ASPECTS REGARDING TO THE DESIGN OF THE FEATURE EXTRACTION ALGORITHMS USED AT STRUCTURAL HEALTH MONITORING SYSTEMS

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ABSTRACT:
THE PAPER PRESENTS A GRAPHICAL PROGRAMMING ALGORITHM WHICH CAN BE APPLIED IN SIGNAL PROCESSING IN ENGINEERING AREA, FOR STRUCTURAL HEALTH MONITORING SYSTEMS. THE MAIN PURPOSE OF THIS ALGORITHM IS TO EXTRACT THE FEATURE FROM A NOISED SIGNAL BY TWO DIFFERENT METHODS: DENOISING (NOISE REMOVAL) WAVELET TRANSFORMS METHOD AND WHITE NOISE CORRELATION METHOD. USING A GRAPHICAL PROGRAMMING ENVIRONMENT, LABVIEW (LABORATORY VIRTUAL INSTRUMENTATION ENGINEERING WORKBENCH), IT DEVELOPED TWO DIFFERENT FEATURE EXTRACTION APPLICATIONS. BY THE SIGNAL ANALYSIS AND PROCESSING TOOLS IT WAS REALIZED A COMPARISON BETWEEN THE TWO METHODS.

KEY WORDS: WAVELET TRANSFORM, FEATURE EXTRACTION, STRUCTURAL HEALTH MONITORING, WHITE NOISE CORRELATION.

INTRODUCTION

The acknowledgements from thermal and mechanical behaviour of the industrial structures are based on the theoretical and experimental researches regarding to the Structural Health Monitoring processes.

According to [1], the Structural Health Monitoring systems involve the integration of the sensors and actuators, the smart materials, the data acquisition and transmission and the computational mechanisms, in a new structure, able to detect, to locate, to evaluate and to estimate the propagation of damage inside a structure.

In aerospace area, the main purpose of the introduction of the Structural Health Monitoring systems is to detect and to diagnose the occurrence of any structural damage from the early stage, to enable the maintenance protocols for the failure case, in order to maintain the aircraft safety.

The signal analysis has an essential role in a good function of the Structural Health Monitoring systems.

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According to [3], the signal analysis is the process through which an analogical signal is taken over from the environment, is transformed into a digital signal and is subjected to different operations based on mathematical algorithms for the extraction of the essential information.

The present paper approaches different programming aspects related to the signal analysis processes.

It is studied and applied two different feature extraction methods, using a graphical programming environment.

It performed a set of tests and finally, a comparative study between the two methods was realized.

THEORETICAL FUNDAMENTALS REGARDING THE ACOUSTIC EMISSION EXPERIMENTAL METHODS

According to [4], the emission acoustic method is based on the measurement of the variation of the number of acoustic impulses emitted, in time unity, by the structure material, at different stage of load, as a result of the structural degradation produced by the materials strains.

The emission acoustic control is based on the detection of the waves emission produced at the fast variation of the local strains from the analysed material. This type of control takes account of the two effects:

- Kaiser effect, which consists in the fact that the acoustic emission restarts after an interruption, at a loading with a load higher than the maximum value from the first emission period,
- Felicity effect that consists in the fact that the acoustic emission restarts at the loading representing such fraction from the previous maximum loading.

The reduced amplitude of the signal indicates the deformation of the material and the presence of the micro fractures and the high amplitude indicates the fracture of the material.

At current days, a set of methods can be applied for the feature extraction process. In this paper two of them were studied.

a) Denoising wavelet transform method

In engineering area, the term “feature” represents the signal of interest. In the most cases, when it is acquired a signal, this contains a second signal that in unknown and it cannot be represented in function of time. This specific signal is called noise.

In the first part of this paper it is studied denoising wavelet transform method. In engineering area, the used transform is a discrete wavelet transformation (DWT), which converts discrete signals to discrete coefficients in the wavelet domain.

According to [2], a wavelet is a mathematical function used to divide a given function or continuous time signal into different scale components.

The term “signal denoising” consists in a process of the recovery of a digital signal which has been contaminated with noise.

