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# Compression Techniques of Underwater Acoustic Signals for Real-Time Underwater Noise Monitoring†

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**Abstract:** Monitoring of the marine environment results in large amounts of data that must be processed and transmitted effectively for efficient resource management. In particular, given its high sampling rate, underwater noise signal acquisition technologies deserve special attention. In this article, a comparative study of the efficiency of different information processing and compression techniques is carried out, depending on the characteristics that want to be transmitted from the original signal. The applications and experiments carried out are focused on responding to the Marine Strategies, a marine environment planning instrument created under Marine Strategy Framework Directive 2008/56/EC, of June 17, 2008 (MSFD), and more specifically to the Descriptor 1 that regards the noise levels (both continuous and impulsive), as well as part of the Descriptor 11, focused on the detection and abundance of cetaceans.

**Keywords:** Underwater noise; Acoustic monitoring; MSFD; Data compression

## 1. Introduction

Underwater acoustic monitoring is essential for the protection of the underwater environment. In recent years, different projects and technologies have been developed for this purpose. Regarding the Marine Strategy Framework Directive (MSFD), the Descriptor 11 (D11) addresses the introduction of underwater noise and its effect on the marine environment. Furthermore, the Descriptor 1 (D1) tackle the biological diversity, including marine mammals whose relationship with underwater noise is relevant, both to quantify its impact and to establish populations.

However, one of the main characteristics of the acoustic signal register compared to other environmental variables is its high sampling rate (of the order of tens of kilo hertz). That is why continuous monitoring of the marine environment results in large amounts of data.

Therefore, it is necessary that the recording systems incorporate processing and compression technologies that, on the one hand, optimize the information that is to be extracted from each measurement and, on the other, guarantee the sending of said information with the best efficiency. At this point, the information compression techniques applied to noise signals, whose experimental advance and contrast is the subject of this document, come into play.

In addition, in the context of large wireless sensor networks, these have a very high consumption, due in large part to the communication between sensors since it needs a lot of power to transmit the data. Therefore, data compression is unavoidable because this reduces the power consumption and sends a greater amount of information [1].

## 2. Compression techniques

Information compression techniques have played a fundamental role due to their potential to minimize the storage space of information, as well as the necessary bandwidth for transmission between remote equipment. However, although today there are numerous digital information compression methods, only some take advantage of the particularities of typical audio signals, which are: the relative short-term predictability and the high degree of redundancy.

In the present study it has been implemented the following techniques have been implemented for the reduction of size in the information of underwater noise signals. The following scheme illustrates the relationship between the techniques studied below.

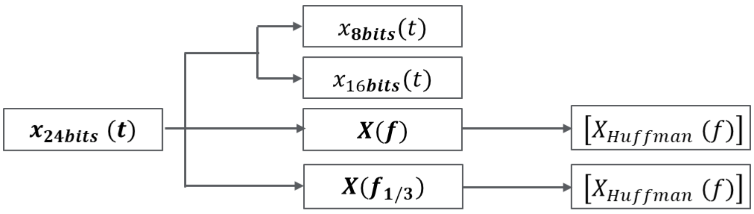


**Figure 1.** Example of building a decision tree and assigning codes in Huffman algorithm.

### *2.1. Bit-Depth Reduction*

It consists in the reduction of the quantization bits of the signal. The procedure consisted of, once the signals were registered, decimate the samples between the maximum and the minimum of the signal in 8 and 16 bits, that is, resulting in $2^8$ and $2^{16}$ samples. It should be noted that this is not a canonical resample bit-rate since, in this application, only the dynamic range of the registered signal is used and not the entire dynamic range of the acquisition system.

### *2.2. Magnitude of the frequency spectrum*

It consists in calculating the frequency spectrum of the signal through the Fast Fourier Transform [2]. When obtaining the spectrum, two additional actions are carried out that allow it to decrease its size:

1. Although the spectrum is composed of complex numbers, for calculations related to amplitude, only its spectrum is used. With this, the angular information is lost but the amount of necessary information is reduced.
2. The calculation of the FFT produces a spectral spill offering redundant information in half of the resulting spectrum. Therefore, this part can be deleted to reduce the number of data that represent it.

