

SIGNAL PROCESSING GROUP

HEAD OF THE GROUP RESEARCH REPORT

The Signal Processing Group (GTS) is devoted to produce quality research to advance in both the theoretical aspects of signal processing and its applications. The areas of application include medicine, industry, underwater acoustics, and arts.

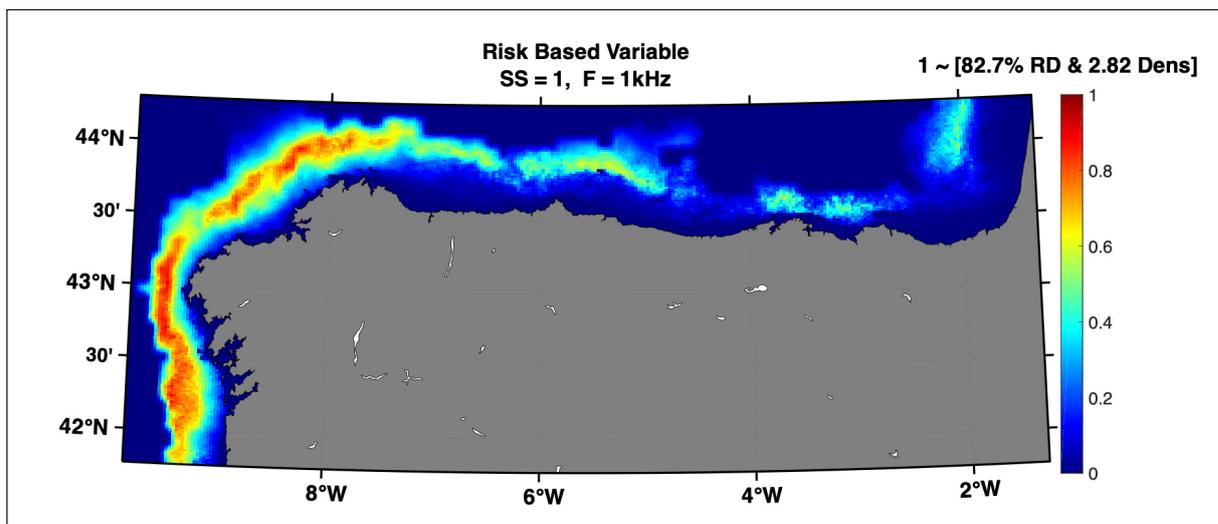
1.- PROJECT ACTIVITIES

The GTS has continued researching in the already established research lines as well as in some other emerging activities. A short summary of some of the main activities is listed below:

- Signal processing techniques applied to ultrasonic and impact-echo methods for the characterization of cementitious materials in the construction industry: The research has produced innovative techniques for material characterization, damage location and tomography reconstruction (FANSIRAS and non-contact airborne ultrasound techniques are clear examples). These techniques have proven to be useful in the characterization of both natural and artificial stones. The GTS collaborates, among others, with the ICITECH (Institute of Science

and Technology of the Concrete), with the Department of Civil & Environmental Engineering (University of Illinois), with the University College Cork, and with the Centro Superior de Investigaciones Científicas (CSIC).

- Passive acoustics monitoring: We develop acoustic sensors and signal processing algorithms to advance in the study of marine animal population and the impact that anthropogenic sounds have on them. The aim is to help to ensure the conservation and sustainable use of marine biodiversity. For this purpose, we design surveillance systems, create real time noise maps for harbours, and evaluate the results using a risk-based approach. The group collaborates with the Oceanogràfic of Valencia, and with the Instituto Español de Oceanografía (IEO) for the Spanish approach to the Marine Strategy Framework Directive (D11).
- Applications of biomedicine.
- Graph Signal Processing (GSP): We continue developing new methods of classification, fusion of classifiers and signal surrogates based on GSP, which are applied to a variety of practical problems.
- Emerging Signal Processing Techniques for Big Data Health Applications.
- Technologies for the Arts (Soundcool): The Group of Performing Arts and Technology (PerformingARTech) continues the developments on the Soundcool system. In its new version Soundcool 4.0 has further video processing capabilities. One of the main novelties this year is that Prof.



Risk map based on density of population and distance reduction from pristine ambient considering sea state 1 at 1kHz. In this case 'Risk index' value 1 is related with maximum values of distance reduction and density of bottlenose dolphins (82.7% & 2.82 respectively).

