Satellite buoy for acoustical detection and classification of marine mammals to monitor industrial noise impact on them.

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***Abstract -* This paper presents the new technologies to put into a practice the new approach to mitigation of impact of manmade sound on Marine Mammals. Our concept is based on Passive acoustic measurements of industrial noise levels with synchronous detection of the presence of vocal marine mammals species by using new algorithm to monitor directly noise impact on them in real time. This work describe the first results of a collaboration on Russian- French Project on developing fully completed system with detecting marine mammals, real time data transmission, and estimating anthropogenic noise impact on them.**

I. Introduction

There are a lot of man-made sound sources which lead to disturbance of marine life - explosions, shipping, seismic surveys, offshore construction (offshore wind farms or hydrocarbon production and transport facilities), and offshore industrial activities (dredging, drilling etc.), sonar of various types, and acoustic deterrent devices. Documented effects on marine life vary greatly from very subtle behavioral changes, avoidance reaction, permanent or temporary hearing loss, injury and even death in extreme cases. The review of observed effects can be found in the literature (Richardson et al. 1995) or OSPAR Commission documents (OSPAR, 2009).

Lately the European waters become a center of offshore wind farm development as described in the respective JAMP assessment (OSPAR, 2008). Some noise generating activities such as, oil and gas developments, sand and gravel extraction and construction of offshore wind farms are regulated by the Environmental Impact Assessment (EIA) Directive (85/337/EEC (as amended by 97/11/EC)). This Directive requires performing an EIA if projects are likely to have significant effects on the Marine environment.

Acoustic monitoring can improve the efficiency of visual surveys and even can replace it, if detection/classification has to be performed reliably and in real time. We propose to make a next step, and to proceed simultaneously to detect the presence of marine mammals species and to measure the industrial noise levels that possibly affect them, in a limited area around industrial activity, and then to transmit both type of data in real time to make decision about the harmlessness of this activity on the marine mammals depending on some noise exposure criteria. The review of the Marine Mammal noise exposure criteria can be found in (Southall, B.L., at al, 2007).

Although separately each of other a self-contained underwater sound recorders, detection tools (like C-POD) and satellite transmission channels to Internet are commercially available, combining it into one low-cost and easy-to-deploy device gives us a new capability to monitor acoustic impact on marine mammals in real time. This opens the possibility for timely alerts of the presence of marine mammals and for that case estimate the necessity of mitigation of the adverse effects.

This communication presents a French-Russian program which aims to develop a buoy with a satellite transmission which at the same time makes it possible to evaluate industrial noises and to

detect marine mammals. This tool can then be used like means of control and reduction, in real-time, of the industrial risks on marine animal life.
This tool is composed of two parts, the buoy on one hand and of the data exploitation platform (DCLS) on the other hand. These two parts are currently the object of developments. It is the case of the optimization of the data to be transmitted and of the processing tools which have to be integrated into DCLS. The latter are illustrated, here, by developments on the detection of clicks for example.

