AUDIO AND COMMUNICATIONS SIGNAL PROCESSING GROUP

HEAD OF THE GROUP RESEARCH REPORT

The Audio and Communications Signal Processing Group (GTAC) reaches 20 years of research. GTAC research focuses in signal processing algorithms for sound and wireless communication applications, in particular related to active noise control systems, sound quality perception, spatial audio rendering and multi-channel audio filtering in the area of sound processing, and related to efficient MIMO receivers, multi-user communications and coordinated multi-point systems in the area of wireless communications. Fig. 1-3 show some of the equipment available at the GTAC facilities of the iTEAM used to develop the previous research lines.

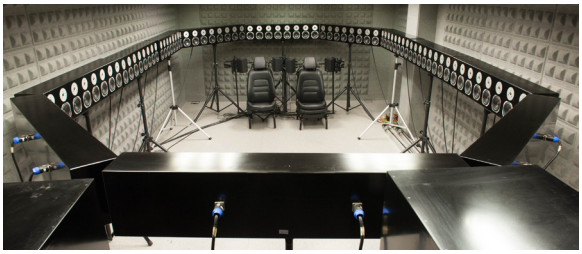

Fig. 1. Acoustic listening room including a render system of 96 loudspeakers.

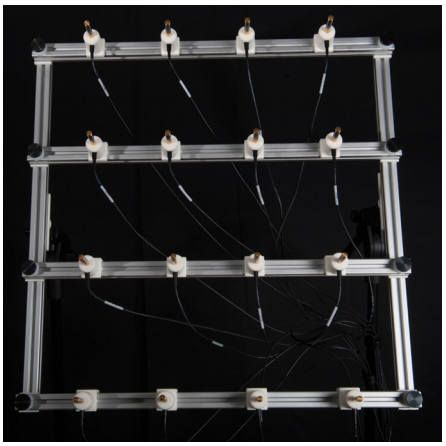

Fig. 2. Microphone array, flexible configurations

Fig. 3. Laboratory prototype of a system implementing multiple personal sound zones with two real car seats.

During 2017/2018 the group has continued its work on the development of sound control applications over different types of acoustic networks. The GTAC main lines of research have been developed within the framework of several research projects, the publication of relevant results in scientific journals and conference proceedings and the presentation of one PhD thesis.

The most important results of the GTAC research production over the past year are summarized in the following. For a more detailed description, visit our webpage: www.gtac.upv.es, where a complete list of projects and papers can be found.

1.- PROJECT ACTIVITIES

The GTAC research activities during 2017/2018 have been focused on developing and implementing sound processing applications on wireless acoustic sensor networks (WASN).

In particular, as the final period of the project "Smart Sound Processing for the Digital Living", a distributed low cost ad hoc sensor network based on Raspberry Pi 3 have been implemented (see Fig.4). One of the nodes acts as the main node (gateway) to communicate with the rest of nodes and the server located in the cloud. In an ad hoc network, each node is part of the routing by forwarding data to other nodes until finding the main node, which will upload the data to the server. Two main applications have been developed: (1) Measuring and monitoring noise conditions

in an industrial environment to detect high sound pressure levels (SPL), and (2) recording, monitoring and classification of sound events.

Fig. 4. Node formed by a Raspberry Pi, one microphone and one solar panel.

Furthermore, the project ***"Distributed Network of Active Noise Equalizers for Multi-User Sound Control"*** has been mainly developed through this period. A laboratory prototype of a multi-ambient sound-field control system consisting of two car seats (see Fig. 3) has been built, where active noise equalization (ANE) can be independently applied to each headrest or user. To allow this, every user controls his local system through an application running in his mobile device. This system formed by multiple ANEs, which act as a node in a WASN-type set up, cooperate to simultaneously solve their node-specific noise equalization problems.

Moreover, two new projects have started in this period. They are summarized below.

