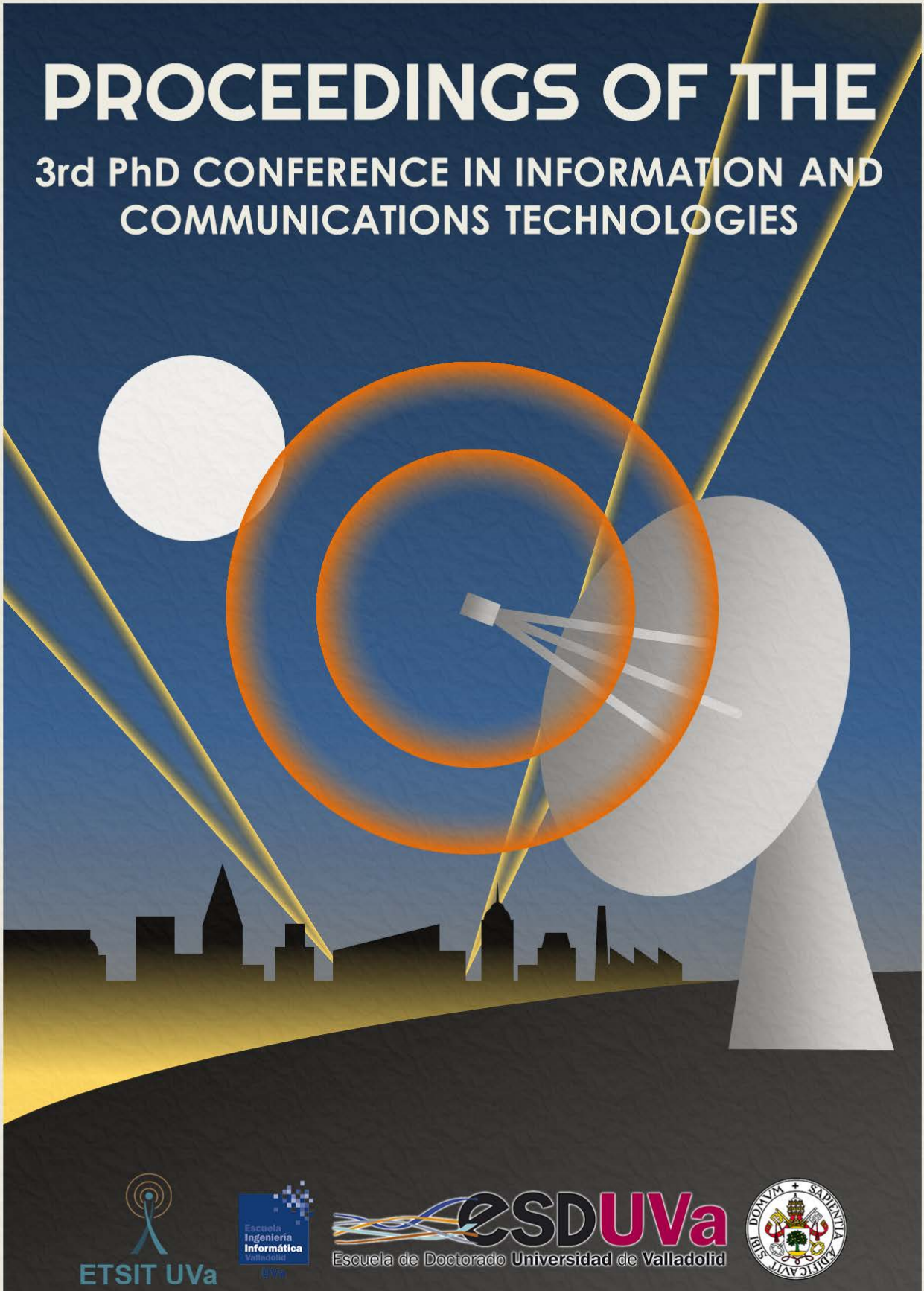
PROCEEDINGS OF THE

3rd PhD CONFERENCE IN INFORMATION AND COMMUNICATIONS TECHNOLOGIES



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Aims and Scope

This Proceedings welcomes contributions on novel studies from the 3rd PhD Conference in Information and Communication Technologies. The main criteria for acceptance are that the study is novel, has general significance for doctoral training and the first author must be working towards the Ph.D. The abstracts and posters that have been published cover a wide range of areas within the sciences related to Information and Communication Technologies. Many of them have relevance to signal processing, image processing and/or health care, among other issues. All articles were sent to an Editorial Board member for an initial assessment, and were returned to authors after an in-depth peer review process. The Editors of the Proceedings of the 3rd PhD Conference in Information and Communication Technologies would like to thank all reviewers who have worked on the abstracts published in this first issue of the journal (2017). Particularly, we want to thank G.C. Gutiérrez-Tobal for his counseling and advice.