II. Buoy presentation (SIO)

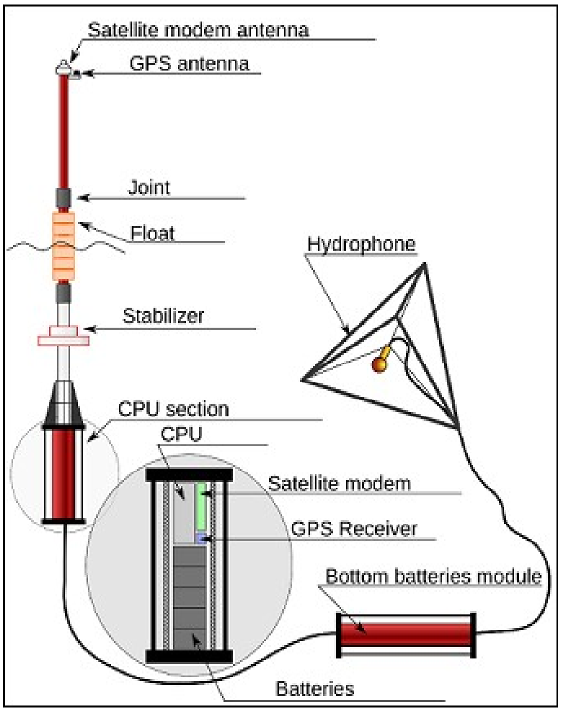
Our Project includes construction of, reliable buoys connecting bottom to surface, in which a bottom acoustic data acquisition system is able to work in presence of strong currents and in which surface buoy provides a satellite transmission channel connected directly to Internet. As prototype for our tool we used the autonomous satellite buoy constructed in SIO Laboratory that was successfully tested at real time acoustic monitoring of the Western Grey Whales during oil platform construction on shelf of the Ohotsk Sea on Far East Russia (Vedenev, A. I., at al, 2009). The prototype of satellite buoy is capable to perform continuous recording of data from it's sensors, analyse recorded raw data with given algorithm and transmit the results with given period. It is possible to remote control the buoy. Devise consists of surface and bottom waterproof modules and a hydrophone, connected by power and signal cables. Surface module is floating on a surface and carries all active electronics, aerials and some batteries. Bottom module is filled with batteries. In case of higher power demand there could be several bottom modules with batteries inside.

The heart of the system is powerful but energy-effective embedded industrial PC capable of processing acoustic data in real-time. At the moment a Diamond Systems Poseidon SBC is used in prototypes, but the target system for production is an ARM-based board because of much lower electric power consumption with sufficient computing power.

Software is based on Linux OS, for hard real-time applications the RTAI modification of Linux kernel is used. A Qualcomm GSP-1620 satellite modem provides internet connection for sending data and receiving commands. In certain cases a radio communication with effective range of 20 km is available as an option. GPS receiver module provides precise time signals and geographical position to the system.

The weight of the floating module on air is about 35 kg, length of– 4 m. Mast with aerials is rising above the surface to 2 m. Max. Depth of buoy deployment – 100 m.

Duration of continuous work-up to 1 month, depends on rate of data transmission and capacity of power supply battery.



Caption.1 : Scheme of the system (top), surface buoy (bottom)

To visualize data and operate the buoy via internet required a web-server, capable to run PHP scripts and a MySQL database.

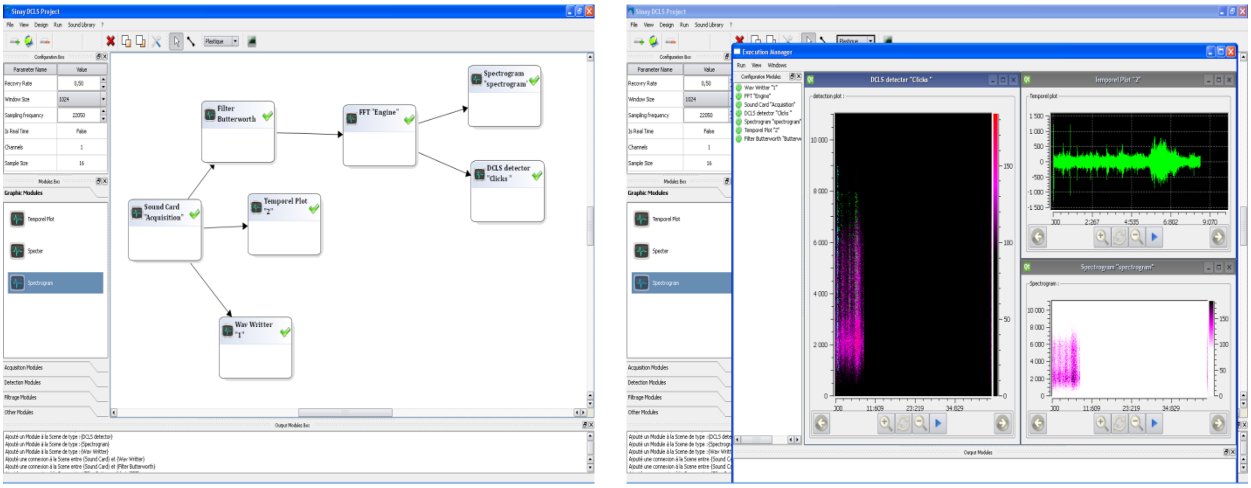
III. DCLS platform (SINAY)

