# SIGNAL PROCESSING GROUP

## HEAD OF THE GROUP RESEARCH REPORT

During the academic year 2017/2018 the Signal Processing Group (GTS) of the iTEAM, has continued researching in the development of solutions for theoretical Signal Processing problems and the application of these algorithms in various fields of the industry, medicine, biology and fine arts.

The research of the group is mostly aimed towards signal processing techniques applied to ultrasonic and impact-echo methods, signal processing techniques applied to bioacoustics and passive acoustics monitoring, signal processing algorithms for surrogate data generation and signal modality, image and video processing for biomedical applications, and technology for the arts. A complete list of research activities can be found at http://www.iteam.upv.es/group/gts/.

The leadership of the group in several work packages of the interdisciplinary QUIETMED European Project has produced some interesting results for the scientific community, such as new techniques for Big Data representations of the ambient noise acoustic indicators that will help biologists to advance in the study of how anthropogenic sounds impact on some marine species.

## 1.- PROJECT ACTIVITIES

The GTS has continued researching in the already stablished research lines as well as in some other emerging activities. Thanks to some research programmes, the group has been able to consolidate many research lines, of which the group is particularly satisfied. In addition, the group has been able to expand beyond their boundaries into other areas or new research activities. A short summary of the main activities being accomplished in the group is given below:

*Signal processing techniques applied to ultrasonic and impact-echo methods for the characterization of cementitious materials in the construction industry.*

We have advanced in the use of signal processing for non-destructive testing, both for the detection and for the characterization of damage in cementitious materials. For these materials, we have developed, among some others, algorithms that allow: material characterization, damage location and tomography reconstruction. As a novel application, GTS and the University College Cork have worked in together applying non-contact airborne ultrasound and signal processing for cement characterization. This advances have been recently published in Ultrasounds.

The GTS collaborates with the ICITECH (Institute of Science and Technology of the Concrete) for the characterization of different types of global damage in cementitious materials using sonic and ultrasonic signals.

*Bioacoustics and passive acoustics monitoring for the characterization of cetacean calls and anthropogenic noises.*

We employ Passive Acoustic Monitoring (PAM) techniques to advance in the study of marine mammals and anthropogenic sounds. This is achieved by developing new acoustic instrumentation and signal processing algorithms to detect and characterize underwater acoustic events. Our goal is to improve the understanding of how anthropogenic sounds impacts on the marine biodiversity as well as to study the population abundance, seasonality and behavior of marine mammals. We combine traditional PAM techniques with recent advances in signal processing algorithms and representation techniques such as Big Data representations and deep learning.

*Signal processing algorithms for surrogate data generation and Recurrence Quantification analysis.*

Surrogate generation has become a widespread tool for the statistical analysis in many fields. However, classical surrogate generation algorithms fail to generate valid data in many specific situations such as: detecting complexity in short oscillatory signals, nonlinear detection in non-stationary signals, etc. During the last year, the GTS has devised new surrogate generation techniques that, alongside with Recurrence Quantification analysis, have allowed to face complex problems such us: measuring the stress on financial markets, detecting irregular animal

vocalizations, and distinguishing explosions from impact pile drivers from Fin Whale pulses.

*Applications of biomedicine:*

We collaborate with the Clinical Area of Medical Image of the Hospital Universitario and Politécnico La Fe (GIBI230) in the processing and analysis of medical images. We provide a long experience in many fields of Signal Processing for the extraction of relevant information, detection of novelty, fusion of decisions when applied to image processing. During the last year, we have focused in extracting image biomarkers for the quantification of changes associated with the disease. We have also excelled in using the available tools to adapt the huge amount of information available in the image environment (DICOM, PACS, RIS) to the effective and real-time control of all quality aspects relevant to service excellence such as: radiation dose, number of procedures per process, temporary adjustment of demand, analysis of large consumers, costs, technological evaluation, etc. Finally, a recent research line consists in the use of automatic segmentation methodologies applied to Magnetic Resonance Images based on artificial intelligence and deep learning.

