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GTS Annual Research Report 2016/2017

Head of the Group research report

I am glad to introduce the 2016/2017 Signal Processing Group (GTS) annual research report, which provides a summary overview of a wide range of research and innovation initiatives undertaken by our staff and students during the last year.

This period agenda reflects, in a large measure, efforts by our researchers to respond many of the challenges that we have faced due to the projects we are working on as well as some strategic imperatives arising from GTS vision of the forthcoming years. Our vision commits GTS to work on both: 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.

Towards this end, the research agenda has been organised around a number of research themes: 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.html.

During 2016/17, the GTS celebrates some flagship projects, of which we are particularly proud. The group is leading a part of a European Project devoted to improve the level of coherence and comparability in the signal processing algorithms, acoustics modelling and hardware calibration for the implementation of the Second Cycle of the Marine Directive (MSFD) in the Mediterranean Sea (listed in page 66). The group faces many challenging problems within the project, such as the design of robust and hardware independent algorithms for cetacean detection or the development of new Big Data representations that 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. 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. A featured result from this collaboration has been the design of a novel technique for the characterization of cementitious structures. This result has been patented (see page 71).

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. For this purpose, we combine traditional PAM techniques with recent advances in signal processing algorithms and representation techniques such as Big Data representations of events automatically obtained by means of 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.

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

This research line is devoted to engineering applications for the arts, and it is carried out by the Group of Performing Arts and Technology (PerformingARTech) based at UPV and led by Dr. Jorge Sastre. This is a multidisciplinary research group that combines artistic and scientific profiles bringing together engineers, musicians, visual artists, pedagogues, and experts in audiovisual communication. Dr. Jorge Sastre has a multidisciplinary profile himself as an engineer, composer and mathematician. Similarly, many members of the group have hybrid profiles combining technology and arts. The group is specially focused on collaborative music and audiovisual creation with different interfaces such as mobile devices or interfaces from videogame consoles.

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.

QUIETMED project aims to improve the level of coherence and the comparability of the implementation of the Second Cycle of the MSFD as regards in Descriptor 11- underwater noise implementation in the Mediterranean Sea Basin Region by enhancing cooperation among Member States, the Barcelona Convention and other third non-EU countries.

Within the framework of the project, common approaches to GES and the definition of

Kick-off meeting of the QUIETMED research project in Brussels.

thresholds, guidance on methodologies (hardware calibration, signal processing, Big Data representations, …) and policy recommendations will be set.

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

Name of the project: Marine Protected Areas: Management of new technologies and Innovation for the monitoring of cetaceans and anthropogenic noises.

Summary of the project: This is a joint collaborative project with the Universidad de Alcalá de Henares (Instituto Franklin), L'Oceanogràfic from Valencia and authorities from Marine protected areas in Columbretes Island, Cabrera Island and Cape San Antonio (Denia). The main purpose of the project is to evaluate how new technologies can be used for monitoring cetaceans and anthropogenic noises in these 3 protected areas. Automatically detected species are shown in a geographic information system (GIS) alongside with the different noise indicators described by the MSFD.

Funding entity: Fundación Biodiversidad.

Name of the project: New Applications of Non-Destructive Tests Based On Mechanical Waves For Assessment Of Cementitious Materials Degradation

Summary of the project: The selection of sustainable construction materials alongside with a proper assessment of their durability are key topics that could transform the construction industry. Currently, there are great efforts to develop methods to evaluate and predict the lifetime of materials and constructions depending on the environment around them, and this would allow better assessment of the lifecycle thereof.

Deployment of the SAMARUC system in Columbretes Marine Protected Area.

In this project, we are developing and applying new techniques, based on mechanical waves, for the assessment of damage in cementitious materials. Some of the techniques include the use

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ONDATEST damage characterization by means of US.

of Lamb waves, nonlinear phenomena, such as nonlinear impact resonance acoustic spectroscopy (NIRAS), signal modality, and non-linearity in guided waves. Thus, all these techniques are tested for different kinds of damages: sulphate attack, acid attack, freeze-thawing, wetting-drying, high temperature and carbonation.

We sought to establish correlations between the parameters extracted from the non-destructive testing and the evolution of the degradation of cement-based materials.

Funding entity: Spanish Government.

Name of the project: Advanced fusion techniques in signal processing

Summary of the project: This project is structured in five objectives, the first three of a theoretical nature and the last two of an applied nature. The first objective is to develop methods for classifier fusion from alpha integration, a technique applied so far in the integration of stochastic models. The second objective is based on the use of copula-based methods for optimal fusion of classifiers. Copulas have been used for the probabilistic model in the financial field, but they are novel in the signal processing. The third objective is to develop a general fusion scheme that incorporates temporal dependencies between scorings given by the same or other classifiers (dynamic fusion), and between different events (multi-event fusion). The fourth and fifth objectives address, respectively, the application of the previous fusion techniques in the monitoring of the brain and in the detection of fraud in the banking operations.

