

# SIGNAL PROCESSING GROUP (GTS) GTS lab

## HEAD OF THE GROUP RESEARCH REPORT

The Signal Processing Group (GTS) is devoted to produce quality basic and applied interdisciplinary research in the field of signal processing and data science. Currently formed by 19 researchers, the GTS faculty, students, and staff have developed scientific knowledge and innovative technologies in national and international research projects. The areas of application include medicine, industry, underwater acoustics, and technologies for the arts.

The GTS is nowadays involved in a LIFE European Green Deal project managed by the European Climate, Infrastructure and Environment Executive Agency (CINEA) "Reducing the impact of underwater noise on the marine environment of the Port of Cartagena" (LIFE PortSounds), and several Spanish government funded projects such as the "Smart sensing of composite materials through non-linear mechanical wave signal processing algorithms" (SMARTSENSE) and the "Informed Methods for Signal Synthesis" (MISS)

A complete list of research activities can be found at <http://www.iteam.upv.es/group/gts/>

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## 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 composite materials (including cementitious materials): 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, among other institutions, with the Instituto Español de Oceanografía (IEO) for the Spanish approach to the Marine Strategy Framework Directive (D11), with the Oceanogràfic of Valencia, and with the Cartagena Harbor Authority.
- ◆ Applications of biomedicine: Advanced digital image processing through artificial intelligence (deep Learning) for biomedical applications, in collaboration with the Clinical Medical Imaging Area of the Hospital Universitario y Politécnico La Fe in Valencia.
- ◆ 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): Last year we have opened a new line of research for the use of creative audiovisual technologies derived from Soundcool for the treatment of neurodegenerative diseases. The system is constantly evolving and has adapted to COVID social distancing to be able to work online with users in their own homes. Most of the group affected by neurodegenerative diseases are elderly and have been the hardest hit by the pandemic. Especially the group of patients with mild-moderate impairment who maintained activity outside the home (day centers, etc.) have



*Aerial view of the Cartagena harbor.*

been those who have shown greater deterioration with confinement due to the interruption of therapies. Providing them with new alternative therapies suitable for social distancing and working from their homes or centers is essential in the current situation.

### 1.1.- Ongoing projects

**Name of the project: Reducing the impact of underwater noise on the marine environment of the Port of Cartagena (LIFE PortSounds)**

**Summary of the project:** The main objective of LIFE PortSounds is the characterization, monitoring and assessment of underwater noise levels in the Port of Cartagena area to reduce underwater noise pollution generated by maritime traffic and to avoid its pressure on the marine environment with the application of mitigation measures. We will measure and identify the anthropogenic and natural sounds while studying the noise impact on the abundance, distribution and physiological state of 3 cetaceans species of Community Interest: bottlenose dolphin, striped dolphin and long-finned pilot whale. Both, underwater sounds and cetaceans populations data, will be integrated in a new management tool which will allow to understand the local noise problems, to develop mitigation measures (MM) which will reduce the pressure on the marine environment, and so the impact on the Special Areas of Conservation (SAC) and to improve its state of conservation

**Funding entity:** LIFE20 ENV/ES/000387.

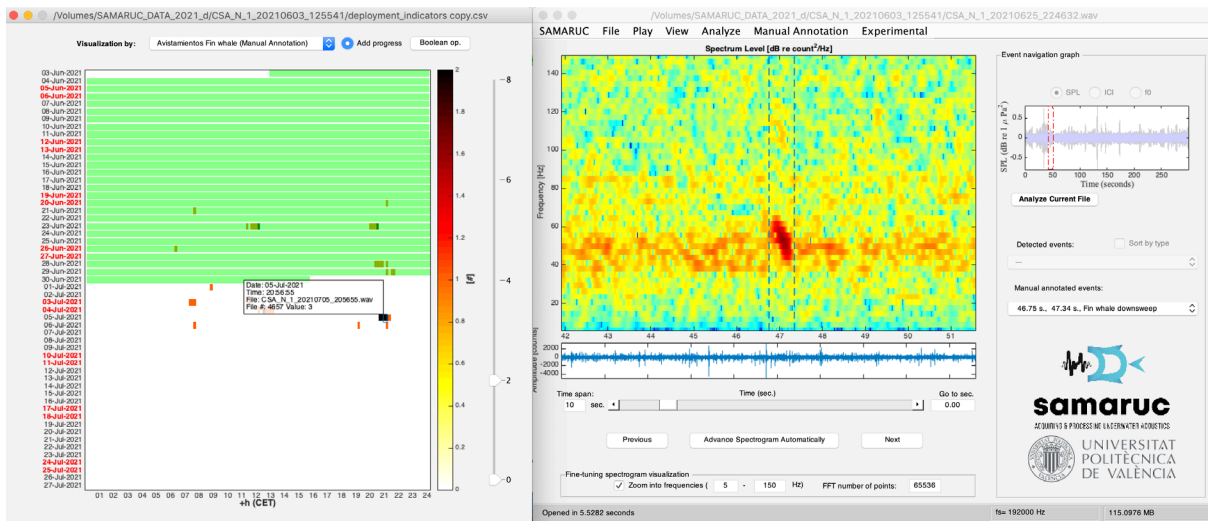
**Name of the project: Spanish implementation of the Marine Strategy Framework Directive.**