Roger Dannenberg, Director of the Computer Music Project at Carnegie Mellon University, is now a member of the board of directors of Soundcool (<http://soundcool.org/en/team/>).

1.1.- ONGOING PROJECTS

Name of the project: Risk-based Approaches to Good Environmental Status (RAGES)

Webpage of the project: <https://www.msfd.eu/rages/>

Summary of the project: The RAGES project continues with the study of how human activities that take place at sea have an impact to the marine environment. A risk-based approach for continuous noise is being studied and different alternatives are evaluated. Specifically, we are using the communication distance reduction from pristine ambient as a result of anthropogenic noise. Risk evaluation can be based on the possibility of a masking effect occurring in areas with presence of a given cetacean species. Combining the communication distance reduction with cetacean density (*T. truncatus* for example), we can identify risk areas with a potential threat of masking (see figure in page 27).

Funding entity: DG for Environment (ENV), European Commission.

Name of the project: Spanish implementation of the Marine Strategy Framework Directive.

Summary of the project: The IEO-UPV has been commissioned by the Ministry of Ecological Transition for the Spanish implementation of European Directive 11 (D11), within the Marine Strategy Framework Directive (MSFD). The project continues by doing the different deployments around the Spanish Marine Waters. New releases are being made in the PAM device SAMARUC obtaining more accurate acoustic data, complying with the regulations marked by de TGNoise (according to D11.2).

Funding entity: Ministry of Ecological Transition.



SAMARUCs ready to deploy

Name of the project: Influence of anthropogenic noise in cetacean populations

Summary of the project: The project aims to evaluate the possible acoustic conditions suffered by the cetacean populations living near of the bay of Cartagena, more specifically between Cabo Tiñoso and Escombreras. For this purpose, different deployments are being made using underwater acoustic devices that allow the monitoring of acoustic data (anthropogenic and animal sounds) to be later analysed by visual inspection techniques (in aerial and nautical visualisation campaigns). This will provide a sample of the diversity of cetacean populations in this area close to the Port of Cartagena and their possible affection due to the existing marine traffic.

Funding entity: Autoridad Portuaria de Cartagena



Aerial view of a pod of dolphins swimming through the Mediterranean Sea

Name of the project: Development and application of non-destructive testing based on mechanical waves for the assessment and monitoring of rheology and self-healing in cementing materials (WAVECON)

Summary of the project: The project aims to develop new techniques for non-destructive evaluation of fresh pastes, mortars and concrete (rheological characterization), and damaged systems (cracking) in which a regeneration or self-healing process takes place. During this year, we have determined the memory capability of the mortar specimens when they are assessed by acoustic spectroscopy. New neural network algorithms have been achieved for ultrasonic tomographic reconstruction and different techniques for lamb waves generation on cement specimens have been also developed.

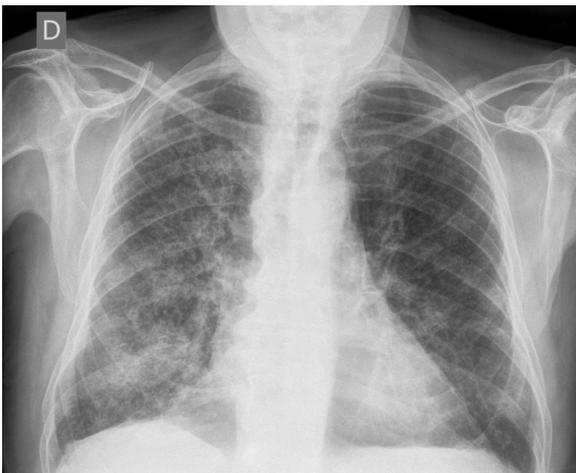
Funding entity: Spanish Government. BIA2017-87573-C2-2-P.



Mortar test probes (4x4x16cm³) with different damage level to be characterized with nondestructive techniques.

Name of the project: Screening covid-19 patients using chest x-ray images

Summary of the project: The goal of this project is to perform a retrospective study to evaluate the performance of deep learning algorithms to predict the presence of covid-19 pneumonia from chest x-ray images.