Abstract Types

All manuscripts are assigned to a specialist member of the Editorial Board, who assesses the paper for its suitability in this Proceedings, based on scientific quality, interest and importance and relevance to a broad readership. Many good papers could be rejected at this stage, often on the ground of being insufficiently novel, due to an extremely high competition for space. If sent to peer review, the final decision will be made by an Editor, whose decision will be based on the reports received from the referees and/or Editorial Board members. There are two different abstract types: oral-presentation-oriented abstracts and poster-oriented abstracts. During the 3rd PhD Conference in Information and Communication Technologies, a competition to determine the best study of each category was performed. Inside this journal and for recognizing purposes, these two studies appear the first of their respective series. In addition, posters have been also published and the end of this Proceedings, when appropriate.

About the Cover

The cover of the book features a striking illustration of an antenna radiating over a city in the middle of the night. The sleek art design, with its simple forms and elegantly retro futuristic aesthetic was inspired by art déco posters of the 1920s and 1930s. In particular, the art of Hungarian painter Róbert Berény influenced the overall design (the knowledgeable reader will recognize the font from the iconic poster that Béreny did for Modiano in 1929). The picture was chosen to represent a key concept from the field of Information and Communications Technology: the interaction between engineering and society. The distance between the antenna and the city suggests that even if the average citizen might not be aware of it, telecommunications are a vital part of everyday life and will continue to be so in the foreseeable future.


III JORNADA
DE INVESTIGACIÓN EN TECNOLOGÍAS DE LA INFORMACIÓN Y LAS COMUNICACIONES
5 DE MAYO DE 2017
en
EDIFICIO DE TECNOLOGÍAS DE LA INFORMACIÓN Y LAS COMUNICACIONES
Campus Miguel Delibes
HORARIO
9:00 a.m. 9:30 a.m. — Recepción
9:30 a.m. 10:00 a.m. — Bienvenida
10:00 a.m. 11:30 a.m. — Sesión de pósteres
11:30 a.m. 11:45 a.m. — Descanso y café
11:45 a.m. 12:30 a.m. — 10 slides 20 seconds
12:30 a.m. 1:15 p.m. — Sesión plenaria
1:20 p.m. 2:00 p.m. — Charla informal (IMP)
2:00 p.m. 4:00 p.m. — Comida
4:00 p.m. 4:30 p.m. — Cierre formal
4:30 p.m. 6:00 p.m. — Research Pursuit
9:00 p.m. Ph.B.(eer)

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Pablo Núñez Novo · Santiago Sanz-Estébanez ·
Óscar Peña-Nogales · Alejandro Ortega-Arranz
Editors

Proceedings of the 3rd PhD Conference in Information and Communicaction Technologies

E.T.S.I. de Telecomunicación & Informática,
University of Valladolid, May 5, 2017,
Valladolid, Spain

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Proceedings of the 3rd PhD Conference in Information and Communicaction Technologies
Libro de Actas de las III Jornadas de Doctorado en Tecnologías de la Información y las Comunicaciones
First edition, October, 2017.
ISBN: 978-84-697-6480-0

Contenido

ORAL PRESENTATIONS

Towards a Brain Connectivity Model and its Relevance in Schizophrenia

Javier Gomez-Pilar

Winner of the Student Competition in Category "Oral Presentation"

Abstract – Decades of research have provided robust evidence of cognitive impairments in psychotic disorders. Specifically, schizophrenia patients consistently display deficits in a number of cognitive domains, but the neurological substrates related to these impairments remains unclear. This Ph.D. dissertation aims to contribute in elucidating abnormalities in the intrinsic communication between specific brain regions during the cognitive processing and to evaluate relationships between these abnormalities and cognitive performance in schizophrenia. In this multidisciplinary thesis, high-density electroencephalographic recordings from healthy individuals and schizophrenia patients have been analyzed in three levels: sensor, connectivity and network level. This division serves to faithfully characterize brain processes and information exchange through the synchronization of their regions. To date, four main results derived from this thesis merit special attention: (i) a noticeable deficit in the brain network organization in schizophrenia patients during a cognitive task compared to healthy subjects; (ii) a hyper-segregation in the brain network of schizophrenics in the time immediately preceding the performance of the cognitive task; (iii) a marked reinforcement in the secondary neural pathways during cognition; and, finally, (iv) a dynamical network modelling of cognition (usually followed by healthy subjects, but schizophrenia patients) has been proposed. These findings, supported so far by four papers in JCR journals as first author as well as several national and international conferences, are intended to be a significant step in the improvement of the everyday functioning of people with schizophrenia. Thus, the outcomes of this study may lead to a more useful diagnosis and subsequent therapeutic intervention that could broadly enhance the quality of life of people with this illness.