*Graph Signal Processing*

Graph Signal Processing (GSP) combines concepts emanating from two largely consolidated areas: signal processing and graph theory. From the perspective of signal processing it leads to a more general definition of a signal by assigning every sample value to the vertex of a graph. From the graph theory perspective, new graph transformations can be defined that extend classical signal processing concepts like filtering, prediction and spectral analysis. Signal processing on graphs is finding progressively new application in the areas of detection and classification due to its flexibility to model general dependencies between variables. Thus, GTS is currently 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*

GTS is currently working in the context of Big Data Health Applications. The proposed approach consists of multimodal fusion for biosignal analysis methods that include monitoring of the very variant dynamics of physiological phenomena sensed at high velocity on real time from several sources. We apply those methods in neurology and neurophysiology areas for the study and diagnosis of epilepsy, Alzheimer, and sleep disorders, collaborating in an interdisciplinary

framework with physicians of the Hospital La Fe of Valencia. A multimodal analysis approach is considered in three specific scenarios: bimodal analysis of simultaneous recordings of fMRI (functional Magnetic Resonance Imaging) and EEG (electroencephalographic) recordings, analysis of EEG in combination with DTI (Diffusion Tensor Imaging) and ECoG (electrocorticographic) recordings for the case of epilepsy patients.

*Technologies for the Arts (Soundcool)*

Soundcool is an innovative system for collaborative creation of music and video using smartphones, tablets, Kinect, computers, Open Sound Control (OSC) and, recently, the Microsoft Hololens (https://bit.ly/2pxig5x). A Soundcool teaser is available at https://youtu.be/VV6bg3HlM4o. Soundcool has recently started a new direction towards an entrepreneurship endeavor. We aim at achieving a sustainable model based on a business solution. We are optimistic about this approach since the Soundcool user community has a growing tendency. In this regard we have recently been shortlisted as semifinalist for the Everis awards that promote innovation. We will compete within the category of "new business models in the digital economy".

## 1.1.- ONGOING PROJECTS

*Name of the project: Joint programme on noise (D11) for the implementation of the Second Cycle of the MSFD in the Mediterranean Sea (QUIETMED)*

*Webpage of the project: http://www.quietmed-project.eu/*

*Summary of the project: Human activities that take place at sea bring many benefits to society and economy but also many impacts to the marine environment. Among these impacts, the most widespread and pervasive is underwater noise. Marine Strategy Framework Directive (MSFD) represents a huge progress to preserve marine environment as it aims to achieve Good Environmental Status (GES) by 2020. It highlights the need to establish anthropogenic noise levels that do not affect marine Biota.*

*During the second year of the QUIETMED project we have performed a Pilot project experiment in the Cabrera Archipelago Maritime-Terrestrial National Park (Spain). This is a Category A monitoring that will be used to stablish information on the ambient noise level in the location, and to give guidance on methodologies such as hardware calibration, signal processing, Big Data representations, etc.*

*Funding entity: DG for Environment (ENV), European Commission.*
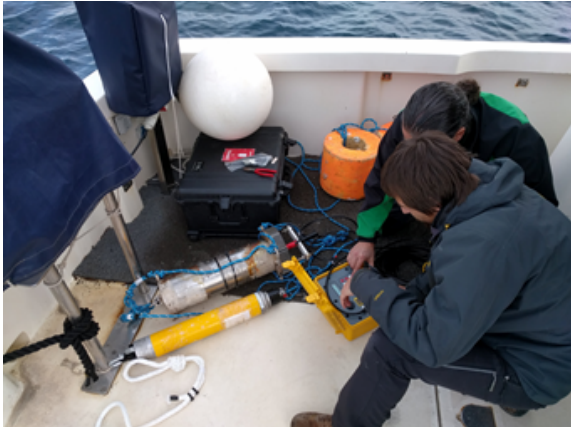
*Testing the surface unit of the acoustic releaser before the QUIETMED Cabrera pilot project deployment.*