Funding entity: Generalitat Valenciana.

Name of the project: Towards the next generation of standards for service life of cement-based materials and structures. COST Action TU1404.

Summary of the project: Cement-based materials (CBM) are the foremost construction materials worldwide, Although, there are widely accepted standards for their structural applications, service life behaviour of CBM structures is still analysed with insufficiently rigorous approaches.

The main purpose of COST Action TU1404 is to bring together relevant stakeholders in order to accelerate knowledge transfer in the form of new guidelines/recommendations, introduce new products and technologies to the market, and promote international and inter-specialty exchange of new information, creating avenues for new developments. The participation of the GTS in TU1404 Cost Action focuses in the robin test which aim is detecting and assessing the setting time and the hardening progress by means of non-destructive parameters, traditional ones and novel ones, as determinism.

Funding entity: Generalitat Valenciana.

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

Summary of the project: The project deals with the study, analysis and testing of new classification

techniques of data and signals, based on a novel methodology called "signal processing on graphs". The structure of graphs is appropriate in scenarios with data of high dimensionality, different types, and irregular relationships. Such features along with high processing speed requirements, are typical of Big Data scenarios, to which the proposal is oriented. Especially relevant will be the study of signals on graphs to design structures of multiple classifiers, associating each node in the graph to every single classifier. The project also includes the study of surrogate techniques oriented to Big Data environments with a double interest: to replicate unbalanced data and to simulate diverse scenarios in a controlled manner. We will also analyze the bidirectional relationship between surrogate models and graph models.

Funding entity: Spanish Government

Name of the project: Soundcool

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

Summary of the project: This is the flagship project of the Group PerformingARTech. Soundcool is an innovative system for music education and collaborative creation using smartphones, tablets, Kinect, Open Sound Control (OSC) and MAX/MSP/Jitter. The system is being used in several European countries through an Erasmus+ project entitled "Technology to Support Learning and Creativity: Building European Networks through Collaborative Music Creation", and has also a line for functional diversity people. Additionally, the Soundcool project counts on the collaboration of Prof. Roger Dannenberg, director of the Computer Music Group at Carnegie Mellon University (USA), and co-creator of Audacity, the famous piece of software for audio recording and editing. Additionally, Soundcool has received public and private funding (http://soundcool.org/es/projects) and several awards.

Worth mentioning are the concerts that students perform outside their schools. Among them, the opera premiere "La Mare dels Peixos" ("The Mother of Fishes") in December, 2016, at the opera house Palau de les Arts Reina Sofía from Valencia (Spain) is our biggest technical and artistic project to date, with music by Sastre and Dannenberg, professional orchestra and singers, and 60 primary, secondary and music school students producing vocal effects, singing and using Soundcool to create and perform wirelessly the opera sound effects.

2.- Research results

2.1.- Featured publications

- **Ultrasonic broadband signals monitoring of glass-fiber reinforced cement (GRC) bending tests**, V. Genovés, Jorge Gosalbez Castillo, Alicia Carrión García, Ramón Miralles Ricós, J. Payá, Cement and Concrete Composites, Elsevier, 2017.

  In this study, complete ultrasonic monitoring of Glass-fiber Reinforced Cement plates under bending tests was addressed. A new ultrasonic procedure based on broadband signals (chirp) has been applied. The analysed ultrasonic parameters have been split into parameters that only depend on time, and parameters that depend on both time and frequency. In particular, the frequency dependent attenuation parameter allows characterizing the evolution of the plate being damaged over a wide frequency range and significantly detecting the main two events happening during the experiment: the first crack and the maximum stress point. This paper demonstrates the suitability of ultrasonic broadband signals for characterizing fiber-reinforced cementitious composites under bending stress.

- **Optimized ultrasonic attenuation measures for non-homogeneous materials**, V.Genovés ; J.Gosalbez; A.Carrion; R.Miralles; J.Paya, Ultrasonics, pp. 345-352, 2016,

  We analysed the frequency-dependent ultrasonic attenuation in strongly heterogeneous materials. For this purpose, three kinds of transmitted signals have been analysed. Sinusoidal and burst signals have higher signal-to-noise ratios (SNRs) but need many measurements to cover their frequency range. However, linear swept-frequency signals (chirp) improve the effective bandwidth covering a wide frequency range with a single measurement and equivalent accuracy, at the expense of a lower SNR. In the case of highly attenuating materials, it is proposed to use different configurations of chirp signals, enabling injecting more energy, and therefore, improving the sensitivity of the technique without a high time cost. Thus, if the attenuation of the material and the sensitivity of the measuring equipment allows the use of broadband signals, the combination of this kind of signal and suitable signal processing results in an optimal estimate of frequency-dependent attenuation with a minimum measurement time.