**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 been 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.



*Recovery of one of the SAMARUC recording devices.*



Fin whale downsweep detection using the SAMARUC software

### Name of the project: Cabo Fin Whale Project (CaboRorcual)

**Summary of the project:** The Cabo Rorcual project is a multidisciplinary project that aims to study the fin whale with the aim of providing information on the movements and migratory routes of these animals.

The Cabo Rorcual project wants to determine which population of these whales belong to and why they pass so close to the coasts, as is the case of Dénia and Xàbia that presume to be areas where these sightings occur most. For this purpose, passive acoustic monitoring techniques will be combined, using signal processing and machine learning techniques, with satellite tracking and traditional visual surveys.

**Funding entity:** Fundación Biodiversidad

### Name of the project: Smart sensing of composite materials through non-linear mechanical wave signal processing algorithms (SMARTSENSE)

**Summary of the project:** The solution to many of the new challenges faced by society

requires research and development into new composite materials with excellent properties as regards to corrosion, high resistance, a good weight/rigidity relationship and a high level of integration. The high cost and severely limited recycling possibilities for these materials make it advisable to develop new methods to enable the average life of composite materials to be monitored, evaluated and predicted depending on the environment surrounding them. The main objective of this project is to develop new NDTs based on mechanical waves for these materials. For this purpose, we develop different techniques that enable signals to be captured optimally and contactlessly, ranging from known direct contact technologies to sensors embedded in the material itself, as well as non-contact technologies such as air-coupled ultrasound and laser interferometry. We will also develop the underlying spectroscopic testing model and new signal processing algorithms that are sensitive and will enable these materials' mechanical parameters to be extracted.

