APT signal using wavelet in a time domain and in image domain

Keywords: wavelet denoise, image enhancements, Time and Image domain analyses

1. INTRODUCTION

NOAA, the National Oceanic and Atmospheric Administration [1], has a rich history of successfully operating geostationary operational environmental satellites (GOES) and polar-orbiting environmental satellites (POES) that have helped take some of the mystery out of atmospheric phenomenon. Through the years, NOAA, with cooperation with NASA, has developed increasingly advanced satellites that have provided higher spatial and temporal resolution images, operational soundings, atmospheric temperature and moisture data in all weather situations [2]. During those 46 years, NOAA has also built strong partnerships within the U.S. and throughout the world, leading to satellite-data sharing agreements that will strengthen the scientific community's understanding of the world's changing climate.[1] NOAA satellite program has stood watch over the American public and partner nations for more than four decades developing and applying space based Earth remote sensing for NOAA's National Weather Service (NWS) forecasts[3]. Over the past half century, NOAA's satellites have evolved from weather satellites to environmental satellites[1]. in the sense that NOAA Data is used extensively for applications related to the oceans, coastal regions, agriculture, detection of forest fires, detection of volcanic ash, monitoring the ozone hole over the South Pole, and the space environment[A]. As NOAA has evolved from weather only sensing to environmental sensing, it has aligned about strategic themes. These strategic themes include Understand climate variability and change for safe, efficient, and environmentally sound transportation.[1][4]

NOOA satellite transmits in 137MHz narrowband FM APT(Automatic Picture Transmission) , NOAA satellite radio signal is FM-modulated in much the same way as regular broadcast-FM radio signals[2].It is highly susceptible to noise and interference and that is obvious specially in a severe weather conditions ,Fig (1) shows sample of time domain NOAA APT signal .Although many common scanning radio receivers can tune to 137MHz FM, the receiver's bandwidth may be too narrow to receive the full signal, as indicated by poorer sound quality and absence of high-pitched tones[5].

Narrow receiver bandwidth becomes apparent when the APT sound is converted into a picture by a computer. These common existing receivers relay on fixed hardware based filters to filter the APT signals. However, due to its inflexibility the efficiency degrade significantly as the random noise level increase.

2. WAVELET TRANSFORMATION

Wavelet is a powerful signal processing technique that has been dragging attention for the last two decades , it has been used for both signal and image processing specially signal and image denoising. In its simplest version, wavelet denoising involves removing the noise from the signal by using the wavelet technique [6]. Wavelet denoising is used in many engineering fields from biomedical, mechanical, civil and telecommunications engineering.[6].In this paper, the wavelet denoising technique theory is first described prior to testing . A wavelet is a waveform, $\psi(t)$ of effectively limited duration that has an average value of zero as expressed below [6]:

$$\int_{-\infty}^{\infty} \psi(t)d(t) = 0 \qquad (1)$$

The wavelet also comprises of functions which are obtained by scaling and translation of a single main function called 'mother wavelet' and is given by:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \quad (2)$$

where a is the 'dilation' or 'scale' and b is the 'translation' or 'position'.[6]

Given a test signal, *s(t)*, the continuous-time wavelet transform (CWT) of the test signal is obtained using the following expression:[7]

$$CWT_s(a,b) = \int_{-\infty}^{\infty} s(t)\psi_{a,b}(t)dt \quad (3)$$

The above expression produces a redundant transform, thus, in order to avoid the redundancy produced by the above expression, the translation, b and scaling, a parameters has to be discretized. One of the most popular discretization methods consists of changing the scaling by 2^j and the translation b by 2^jn, where j is the level of decomposition [7]. This produces the dyadic wavelet as shown in eq. (4)

$$\psi_{2^j}(t) = \frac{1}{2^j}\psi_s\left(\frac{t}{2^j}\right) \quad (4)$$

The dyadic Discrete Wavelet Transform (DWT) of a signal s(t) can be obtained by using [7]:

$$DWT_s(j,n) = CWT_s(2^j, 2^j n) = \frac{1}{\sqrt{2^j}}\int_{-\infty}^{\infty} s(t)\psi\left(\frac{t}{2^j} - n\right)dt \quad (5)$$

Previous expression produces orthogonal and non-redundant wavelet decomposition. The DWT of a signal can be computed by means of a digital filter bank tree combined with decimation blocks. In its simplest version, wavelet denoising can be summarized as [6]:

i. Decomposition.
ii. Thresholding of the coefficients in the transformed domain.
iii. And Reconstruction of the denoised signal by the inverse transform