Chest x-ray from a covid-19 patient

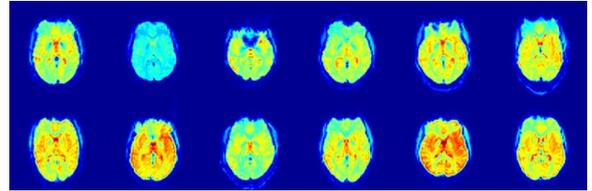
Name of the project: Carlos III Health Institute (Spain) in cooperation with Consejo Superior de Investigaciones Científicas.

Summary of the project: Informed Methods for Signal Synthesis (MISS)

The project has advanced in the expected way. It has been developed a newscheme for increasing the number of training samples in scenarios of extreme scarcity of original data. It is based in a Generative Adversarial Network, which combine a linear discriminant with a generator of synthetic samples based on the concept of surrogates and Markov Random Fields. It has been successfully applied in different types of diagnosis from EEG and fMRI signals. Thus, for

example, an automatic classifier to detect schizophrenia, has been trained with just 6 examples of every class (see figure)

Funding entity: Spanish Government, TEC-2017-84743-P.



Axial view of fMRI slices from 12 subjects The top row corresponds to individuals with schizophrenia and the bottom row corresponds to healthy controls (subject database identification 11, 12, 15, 37, 46, 49, from left to right).

Name of the project: "Soundcool: Mobile Phones and Digital Tools for Music and Audiovisual Art Education" (16-AC-2016) and "Soundcool: Collaborative Music and Video Creation" (GJIDI/2018/A/169).

Webpage of the project: <http://soundcool.org>.

Summary of the project: The new version 4.0 of the Soundcool application adds new video modules such as video Delay, ChromaKey, or audio to artistic video conversion, new MIDI and OSC interface modules, and improvements on the existing modules. In addition, due to the current situation of social distancing due to COVID19, our team has taken a step further to carry out the connection of the Soundcool app for smartphones and tablets through internet controlling remotely the Soundcool application running in the central computer. This allows live collaborative sound, music and audiovisual remote creation even in confinement with the participants in their own homes. Two tests of remote audiovisual performances have been carried out with students and teachers at their homes in several



Soundcool patch for the Earth Chronicles show, performed remotely with participants in several cities in Spain and in Pittsburgh (USA), July 28th, 2020.

cities in Spain and the USA, and several workshops have been given.

Funding entity: Daniel and Nina Carasso Foundation and Generalitat Valenciana, European Social Fund, Garantía Juvenil.

2.- RESEARCH RESULTS

2.1.- FEATURED PUBLICATIONS

Evaluation of Combined Artificial Intelligence and Radiologist Assessment to Interpret Screening Mammograms. Thomas Schaffter, et al., JAMA network open 3 (3), 2020.

Mammography screening currently relies on subjective human interpretation. Artificial intelligence (AI) advances could be used to increase mammography screening accuracy by reducing missed cancers and false positives. In this paper, we evaluate whether AI can overcome human mammography interpretation limitations with a rigorous, unbiased evaluation of machine learning algorithms. Overall, 144 231 screening mammograms from 85 580 US women (952 cancer positive ≤ 12 months from screening) were used for algorithm training and validation. A second independent validation cohort included 166 578 examinations from 68 008 Swedish women (780 cancer positive). The top-performing algorithm achieved an area under the curve of 0.858 (United States) and 0.903 (Sweden) and 66.2% (United States) and 81.2% (Sweden) specificity at the radiologists' sensitivity, lower than community-practice radiologists' specificity of 90.5% (United States) and 98.5% (Sweden). Combining top-performing algorithms and US radiologist assessments resulted in a higher area under the curve of 0.942 and achieved a significantly improved specificity (92.0%) at the same sensitivity.

DOI:10.1001/jamanetworkopen.2020.0265

Densitometric radiographic imaging with contour sensors. Francisco Albiol, Alberto Corbi, Alberto Albiol. IEEE Access, 2019, Vol.7,

This paper presents the technical/physical foundations of a new imaging technique that combines ordinary radiographic information (generated by conventional X-ray settings) with the patient's volume to derive densitometric images. After measuring the patient's volume with contour recognition devices, the physical traversed lengths within it (as the Roentgen beam intersects the patient) are calculated and pixel-wise associated with the original radiograph (X). The patient's surface is also translated to the point-of-view of the X-ray beam and all its entrance/exit points are sought with the help of ray-casting methods. The derived L is applied to X as a physical operation (subtraction), obtaining soft tissue- (DS) or bone-enhanced (D0 B) figures. In the DS type, the contained

graphical information can be linearly mapped to the average electronic density (traversed by the X-ray beam). This leads to other advantages: improvement in the visibility of border/edge areas (high gradient), extended manual window level/width manipulations during screening, and immediate correction of underexposed X instances. In the D0 B type, high-density elements are highlighted and easier to discern. All these results can be achieved with low-energy beam exposures, saving costs and dose.