**Name of the project**: *Underwater ambient noise levels assessment and modelling of the noise probably due to the increase of marine traffic in the area of "El Gorguel".*

**Summary of the project**: *This is a joint collaborative project with the Universidad de Alcalá de Henares (Instituto Franklin), L'Oceanogràfic from Valencia and the iTEAM-UPV. The main purpose of the project is to assess the ambient noise levels and to model the underwater noise which might be due to the increase of marine traffic in the area of "El Gorguel", Cartagena, Spain.*

**Funding entity**: Port authority of Cartagena.



*One of our SAMARUC systems deployed in "El Gorguel" for the assessment of ambient noise levels.*

**Name of the project**: *Underwater ambient noise levels assessment of the installation of an undersea cable.*

**Summary of the project**: *In this project we are collaborating with ELITTORAL for the evaluation of the ambient noise levels produced during the installation of an undersea cable.*

**Funding entity**: *elittoral S.L. Estudios de ingeniería costera y oceanográfica*

**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 methods 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. We intend to establish ultrasonic based methods to evaluate the basic rheological properties, such as viscosity and yield stress. We analyze self-healing due to autogenous healing properties (by the own nature of hydrated cement) as well as due to autonomous processes (by addition of commercial products based on bacteria and reagent capsules). Monitoring is done using ultrasonic techniques and non-linear acoustic resonance impact spectroscopy. Regarding the ultrasonic techniques, we employ contact techniques (velocity, attenuation, signal modality, lamb waves, reflection...), tomography techniques (based on neural network) and non-contact techniques (airborne ultrasound).*

**Funding entity**: *Spanish Government.*
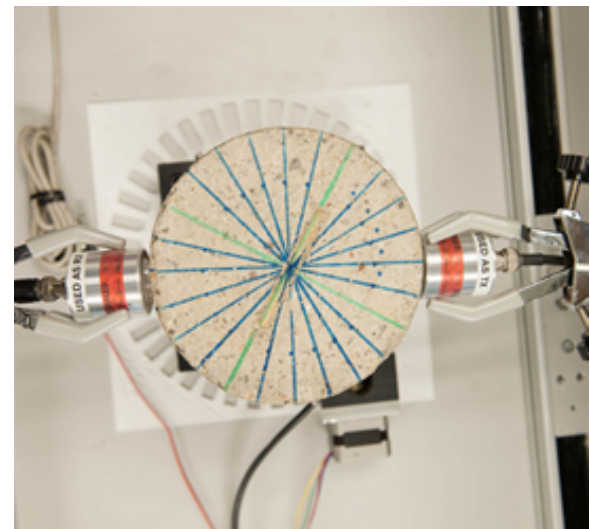


*Characterization of a cylindrical cement specimen by means of airborne ultrasound sensors.*

**Name of the project**: Signal Processing on Graphs for Classifier Systems

**Summary of the project**: *GTS keeps working on this topic in different areas of application. In particular Graph Signal Processing (GSP) is being applied to multimodal biomedical signals in neurology and neurophysiology areas for the study and diagnosis of epilepsy, Alzheimer, and sleep disorders, collaborating in an interdisciplinary framework with*

physicians of the Hospital La Fe of Valencia. A multimodal analysis approach is considered in three specific scenarios: bimodal analysis of simultaneous recordings of fMRI (functional Magnetic Resonance Imaging) and EEG (electroencephalographic) recordings, analysis of EEG in combination with DTI (Diffusion Tensor Imaging) and ECoG (electrocorticographic) recordings for the case of epilepsy patients. An "ad hoc" interface is being developed to facilitate the visualization of signals and images, and to ease the interaction with the physicians.