The following sub sections provide more description for wavelet denoising and how it is applied

2.1 Decomposition

As mentioned above DWT is used instead of CWT. The DWT is based on the concept of multi-resolution analysis (MRA) introduced in [4]. according to that a signal is decomposed recursively into a sum of details (D1….Dn) and approximations (A1….An) at different levels of resolution. The details represent the high-frequency components, while the approximations represent the low-frequency components of the signal[7]. Now let s(t) be the analytical NOOA received signal given by:

$$s(t) = A_C \cos(2\pi f_c t + f\Delta / f_m \cos(2\pi f_m t)) \quad (6)$$

Where A_C is the Carrier amplitude f_c is the carrier frequency f_m is the message frequency and $f\Delta$ is the frequency deviation .After digitizing, the received signal will become s[n]

$$s[n] = s[nT] \qquad -\infty < n < \infty \quad (7)$$

where T is the sampling time. By multiplying the received signal in the time domain with a periodic train of pulses p(t) with period *T* the resulting digitized signal is now [7]:

$$s[n] = s(t)\,p(t) = \sum s(nT)\delta(t - nT) \quad (8)$$

where

$$p(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT)$$

The approximations and details before decimation can be calculated as in [8]:

$$Ds_k[n] = \sum_{m=-\infty}^{\infty} \hbar_{k,1}[n-m]s[m]. \qquad 0 \le k \le L-1 \quad (9)$$

$$As_k[n] = \sum_{m=-\infty}^{\infty} \hbar_{k,0}[n-m]s[m]. \quad (10)$$

where $\hbar_{k,1}[n]$ is the impulse response of the wavelet function and is used to calculate the details. $\hbar_{k,0}$ is the impulse response of the scaling function that used to calculate the approximation and $j=k$ are the level numbers. The decimation process takes place after the filtering. The equivalent representation of DWT for *s(t)* with a decimation factor 2^l is given below [7]:

$$As_k[n] = \sum_{m=-\infty}^{\infty} \hbar_{k,0}[2^k n - m] s[m]. \quad (11)$$

$$Ds_k[n] = \sum_{m=-\infty}^{\infty} \hbar_{k,1}[2^{k+1} n - m] s[m]. \quad (12)$$

2.2. Threshold Detail Coefficients

After the signal is decomposed by using DWT, the signal is left with a set of wavelet coefficients that correlates to the high frequency sub bands. These high frequency sub bands consist of the details in the signal., these small details are often associated with noise; therefore, by setting these coefficients to zero, the noise is essentially filtered out of the signal. This is the basic concept of thresholding [6], setting all frequency sub band coefficients that are less than a particular threshold to zero and using these coefficients in an inverse wavelet transformation to reconstruct the signal. There are several common rules which are used to calculate the threshold value. [7]. It was concluded that a fixed form of threshold selecting rules is the best for noisy NOAA signals. Based on this result, the FIXED FORM THRESHOLD was selected as a threshold this paper. This is defined by[7]:

$$\sqrt{2\log(length(x)} \quad (13)$$

where x is the length of the signal.

2.3. Reconstruct

The reconstruction process will regenerate the final signal without significant loss of information from the target. This process is called Inverse Discrete Wavelet Transform (IDWT) or in other words wavelet reconstruction[6]. The wavelet reconstruction process consists of up sampling and filtering by reconstruction filters as in Fig (5). The equivalent representation of IDWT is shown in (14)[7]:

$$s[n]_{denoised} = A_j + \sum_{j \le J} D_J \quad (14)$$

$$s[n]_{denoised} = \sum_{k=0}^{L-1} \sum_{m=-\infty}^{\infty} g_{k,1}[n - 2^{k+1} m] As_k[m]. + \sum_{m=-\infty}^{\infty} g_{L,0}[n - 2^{k+1} m] Ds_k[m]. \quad (15)$$

3. NOAA DENOISING USING WAVELET

A sample of APT NOAA FM modulated signal have been downloaded from [9], this raw signal will be converted into an image using WXtoImg software , the computer software takes the raw NOAA APT , and convert it into a visually clear image .The time domain 30db signal to noise ratio (SNR) APT NOAA signal and the converted image are shown in Fig(1) and Fig(2) respectively.