The general wavelet denoising procedure follows different steps, as [2]:

- the applying of the wavelet transform to a noisy signal to produce the noisy wavelet coefficients to the level which it can properly distinguish the PD signal occurrence;
- the selecting an appropriate threshold limit at each level and threshold method to best remove the noises;
- the applying an inverse wavelet transform of the thresholded wavelet coefficients to obtain a denoised signal.

b) White noise correlation method

According to [3], White Noise, or Gaussian Noise is called a random uniform signal because it affects all the frequency components of a signal equally.

In signal processing, white noise is considered a random signal with a constant power spectral density.

In fact, this is a signal that contains equal power within any frequency band with a fixed width.

In engineering, the physical systems are never disturbed by white noise, although white noise is a useful theoretical approximation when the noise disturbance has a correlation time that is very small relative to the natural bandwidth of the system.

After [3], White Noise Correlation is a mathematical tool, often used in signal processing, for finding repeating patterns, such as the presence of a periodic signal obscured by noise, or identifying the missing fundamental frequency in a signal implied by its harmonic frequencies.

ASPECTS REGARDING THE DESIGNING OF THE FEATURE EXTRACTION ALGORITHM, USING LABVIEW CODE

The both algorithms used in this paper were developed in a graphical programming environment – LabVIEW. According to [5], LabVIEW is a system developed by NI (National Instruments) that allows the user to design software using a graphical language.

Using this graphical programming environment, the feature extraction algorithm, based on wavelet denoising method is created.

Figure 1 presents the diagram of feature extraction process based on wavelet denoising method. It consists in signal processing and programming tools.

The data acquisition process supposes a set of steps: the configuration setting, the task starting, the signal acquiring, the signal processing, the stopping and clearing of the task.

For displaying the results it is used two oscilloscopes of graph type: one for the noised signal and other for the signal without noise.

The settings configuration is referred to the specification of the device type, the sample mode and the number of samples/channel. For denoising tool, the wavelet type, the approximate coefficient and the threshold value were set. As threshold settings, the *minimax* type and *multiple* level mode is applied.

It can observe in Figure 1 that the LabVIEW code is introduced in a While Loop. This loop allows to application to run in a continuously mode. Inside the loop it is put a timer, which offers the possibility to the software to wait a specific time between two successively runs.

The system response largely depends on the amplitude value. For this purpose, to identify the system response, an amplitude measure tool was used.

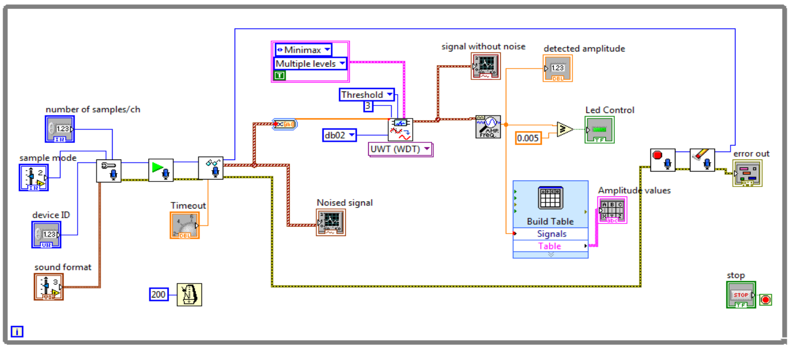

Fig. 1. Feature extraction by wavelet denoising method diagram

Figure 2 presents the panel of the feature extraction algorithm based on the first studied method. In the right corner of the interface a numeric indicator, a LED and an amplitude values table were placed. The LED was used to highlight the system acoustic response.

Fig. 2. Feature extraction by wavelet denoising method panel

The second algorithm, shown in Figure 3, is based on white noise correlation method. In this case, the acquired signal follows the same steps as in the previous algorithm. So, after the signal is acquired this in introduced together with a white noise signal, in a correlate function. The pure signal (with noise) is represented on the “noised signal” graph and the processed signal is showed on the “signal without noise” graph.