### *2.3. Spectrum of 1/3Ooctave*

This method basically consists in sending the spectral information contained in third octave bands of the original signal. This is one of the methods that most reduce the original signal at the cost of more skewed information.

### *2.4. Lossless Compressed Spectrum*

For wireless communications and sensor networks, the most studied lossless data compression algorithms have been the Huffman and Lempel-Ziv Welch (LZW) algorithms [3-6]. In the present study, it has been implemented the Huffman algorithm for the compression of the spectrum of underwater noise data. Huffman coding allows, in a simple and optimal way, to map each symbol of an alphabet with an optimal length code. To achieve this optimal assignment, the symbols are represented with codes whose length is inversely proportional to the probability of the symbol. In this way, the least likely symbols are represented with longer codes, and the most likely with shorter symbols.

The process of assigning codes is carried out by building a binary tree, from the leaves to the root, so that the leaf nodes are the assigned symbols. In the construction of the tree, the less probable nodes join successively to form another node of greater probability, so that each of the links adds a bit to the code of the symbols that we are joining. This process ends when only one node is available, so that it represents the root of the tree [9]. A representative example of the process carried out from the recording of the noise signal, to the assignment of codes and the construction of the decision tree is shown in Figure 2.

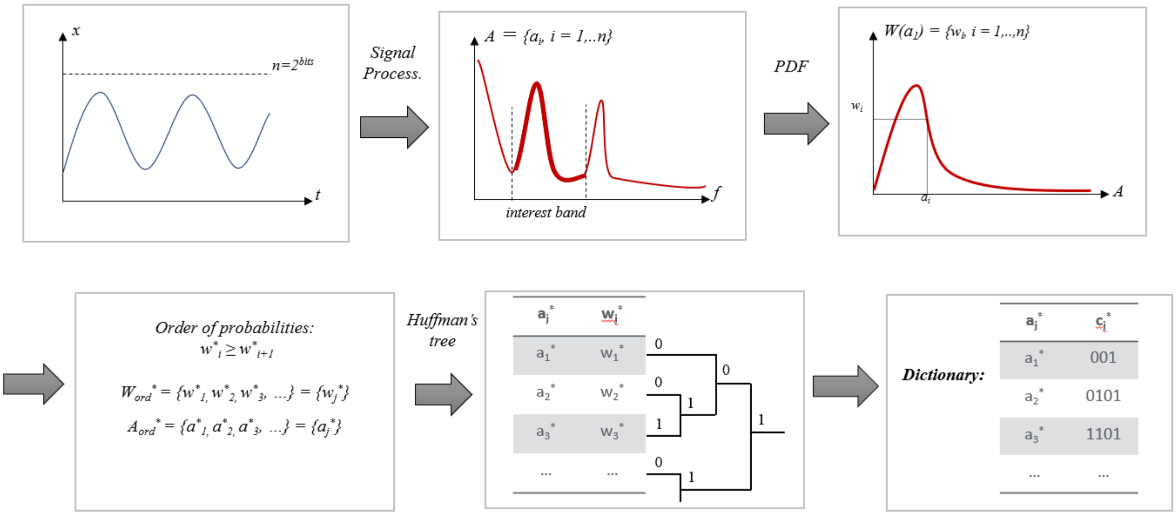


**Figure 2.** Example of building a decision tree and assigning codes in Huffman algorithm.

As it will be seen later, with this algorithm a significant reduction in the size of the spectrum to be sent is achieved at the cost of a longer computational time.