DOI: 10.1109/ACCESS.2019.2895925

New Insights into the Design and Application of a Passive Acoustic Monitoring System for the Assessment of the Good Environmental Status in Spanish Marine Waters, Guillermo Lara, Ramón Miralles, Manuel Bou-Cabo, José Antonio Esteban and Víctor Espinosa, Sensors, 20 (18), 2020.

Passive acoustic monitoring systems allow for non-invasive monitoring of underwater species and anthropogenic noise. One of these systems has been developed keeping in mind the need to create a user-friendly tool to obtain the ambient noise indicators, while at the same time providing a powerful tool for marine scientists and biologists to progress in studying the effect of human activities on species and ecosystems. The device is based on a low-power processor with ad-hoc electronics, ensuring that the system has efficient energy management, and that the storage capacity is large enough to allow deployments for long periods. An application is presented using data from an acoustic campaign done in 2018 at El Gorguel (Cartagena, Spain). The results show a good agreement between theoretical maps created using AIS data and the ambient noise level indicators measured in the frequency bands of 63 Hz and 125 Hz specified in the directive 11 of the EU Marine Strategy Framework Directive. Using a 2D representation, these ambient noise indicators have enabled repetitive events and daily variations in boat traffic to be identified. The ship noise registered can also be used to track ships by using the acoustic signatures of the engine propellers' noise.

DOI: 10.3390/s20185353

Comparative Study of Coupling Techniques in Lamb Wave Testing of Metallic and Cementitious Plates. Vazquez-Martinez, Santiago; Gosálbez Castillo, Jorge; Bosch Roig, Ignacio; Carrión García, Alicia; Gallardo-Llopis, Carles; Paya Bernabeu, Jorge Juan., Sensors, 19 (19), 1 - 30, 2019.

Lamb waves have emerged as a valuable tool to examine long plate-like structures in a faster way compared to conventional bulk wave techniques, which make them attractive in non-destructive testing. However, they present a

multimodal and dispersive nature, which hinders signal identification. Oblique incidence is one of the most known methods to generate and receive Lamb waves and it is applied in different experimental arrangements with different types of sensors. In this work, several setups were conducted and compared to determine the optimal ones to launch and detect ultrasonic Lamb waves, especially in non-homogeneous specimens. The chosen arrangements were contact with angle beam transducers, immersion in a water tank, localised water coupling using conical containers and air coupling. Plates of two different materials were used, stainless steel and Portland cement mortar. Theoretical and experimental dispersion curves were compared to verify the existence of Lamb modes and good correspondence was achieved.

DOI: 10.3390/s19194068

Effects of slow dynamics and conditioning on non-linear hysteretic material assessment using impact resonance acoustic spectroscopy,

A. Carrión, V. Genovés, G. Pérez, J. Bittner, J.S. Popovics, J. Payá, J. Gosálbez, *Mechanical Systems and Signal Processing* 150, 1-15, 2021.

The microstructural features of heterogeneous and porous materials give rise to unique non-linear dynamic behaviour. The purpose of this work is to investigate the dynamic response of thermally damaged concrete specimens measured by two different techniques: Non-linear Impact Resonance Acoustic Spectroscopy (NIRAS) and new Flipped Accumulative Non-linear Single Impact Acoustic Spectroscopy (FANSIRAS). Specimens were characterised in two different dynamic condition states of the material: relaxed and conditioned. The specimen's relaxed state indicates that no previous dynamic excitation event occurred. The conditioned state denotes that the specimen has been dynamically tested before. The NIRAS results show that the non-linear material parameters, and, are affected by their previous dynamic history (its conditioning). The recently proposed algorithm, FANSIRAS, extracts from a single resonant signal equivalent results to NIRAS when the specimen is conditioned. In this situation, both parameters and were equivalent. The results suggest that new NDT parameters based on non-linear hysteretic parameters can quantify the damage level of thermally treated mortar specimens.