**Funding entity:** Spanish Government, PID2020-120262GB-I00.

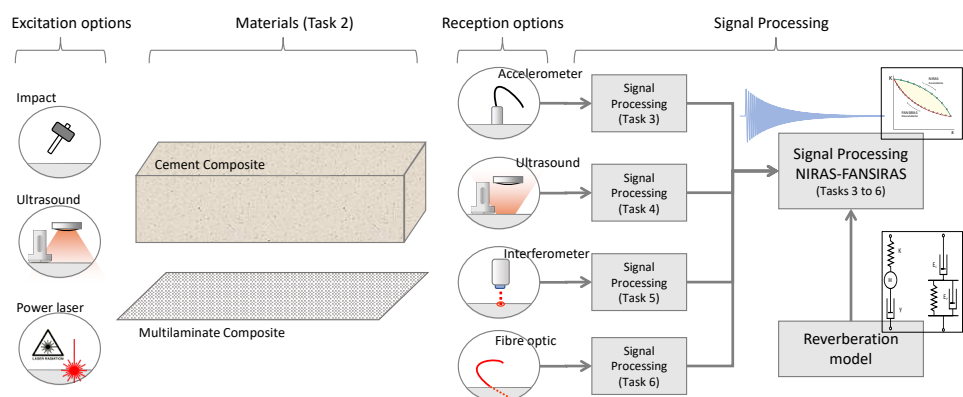
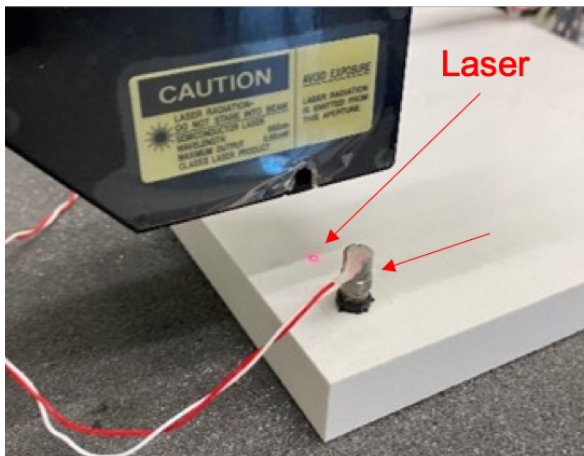
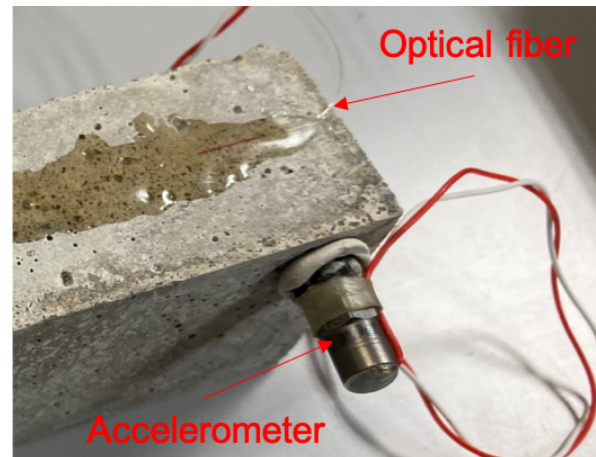


Diagram of the relationship of the technologies, materials and signal processing.





Monitoring a marble probe using accelerometers and laser sensors.



Monitoring a cement probe using accelerometers and optical fiber sensors.

**Name of the project: Development of transfer learning-based techniques for massive multi-groups segmentation**

**Summary of the project:** This project aims to establish an Artificial Intelligence (AI) methodology based on Transfer Learning (TL) for automatic multi-organ segmentation (liver, spleen, kidneys, perirenal fat, paravertebral muscle, etc.) from different modalities (CT, MRI) and potentiation's (T1, T2, DWI, etc.), which minimizes manually generated segmentations. Based on the following situations:

- (a) When the target organ to be segmented is available, segmented in another modality or potentiation.
- (b) When there are other organs other than the one to be segmented in the same modality or potentiation.

This is performed in collaboration with the

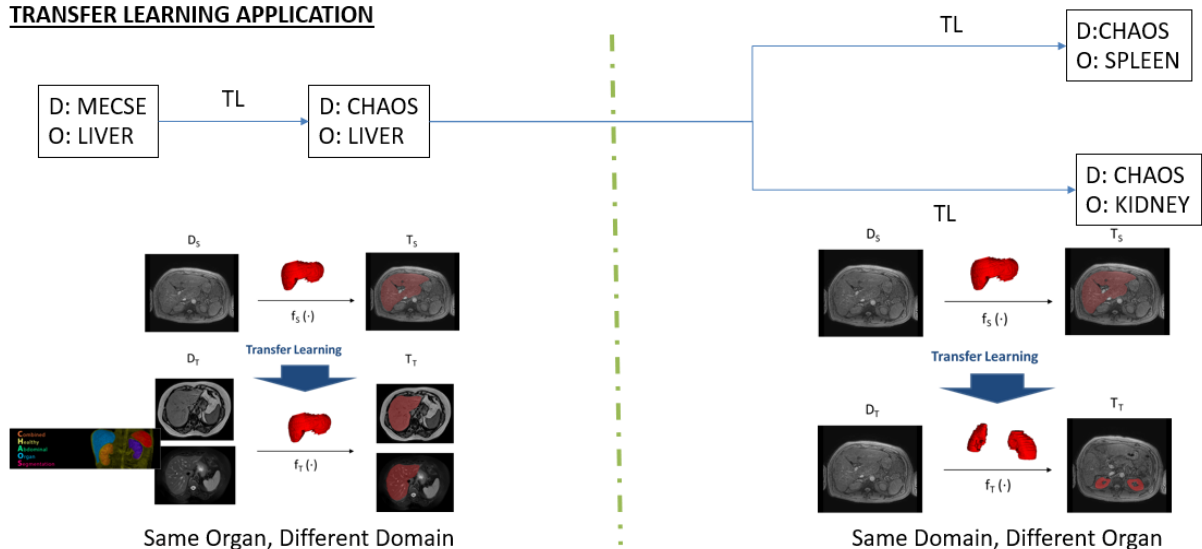
GIBI2^30 of the Clinical Medical Imaging Area of the Hospital Universitario y Politécnico La Fe in Valencia. It provides abdominal MRI studies in different potencies for the characterization of the liver by means of non-invasive imaging biomarkers, from the current Virtual Liver Biopsy (VHLB) project. The proposed methodology will be evaluated on the particular case of kidney segmentation using the studies of this project.