## 3. Results

The application results of each of the prior techniques are shown below in terms of the resulting size of the data and the processing time. For each technique implemented, graphs will be shown with the dependence on the original signal size of the following parameters:

1. Size [bits]: data size after applying the technique (color line) and size of the original signals (black line).
2. δ Size [%]: percentage ratio between the size of the data once the technique has been applied with respect to the original size.
3. Time: processing time of application of the technique in question (color line).
4. δ Time [%]: percentage relationship between the processing time and that of the original signal.

In the first place, the following figure shows the results of the *bit-depth reduction* technique. Respect to the size, it is observed that the signals are reduced to approximately 34% of the original size, except for durations of less than 10 seconds, where the reduction is somewhat larger (smaller size). Respect to the processing time, this is less than 1 second in all the analyzed signals, which is below 0.1% of the original signal time.

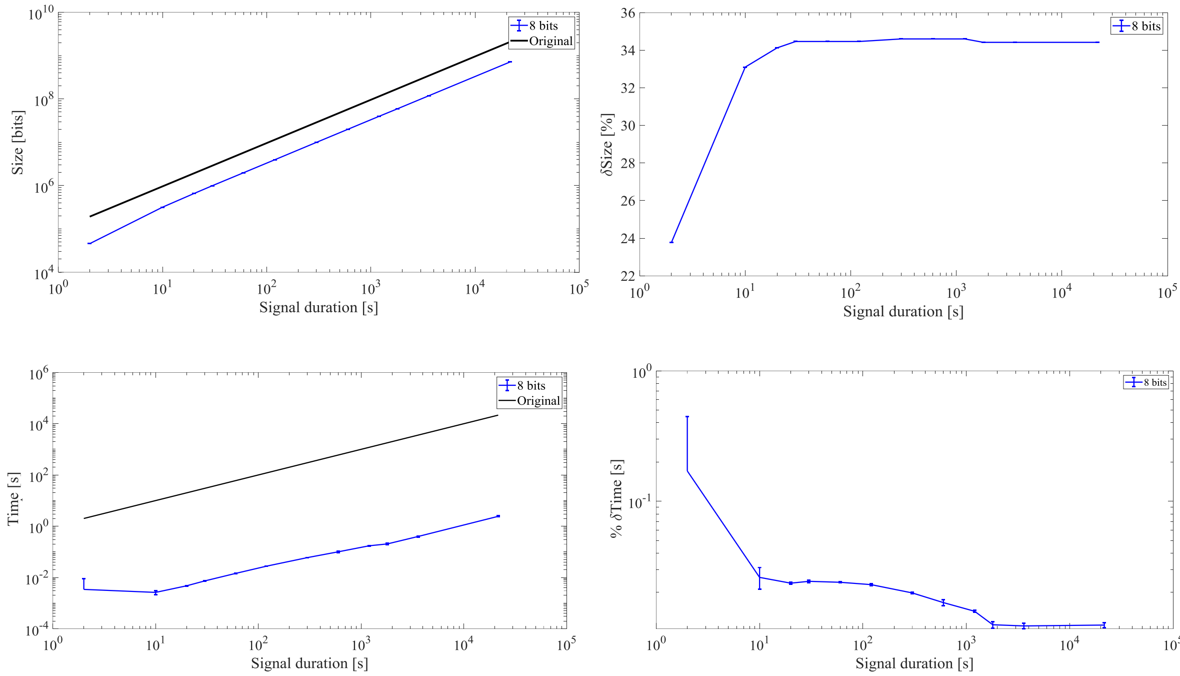


**Figure 3.** Results of application of the technique based on bit-depth reduction.

After this, the results of applying the *frequency spectrum* and *spectrum of 1/3 octave* are shown below, without applying any additional compression. Regarding the size, by applying the *frequency spectrum* to the original signals, these are scarcely reduced, in contrast to applying the same method but to the signals converted into 8 bits, with which the reduction achieved is 1%. On the other hand, by applying the *spectrum of 1/3 octave* technique both to the original signals and to the signals converted into 8 bits, the reduction achieved is less than 2% and 0.03%, respectively. As for the processing time, regarding the both techniques, the results are below than 1 second in each case of study, being less than $10^{-4}$ % with respect to the original signal for the *frequency spectrum* and the *spectrum of 1/3 octave* technique and being less than $10^{-2}$ % and $10^{-3}$ % for the signals converted to 8 bits due to this processed.

