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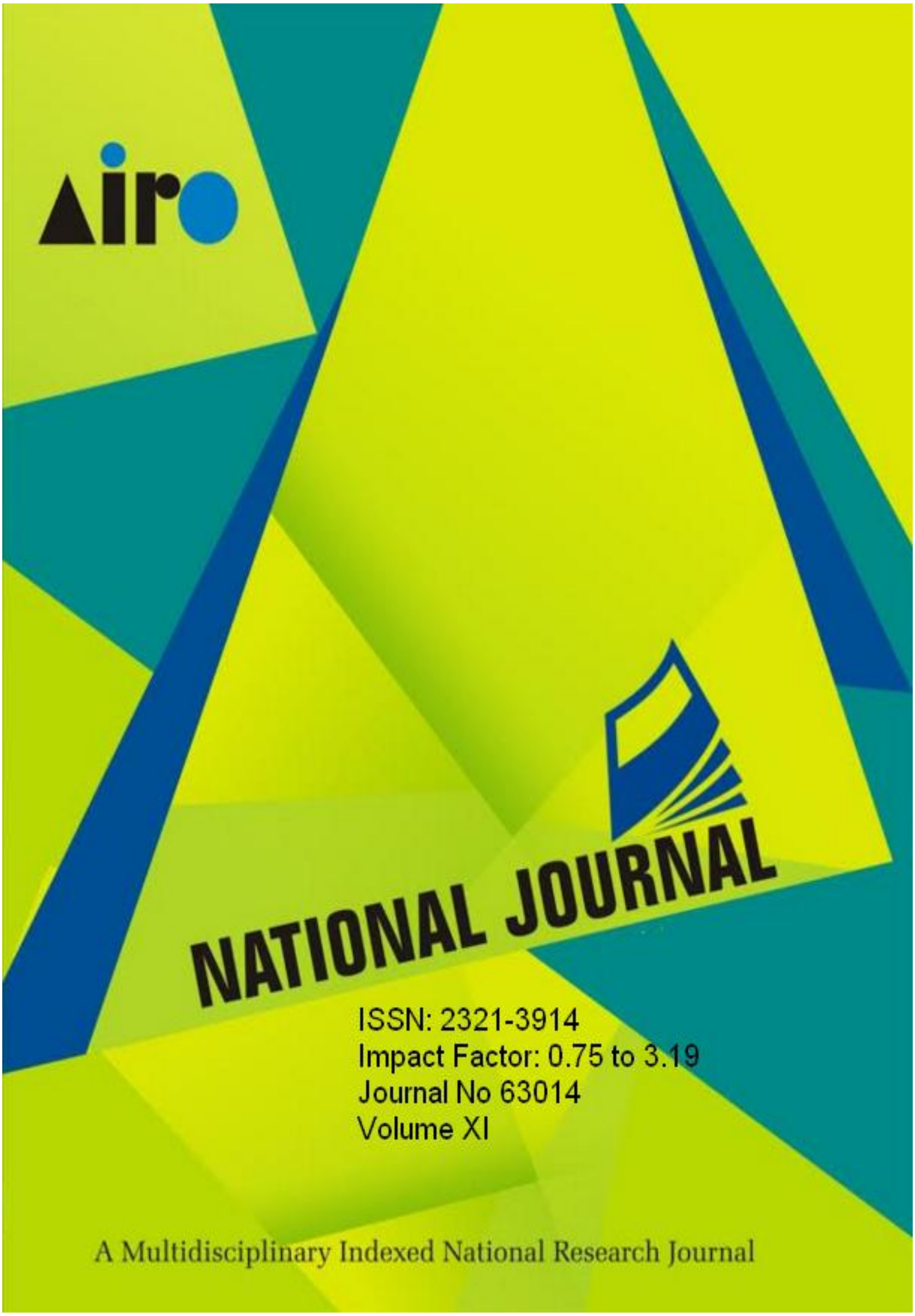

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DIGITAL CORRELATION TECHNIQUE: AN EFFICIET METHOD OF SIGNAL DETECTION AND RECREATION WITH EMBEDDED NOISE

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ABSTRACT

The application of signal processing techniques in non-destructive testing, especially in ultrasonic, is widespread. Signal recreation, matched filtering, frequency spectrum analysis, signal detection, and autoregressive analysis have all been used to analyze ultrasonic signals and for various applications. The Wavelet Transform is the most recent technique for processing signals with time-varying spectra. Interest in wavelets and their potential applications has resulted in an explosion of papers; some have called the wavelets the most significant mathematical event of the past decade.