*Funding entity: Spanish Government, TEC2014-58438-R*
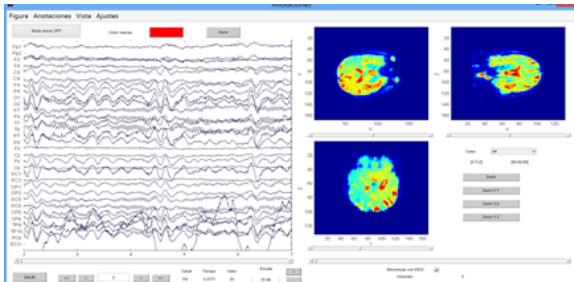


*Name of the project: Soundcool*

*Webpage of the project:* [http://soundcool.org](http://soundcool.org).

*Summary of the project: Soundcool is active this year with the grant from Daniel and Nina Carasso Foundation, Project 16-AC-2016 (9/2016-8/2019): focused on the development of interactive video art systems, new OSC apps, new developments for functional diversity students, and increasing national and international dissemination.*

*The achievements of 17-18 year are summarized in the following lines. Firstly, we began incorporating Soundcool into the music education system in the Valencian Community (population of over 5 million people) with the support of the Valencian education council. With them, we are conducting a pilot test in 28 educational centers and have released a MOOC on the basics of collaborative music and sound creation with Soundcool ([https://bit.ly/2yQRZrK](https://bit.ly/2yQRZrK)). All the videos of the MOOC have English Subtitles and are also at [https://bit.ly/2lJUi6S](https://bit.ly/2lJUi6S). A new MOOC Soundcool 2 about video modules and creative proposals was released on October 2018 (see [https://bit.ly/2JTfqCO](https://bit.ly/2JTfqCO)). Additionally, The Act I of the opera "The Mother of Fishes" involving Soundcool and composed by Jorge Sastre and Roger Dannenberg, has been performed in different times ([https://bit.ly/2KztwsJ](https://bit.ly/2KztwsJ)), in México at the Monterrey Institute of Technology and Higher Education (ITESM), and twice more in Spain. IIn October 30th 2018 the full opera was premiered in Mexico at the ITESM Puebla, see [https://bit.ly/2PN5YX6](https://bit.ly/2PN5YX6), and then it is planned to perform the opera at the main campuses*

of the ITESM, and the best version at a main theatre in Mexico City. The experience has been so satisfactory that we reach an agreement with the ITESM for the premiere of a new opera with Soundcool in 2020 composed again by Sastre and Dannenberg.



*Preview of the opera The Mother of Fishes at the ITESM. For the creation of the Mother of Fishes' voice in real-time with Soundcool see [http://youtu.be/oyLDUMZgPX4?t=334](http://youtu.be/oyLDUMZgPX4?t=334)*

## 2.- RESEARCH RESULTS

### 2.1.- FEATURED PUBLICATIONS

· *Ultrasonic signal modality: A novel approach for concrete damage evaluation*, A. Carrión, V. Genovés, J. Gosálbez, R. Miralles, J. Payá, Cement and Concrete Research 101 (2017) 25–32.

*In this paper, a new approach for characterizing material damage, using ultrasonic waves, is proposed. Two concrete series with two types of cement with different C3A content and similar mechanical properties were subjected to external sulphate attack (ESA) and evaluated using a novel Recurrence Plot Quantification Analysis (RQA) method. This brand new technique was compared with several methods, such as mechanical tests (compressive and flexural strength determination), dynamic test (dynamic modulus) measurements, and traditional ultrasonic measurements (propagation velocity and ultrasonic wave attenuation). In these experiments, RQA showed a high sensitivity to damage in spoiled series, improving the reliability of damage detection with ultrasonics in non-homogeneous materials compared to other non-destructive techniques. Interesting advantages of this new non-destructive technique are: a) the RQA parameter is normalized (range of 0 to 1); b) a calibration process is not required; c) the values of its standard deviation show the dispersion of the damage.*