DOI: 10.1016/j.ymssp.2020.107273

LoRaWAN Network for Fire Monitoring in Rural Environments, Sendra, Sandra; García-García, Laura; Lloret, Jaime; Bosch Roig, Ignacio; Vega-Rodríguez, Roberto, *Electronics*, 3 (9), 1 - 29, 2020.

The number of forest fires that occurred in recent years in different parts of the world is causing

increased concern in the population, as the consequences of these fires expand beyond the destruction of the ecosystem. However, with the proliferation of the Internet of Things (IoT) industry, solutions for early fire detection should be developed. The assessment of the fire risk of an area and the communication of this fact to the population could reduce the number of fires originated by accident or due to the carelessness of the users. This paper presents a low-cost network based on Long Range (LoRa) technology to autonomously evaluate the level of fire risk and the presence of a forest fire in rural areas. The system is comprised of several LoRa nodes with sensors to measure the temperature, relative humidity, wind speed and CO₂ of the environment. The data from the nodes is stored and processed in a The Things Network (TTN) server that sends the data to a website for the graphic visualization of the collected data. The system is tested in a real environment and, the results show that it is possible to cover a circular area of a radius of 4 km with a single gateway.

DOI: 10.3390/electronics9030531

Computing the partial correlation of ICA models for non-Gaussian graph signal processing,

Belda, J., Vergara, L., Safont, G., Salazar, A., *Entropy*, Volume 21, Issue 1, 1 January 2019.

Conventional partial correlation coefficients (PCC) were extended to the non-Gaussian case, in particular to independent component analysis (ICA) models of the observed multivariate samples. Thus, the usual methods that define the pairwise connections of a graph from the precision matrix were correspondingly extended. The basic concept involved replacing the implicit linear estimation of conventional PCC with a nonlinear estimation (conditional mean) assuming ICA. Thus, it is better eliminated the correlation between a given pair of nodes induced by the rest of nodes, and hence the specific connectivity weights can be better estimated. Some synthetic and real data examples illustrate the approach in a graph signal processing context.

Nonlinear estimators from ICA mixture models

Safont, G. Salazar, A., Vergara, L., Rodríguez A., *Signal Processing*, Volume 155, February 2019, Pages 281-286.

Independent Component Analyzers Mixture Models (ICAMM) are versatile and general models for a large variety of probability density functions. In this paper we assume ICAMM to derive new MAP and LMSE estimators. The first one (MAP-ICAMM) is obtained by an iterative gradient algorithm, while the second (LMSE-ICAMM) admits a closed-form solution. Both estimators can be combined by using LMSE-

ICAMM to initialize the iterative computation of MAP-ICAMM. The new estimators are applied to the reconstruction of missed channels in EEG multichannel analysis. The experiments demonstrate the superiority of the new estimators with respect to: Spherical Splines, Hermite, Partial Least Squares, Support Vector Regression, and Random Forest Regression.

Pattern recognition techniques for provenance classification of archaeological ceramics using ultrasounds, Salazar, A., Safont, G., Vergara, L., Vidal, E., *Pattern Recognition Letters*, Volume 135, July 2020, Pages 441-450.

This paper presents a novel application of pattern recognition to the provenance classification of archaeological ceramics. This is a challenging problem for archaeologists, which involves assigning a making location to a fragment of archaeological pottery that was found along with other fragments of pieces made in different distant locations from the find. The pieces look very similar to each other and, often, other contextual information about the use of the pieces cannot be used due to the small size of the fragments. Current standard methods to solve this problem are limited since they are time consuming, require costly equipment, and can lead to the destruction of a part of the pieces. The proposed method overcome those limitations using non-destructive ultrasonic testing and incorporates versatile data analysis through advanced pattern recognition techniques. Those techniques include the following: feature ranking, sample augmentation, semi-supervision based on active learning; and optimal fusion. This latter is based in the concept of alpha integration, which allows optimal fitting of the fusion model parameters. Different provenance classification problems are showcased: provenance classification of terra sigillata ceramic pieces from Aretina, Northern Italy and Sud-Gaul origins; and provenance classification of Iberian ceramic pieces from archaeological sites of Paterna, and Les Jovaes in Valencia, Spain. We demonstrate that the proposed fusion-based method achieves the best results, in terms of balanced classification accuracy and F1 score, compared with competitive methods like linear discriminant analysis, random forest, and support vector machine. Experiments for simulating small sample sizes and uncertainty in labeling of the pieces are included. In addition, the paper provides a design of a practical specialized device that could be used in different applications of archaeological ceramic classification.