In this work, the data mining algorithm is utilized to improve signal detection in noisy signals as an alternative to the Split-Spectrum Processing (SSP) technique. In SSP, the frequency spectrum of the signal is split using overlapping Gaussian pass band filters with different central frequencies and fixed absolute bandwidth. A similar approach is utilized in the WT, but in this case the relative bandwidth is constant, resulting in a filter bank with a self-adjusting window structure that can display the temporal variation of the signal's spectral components with varying resolutions.

This property of the signal mining algorithm is extremely useful for detecting flaw echoes embedded in background noise. The detection of ultrasonic pulses using the wavelet transform is described and numerical results show good detection even for signal-to-noise ratios (SNR) of -15 dB. The improvement in detection was experimentally verified using steel samples with simulated flaws.

Keywords: *digital correlation, detection and recreation, embedded noise*

INTRODUCTION

Baseband signal detection has become an object of interest due to its utility and applicability in fields such as particle detection, underwater communication, medical issues, etc. The group of devices Applied for signal Detection from the technical universities in collaborates with the waveforms detectors ANTARES. Acoustic technologies and processing analyses are developed and studied for positioning, calibration and particle detection tasks of the detectors.

Following its inception in 2009, Pharmacy vigilance at Lambda has grown organically and signal management activities are conducted by Lambda PV since 2010. Initially, signal detection was performed based on vol. 9. However, current processes (from 2012) are based on new signal detection module IX under GVP guideline, along with an additional guidance taken from CIOMS VIII. Both the process as well as the expertise on signal detection has evolved over time. Lambda is capable of carrying out not only the traditional (qualitative) methods for detecting signals but also have equal caliber on statistical (quantitative) methods.

Acoustic emitters and receivers are used for the recreation of signal underwater neutrino telescopes ANTARES and KM3NeT in order to monitor the position of the optical recreation modules of these devices. The position of devices need to be monitored with 10 cm accuracy to be able to determine the trajectory of the waveform produced after a neutrino interaction in the vicinity of the filter from the Cherenkov light that it produces . An important aspect of the acoustic positioning system is the time accuracy in the acoustic signal detection since the positions are evaluated from triangulation of the distances between emitters and receivers, which are determined from the travel time of the acoustic wave and the knowledge of the sound speed. The distances between emitters and receivers are of the order of 1 km. Therefore, the acoustic emitted signals suffer a considerable attenuation in the medium and arrive to the acoustic receivers with a low signal to noise ratio.

REVIEW OF LITERATURES

Acoustic signal detection has become an object of interest due to its utility and applicability in fields such as particle detection, underwater communication, medical issues, etc. The group of Acoustics Applied to Astro-particle Detection from the Polytechnic University of Valencia collaborates with the particle detectors ANTARES, KM3NeT and COUPP/PICO.

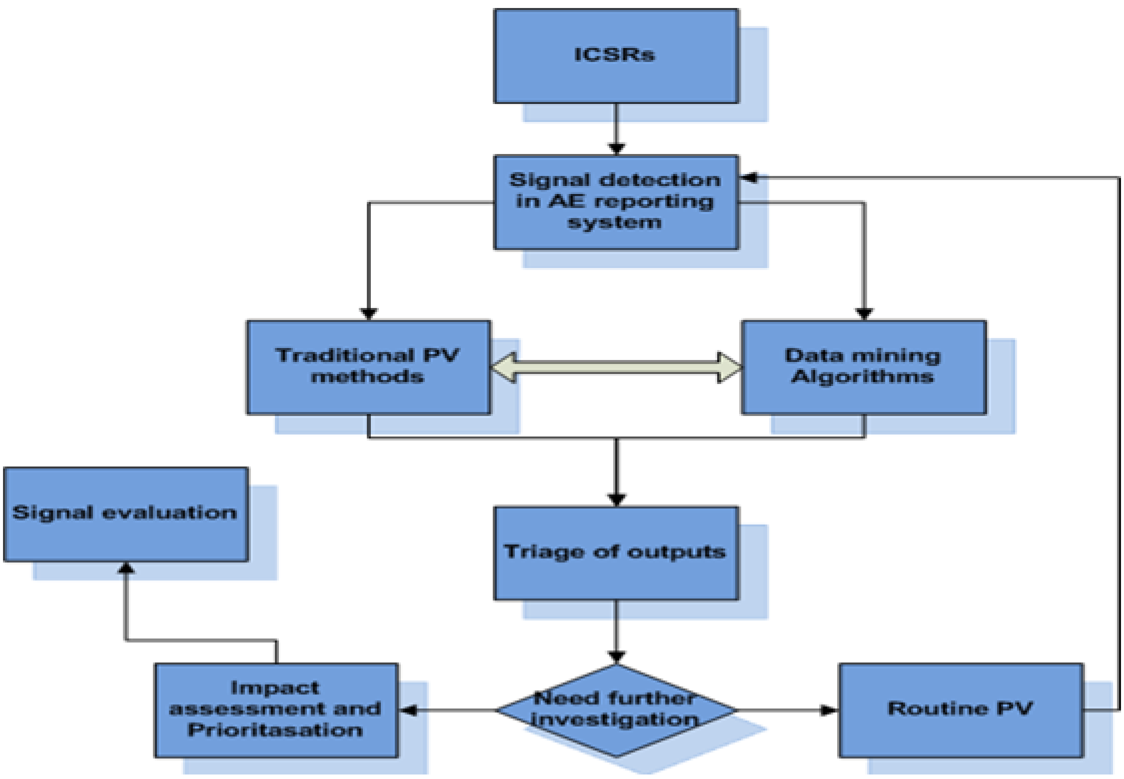
Acoustic technologies and processing analyses are developed and studied for positioning, calibration and particle detection tasks of the detectors. Acoustic emitters and receivers are used for the positioning systems of underwater neutrino telescopes ANTARES and KM3NeT in order to monitor the position of the optical detection modules of these telescopes. The position of optical sensors need to be monitored with 10 cm accuracy to be able to determine the trajectory of the muon produced after a neutrino interaction in the vicinity of the telescope from the Cherenkov light that it produces.