DCLS software is designed to detect, classify, localize and synthesize marine mammal's sounds. It is flexible, i.e. with a modular architecture based on multi-platform framework, it can work with several operating systems (ex : Windows/Linux, Mac OS…etc) and for embedded systems with embedded Linux or windows CE. DCLS provides to users several basic signal processing functionalities and specific modules, to detect, classify, localize and can be used to synthesize marine mammal's vocalization. It enables to incorporate new modules, developed according to our architecture, by making any change in DCLS. As we can see in caption 2, on the left, users can choose the modules they need (FFT engine, filters, display modules…) and put them on the workspace to design their own configuration as they want. Also, there are parameterized configurations for DCLS functionality which can be loaded and work in order to analyze audio files or data coming from acquisition cards. The execution manager window, given in the right part of the caption, shows the configuration modules status and display results. Furthermore, DCLS can analyze database of recorded signals and save the generated results automatically.

The DCLS software allows to test several algorithms with large database and compare their respective performances. With such tool, it is easier to evaluate algorithm performance and choose the best one, according to the results obtained from all kinds of large analyzed data.

In this project, some DCLS modules, embedded on the satellite buoy, have to detect the presence of marine mammal species, and in the same time, have to measure the levels of industrial noise. With such tool, a decision to stop or reduce noise caused by the industrial activity could be taken at the right time when the measured sound level is too high and possibly affect animals.

Obviously, in the presence of industrial noise, we need a robust method which can detect several kinds of marine mammal's sounds in a very noisy environment. To provide such a tool, two approaches can be adopted: The first one, consist in implementing, on the buoy, a preprocessing algorithm in order to compress and reduce the volume of data which have to be transmitted with wireless to the DCLS server for post processing (detection). Therefore, the data volume transmitted by satellite will be acceptable. The second one is to implement detection algorithm completely on the buoy and send only information needed to mitigate impact of industrial noise on marine mammal.



Caption.2 : From left to right: user interface for designing the signal processing chain, execution interface of the considered configuration.

IV. Correlation algorithms (ISEN Brest)

One of the algorithm plugged in DCLS platform and embedded in the satellite buoy is the 2D correlation algorithm which is based on a global processing of the spectrogram (matched filtering), to detect specific songs of marine mammals. This technique is slower than the temporal correlation (1D) already tested for song detection of "bowhed whale" (D.K. Mellinger and C.W.Clark 2000), but it is much more robust. Indeed, the correlation 1D requests a modeling of the target signal (a difficult task, because of the large diversity of frequential distributions) while in the 2D correlation, for the reference, a mask of simple similar signal shape or a reference trained from a real spectrogram (training) are appropriate enough.

To illustrate the advantages of this method we have tested it on clicks detection with both methods and we have compared their respective results. Ultimately, this algorithm will have to be embedded in the buoy (satellite Buoy).

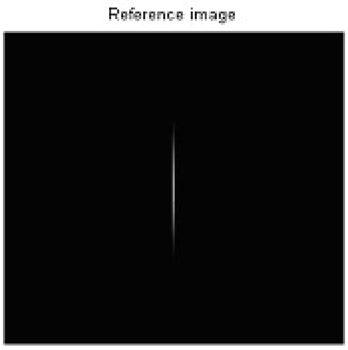
A. Method's principle

The method principle is rather simple, it consists in comparing the object to recognize s (target) appearing in an image, with one or more predetermined reference objects (references r_i). To carry out this comparison, the spectrum of the target (S), obtained in the frequency domain, is multiplied by the complex conjugate $\boldsymbol{H} = \boldsymbol{R}^*$ of the spectrum of the considered reference. Then, a second Fourier transform provides the correlation product (the correlation plan target/reference). If the target S is similar to the reference R_i , then, we obtain an important energy peak in the correlation plan where is located, if not, the correlation plan is noisy and nearly flat. More details on 2D correlation can be found in the literature (A. Al Falou, 1999) or (J.D Armitage and A.W Lohmann 1965).
To detect marine mammal's signals, we consider our spectrogram as an image to be processed. The spectrogram is designed from the signal FFT computed on a moving window, and then, the spectra are accumulated so as to obtain square spectrograms (NxN size where N is a power of 2). At every loop of the algorithm, a spectrogram is processed in order to extract from it the target song.