  DOI: 10.1016/j.ultras.2015.09.007

- **New Insights for Testing Linearity and Complexity with Surrogates: A Recurrence Plot Approach**, A. Carrión, R. Miralles, Recurrence Plots and Their Quantifications: Expanding Horizons, pp. 91-112, 2016.

  The detection and characterization of non-linearities in temporal series is a hot topic in some disciplines such as nondestructive

testing of materials, bioacoustics and biomedical research domains. This is a complex interdisciplinary field where many different researchers are striving to achieve better and more sophisticated techniques. In this scenario, the search for new perspectives that can explain and unify some of the theories is of key importance. Recurrence Plots (RPs) and Recurrence Quantification Analysis (RQA) can play such a role. In this work, we show how RPs can be used to design tests for non-linear detection and characterization of complexity. The proposed tests are less parameter dependent and more robust than some of the traditional discriminating measures. We also illustrate the applicability of the proposed algorithms in simulations and real-world signals such as the analysis of anomalies in the voice production of mammals. DOI: 10.1007/978-3-319-29922-8_5

- **Ultrasound-based density estimation of composites using water-air Interface**, A. Aleksandrovas, A. Rodriguez, L. Svilainis, M.A. de la Casa, A. Salazar, Elektronika ir Elektrotechnika, 22, 6, 28-32, 2016.

  In this paper we present a new method to obtain the density of solid composites using ultrasound. The method exploits the relation between density and acoustic impedance and only requires the measurement of a reference signal form the interface water-air. Once made in a controlled environment, it can be used for any material, and does not require any additional measurement or set-up, so that with a simple calculus it can be used with automatic ultrasonic measurements to calculate the density and therefore elastic constants of the composite for its complete characterization. The method is applied to 3 different materials: two composites based on epoxy and polyester resins respectively with unknown final properties and a common methacrylate sample used as reference. Results show good concordance between obtained and expected results.

- **On the fusion of non-independent detectors**, L. Vergara, A. Soriano, G. Safont, A. Salazar, Digital Signal Processing 50, 24-33, 2016.

  In this paper, we derive the optimum fusion rule of N non-independent detectors in terms of the individual probabilities of detection and false alarm and defined dependence factors. This has interest for the implementation of the optimum detector, the incorporation of specific dependence models and for gaining insights into the implications of dependence. This later is illustrated with a detailed analysis of the two equally-operated non-independent detectors case. We show, for example, that not any dependence model is compatible with an arbitrary point of operation of the detectors, and that optimality of the counting rule is preserved in presence of dependence if the individual detectors are "good enough". We have derived also the expressions of the probability of detection and false alarm after fusion of dependent detectors. Theoretical results are verified in a real data experiment with acoustic signals.

- **Probabilistic Distance for Mixtures of Independent Component Analyzers**, G. Safont, A. Salazar, L. Vergara, E. Gómez, V. Villanueva, IEEE Transactions on Neural Networks and Learning Systems, in press. 2017.

  This paper proposes a new probabilistic distance (PDI) between PDFs expressed by using the parameters of two ICA (Independent Component Analysis) mixture models. PDI can be employed for change-detection, considering that the detection is done by estimating whether or not the model changes. The proposed distance is explicitly computed and does not require numerical integration, and furthermore, it is bounded within the interval [0, 1]. This is unlike the popular Kullback-Leibler divergence (KLD) and other similar metrics. The performance of the proposed distance was tested in two applications using simulated and real data: (i) detecting flaws in materials using ultrasounds and (ii) detecting changes in electroencephalography signals from humans performing neuropsychological tests. The results demonstrate that PDI outperforms KLD in change-detection capabilities.

- **3D measurements in conventional X-ray imaging with RGB-D sensors**, F Albiol, A Corbi, A Albiol, Medical Engineering & Physics 42, 73-79, 2017

  A method for deriving 3D internal information in conventional X-ray settings is presented. It is based on the combination of a pair of radiographs from a patient and it avoids the use of X-ray-opaque fiducials and external reference structures. To achieve this goal, we augment an ordinary X-ray device with a consumer RGB-D camera. The patient's rotation around the craniocaudal axis is tracked relative to this camera thanks to the depth information provided and the application of a modern surface-mapping algorithm. The results show that it is possible to resolve anatomical positions and lengths with a millimetric level of precision.