An important aspect of the acoustic positioning system is the time accuracy in the acoustic signal detection since the positions are evaluated from triangulation of the distances between emitters and receivers, which are determined from the travel time of the acoustic wave and the knowledge of the sound speed.

The distances between emitters and receivers are of the order of 1 km. Therefore, the acoustic emitted signals suffer a considerable attenuation in the medium and arrive to the acoustic receivers with a low signal to noise ratio. The environmental noise may mask the signal making the detection and the accurate determination of its arrival time a difficult goal, especially for the larger future telescope KM3NeT with larger distances. On the other hand, an acoustic test bench has been developed for understanding the acoustic processes occurred inside of the vessels of the COUPP Bubble Chamber detector when a particle interacts in the medium transferring a small amount of energy, but very localized, to the superheated media.

This interaction produces a bubble through the nucleation process. Under these circumstances the distance from the bubble to the vessel walls are very short (cm order) and a reverberant field generated by multiple reflections in the walls takes place. With these conditions, the distinction of the direct signal from reflection is quite difficult to achieve, being also quite complex to determine the time and amplitude of the acoustic signal produced.

RESEARCH METHEDOLOGY



Signal Detection Methodology: By and large, Lambda relies on an integrated approach using either qualitative or quantitative data mining algorithms for identification of potential signals. However identified potential signals through quantitative methods are restructured by qualitative assessment of each of the statistically identified signals to validate a true signal.

Traditional (Qualitative) Methods:

Most of the organizations weigh their choices on signal detection methodology primarily based on the amount of safety information that has been gathered for the product under evaluation. Qualitative signal detection method will be performed based on an overall evaluation of the product's profile keeping in lieu the key favorable factors like completeness of the available data, event-drug relatedness, strength of the causal relationship of the product with the adverse reactions, specificity of the causal association, and objective data based evidence for identified event and it's frequency.

Quantitative Data Mining Algorithms (DMA):

For products with large safety datasets, besides traditional methodology, we also perform Quantitative Signal Detection, using an inbuilt data mining method within our safety database. For an MAH's product, the safety database (PvNET) condenses large and complex dataset into 2×2 contingency tables for analysis of signals of disproportionate reporting that provides a platform for identification of Drug Event combinations (DEC) in terms of PRR (Proportionate Reporting Rate). PRR (+) & PRR (-) provides Signals of disproportionate reporting (SDR) respective upper and lower limits on CIs (Confidence Intervals).

Generally 95% CI is considered. Other methods while evaluating the PRR in the 2×2 contingency table can be compounded with Chi square values. Based on the above outputs, SDR are identified depending on the threshold values entered at the start of quantitative SD activity. In addition to identifying DEC at LLT or PT level, our database (PvNET) also allows data mining at Standardized MedDRA Queries (SMQ) level. The SDRs thus identified, are further evaluated clinically, using a functionality that is inbuilt within PvNET for Qualitative signal detection that allows appropriate segregation of true clinical signals from those of the "statistical noise"

Correlation techniques and limits of accuracy

Many time delay estimation techniques use cross-correlation of two sequential echoes to get fine time delay differences. Consequently it is appropriate to review the techniques of cross-correlation — and the limits of accuracy. We can assume the transmitted signals and the two noise corrupted, real echo signals have a double-sided, narrow-band, spectrum $Gr(\omega)$ with the positive and negative frequency response perfectly symmetrical

about the carrier frequency $\omega 0$. In that case,

$$gr0(t) = F{-}1\{Gr(\omega)\}$$

$gr1(t) = F-1\{Gr(\omega)\exp(-j\omega t1)\} + n1(t)$ (0.14)

$gr2(t) = F-1\{Gr(\omega)\exp(-j\omega t2)\} + n2(t)$ (0.15)

$\approx gr1(t - \Delta t)$

RESEARCH AND DISCUSSIONS

Measuring recreation and detection accurately is a common requirement in many signal processing and filtering operations. This is mostly done using correlation techniques. With sampled signals this can be done at the Nyquist sample rate in which case the signals are all positive real or more commonly at complex baseband in order to minimize the computational requirements. The actual mathematical operation can be carried out in the time domain or more efficiently in the frequency domain using the digital correlation equivalents of the Fourier transform.