1.1.- ONGOING PROJECTS

Title of the project: *MAXIMIZING THE UPSCALING AND REPLICATION POTENTIAL OF HIGH LEVEL URBAN TRANSFORMATION STRATEGIES (MATCHUP)*

Webpage of the project: *https://www.matchup-project.eu/*

Summary of the project: *MAtchUP is an EU-funded Smart City project involving three lighthouse cities and four follower cities. MAtchUP cities will join forces to reshape their social, economic and environmental models and to promote social inclusion, liveability and prosperity for their citizens.*

MAtchUP will design and implement a palette of innovative solutions in the energy, mobility and ICT sectors that will serve as a model of urban transformation for other cities in Europe and beyond. MAtchUP's objective is to create and adopt solutions that can turn urban problems into smart opportunities to improve the citizens' quality of life and boost the local economies. The final aim is to create a prosperous and more liveable urban environment for communities.

MAtchUP approach is built on three main axes:

- *Planning of sustainable urban transformation, which means to get rid of old and inefficient technologies to seize new efficient solutions in the energy, mobility and ICT fields*
- *Effective replication and upscaling of smart city solutions by ensuring the convergence of the demand and supply sides*
- *Implementation of these upscaling and replication plans to successfully reshape and repaint cities and their communities*

The MAtchUP consortium is made of 28 organizations from 8 different countries. Three lighthouse cities and four follower cities are supported by the expertise of universities and research institutions, SMEs, industrial and non-profit partners. They include research experts, policy makers, industrial partners, investors and dissemination and exploitation experts which basically represent all the targets of MAtchUP.

Fig. 5. Valencia is one of the three cities where the MatchUp project will be developed.

Funding entity: *European Union's Horizon 2020 research and Innovation programme.*

Title of the project: *SOUND-AIDED SMART ENVIRONMENTS FOR THE CITY, HOME AND NATURE (SSENCE)*

Webpage of the project: *www.sound-aided-IOT.upv.es*

Summary of the project: *The ``Sound-Aided Smart Enviroments for the City, Home and Nature'' (SSEnCe) project aims to encourage the dissemination and development of real and practical prototypes focused on the Global concept of Intelligence in the Internet of Things (IoT). Particularly, their applications are based mainly on the acoustic information of the environment. Thus, the main objectives of this project are the creation of an observatory and the development of three technological demonstrators of immediate practical application.*

The demonstrators have the following specific objectives:

- *In the home environment, it is intended to detect the acoustic events that indicate danger or emergency situation, especially for people with reduced mobility (sick people, elderly people, etc..). This application is related to IoT application in eHealth.*
- *In the Smart Cities field, the project aims to develop applications which detect violent situations and disturbance of social coexistence (concerts, unauthorized manifestation, etc) and to monitor noise pollution.*
- *In natural parks is intended to detect any alteration of the natural environment produced by people.*

Funding entity: *Cátedra Telefónica-UPV.*

2.- RESEARCH RESULTS

The main publications in scientific journals and conference proceedings of this period are summarized in the following.

2.1.- FEATURED JOURNAL PUBLICATIONS

- ***Soft MIMO detection through sphere decoding and box optimization.*** *M. Ángeles Simarro, Víctor M. Garcia-Mollá, Antonio Vidal, F.J. Martínez-Zaldívar, Alberto Gonzalez, Signal Processing, vol. 145, pp. 48-58, 2018.*

DOI: *10.1016/j.sigpro.2017.11.010.*

Abstract: *Achieving optimal detection performance with low complexity is one of the major challenges, mainly in multiple-input multiple-output (MIMO) detection. This paper presents three low-complexity Soft-Output MIMO detection algorithms that are based mainly on Box Optimization (BO) techniques. The proposed methods provide good performance with low computational cost using continuous constrained optimization techniques. The first proposed algorithm is a non-optimal Soft-Output detector of reduced complexity. This algorithm has been compared with the Soft-Output Fixed Complexity (SFSD) algorithm, obtaining lower complexity and similar performance. The two remaining algorithms are employed in a turbo receiver, achieving the max-log Maximum a Posteriori (MAP) performance. The two Soft-Input Soft-Output (SISO) algorithms were proposed in a previous work for soft-output MIMO detection. This work presents its extension for iterative decoding. The SISO algorithms presented are developed and compared with the SISO Single Tree Search algorithm (STS), in terms of efficiency and computational cost. The results show that the proposed algorithms are more efficient for high order constellation than the STS algorithm.*