*DOI: 10.1016/j.cemconres.2017.08.011*

• *Ultrasonic and impact spectroscopy monitoring on internal sulphate attack of cement-based materials*, V. Genovés, F. Vargas, J. Gosálbez, A. Carrión, M.V. Borrachero, J. Payá, Materials and Design 125 (2017) 46–54

*An exhaustive monitoring of an internal sulphate attack of Portland cement-based materials is addressed. Four series of Portland cement mortars with different amounts of gypsum (0%–2% SO3 respect to the cement by mass) were monitored by means of physical, microstructural and non-destructive tests, studying specimens with a low expansion rate to examine the sensitivity of the applied techniques. Mechanical analysis has been correlated with non-destructive tests: impact resonance acoustic spectroscopy and ultrasonic measures. The dynamic modulus and ultrasonic pulse velocity have closely predicted the stiffness of the specimens. The total material attenuation (absorbed energy of the chirp signal ultrasonic wave) presented different trends, showing clear differences for the most damaged series (2% SO3). Attenuation supplied interesting information about the hardening process and the microcracking effect due to a mortar expansion higher than 0.04%. The novelties of this study are the exhaustive monitoring of an internal sulphate attack, as well as the examination of the sensitivity of brand new NDT techniques when this damage process overlaps with the curing process.*

*DOI: 10.1016/j.matdes.2017.03.068*

• *Airborne non-contact and contact broadband ultrasounds for frequency attenuation profile estimation of cementitious materials*, J. Gosálbez, W.M.D. Wright, W. Jiang, A. Carrión, V. Genovés, I. Bosch, Ultrasonics 88 (2018) 148–156-

*The study of frequency-dependent ultrasonic attenuation in strongly heterogeneous cementitious materials is addressed. To accurately determine the attenuation over a wide frequency range, it is necessary to have suitable excitation techniques. We have analysed two kinds of ultrasound techniques: contact ultrasound and airborne non-contact ultrasound. The mathematical formulation for frequency-dependent attenuation has been established and it has been revealed that each technique may achieve similar results but requires specific different calibration processes. In particular, the airborne non-contact technique suffers high attenuation due to energy losses at the air-material interfaces. Thus, its bandwidth is limited to low frequencies but it does not require physical contact between transducer and specimen. In contrast, the classical contact technique*

can manage higher frequencies but the measurement depends on the pressure between the transducer and the specimen.

*Cement specimens have been tested with both techniques and frequency attenuation dependence has been estimated. Similar results were achieved and it has been demonstrated that the air- borne non-contact ultrasound technique could be a viable alternative to the classical contact technique.*

*DOI: 10.1016/j.ultras.2018.03.011*

• *Fusion Methods for Biosignal Analysis: Theory and Applications*, A. Salazar, V. Zarzoso, M. Rosa-Zurera, L. Vergara: Computational Intelligence and Neuroscience, 2017.

*Recent advances in data acquisition and biosignal processing are paving the way for the optimal integration or fusion of complementary data modalities in a wide variety of clinical settings. Data modalities include electrocardiography (ECG), electroencephalography (EEG), electrocorticography (ECoG), magnetic resonance imaging (MRI), functionalMRI (fMRI), positron emission tomography (PET), and diffusion tensor imaging (DTI). Integration can be performed by exploiting the analyses sequentially or simultaneously, depending on issues related to synchronization, physical compatibilities, and standard clinical procedures. Fusion approaches aim at integrating analyses of data from different modalities, establishing synergic relationships for improved clinical hypothesis testing and medical diagnosis.*

*DOI: 10.1155/2017/7152546*

• *On the Detection of Impulsive and Tonal Events in Passive Acoustics Monitoring*, R. Miralles, G. Lara, A. Carrión, J. Gosalbez, I. Bosch, 22nd IEEE International Conference on Digital Signal Processing (DSP 2017).