**Funding entity:** UPV- La Fe 2021 Preparatory Actions.

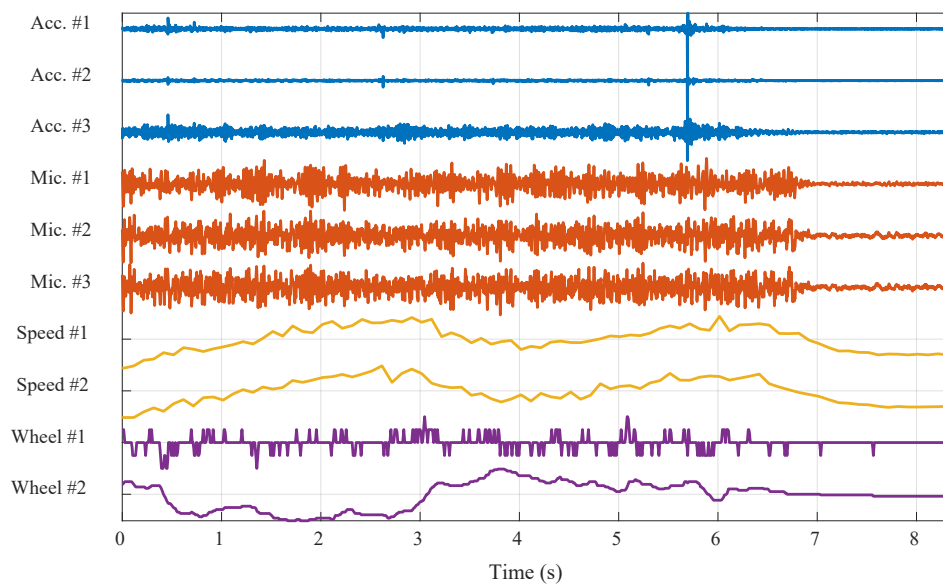
**Name of the project: Informed Methods for Signal Synthesis (MISS)**

The project is in the final phase mainly focused on experimental verification of the new algorithms developed so far for signal synthesis. Two application domains were considered in the project: biomedical and automotive signal analysis. In this final phase, extensive work has been applied to the problem of training road

**TRANSFER LEARNING APPLICATION**



TIAbdSeg project summary block diagram



Example of the captured signals from four sensors: three accelerometers (Acc.), three microphones (Mic.), two speed channels (Speed), and two handwheel signals (Wheel).

surface classifiers by data augmentation. The context is on-board systems for autonomous or semi-autonomous driving assistance. Evidences are obtained by experiments involving 63 captures of a 10-channel multisensor deployment under different settings of the involved parameters. It has been demonstrated significant reductions of the overall capture time by data augmentation. (see figure)

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

**Name of the projects:** Alternative Therapies based on New Audiovisual Technologies for Neurodegenerative Diseases in Social Distancing COVID-19 (TANTAENDSCovid)

**Summary of the projects:** The TANTAENDSCovid project aimed to carry out a preliminary study for future research projects, including the AICO / 2020/151, which will generate cognitive stimulation therapies / activities for neurodegenerative diseases. These therapies are based on individual and collaborative musical, sound and image / video activities with tablets, smart phones and augmented reality using the Soundcool system created at the UPV, and systems derived from Soundcool. The TANTAENDSCovid project is studying the possibility of applying Soundcool's new audiovisual technologies in new therapies and collaborative activities in Alzheimer's, and a first therapy will be designed and tested for working even in the distance.