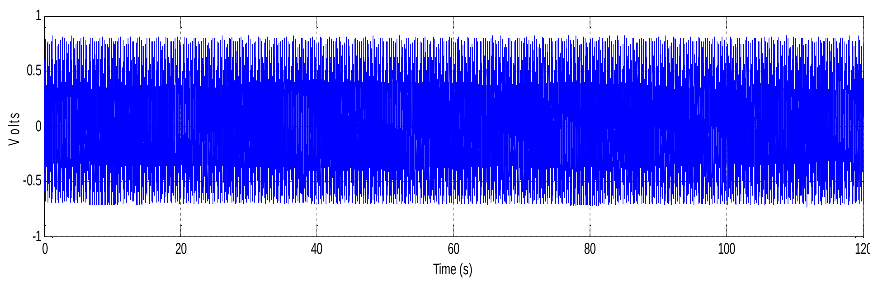


Figure 1: 30db SNR APT NOAA signal

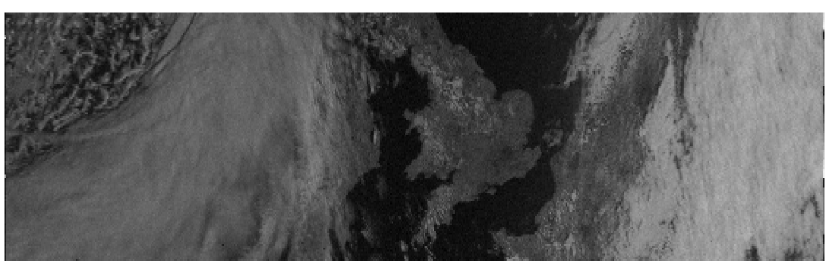
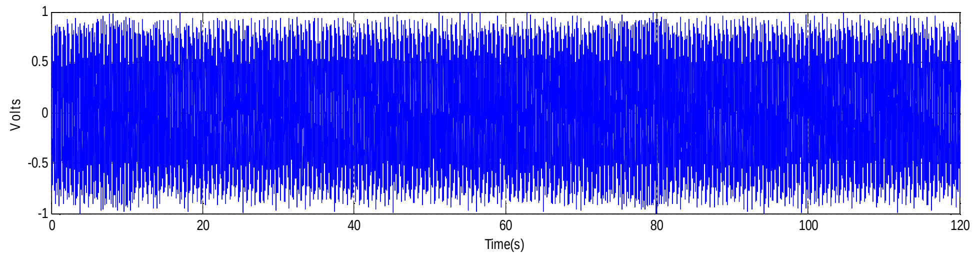
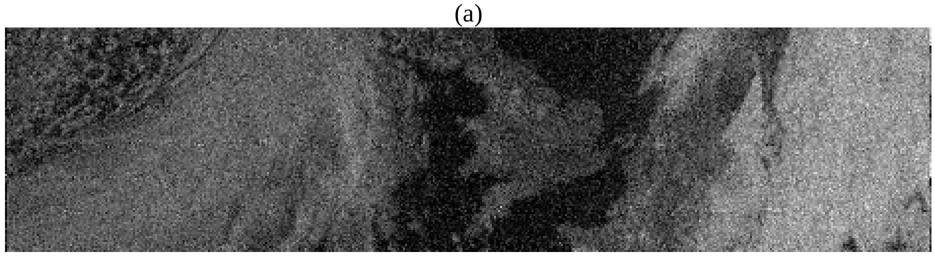


Figure 2: The converted image of 30db SNR APT NOAA signal

Fig(2) shows clearly the southern part of the United Kingdom (UK) with some clouds on the left side of the image . Now Noise is added to the time domain signal using matlab ,several types of noise distributions are exist .However, Gaussian noise is chosen to be added to the time domain APT signal ,the process of adding the Gaussian noise will consequently affects the SNR, therefore the level of the added noise will be correlated with overall SNR ,Fig (3a) and (3b) shows the APT time domain signal and its corresponding images for SNR 10db and 5db respectively



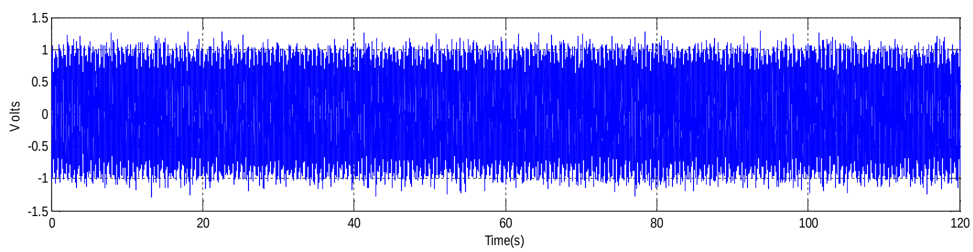
(a)