Keywords – Functional connectivity; brain network; cognition; schizophrenia; EEG.

ADC-Weighted Liver DWI Registration

Santiago Sanz-Estébanez

Abstract – The purpose of this work is to develop a method for direct ADC estimation on Diffusion weighted images to obtain more precise and robust measurements by extending groupwise registration algorithms. We introduce a joint formulation to simultaneously solve the registration and estimation problems, taking into account appropriate smoothness constrains for each problem in order to avoid non-reliable transformations and denoise ADC maps preserving the structures inside the liver. We present an extension to the multimodal metric based on ADC estimation residuals by introducing weights that prevent from undesired biases. Results have shown the joint formulation to benefit from the goodness of both procedures and multimodal registration under the groupwise paradigm to provide a significant improvement in the accuracy on ADC estimates. Reproducibility has also been measured on real data in terms of ADC differences distribution obtained from two different b-values subsets. The proposed algorithm has proven to be flexible enough to incorporate smoothness and denoising terms capable of dealing both with the presence of motion and inherent multimodality on these datasets, increasing accuracy and reproducibility in diffusion parameter estimation.

Keywords – Diffusion Weighted Imaging (DWI); groupwise Registration; ADC estimation; liver diffusion simulation, NESTA.

Supporting the Management of Students' Collaborative Teams in MOOCs

Luisa Sanz-Martínez

Abstract – The increasing popularity of MOOCs (Massive Open Online Courses) as a new and powerful paradigm in educational contexts has fostered many discussions within the higher education domain. Many authors are concerned about their low instructional quality and high dropout rate, while others highlight the variety of research challenges triggered by the massive scale feature. Some of these challenges are related to the promotion of social interactions that generate knowledge or the development of new pedagogical approaches that take advantage of the benefits of large scale. Over the last decades, active pedagogies, such as Collaborative Learning (CL), have been largely established at small-scale educational contexts. Collaboration enriches learning with social and cognitive dimensions that maintain student motivation and elicit verbal communication. The studies on CL have shown that group formation is a crucial factor to put in practice collaboration, because successful collaboration depends largely on the suitability of the peers included in the group. However,

group formation presents particular difficulties in MOOC contexts that deserve a deep analysis. The massive scale and its variability (due to latecomers and dropouts), the irregular level of engagement of students and their variable learning paces hinder the orchestration tasks of teachers for the management of groups. Due to this, our research goal focuses on supporting MOOC teachers in the management of groups to perform CL. We plan to support them both in the design phase (giving advice with guides, wizards, etc.) and in the enactment phase of the course (by means of tools for creating, monitoring and restructuring groups). We conduct our work through an iterative methodology (Design Science Research Methodology) developing artifacts that will be evaluated through interventions and studies in real MOOCs. We use mixed methods, combining qualitative and quantitative data gathering techniques in order to gain a deeper understanding of the problem.
Keywords – MOOCs; group formation; teams; Collaborative Learning (CL); Technology Enhanced Learning (TEL).

Monte Carlo Estimation of the Elongation of Two-Dimensional Poisson-Voroni Cells

Narciso Javier Aguilera Centeno

Abstract – We have worked on the approximation of tessellations of the plane using Voronoi diagrams. It was observed empirically that, apparently, the elongated forms of certain tessellated regions influenced the efficiency of the algorithms implemented in their approximation by Voronoi diagrams. For that reason, it was considered opportune and necessary to delve into an aspect that had not been considered initially. For this purpose, it was estimated the elongation in the Euclidean plane of randomly generated Voronoi cells. Those estimates were performed with de aid of Monte Carlo simulation and other statistical methods.