**Funding entity:** Polisabio program from the Foundation for the Promotion of Health and Biomedical Research of Valencia Region (FISABIO) and the UPV.

**Name of the Project:** New Technologies for Music and Audiovisuals for the Treatment of Neurodegenerative Diseases (AICO/2020/151)

**Summary of the project:** In the AICO / 2020/151 project, activities and therapies are being expanded, also applying to other neurodegenerative diseases. Currently the tests of these activities and therapies are being tested with the users of the center of the Association of Relatives and People with Alzheimer's and other dementias of Canals (AFA Canals) and the residence of La Saleta Campolivar of the Colisée group. Among the activities carried out is the Conference "New Therapies for Neurodegenerative Diseases" held in collaboration with FISABIO in March 2021.

**Funding entity:** Generalitat Valenciana (Spain)

## 2.- Research results

### 2.1.- Featured publications

**Estimation of the number of endmembers in hyperspectral images using agglomerative clustering.** J. Prades, G. Safont, A. Salazar, L. Vergara, Remote Sensing, vol. 12(21), pp.1-22, 2020.

We present an algorithm that estimates the number of materials in the scene using agglomerative clustering. The algorithm is based on the assumption that a valid clustering of the image has one cluster for each different material. After reducing the dimensionality of the hyperspectral image, the proposed method obtains an initial clustering using K-means. In this stage, cluster densities are estimated using

Independent Component Analysis. Based on the K-means result, a model-based agglomerative clustering is performed, which provides a hierarchy of clustering. Finally, a validation algorithm selects a clustering of the hierarchy; the number of clusters it contains is the estimated number of materials. Besides estimating the number of endmembers, the proposed method can approximately obtain the endmember (or spectrum) of each material by computing the centroid of its corresponding cluster.

**DOI:** 10.3390/RS12213585

**Generative Adversarial Networks and Markov Random Fields for oversampling very small training sets.** A. Salazar, L. Vergara, G. Safont, Expert Systems with Applications, vol. 163, pp.1-12, 2021.

We propose a new method for oversampling the training set of a classifier, in a scenario of extreme scarcity of training data. It is based on two concepts: Generative Adversarial Networks (GAN) and vector Markov Random Field (vMRF). Thus, the generative block of GAN uses the vMRF model to synthesize surrogates by the Graph Fourier Transform. Then, the discriminative block implements a linear discriminant on features measuring clique similarities between the synthesized and the original instances. Both blocks iterate until the linear discriminant cannot discriminate the synthetic from the original instances. We have assessed the new method, called Generative Adversarial Network Synthesis for Oversampling (GANSO), with both simulated and real data in experiments where the classifier is to be trained with just 3 or 5 instances. The applications consisted of classification of stages of neuropsychological tests using electroencephalographic (EEG) and functional magnetic resonance imaging (fMRI) data and classification of sleep stages using electrocardiographic (ECG) data.

**DOI:** 10.1016/J.ESWA.2020.113819

**A Machine Learning SDN-Enabled Big Data Model for IoMT Systems,** Haseeb, K.; Ahmad, I.; Awan, I.I.; Lloret, J.; Bosch, I. A, Electronics 10, 2228, 2021.

This paper presents a machine-learning model with Software Define Network (SDN) enabled security to predict the consumption of network resources and improve the delivery of sensors data when using the Internet of Medical Things (IoMT). Additionally, it offers centralized-based SDN architecture to overcome the network threats among deployed sensors with nominal management cost. Firstly, it offers an unsupervised machine learning technique and decreases the communication overheads for IoT

networks. Secondly, it predicts the link status using dynamic metrics and refines its strategies using SDN architecture. In the end, a security algorithm is utilized by the SDN controller that efficiently manages the consumption of the IoT nodes and protects it from unidentified occurrences.

**DOI:** 10.3390/electronics10182228

**Klebsiella aerogenes and Comamonas testosteroni as bioremoval agents on graffiti-coated concrete and granite: Impact assessment through surface analysis.** P. Sanmartín, P. Bosch-Roig, D. Gulotta, R. Fort, I. Bosch, F. Cappitelli, International Biodeterioration & Biodegradation, Volume 161, 2021.