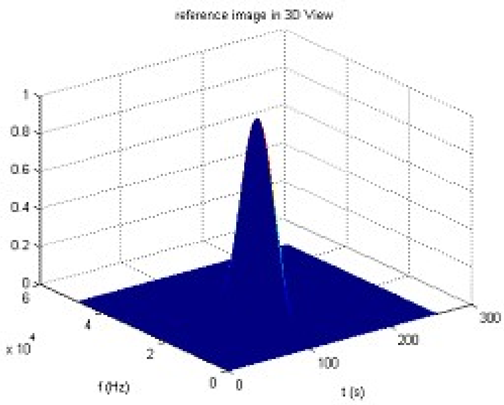
B. Filter design

The filter (reference) selected to detect the clicks by 2D correlation has the same image size than the spectrogram. In a preliminary approach, it is simply a centered Hamming window (caption 3-a). The caption 3-b gives the 3D representation of its energy distribution.

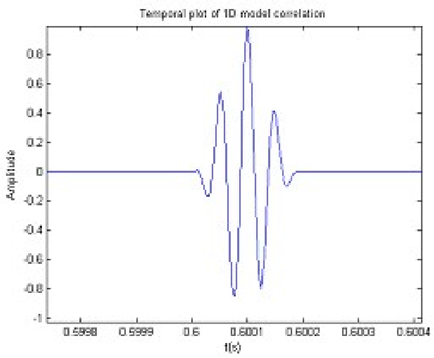
For the temporal correlation (1D correlation), a model of 2 ms duration click is synthesized, which wave shape is given (caption 3-c), whose mid-frequency is 20 Khz (caption 3-d).



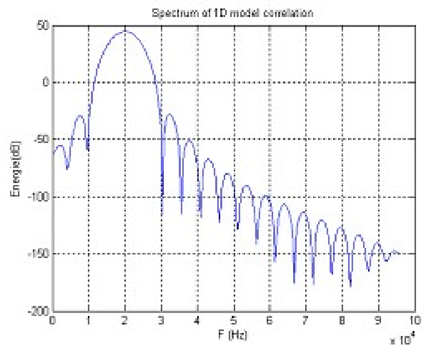
(a)



(b)



(c)

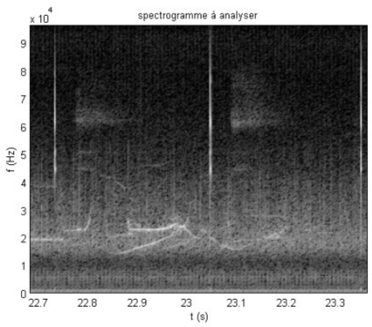


(d)

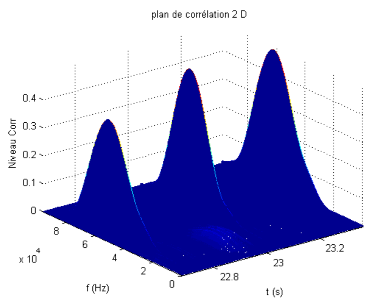
Caption.3 : (*a*) Reference image for 2D correlation, (*b*) 3D view of the reference image, (*c*) click wave form for 1D correlation, (*d*), its spectrum.