*Anthropogenic underwater sound is now recognized as a world-wide problem. Shipping, seismic surveys and pile driving, among some other human activities, have shown a broad range of negative effects in a variety of species. It is thus important to control, register and characterize these activities in order to establish policies that mitigate its effects. For this purpose, automatic detectors of the major anthropogenic sound categories (impulsive and tonal sounds) are needed. An efficient algorithm capable of detecting impulsive and tonal sound categories is proposed. The detection algorithm is based on the Pulsed to Tonal Ratio (PTR) and, in this work, we show not only its simplicity but also how well it performs in a variety of situations. In contrast to what happens with some other techniques,*

the proposed detector generally succeeds in detecting pulsed and tonal events with additive white and pink noise. This makes the PTR detector particularly appropriate for passive acoustic monitoring.

DOI: 10.1109/ICDSP.2017.8096125

· *Effect of exploitation and exploration on the innovative as outcomes in entrepreneurial firms.* N. Vargas, M.B. Lloria, A. Salazar, L.Vergara, International Entrepreneurship and Management Journal, 2018.

The main aim of this study is to establish the effect of the Exploitation and Exploration; and the influence of these learning flows on the Innovative Outcome (IO). The Innovative Outcome refers to new products, services, processes (or improvements) that the organization has obtained as a result of an innovative process. For this purpose, a relationship model is defined, which is empirically contrasted, and can explains and predicts the cyclical dynamization of learning flows on innovative outcome in knowledge intensive firms. The quantitative test for this model use the data from entrepreneurial firms biotechnology sector. The statistical analysis applies a method based on variance using Partial Least Squares (PLS). Research results confirm the hypotheses, that is, they show a positive dynamic effect between the Exploration and the Innovative as outcomes. In the same vein, they results confirm the presence of the cyclic movement of innovative outcome with the Exploitation.

DOI: 10.1007/s11365-018-0496-5

· *Estimating the Laplacian matrix of Gaussian mixtures for signal processing on graphs Signal Processing,* J. Belda, L.Vergara, A. Salazar, G. Safont, Signal Processing, vol 148, pp. 241-249, 2018.

Recent works in signal processing on graphs have been driven to estimate the precision matrix and to use it as the graph Laplacian matrix. The normalized elements of the precision matrix are the partial correlation coefficients which measure the pairwise conditional linear dependencies of the graph. However, the non-linear dependencies inherent in any non-Gaussian model cannot be captured. We propose in this paper a generalized partial correlation coefficient which is derived by assuming an underlying multivariate Gaussian Mixture Model of the observations. Exact and approximate methods are proposed to estimate the generalized partial correlation coefficients from estimates of the Gaussian Mixture Model parameters. Thus it may find application in any non-Gaussian scenario where the Laplacian

matrix is to be learned from training signals.
DOI:10.1016/j.sigpro.2018.02.017

· *New Perspectives of Pattern Recognition for Automatic Credit Card Fraud Detection,* A. Salazar, G. Safont, A. Rodriguez, L. Vergara, Encyclopedia of Information Science and Technology, IGI Global, 2017.

We have presented a new application having unquestionable interest for the signal processing community. Some similarities and differences with classical detection problems in the signal processing area have been emphasized. Then it has been considered the use of fusion as a powerful technique to derive algorithms having reasonable performance to solve this very complex problem. Experimental results using large real and surrogate datasets have been showed, where the improvements of using fusion of scores have been illustrated. Different well-known methods were compared with the new approaches. The detection results obtained for different mixtures of real and surrogate data were comparable under real requirements of very low false alarm.