We explore further the graffiti bioremoval capacity of *Klebsiella aerogenes* ATCC 13048 and *Comamonas* sp. ATCC 700440 (*C. testosteroni*), by means of an experiment that was carried out encompassing an improved assay protocol (protocol time was reduced from 20 to 14 days). The formation of pinholes - noticeably higher on concrete than on granite - was already observable by naked eye and further proved by digital image analysis, novel to this experiment, which showed holes greater in number due to *K. aerogenes* and greater in size due to *C. testosteroni*. Complementarily, surface microtopography - also novel for bioremoval studies with bacteria - offered detailed information on surface irregularities that allows better understanding of the performance of the bacteria. In contrast, non-mapping techniques, such as wetting by droplet, specular gloss and roughness measured in line transects provided less information for the study. Infrared (ATR-FTIR) spectroscopy and colour change assessment - mainly in the achromatic parameter  $L^*$  - showed more intense changes by *C. testosteroni*.

**DOI:** 10.1016/j.ibiod.2021.105244

**Assessment of Arrow-of-Time Metrics for the Characterization of Underwater Explosions,** A. Miralles, R.; Lara, G.; Carrión, A.; Bou-Cabo, M., Sensors, 21, 5952, 2021.

Anthropogenic impulsive sound sources with high intensity are a threat to marine life and it is crucial to keep them under control to preserve the biodiversity of marine ecosystems. Underwater explosions are one of the representatives of these impulsive sound sources, and existing detection techniques are generally based on monitoring the pressure level as well as some frequency-related features. We propose a complementary approach to the underwater explosion detection problem through assessing the arrow of time. The arrow of time of the pressure waves

coming from underwater explosions conveys information about the complex characteristics of the nonlinear physical processes taking place as a consequence of the explosion to some extent. We present a thorough review of the characterization of arrows of time in time-series, and then provide specific details regarding their applications in passive acoustic monitoring.

**DOI:** 10.3390/s21175952

**Application of a risk-based approach to continuous underwater noise at local and subregional scales for the Marine Strategy Framework Directive**, E. Verling, R. Miralles, M. Bou-Cabo, G. Lara, M. Garagouni, JM. Brignon, T. O'Higgins, Marine Policy, Volume 134, 2021.

The Marine Strategy Framework Directive's (MSFD) goal of achieving Good Environmental Status (GES) in European waters presents Member States (MS) with a significant challenge in measurement and monitoring of a suite of descriptors of GES, some of which are poorly understood. To address the burden for MSs of monitoring and measuring environmental status and trends over vast areas, provisions have been made for the use of risk-based approaches to assessment and monitoring. Here, a standardised risk-based approach is described, aligned with the articles of the directive and with the DAPSI(W)R(M) conceptual frame. The parallel applications of the risk-based approach illustrate that it is a powerful tool that can provide useful outputs, even where significant data gaps and limitations in understanding exist.

**DOI:** 10.1016/j.marpol.2021.104786

**Collaborative Creation with Soundcool for Socially Distanced Education**, J. Sastre-Martínez, N. Lloret-Romero, S. Scarani, R.B. Dannenberg, J. Jara, Proceedings of Korean Electro-Acoustic Music Society's Annual Conference (KEAMSAC) 2020, Seoul, Korea, 30-31 Oct. 2020, pp. 47-51.

Soundcool is a flexible, modular computer music software system created for music education. Moreover, Soundcool is an educational approach that embraces collaboration and discovery in which the teacher serves as a mentor for project-based learning. To enable collaboration, Soundcool was designed from the beginning to allow individual modules to be controlled over WiFi using smartphone and tablet apps. This collaborative feature has enabled network-based performance over long distances. In particular, the recent demand for social distancing motivated further explorations to use Soundcool for distance education and to enable young musicians to perform together in a creative way. We describe the educational

approach of Soundcool, experience with network performances with children, and future plans for a web-based social-network-inspired collaborative music creation system.