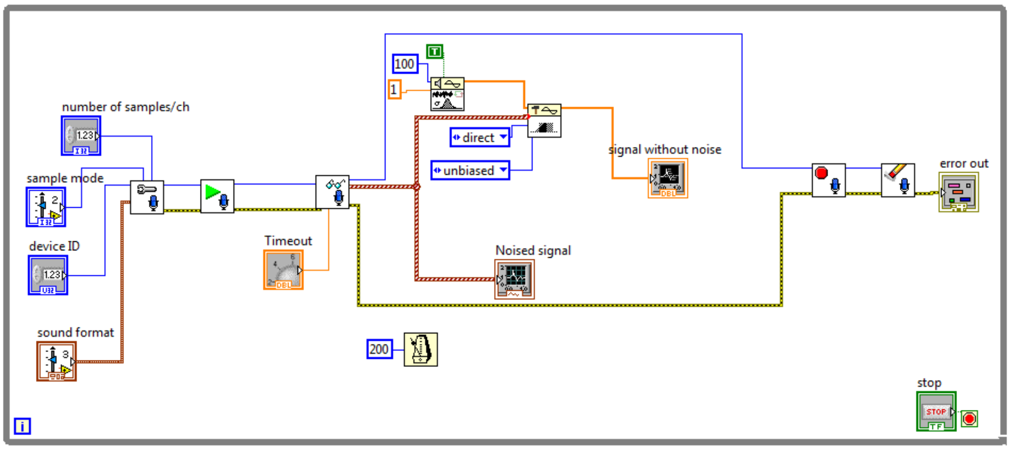

Fig. 3. Feature extraction by white noise correlation method diagram

The image from the Figure 4 illustrates the panel for the feature extraction algorithm based on white noise correlation method.

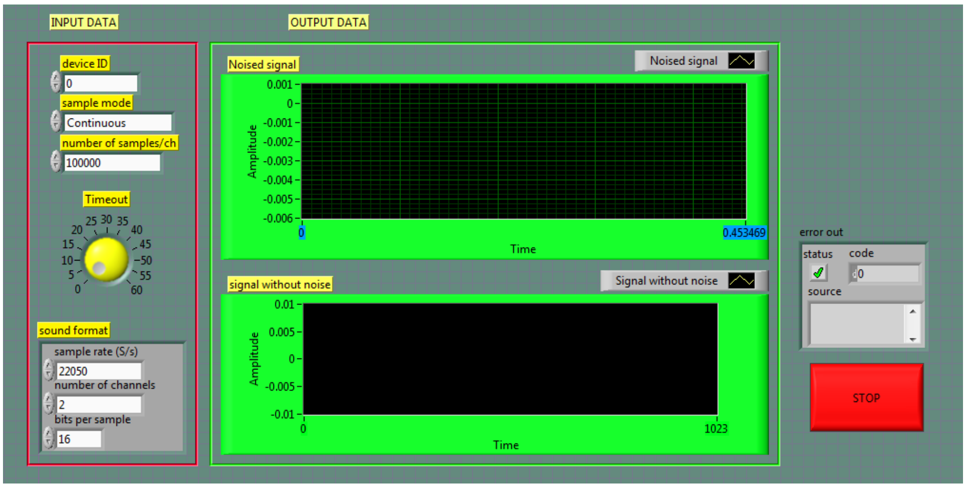

Fig. 4. Feature extraction by white noise correlation method panel

RESULTS – A COMPARATIVE STUDY BETWEEN THE TWO DIFFERENT FEATURE EXTRACTION METHODS

To highlight the advantages and disadvantages of the two feature extraction methods proposed, a set of testing were performed. In the both situations, it recorded the system acoustic response in two cases:

- with no force applied under the system;
- with a small force applied under the system.

For the first situation (the wavelet denoising method), in Figure 5 it presents the system response in the case where is no force applied on the system. The first graph shows the pure signal and the second one presents the signal without noise. It can observe that the amplitude values are low; these are due only to the vibrations from the environment.