- ***Control Effort Strategies for Acoustically Coupled Distributed Acoustic Nodes.*** *Christian Antoñanzas, Miguel Ferrer, Maria de Diego, Alberto Gonzalez, Wireless Communications and Mobile Computing , 2017.*

DOI: *10.1016/j.sigpro.2017.11.010.*

Abstract: *This paper considers the effect of effort constraints on the behavior of an active noise control (ANC) system over a distributed network composed of acoustic nodes. A distributed implementation can be desirable in order to provide more flexible, versatile, and scalable ANC systems. In this regard, the distributed version of the multiple error filtered-x least mean square (DMEFxLMS) algorithm that allows collaboration between nodes has shown excellent properties. However, practical constraints need to be considered since, in real scenarios, the acoustic nodes are equipped with power constrained actuators. If these constraints are not considered within the adaptive algorithm, the control signals may increase and saturate the hardware devices, causing system instability. To avoid this drawback, a control effort weighting can be considered in the cost function of the distributed algorithm at each node. Therefore, a control effort strategy over the output signals at each node is used to keep them under a given threshold and ensuring the distributed ANC system stability. Experimental results show that, assuming ideal network communications, the proposed distributed algorithm achieves the same performance as the leaky centralized ANC system. A performance evaluation of several versions of the leaky DMEFxLMS algorithm in realistic scenarios is also included.*

- ***Optimized Fundamental Signal Processing Operations for Energy Minimization on Heterogeneous Mobile Devices.*** *Jose A. Belloch, José M. Badía, Francisco D. Igual, Alberto Gonzalez, Enrique S. Quintana-Ortí, IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 65, no. 5, pp. 1614-1627, 2017.*

DOI: *10.1109/TCSI.2017.2761909.*

Abstract: *Numerous signal processing applications are emerging on both mobile and high-performance computing systems. These applications are subject to responsiveness constraints for user interactivity and, at the same time, must be optimized for energy efficiency. The increasingly heterogeneous power-versus-performance profile of modern hardware introduces new opportunities for energy savings as well as challenges. In this line, recent systems-on-chip (SoC) composed of low-power multicore processors, combined with a small graphics accelerator (or GPU), yield a notable increment of the*

computational capacity while partially retaining the appealing low power consumption of embedded systems. This paper analyzes the potential of these new hardware systems to accelerate applications that involve a large number of floating-point arithmetic operations mainly in the form of convolutions. To assess the performance, a headphone-based spatial audio application for mobile devices based on a Samsung Exynos 5422 SoC has been developed. We discuss different implementations and analyze the tradeoffs between performance and energy efficiency for different scenarios and configurations. Our experimental results reveal that we can extend the battery lifetime of a device featuring such an architecture by a 238% by properly configuring and leveraging the computational resources.

2.2.- FEATURED CONFERENCE PROCEEDINGS

- ***Personal active control over coupled networks.*** *Christian Antoñanzas, Miguel Ferrer, Maria de Diego, Alberto Gonzalez, 24th International Congress on Sound and Vibration (ICSV), London, UK, 2017.*
- ***Improved least-mean-square algorithm using a block-based strategy for active noise control.*** *Maria de Diego, Laura Fuster, Miguel Ferrer, Christian Antoñanzas, 24th International Congress on Sound and Vibration (ICSV), London, UK, 2017.*
- ***Distributed Sensor Network for Noise Monitoring in Industrial Environment with Raspberry Pi.*** *Natalia Blasco, Maria de Diego, Román Belda, Ismael de Fez, Pau Arce, Francisco J. Martinez, Alberto Gonzalez, Juan Carlos Guerri, INTELLI 2017: The Sixth International Conference on Intelligent Systems and Applications , Niza, Francia, 2017.*
- ***Block diagonalization aided precoding algorithm for large MU-MIMO systems.*** *Maria A. Simarro, Fernando Domene, Francisco J. Martinez, Alberto Gonzalez, 13th International Wireless Communications and Mobile Computing Conference , Valencia, Spain, 2017.*
- ***Parallel SUMIS soft detector for MIMO systems on multicore.*** *Carla Ramiro, Maria A. Simarro, Alberto Gonzalez, Antonio M. Vidal, 17th International Conference on Computational and Mathematical Methods in Science and Engineering (CMMSE 17) , Rota, Spain, 2017.*