**Available at:** [https://www.researchgate.net/publication/350688934\\_Collaborative\\_Creation\\_with\\_Soundcool\\_for\\_Socially\\_Distanced\\_Education](https://www.researchgate.net/publication/350688934_Collaborative_Creation_with_Soundcool_for_Socially_Distanced_Education)

**Soundcool: A Business Model for Cultural Industries Born Out of a Research Project**, Lloret-Romero N., Sastre-Martínez J., Ospina-Gallego C., Scarani S., Music as Intangible Cultural Heritage pp 41-49, 2021

Soundcool is a system for musical, sound and visual collaborative creation through mobile phones, tablets and other interfaces. This paper describes the creation of the app from the outset, illustrating not only how the Soundcool® system has been developed from the initial idea to the current reality, but also the evolution that the app has had during this period and how it has become ready to use. The research group in the Universitat Politècnica de Valencia (UPV) has played a key role in the development of the app. We also explain the opportunities for Soundcool in different markets and economic sectors. Last but not least, we describe how the idea has been financed to make it a reality.

**DOI:** 10.1007/978-3-030-76882-9\_4

**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, Vol. 150, 2020

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 recently proposed algorithm, FANSIRAS, extracts from a single resonant signal equivalent results to NIRAS when the specimen is conditioned. 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



## 2.2.- Awards and exhibitions.

Workshop and exhibition at the Korean Electro-Acoustic Music Society's Annual Conference 2020. Within this Conference the musical and audiovisual show "Autumn" was premiered. It was the first professional remote show taking advantage of the new Soundcool capability of working with the participants connected through the internet. The participants controlled a computer with Soundcool in Valencia from South Korea, Indonesia, the USA and Spain on Saturday October 31, 2020. Prior to the premiere, the Collaborative Creation with Soundcool for Socially Distanced workshop was held. The workshop and the show was streamed and it is available at <https://youtu.be/kRp4SMfpLOY>.

The Soundcool team has been a finalist in the Creative Spain Cup with the project "Collaborative creation with Soundcool for multimedia opera on a traditional story", being the best-rated project in the category of universities and non-profit companies. The project teaser is available at <https://youtu.be/fYnp1HF-bIs>, and the presentation of the project is available at [https://youtu.be/xQq68mn\\_TNs?t=9666](https://youtu.be/xQq68mn_TNs?t=9666). In addition, Soundcool was selected to participate in the VI meeting of Culture and Citizenship of the Ministry of Culture and Sports ([https://youtu.be/\\_0\\_tWC5gBa4](https://youtu.be/_0_tWC5gBa4))

Soundcool has also been selected in the 3rd Collab de las Naves program, receiving training in the acceleration process for Startups. We continue with the education field extended to

any subject thanks to the new video modules, including chroma, mixers, effects, etc...; This video shows a demo of the new Soundcool capabilities: <https://youtu.be/zISYV-Jw9es> (English subtitles available). Advanced artistic examples of use even at a distance can be seen by composers (<https://youtu.be/QyCYa71SCtc>), PhD students (<https://youtu.be/onAHkyMc9IU> and <https://youtu.be/maHRMXn92JE>) and undergraduate students in Fine Arts (<https://youtu.be/fqGxoDmW3oQ>).

On Sept. 23rd, 2021, Soundcool was invited to participate in "Visiones sonoras, International Festival of Music and New Technologies, Creative Minds Come Together" with a Workshop with a new performance of the piece "Autumn" with performers in the distance (USA, Mexico and Spain) composed by the Soundcool PhD student Pedro Miguel Astasio Molina. The Workshop was presented by J. Sastre, R.B Dannenberg, S. Scarani and P. Astasio (<https://en.cmmas.com/taller-soundcool>).

Finally, the Soundcool team created and performed the audiovisual show "Africa" controlled by dance with augmented reality on June 28th, 2021. The show was commissioned for the Africa Table event for the digitization of the African continent organized by the Ministry of Foreign Affairs, European Union and Cooperation (Spain), chaired by the Secretary of State for Foreign Affairs and for Latin America and the Caribbean, Cristina Gallach. The event counted on the participation of the General Director of Smart Africa, Lacina Koné (<https://youtu.be/0hbcscvIktw?t=5859>)



Show "Africa" with Soundcool controlled by dance with augmented reality commissioned by the Ministry of Foreign Affairs, European Union and Cooperation (Spain)