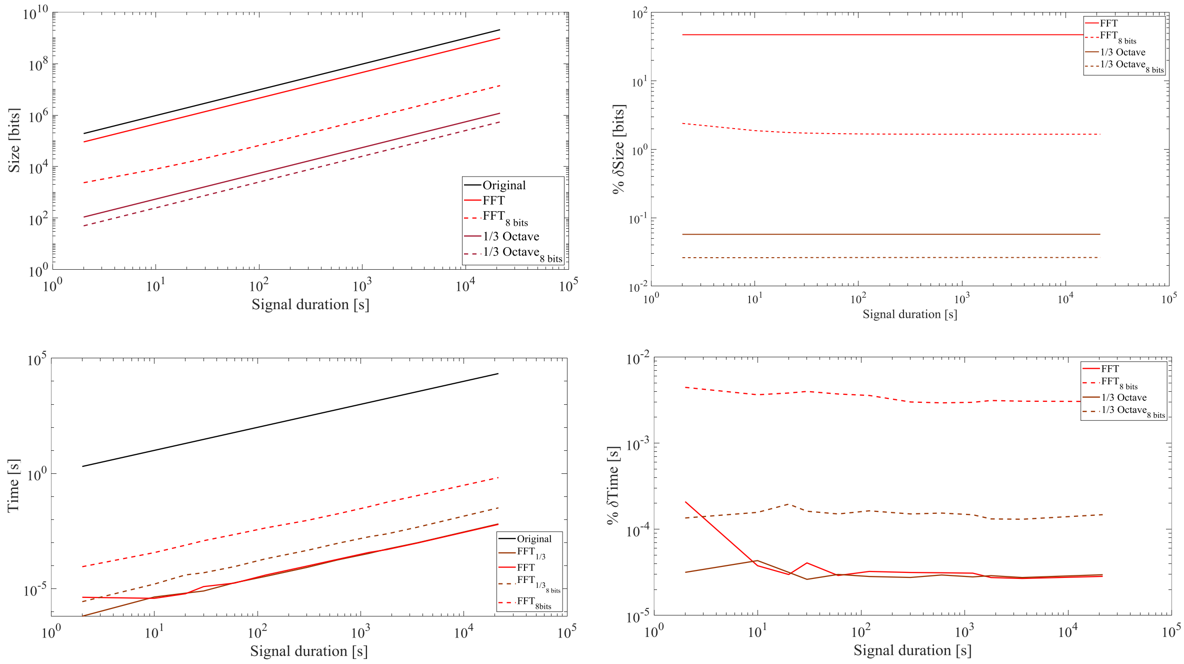


**Figure 4.** Results of application of the technique based on frequency spectrum and 1/3 octave reduction.

Applying the lossless compression of the Huffman technique to the previous processes, the following results are obtained. In **Error! Reference source not found.**, it can be observed that regarding the size, the result achieved by applying Huffman to the *frequency spectrum* and the *spectrum of 1/3 octave* converted into 8 bits is 1% and 0.02%, respectively. Regarding the processing time, applying the compression algorithm to the *frequency spectrum* and the *spectrum of 1/3 octave* of the original signal, the processing time achieved is less than $10^{-3}$ % while, applying Huffman to the signal converted to 8 bits, the processing time is 2 % for the *frequency spectrum* and 0.3 % for the *spectrum of 1/3 octave.*