POSTER PRESENTATIONS

Automatic Analysis of Fundus Images to Aid in the Diagnosis and Severity Grading of Diabetic Retinopathy

Roberto Romero-Oraá

Winner of the Student Competition in Category "Poster Presentation"

Abstract – Diabetic Retinopathy (DR) is a visual complication of diabetes which has become a major cause of blindness and vision loss in developed countries. Digital retinal images are an effective means of detecting the early clinical signs of DR, provided they are examined by expert readers. The most common of these early signs of DR are hard exudates (EXs) and red lesions (RLs), such as microaneurysms and haemorrhages. Early detection and monitoring of DR is paramount to prevent vision loss. However, this is very difficult because this condition is asymptomatic in its early stages, when treatment would be more effective. For this reason, diabetic patients should undergo regular eye examinations in which digital images of the retina are captured. With the growing incidence of diabetes, the high cost of examinations and the lack of specialists, those periodic examinations become unfeasible. Our hypothesis is that it is possible to automatically analyse retinal images in order to detect the early clinical signs of the disease and establish DR severity in a patient. In this sense, the first objective of this Thesis is to automatically detect EXs and RLs in retinal images. This information will be the basis for the development of automated methods to determine DR severity in a patient in the second stage of the investigation. Determining the presence or absence of pathology as well as the severity of RD in a patient is novel since there is limited research on this. For these tasks, we propose a methodology in which different methods for digital image analysis are combined with convolutional neural networks. We believe that these automatic methods could be an important aid for ophthalmologist in their clinical practice and in DR screening programmes.

Keywords – Diabetic retinopathy (DR); retinal image, image processing, machine learning; DR severity.

Retinal Vessels Segmentation by Improvement of a Multi-Scale Line Detector

Jorge Jiménez-García

Abstract – The retina is the only location where the blood vessels can be non-invasively imaged. The analysis of retinal blood vessels can reveal signs of diseases such as Diabetic Retinopathy (DR), Hypertension, Arteriosclerosis, and other cardiovascular diseases. The objective of blood vessel segmentation is to analyze the vessels shapes and improve the results of methods aimed at detecting lesions with similar color in fundus images. Our Final Assignment focused on the improvement of a recent and well-known Multi-Scale Line Detector (MSLD). MSLD evaluates the presence of vessels as line-shaped objects by filtering the image with multiple line operators of different lengths centered in a fixed size neighborhood. However, the MSLD method alone leads to false detections, mainly in the optic disk (OD) boundary, and misses some small and low-contrasted vessels. To improve MSLD results, we included a novel preprocessing stage using Contrast Limited Adaptive Histogram Equalization (CLAHE), OD removal using median filtering and unsharp masking. Then, MSLD was applied and the result was thresholded to obtain an outline of the blood vessels. We further improved the original algorithm by including a postprocessing stage based on morphological operations and removal of small unconnected objects to obtain the final segmentation of the vessel network. The method was tested on the DRIVE and STARE public retinal image databases. Our results reached a segmentation accuracy of 94.4% on the DRIVE database and 94.8% on the STARE database. The proposed algorithm outperformed the original MSLD and resulted in an improvement of the segmentation accuracy in the OD boundary and small vessels. Our results indicate that the proposed method could be useful in retinal image analysis. In this sense, we intend to include it as one of the stages of a more general algorithm for DR screening.

Keywords – Vessel Segmentation; retinal imaging; line detector; histogram equalization; morphological processing.

Swarm Intelligence Methods Applied to P300-Based Brain-Computer Interface Systems Channel Selection

Víctor Martínez-Cagigal

Abstract – Brain-Computer Interface (BCI) systems need to work with large amount of data in real time, which makes the channel selection procedures essential to reduce the curse of dimensionality and increase users' comfort. Although there were previous approaches that have addressed this problem in P300-based BCIs, metaheuristics based on swarm intelligence (SI) have not yet been fully exploited. The aim of this study is to compare the performance of five SI methods, inspired by the behavior of biological systems, when applied to the channel selection procedure in P300-BCI systems. The typical 8-channel set is also computed in order to improve the comparison. Methods have been tested with the 'III BCI Competition 2005' dataset II, reaching similar accuracies, or even higher, than that obtained with standard channel approaches, and simultaneously using less than the half part of the original 64-channel set. The rapid convergence and the high accuracies that have been obtained suggest that SI-based methods are indeed suitable for use in P300-BCI channel selection procedures.

Keywords – Brain-Computer Interface, electroencephalography, P300 evoked potentials, swarm intelligence, optimization algorithms.