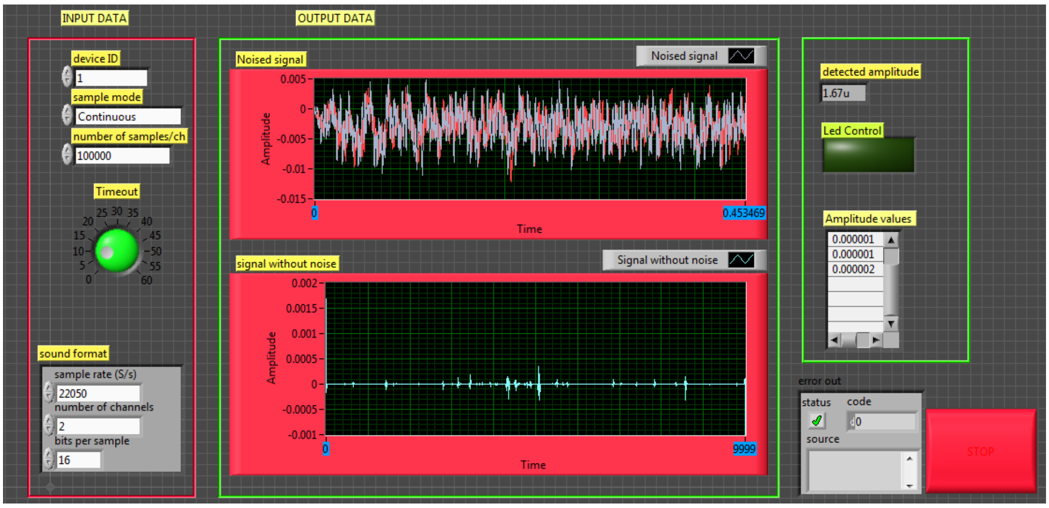

Fig. 5. System acoustic response using wavelet denoising method (there is no force applied to the system)

When it is applied a low force under the system it observes, in the Figure 6, a sudden increase of signal amplitude. By programming, an amplitude threshold was set. Each amplitude value of the acquired signal was compared with this threshold. The Led was used to indicate when the force is too high and it could produce damages in the system.

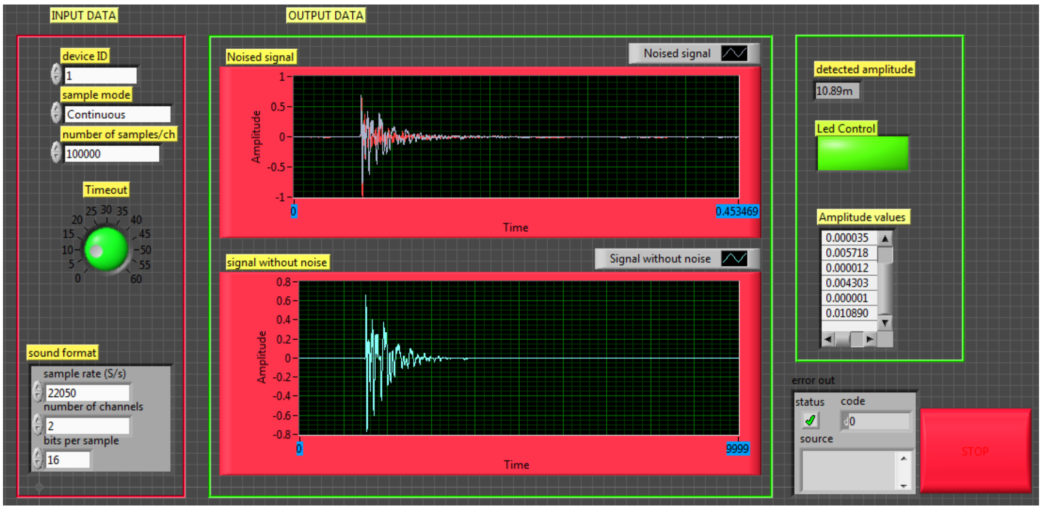

Fig. 6. System acoustic response using wavelet denoising method (there is a small force applied to the system)

Such tests were performed for the case when the white noise correlation method was used. In Figure 7 is illustrated the system acoustic response when is no force applied under the system. It can observe that a feature extraction exists but for this case only a single level of denoising is possible.