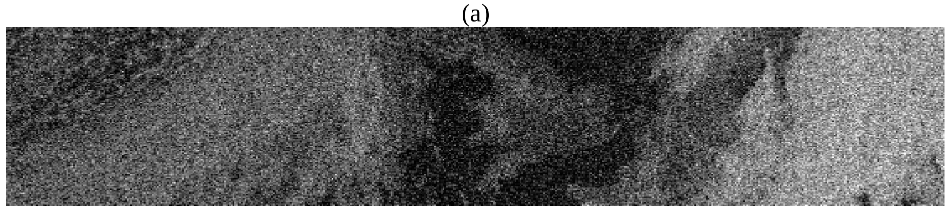
(b)

Figure 3 APT time domain signal and its corresponding images for SNR for 10 db

It is obvious how the image quality has been affected significantly as the SNR value decrease especially with SNR 5db, the image features are barely distinguished when compared to the original signal as shown in figure (3a) and (3b) respectively



(a)



(b)

Figure 4: APT time domain signal and its corresponding images for SNR for 5 db

3.1 Denosing procedure

To denoise a time domain signal or image using wavelet ,a mother wavelet has to be identified first , in this paper, wavelet function Discrete Meyer wavelet known shortly as ‘dmey’ is used as the selected mother wavelet for Decomposition , low pass and high pass filters are shown in Fig (4). The choice of wavelet function is based on applying different mother wavelet functions to the APT signal then the image quality is observed, the selection of the mother wavelet has a great impact on the denoisng process and the image quality as well .

Now the denoising process is implemented on level one only, because as decomposition levels increase the more the signal loses more of its features and image quality degrade significantly .The converted image from the denoised APT signal as a final step is then denoised using the same mother wavelet function ‘dmey’, from different trials that has been carried out it was found that level 7 provide the optimum denoised image,

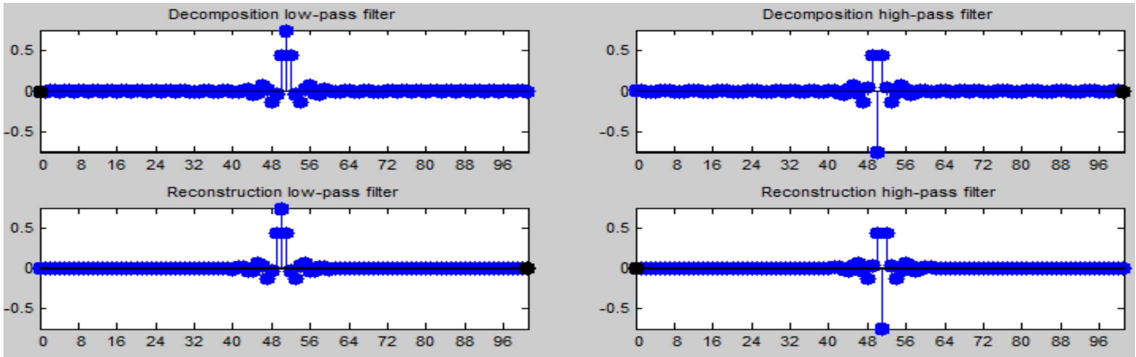


Figure (5): low pass and high pass filters for ‘dmey’

Image threshold technique that has been chosen is Balsparcity-norm .The selection of the threshold was chosen using the same methodology of selecting the mother wavelet for the time domain signal

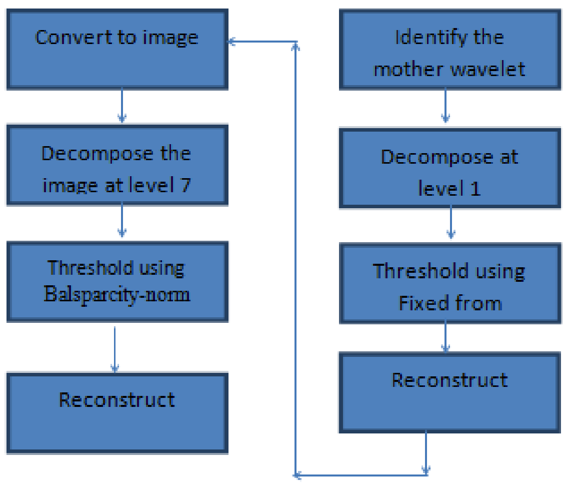


Figure 6: Steps of NOAA denoising

Fig(7) show the denoised image using the procedure in Fig(6) for the 10 db and Fig (8) show the denoised image using the same procedure for the 5 db. It is obvious how the proposed procedure effectively denoise the noisy signal .It can be also seen that there are no much enhancement in the 5 db SNR ,this is due to the high noise level masking the original signal .Therefore the denoisng efficiency decrease significantly in the very high noise level specially below 5 db.