In this work the detection and recreation of modulating signals with a unique receiver under a reverberant field or a high noise environment is shown. The correlation method has been studied and applied for this purpose. Moreover, a method for obtaining the real amplitude of the signal (voltage) by using cross-correlation technique has been developed. Its validation has been done by comparing the results with the ones obtained by analytic methods in time and frequency domain, achieving a high reliability for the accurate detection of acoustic signals and the analysis of them. The results obtained in these tests in different environments using different kind of signals are shown. The cross-correlation technique is described, as well as the method proposed for signal detection. The application of the method under different situations: high reverberation, low signal-to-noise ratio (S/N) or very low S/N, is presented. Finally, the conclusions are summarized.

When emitter and receiver are close and the dimensions of the enclosure where the acoustic processes occur are comparatively small, both signal and reverberation are high. This is the case of the configurations shown in Figure 3 that corresponds to a part of the acoustic test bench for COUPP detector. On the left, the two experimental setups are shown. The first one corresponds to acoustic propagation studies inside a vessel, and the second one was used to study the acoustic attenuation. On the right the transducers used are shown. The signal was emitted with the pre-amplified ITC 1042 transducer and received with the needle-like RESON TC 4038 transducer.

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Fig. 3. Experimental setups (left) and transducers used (right).

Figure 4 shows an example of a 30 kHz tone of 5 cycles of duration emitted and recorded under these conditions and their cross-correlation. It can be seen that the maximum of the correlation corresponds with the reception time of the received signal.

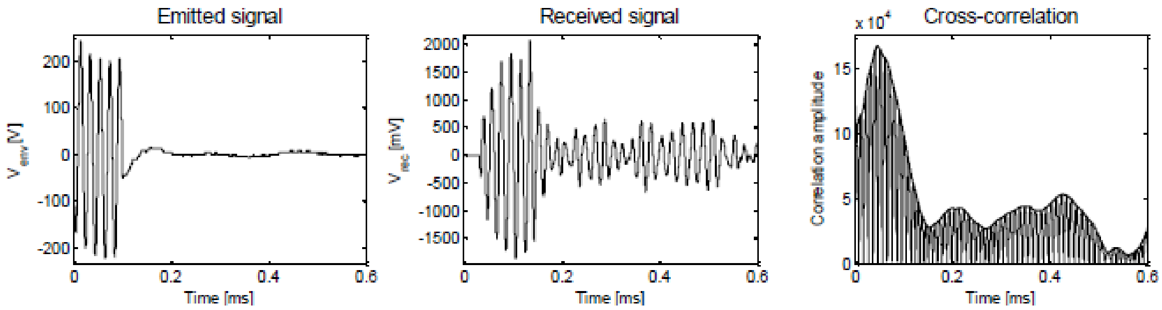

Fig. 4. Example of emitted signal, received signal, and cross-correlation.

CONCLUSION

Measuring relative time delays accurately is a common requirement in many signal processing and filtering operations. This is mostly done using correlation techniques. With sampled signals this can be done at the Nyquist sample rate in which case the signals are all positive real or more commonly at complex baseband in order to minimize the computational requirements. The actual mathematical operation can be carried out in the time domain or more efficiently in the frequency domain using the convolution/ multiplication equivalents of the Fourier transform.

Identification, tracking and monitoring of signals can be a difficult task, however we at here have initiated signal management activities and are continuously evolving on this process. The guiding bodies with their guidelines and a robust data mining tool is what we have; we definitely are looking forward for further improvisations in this field to create an edge in the competitive landscape. We have seen that, using different signal emission-detection-acquisition systems, working on a wide range of distances and in very different environmental conditions, good acoustic detection through the technique of cross-correlation between the emitted and received signals can be obtained. This technique is more favorable for broadband signals because they have a narrower correlation peak and consequently they are easier to discern than others peaks. Furthermore, this technique is powerful in measurement conditions with a reduced S/N ratio, as the case in marine environments over long distances where the recorded signal is weak, or in environments with high background noise. In addition, we have obtained a relation between the peak value of the cross-correlation and the voltage value of the received signal, which synthesizes and optimizes the signal analysis.

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