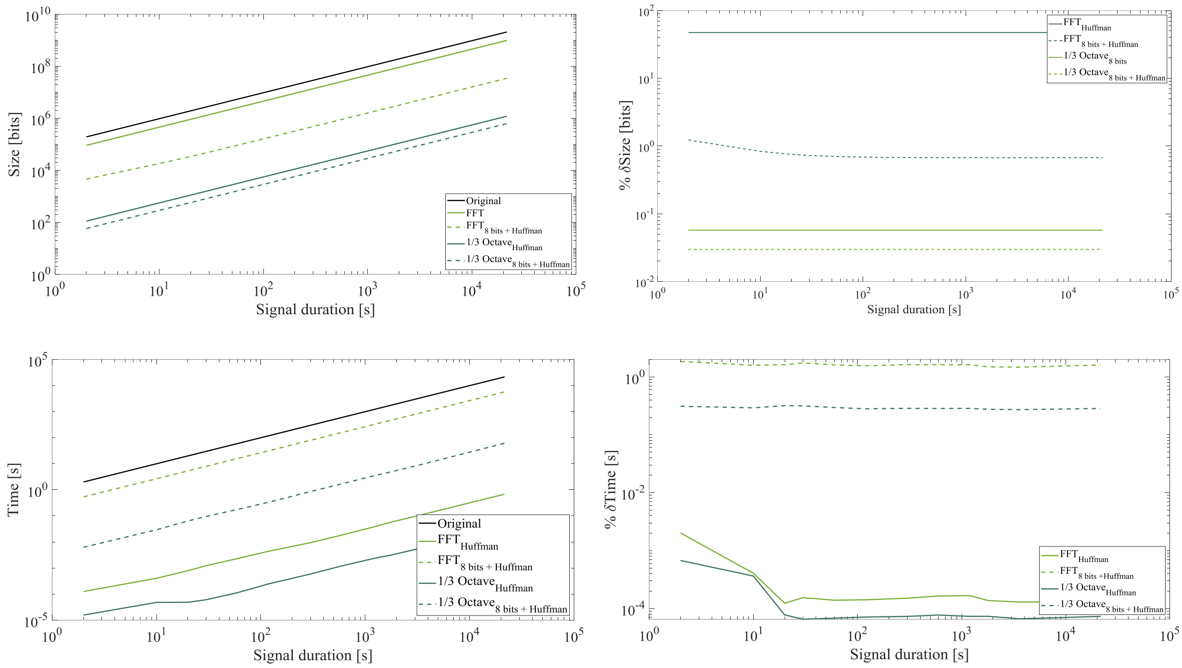


**Figure 5.** Results of application of the technique based on frequency spectrum and 1/3 octave reduction.

## 4. Conclusions

The following table shows the results of the different compression methods expressed in terms of final percentage of size and calculation time with respect to the original signals. Respect to the FFT it can be obtained size up to 1 % respect to the original signal, with a processing time of 2 %. Considering the 1/3 Octave, it is obtained a reduction of 0.02 with a procession time of 0.3 %.

**Table 1.** Results of the different compression methods expressed in terms of % size and calculation time with respect to the original signals.

| **Method** | **8 bits** | **FFT** | 1/3 Octave | 8 bits | | Huffman | | 8 bits + Huffman | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | FFT | 1/3 Octave | FFT | 1/3 Octave | FFT | 1/3 Octave |
| **% Size** | **34** | **50** | 0.05 | 2 | 0.03 | 15 | 0.08 | 1 | 0.02 |
| % Time | $2 \cdot 10^{-2}$ | $3 \cdot 10^{-5}$ | $3 \cdot 10^{-5}$ | $4 \cdot 10^{-3}$ | $2 \cdot 10^{-4}$ | $7 \cdot 10^{-4}$ | $7 \cdot 10^{-5}$ | 2 | 0.3 |

Applying these results to underwater acoustic monitoring, they allow to suite the processing technique to the original signal according to the consumption and transmission needs of the monitoring system.

This results, combined with previous studies on the transmission efficiency of each of the compressed data set [11], gives an overview of the optimization possibilities of these sensor networks based underwater acoustic motorization technologies.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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