C. Demonstration example

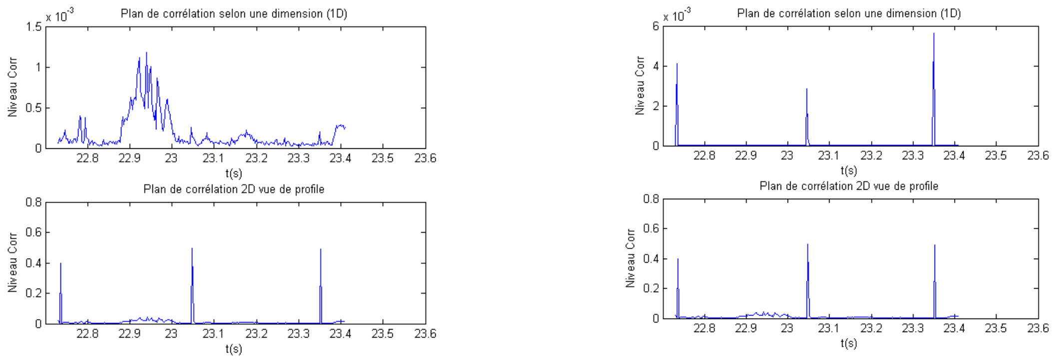
Both methods are applied to the spectrogram given in caption 4-a, and the results are presented caption 4-c&d. The spectrogram is a part of a recording coming from Mobysound data base. The recording contains whistles in a frequency domain close to the studied click frequency band and also three clicks of "Ziphuis" with a frequency bandwidth spreading out from 40 Khz to 90 Khz. The recording contains also low and high frequencies noises. The caption 4-b gives the 2D correlation plan. One can see three important peaks at the moments corresponding to the clicks. These peaks are smoothed by the filter, and it is then possible, via a thresholding, to detect the click, to measure its time advent, the mid frequency, the start frequency and the end frequency for every detected click, as well as the inter click intervals. To compare the results obtained with those of the 1D filter, we present on the same caption (4-c) the correlation curves for each method, the 1D correlation plan on the upper part and 2D correlation plan in the lower part (for this last, at each time, we use the line profil corresponding to the column vector of the maximum energy value). On caption (4-d), we give the results obtained by shifting only the central frequency of the synthetic click from 20 Khz to 45 Khz. From these results, we can note that, although the 1D correlation allows to detect the clicks (caption 4-d), the correlation level for the analyzed signal is however much less important than that obtained in 2D correlation, moreover, it can detect only the clicks whose frequency band is nearly the same that the modelling used. Moreover, it is sensitive to the structured noises which is present in the same frequency band as one can see on caption 4-c (upper part). In 1D method, whistles generate peaks which are confusing with clicks, while, the 2D correlation can detect and locate correctly all the clicks in time-frequency domain, thus, much less click references are needed. In the images to be processed (spectrogram), the click presents a particular energy distribution (an horizontal line), contrary to the whistle and any slow frequency modulation which presents a diagonal distribution in the image. This characteristic is particularly interesting in our case where we are looking for detecting clicks in a zone polluted by industrial noises, because, the filter can be easily adapted to a type of specific signal and can reject signals which do not interest us.



(a)



(b)



(c) ***(d)***

Caption. 4 : (*a*) the analysed spectrogram, (b) the 2D correlation plan, (c) the 1D correlation curve (upper part) and the 2D correlation curve (lower part), (d) same results obtained from a synthetic click with 45 kHz mid-frequency.