Vector score alpha integration for classifier late fusion, Safont, G., Salazar, A. Vergara, L., *Pattern Recognition Letters*, Volume 136, August 2020, Pages 48-55.

Alpha integration is a family of integrators that encompasses many classic fusion operators (e.g., mean, product, minimum, maximum) as particular cases. This paper proposes vector score integration (VSI), a new alpha integration method for late fusion of multiple classifiers considering the joint effect of all the classes of the multi-class problem. Theoretical derivations to optimize the parameters of VSI for achieving the minimum probability of error are provided. VSI was applied to two classification tasks using electroencephalographic signals. The first task was the automatic stage classification of a neuropsychological test performed by epileptic subjects and the second one was the classification of sleep stages from apnea patients. Four single classifiers (linear and quadratic discriminant analysis, naive Bayes, and random forest) and three competitive fusion methods were estimated for comparison: mean, majority voting, and separated score integration (SSI). SSI is based on alpha integration, but unlike the proposed method, it considers the scores from each class in isolation, not accounting for possible dependencies among scores corresponding to different classes. VSI was able to optimally combine the results from all the single classifiers, in terms of accuracy and kappa coefficient, and outperformed the results of the other fusion methods in both applications.

Software for Interactive and Collaborative Creation in the Classroom and Beyond: An Overview of the Soundcool Software, S. Scarani, A. Muñoz, J. Serquera, J. Sastre, R.B. Dannenberg, *Computer Music Journal*, MIT Press, Vol. 43, No. 4, 2019.

This article presents a free framework for collaborative creation of interactive and experimental computer music called Soundcool. It is designed to fill a gap between rigid ready-to-use applications and flexible programming languages. The system offers easy-to-use elements for generating and processing and sound, much like ready-made applications, but it enables flexible configuration and control, more like programming languages. The system runs on personal computers with an option for control via smartphones, tablets, and other devices using the Open Sound Control (OSC) protocol. Originally developed to support a new music curriculum, Soundcool is being used at different educational institutions in Spain, Portugal, Italy and Romania through EU-funded Erasmus+ projects. In this article we present our system and showcase three different scenarios as examples of how our system meets its objectives as an easy-to-use, versatile, and creative tool.

Soundcool: collaborative sound and visual creation, Sonic Ideas (CMMAS), J. Sastre & R.B. Dannenberg, *Ideas Sónicas (ISSN 2317-9694)*, Vol. 12, No. 22, pp. 75-86, 2020.

*This paper describes Soundcool from its inception up to the premiere of the Soundcool opera *The Mother Fishes* in the US in February 2020: educational applications, professional applications and applications for functional diversity, awards and latest news.*

Available at: <https://bit.ly/301CtVd>

2.2.- AWARDS AND EXHIBITIONS.

Interactive audiovisual art applications of the Soundcool system in the Higher Conservatory of Dance from Valencia (CSDV) for a project based on the Yerma play from the Spanish Lorca poet have been carried out.

Face-to-face workshops were held with soundcool at the reformatory of Alicante (EDUSI youth group) and in the functional diversity center of the APSA association in Alicante funded by the Spanish Foundation for Science and Technology within the Atenea association (<http://atenea.in>) mentoring program.

The Mexico City Region of the Monterrey Institute of Technology and Higher Education and the



Soundcool Yerma project with CSDV students

*National Center of the Arts (CENART) of Mexico premiered the Soundcool opera "*La Mare dels Peixos*" in Nov. 2019 (<https://bit.ly/32V0qzA>, see *El Mundo* newspaper <https://bit.ly/2CY8DJ8>), and the English version "*The Mother of Fishes*" of the opera was premiered in 2020 in the USA with the support of the Audacity team (<http://bit.ly/tmof-audacity>, <https://bit.ly/32V0RtI>).*



*American premiere of the opera *La Mare dels Peixos* at CENART (Mexico, 2019)*