- **Local deep neural networks for gender recognition**, J Mansanet, A Albiol, R Paredes, Pattern Recognition Letters 70, 80-86, 2016

Deep learning methods are able to automatically discover better representations of the data to improve the performance of the classifiers. However, in computer vision tasks, such as the gender recognition problem, sometimes it is difficult to directly learn from the entire image. In this work we propose a new model called Local Deep Neural Network (Local-DNN), which is based on two key concepts: local features and deep architectures. The model learns from small overlapping regions in the visual field using discriminative feed-forward networks with several layers. We evaluate our approach on two well-known gender benchmarks, showing that our Local-DNN outperforms other deep learning methods also evaluated and obtains state-of-the-art results in both benchmarks.

- **Using latent features for short-term person re-identification with RGB-D cameras**, J Oliver, A Albiol, A Albiol, JM Mossi, Pattern Analysis & Applications 19 (2), 549-561, 2016

  This paper presents a system for people re-identification in uncontrolled scenarios using RGB-depth cameras. Compared to conventional RGB cameras, the use of depth information greatly simplifies the tasks of segmentation and tracking. In a previous work, we proposed a similar architecture where people were characterized using color-based descriptors that we named bodyprints. In this work, we propose the use of latent feature models to extract more relevant information from the bodyprint descriptors by reducing their dimensionality. Latent features can also cope with missing data in case of occlusions. Different probabilistic latent feature models, such as probabilistic principal component analysis and factor analysis, are compared in the paper. The main difference between the models is how the observation noise is handled in each case. Re-identification experiments have been conducted in a real store where people behaved naturally. The results show that the use of the latent features significantly improves the re-identification rates compared to state-of-the-art works.

- **Soundcool Project Collaborative Network Website**, E. Robles1, N. Lloret1, J. Sastre, A. Murillo, E. Carrascosa, R. Morant, NEM Summit, Oporto, 2016.

  This paper exposes the possibilities of creating a collaborative network website for our technologic and educational music project: Soundcool. It means a new model for music education based on the use of this application, a modular system with smartphones, tablets and Kinect developed at the Universitat Politècnica de València (UPV) through several grants from UPV, Generalitat Valenciana and Carasso Foundation (Spain).

- **Soundcool: New Technologies For Music Education**, J. Sastre, A. Murillo, E. Carrascosa, R. García, R. B. Dannenberg, N. Lloret, R. Morant, S. Scarani, A. Muñoz, 8th annual International Conference of Education, Research and Innovation (ICERI), Seville, Proc. ICERI2015, pp. 5974-5982, 18-20 Nov., 2015

  This paper proposes a new model for music education based on the use of the application Soundcool, a modular system for music education with smartphones, tablets and Kinect developed at the Universitat Politècnica de València (UPV).

2.2.- Patents

1.- Gosalbez Castillo, Jorge; Carrión García, Alicia; V. Genovés; Miralles Ricós, Ramón; Paya Bernabeu, Jorge Juan, "Testing method for damage detection in materials", P201630212, Publication date: 25/02/2016, Priority date: 19/01/2017, Universidad Politecnica De Valencia

2.2.- Awards.

The GTS has participated in the Dream Mammography challenge. The ultimate goal of the challenge is to reduce the false alarm probability in screening mammography. The challenge is sponsored by companies such as IBM among others. During the challenge, every team must train a classifier that takes as input 4 mammograms (two views of each breast) and returns a score that indicates that cancer will be diagnosed within less than 12 months. Once that the classifier is trained it is evaluated by the challenge organisers in order to measure the performance. Our research team has ended among the top eight teams in the world in the competitive phase. They are now invited to participate in the collaborative phase, where these 8 top teams will try to improve the best team score and also human radiologist performance.

The purpose of the "Emprendedor Universitario" STARTUPV 2K16 awards is to recognize those graduate students who have an exceptional initiative and entrepreneurial spirit. It is part of the UPV2020 strategic plan. One of the awards is for those PhD students presenting a new and innovative business idea as a result of their doctoral thesis. The objective is to reward the approach, adaptation and conversion of the doctoral thesis into a real innovative business idea. The PhD student D. Guillermo Lara has received this year the doctoral thesis award for his thesis "Caracterización y modelado de la producción de sonidos de las ballenas beluga (Delphinapterus Leucas) basado en modelos de

análisis / síntesis de voz". He proposes to employ his thesis results to develop an integral solution combining hardware & software to reduce the time needed to analyze the raw recordings and to elaborate acoustic impact reports that are clear and straight-forward to interpret.

Soundcool has received two Bankia awards for musical talent in the Valencian Community (Spain, 2017): Best musical researcher to Dr. Sastre for his contributions on music technology especially with Soundcool, and best musical educative project to 'Experimentarts: music, creativity and collaborative learning', by Arabista Ribera Secondary School, (Carcaixent, Spain), first group that started using Soundcool, in 2013. Award from the UPV Social Board, XVI Edition, for the work on Music Technologies for functional diversity people (2017). And finally, the award for the Best Experience in Programming and Robotics from the "SIMO Education 2016" Learning Technology Exhibition in Madrid (2016).