Matrix Pencil Method applied to the compression of audio data in naval operations

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***Abstract*—In this paper, a technique for compressing data from a time-domain audio digital signal, using the Matrix Pencil Method (MPM) is presented. The results show that the selection of critical parameters like time window and sampling frequency can effectively work alongside MPM, to reduce an audio signal data to a set of residues and poles, and have an accurate reconstruction of the vector related to the original audio. The compression process is focused on acoustic signals coming from boat engines and the reconstruction made for these poles and residues provides an R^2 correlation coefficient near to 100%. Besides, is possible to obtain a rate of compression between 80 and 93%. The audio signals are collected by hydrophones deployed in a coastal area, close to the shore. The signal under process is expected to present frequency components up to 1KHz. The data reduction enhances the transfer time and the bandwidth of the wireless communication channel under maritime conditions. Also, the proposed system considers the case of multiple sensor locations, acquiring a signal from multiple points in the area of influence allowing higher-level processes as the identification and tracking of the observed boat in naval operations.**

***Index Terms*—Matrix Pencil, Acoustic signals, frequency, poles, compression, reconstruction.**

I. Introduction

In apps related to naval operations, where processes to location and identification of targets are implemented using acoustic signals coming from hydrophones, the information processing should be hard. With the purpose of to reduce specifications of weight, energy, hardware and software are advised that the processing is done at earth, where is possible to supply all the requirements mentioned above, more effectively and economically than in the sea.

In order to send an acoustic signal from an offshore buoy to a base station in the earth, with a large number of points a method to reduce data is relevant and this reduction has to be reliable enough to be able to do the information processing keeping the principal characteristics of the signal.

The Singularity Expansion Method (SEM), described by Baum (1976) [1] is based in the extraction of the principal poles and residues to a determined signal. This is possible to describe a signal using its principal physics characteristics regardless of whether it is in the frequency or time domain. specifically, in the frequency domain it is possible to use MPM.

II. Matrix Pencil Method

MPM gives an approximation of a signal ($f(t)$) in the time domain based in its principal singularities. The poles ($s_1, s_2, ..., s_M$) are found using the *Singular Value decomposition* in an algebraic process based on the information to the discrete signal.

$$f(t) = f(p\Delta t) = f_p \tag{1}$$

Where Δt is the inverse of frequency sample and ($f(p\Delta t)$) represents the $p-th$ term of the discrete signal. The signal, with N components, can be approximated by an summation of the exponentials using to poles (s_i) and residues (R_i) [4] .

$$f_p = \sum_{i=1}^{M} R_i e^{s_i p \Delta t}, p = 1, 2, 3, ..., N \tag{2}$$

The accuracy of the summation depends on M, that is the quantity of singularities that we need. According to the Fourier theory, it is necessary to use an infinite quantity of frequency components for having all the information of the signal, but the approximation can be successful using a value of M according to the characteristics of the signal.

To find the required values is necessary to carry out an algebraic process using Hankel and Vandermonde matrix, SVD and the standard Moore–Penrose pseudo-inverse. This process is described by Tapan in [4] and [5].

Once the singularities have been found, the signal is reduced from an N position vector to a group of M complex singularities. These poles and residues can be sent by wireless communication and can be used to the signal reconstruction in the data processing place.

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III. METHOD IMPLEMENTATION

The implementation begins with a monophonic acoustic signal referent to a boat in the ocean. This comes from a speedboat with the motor at 1500rpm taken by a hydrophone, the sampling frequency is to 2,2KHz and duration of 1 second. The principal components of the motor noise are under 1KHz, for that reason the sampling frequency can be around to 2,2KHz taking into account Nyquist theory. The signal taken for this job is shown in the figure 1.

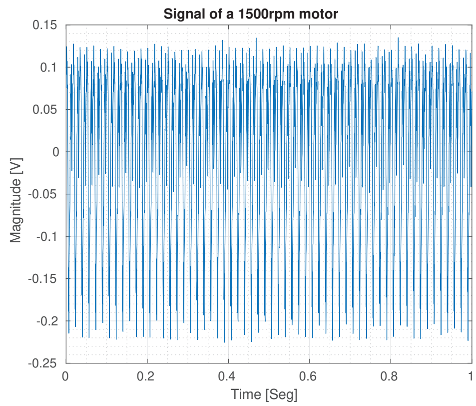

Fig. 1. Signal of speedboat

If we wanted to transmit this signal for a wireless channel, we would have to send a double type vector of 2.200 positions. This involves the transfer of a string to 141.121 bits. Using Fourier theory and implementing MPM, we can estimate a limited number of singularities according to the characteristics of the signal. In figure 2 are represented the 20 poles corresponding to the first frequency components to the signal.

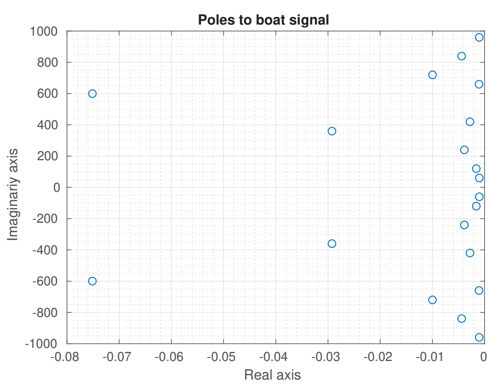

Fig. 2. Poles of acoustic signal

After this point we have 20 complex poles and the same quantity of double residues. This represents 60 numbers type double which are 3.600 bits of information. Compared to the raw signal data, we have a compression of $97,448\%$.

Now, with the singularities is possible to do the reconstruction in the processing data place, we have to ensure that the

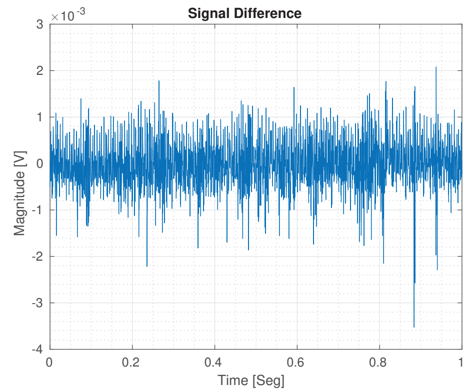

Fig. 3. Difference between original and reconstructed signal

reconstruction is valid. For this, we use the process related to MPM and we compare the new vector with the original signal. Figure 3 shows the difference in magnitude between the original and the reconstructed signal with MPM. A quantitative comparison can be done using the correlation coefficient of R^2, for this case is 99.7%. Table I shows the information of compression and correlation coefficient to the signal with different quantities of M [4] [5].

TABLE I
INFORMATION ABOUT COMPRESSION OF SIGNAL

M	*Compression percentage[%]*	*Correlation coefficient[%]*
5	99,318	89,12
10	98,63	96,89
15	97,95	98,18
20	97,27	99,13
30	95,909	89,96

IV. DISCUSSION

Data compression is useful in apps like naval operations. Mpm gives a possibility to get better the size of data without improve information size without losing important data. With this process, we managed to reduce the size of the data with percentages of up to 99% keeping a correlation of 89%. The number of singularities depends on the app and to the characteristics of the signal of interest and of the percentage of similarity that is required. Additional to what was written above, the singularity calculation allows knowing physical characteristics about the signal and this information can be helpful in the data processing in apps related to location and identification of targets. A factor to evaluate in this type of procedures is time processing because the algebraic process can be strong in cases of signals with more points.

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