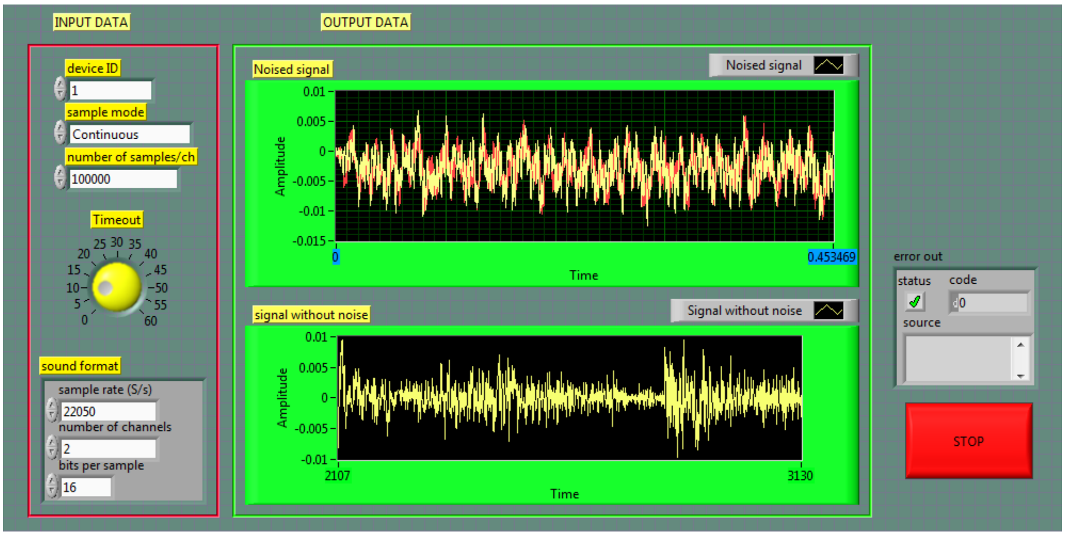

Fig. 7. System acoustic response using white noise correlation method (there is a no force applied to the system)

In the case of the applying of a low force under the system, it can see in Figure 8 that the system behaves in the same way. On the both graphs it appears a sudden amplitude increase of the acquired signal. Taking account that the signals were acquired on two channels, a noise removal is observed but is not as effective as in the first case.

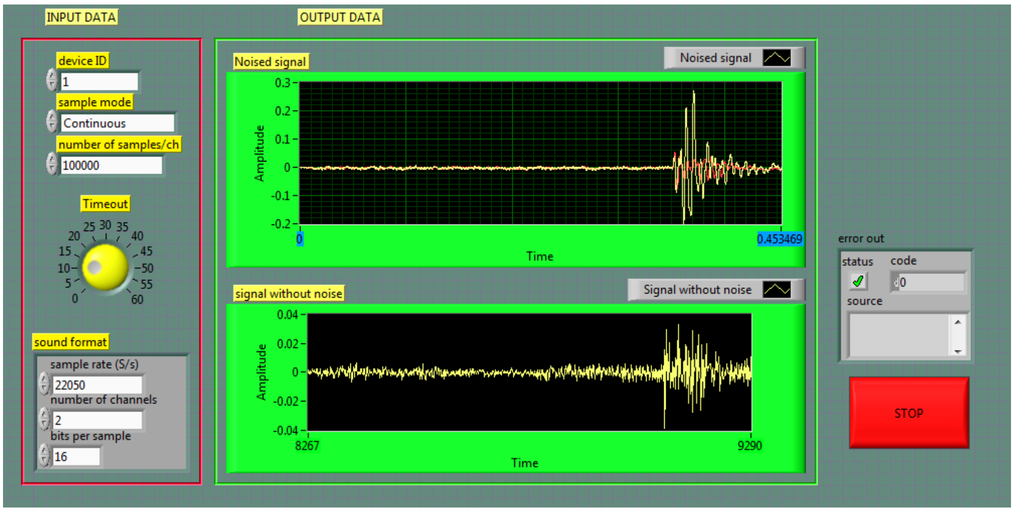

Fig. 8. System acoustic response using white noise correlation method (there is a small force applied to the system)

CONCLUSION

Feature extraction is a very important procedure that can be used in data acquisition area, especially in the industrial processes.

In Structural Health Monitoring (SHM) techniques it is often used this kind of process. This technique is based on a signal acquiring, processing and analysing to can obtain a structure life prediction.

In this paper, two feature extraction methods were studied and tested: wavelet denoising transform and white noise correlation method. In function of the requirements of an application, the both methods have advantages and disadvantages, too.

The first case offers a good extraction of the interested signal but cannot totally remove the influence of the vibration from the environment. For this reason it can observe in the graphs small amplitude values. Feature extraction by wavelet transform is a better option in all the data acquisition processes because it allows a multilevel threshold of the recorded signal.

The second case, white noise correlation method, is suitable for the voice signal analysing because offers a good extraction of the signal obscured in noise but its disadvantage is that this method cannot allows multiple levels of signal filtering. Using this method it is possible to obtain a system acoustic response but this technique is not so accurate that the first one.

As a final conclusion it can asserts that, in SHM techniques, for best results, it is necessary to use a feature extraction method based on wavelet denoising transform.

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