· *Soundcool Project: Collaborative Music Creation,* Elena Robles Mateo, Jaime Serquera, Nuria Lloret Romero, Jorge Sastre Martínez, Springer International Publishing, 2018

This paper addresses four criteria that the Soundcool project meets: to "be sustainable", "be future-oriented", "be transformative" and "be innovative". Soundcool is a pedagogical and technological project. A brief description of the technology behind Soundcool will be useful for the reader before addressing the four criteria. Soundcool is like a "Lego" for sound; Soundcool is composed of a series of software modules that run on a central computer, or host computer. Each module is sort of a musical instrument; it could be a synthesizer, a sampler, a sound effect processor, etc. these modules can be interconnected in different ways allowing the users, i.e. the students, to create their own arrangements, as we call the module creations and interconnections. Then, each module can be controlled either with the mouse or, what is more interesting, with a mobile device through WiFi. This way, every student can control one or several modules of the whole arrangement from their mobile device contributing to a collaborative and participative experience.

· *Sound Creation and Artistic Language Hybridization Through the Use of the Collaborative Creation System: Soundcool,* Noemy Berbel-Gómez, Adolf Murillo-Ribes, Jorge Sastre-Martínez, María Elena Riaño-

*Galán, 2017. Turkish Online Journal of Educational Technology.*

*We submit the development of a collaborative sound creation proposal made reality using the Soundcool system from its initial design phase to the scenic performance at the International Festival of Contemporary Music ENSEMS, Valencia (Spain). The "interstellar machine", a transdisciplinary piece whose linking thread is a story, is characterized by hybridization of languages and artistic fusion. It's a piece made possible by the joint work between students of Primary and Secondary Education, a group of experts and musical educators. From a qualitative approach, all the participants were interviewed and the analysis of an audiovisual recorded during the work process of the artistic proposal was carried out. From using data triangulation, the results obtained show indicators related to the hybridization of contemporary art languages, the use of a collaborative didactic methodology and the strategies developed for innovation and creation. The conclusions we came to just confirm a horizontal and participative way of working throughout the proposal, the success of the system used, the interconnection of artistic languages, the promotion of bridges in and outside the classroom or the approach of contemporary music to young people, among others. In addition, it focuses on some aspects of improving teaching technique and the need to continue working on this line.*

## 2.2.- AWARDS.

In May 2018 we beat a Guinness World Record of the Largest Music Lesson with 4130 students (https://bit.ly/2MAH1Zp); the title of the class was "Introduction to Soundcool" given by Jorge Sastre, Soundcool director, Adolf Murillo and Pere Vicalet. Soundcool also won the Art & Design Competition of NEM (New European Media) Summit 2017; more information is available at https://bit.ly/2H9OEYT. NEM is a European Technology Platform, fostering the convergence among Media, Content, Creative industries, Social Media, Broadcasting and Telecom sectors (https://nem-initiative.org/). Also, in 2017 we won two Bankia awards to musical talent to, (A) best researcher, Jorge Sastre and (B) the best educative group using technologies to ExperimentArts for our work with Soundcool (https://bit.ly/2tPUiWf).

## SPECIAL EVENTS

*Soundcool innovation has been showcased at different technological festivals, since our engineers have recently taken the project to the next level. They incorporated a new set of*

*modules for live processing of images/videos and control using Hololens. With these new features Soundcool becomes a complete audiovisual system. To introduce videos the Video Sampler can be used which also can reproduce a video from specific time or reproduce specific loops from the video. Several modules can be used to edit the content: for example up to 8 inputs can be switched easily with the Switcher module and the Blending module allows the user to apply visual effects in real time.*

*The above mentioned festivals include the Marketlab of Sonar+D and Kikk Festivals, in Barcelona and Belgium respectively, in 2017. More recently, for the 2018 edition we repeated in Barcelona again with the stand, and the organization has selected us to make a presentation and concert in Sonar itself. We presented the audiovisual work HoloSound, where Soundcool is controlled by the Hololens of augmented reality, see https://youtu.be/Ql_J5KQIII0. The piece was also performed at the 50 anniversary of the UPV https://youtu.be/V-B1gE448tw and MEVArt Festival https://youtu.be/hLwjBvbpqgg. This is an exceptional showcase with artists and creatives from all around the world for the professional use of Soundcool.*