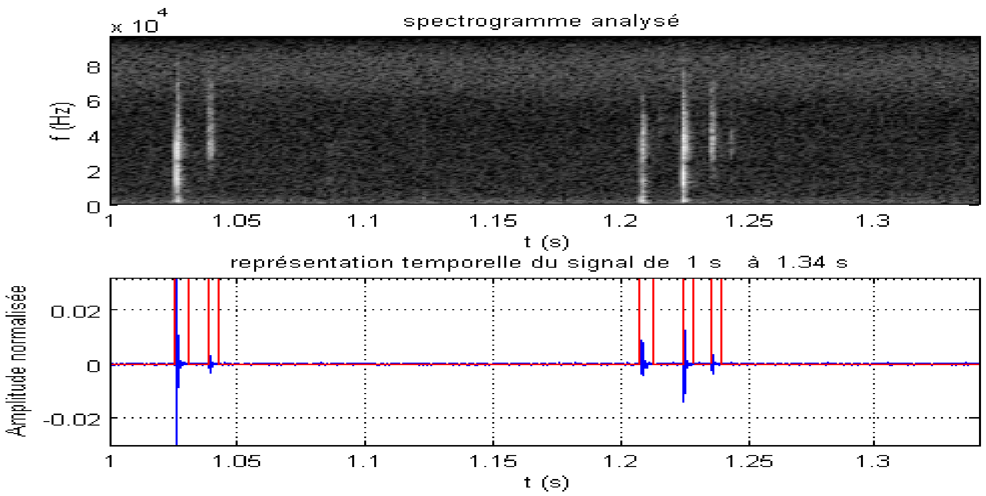
D. Validation on experimentation data

In order to evaluate our method performances, we have processed a downloaded file from Mobysound's database, to measure the detection rate and the false alarms rate. The recording is coming from a series of measurements carried out in the gulf of Genova in Italy using Tag technique, called DTAG, posed on a beaked whale. The file is at wav standard, 16 bits, 1 channel, sampled to 192 Khz with a good SNR at the beginning and a poor SNR towards the end. The species which were present at the same time on the recording, are Ziphius cavirostris and Cuvier's beaked whale. To build the spectrograms, a FFT on 512 points is carried out with a superposition factor of 50% (temporal resolution 1.3 ms). Before thresholding, the correlation curves are standardized by dividing each peak value by the total energy of the correlation plan. The threshold is then fixed empirically to 0.01.

E. Performances

Caption 5 gives the preliminary result of the 2D processing spectrogram. In the up part, the analyzed spectrogram, in the low part, the temporal representation of the analyzed signal and superimposed to this curve, the red lines which delimit during time the temporal zones which are declared to be clicks by the algorithm. One can note that the method detects and locates well in the time the clicks present in the recording.

On the whole series, the detection rate is 97% with 4% of false detections. The goal of this study is to load the method on the buoy described above, so, we have measured the speed of the algorithm on Matlab® software with Windows environnment and on a computer equipped with a processor Intel® 2.26 GHz. The algorithm holds real-time with such a sampling rate (192 Khz).



Caption.5 : Result of the 2D correlation processing of a spectrogram.

V. Conclusion

We presented in this communication a complete system for investigating and getting information, in real-time, on the impact of industrial noises on marine mammal populations. It includes an optimization of all the processing chain, from the underwater acquisition to the information delivered to the users. The processing part is integrated in modular way into a platform which allows algorithms tests as much as their evaluations and training (thanks to an access to broad databases), and also their uses operational. Taking into account the information transmission mode (satellite or radio), part of the processing (low level step) must be realized on the buoy (matched filters, filterings). Some tracks are open to answer this constraint, first on the algorithmic aspect. It will be then necessary to work on their implementation on dedicated processors. Any way, the current system can already be used for simple applications.

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Bibliography

A. Al Falou, « Implémentation optique de correcteurs monovoie et multivoies appliqués à la reconnaissance des formes » thèse de doctorat, université de Renne I, France 1999.

Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment. OJ L 175, 5.7.1985, p. 40–48

D.K. Mellinger and C.W.Clark : Recognizing transientlow-frequency whale sounds
By spectrogram correlation J.Acoust.Soc.Am.,Vol.107,No.6,June2000

J.D Armitage and A.W Lohmann « Character recognition by incoherent spatial filtring ». Applied optics, vol 4: 461-467, 1965.

OSPAR, 2008. Assessment of the environmental impact of offshore wind-farms, 2008. OSPAR Commission, 2008. Publication number 385/2008.

OSPAR, 2009. Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Commission, 2009. Publication number 441/2009.

Richardson, W.J, Malme, C.I., Green, Jr C.R., Thomson, D.H., 1995. Marine mammals and noise, Vol 1. Academic Press, San Diego, California, USA

Southall, B.L., at al, 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33:411-521

Vedenev, A. I., Ivanov, V.N., Kochetov, O.Y. 2009. Autonomous Hydro acoustic stations for the control of an industrial noise levels and signals of seismic survey on the sea shelf. Proceedings of the 12 L. M. Brekhovskih's conference, Moscow, Nayka, GEOS, p. 361-364