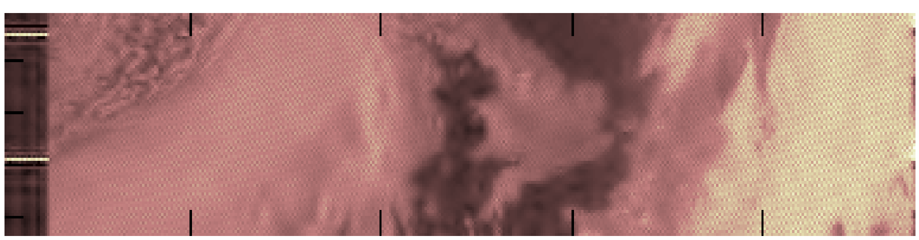


Figure 7: denoised image using the procedure in Fig(6) for the 10 db

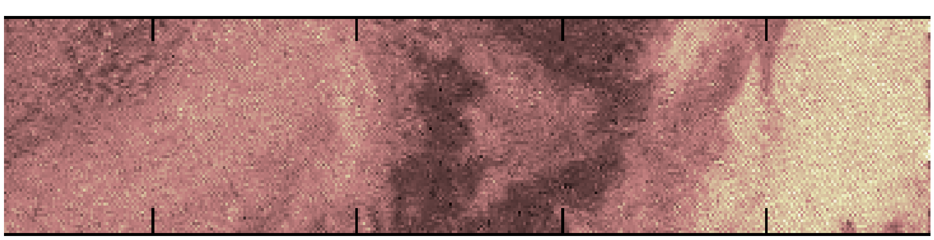


Figure 8: denoised image using the procedure in Fig(6) for the 5db

4. Conclusion

This paper has presented an analytical and experimental study for NOAA signal and image enhancements using wavelet denoising. Time domain signal under the influence of simulated environmental noise has been successfully denoised by using the proposed procedure. Relying on hardware based filtering only is less efficient in denoising the same signals, denoising using the proposed procedure is more robust against high noise. However, it is more efficient if the signal has difference from the average noise level generally not less than 5db SNR . The proposed Wavelet based procedure is also suitable to be applied as part of the automatic enhancements and detection algorithm for NOAA.

References

[1] Gary Davis. "History of the NOAA Satellite Program" , Jun ,2011. [Online]. Available: www.osd.noaa.gov . [Accessed: Jul 2013]

[2] Public affairs "NOAA environmental satellites "[Online] .Available at http://www.publicaffairs.noaa.gov/grounders/ environmentalsats.html , [Accessed :Jul.12,2013]

[3] Public affairs "NOAA Environmental Satellites "[Online].Availablehttp://www.publicaffairs.noaa.gov/grounders npoess.html, [Accessed:Jul.12,2013]

[4] Public affairs "NOAA Environmental Satellites "[Online].Availablehttp://www.publicaffairs.noaa.gov/release2003 /jan03/noaa03007.html[Accessed:Jul.,2013]

[5] Andre Phillips." Home - brewing your own NOAA weather satellite receiving station". Jun,2005[Online]. Available at http://www.phys.unsw.edu.au [Accessed:Jul.,2013]

[6] Mohamed KhalafAlla Hassan, Raja Syamsul Azmir," Ground Target Detection In Forward Scattering Radar Using Hilbert transform and Wavelet technique ", International review of electrical and electronic engineering ,June,2009

[7] Raja Syamsul Azmir Raja Abdullah, Mohd Fadlee A. Rasid and M. Khalaf Mohamed, " Improvement in detection with forward scattering radar ",SCIENCE CHINA Information Sciencesn, Volume 54, Number 12, Pages 2660-2672, December ,2011

[8] K.M. Sanjit, Digital Signal Processing, 3rd, California McGraw-Hill, 2006

[9] Satsignal . [Online]. Available at www. damside.freeserve.co.uk/miniNOAA.zip,[Accessed:Jul.12,2012]

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