Usefulness of Discrete Wavelet Transform in the Analysis of Oximetry Signals to Assist in Childhood Sleep Apnea-Hypopnea Syndrome Diagnosis

Fernando Vaquerizo-Villar

Abstract – Pediatric sleep apnea-hypopnea syndrome (SAHS) is a highly prevalent sleep-related respiratory disorder that may cause several negative consequences for the health and development of children. The gold standard for diagnosis is overnight in-laboratory polysomnography (PSG), which is highly cost, complex, time demanding, and particularly intrusive for children. Therefore, there is a great demand for simplified and reliable alternative techniques. In order to improve early detection of pediatric SAHS, we propose an

automated analysis of the blood oxygen saturation (SpO2) signal from nocturnal oximetry. A database composed of 298 SpO2 recordings from children ranging from 0 to 13 years old was used for this purpose. Independent training (50%) and test (50%) groups were randomly composed. Our goal was to evaluate the diagnostic ability of this signal by means of the discrete wavelet transform (DWT), due to the abrupt changes caused by repetitive apneic events in the SpO2 signal. To achieve that objective, we conducted a signal processing approach divided into two main stages: (i) feature extraction, where features (mean and variance) from the DWT detail coefficients were computed in the frequency bands linked with pediatric sleep apnea (0.024-0.049 Hz and 0.012-0.024 Hz), and (ii) feature classification, where a logistic regression (LR) model was used to classify children into SAHS negative or SAHS positive. Our results showed increased variance in the DWT coefficients of childhood SpO2 recordings in these frequency bands, which appears to be related to slow variations in the SpO2 signals due to SAHS. Moreover, the LR classifier achieved an 81.9% accuracy (79.1% sensitivity and 84.1% specificity) in the test set using a standard clinical cutoff of 5 events/h from PSG for positive SAHS. These results suggest that DWT may be a useful tool to characterize changes in SpO2 recordings in the context of childhood SAHS.
Keywords – Sleep Apnea Hypopnea Syndrome (SAHS); children; oximetry, wavelet, logistic regression.

Poincaré Plot Measures to Characterize the Paediatric Sleep Apnoea-Hypopnoea Syndrome Severity in Airflow Recordings

Verónica Barroso-García

Abstract – The Sleep Apnoea-Hypopnoea Syndrome (SAHS) is a chronic respiratory disorder that causes severe medical consequences in paediatric patients suffering from it, which lead to decreases in health and quality of life. Therefore, SAHS requires early detection and treatment. However, the gold standard diagnostic test (polysomnography, PSG) is complex, costly, with limited availability, and particularly uncomfortable for children. In order to overcome these drawbacks, we propose the assessment of a new methodology to simplify paediatric SAHS diagnosis. Our hypothesis is that the variability analysis is able to characterize SAHS severity in airflow (AF) recordings from children. Accordingly, our aim is to evaluate the evolution of variability of AF signal as SAHS severity increases in children. Thus, single-channel AF recordings from 501 children are divided into four severity groups according to the apnoea-hypopnoea index (AHI): AHI<1 events/hour (e/h), 1≤AHI<5 e/h, 5≤AHI<10 e/h and AHI≥10 e/h. The proposed methodology involves an analysis of first-order difference plots, which are scatter diagrams centred on the origin that represent

displaced subsequences of the original time series: (x[i+2]-x[i+1]) vs. (x[i+1]-x[i]). In order to carry out this analysis, features of Poincaré Plot will be extracted to quantify variability of AF in each SAHS severity group. Poincaré plots graphically display the correlation between consecutive time intervals. Typically, this appears as an elongated cloud of points oriented along the line-of-identify shaping an ellipse. Thereby, the dispersion of points around the ellipse axes will allow us to quantify short-term, long-term, and overall variability in AF. These features will be computed through an ellipse fitting, histogram techniques, ratios and correlation coefficient. Finally, the extracted features will be evaluated in AHI cutoffs 1, 5, and 10 e/h.

Keywords – Sleep Apnoea-Hypopnoea Syndrome (SAHS); airflow; variability analysis; Poincaré plots; children.

Characterization of Neural Substrates in Schizophrenia and Alzheimer's Disease by means of Complex Network Theory

Pablo Núñez

Abstract – Schizophrenia (SCH) and dementia due to Alzheimer's disease (AD) are pathologies of high prevalence and high social and personal costs. In addition, they have complex diagnoses, which involve the use of diverse techniques, such as clinical examinations, cerebral scanners, and cognitive tests. Consequently, new tools are needed to help diagnose these pathologies due to their complex identification. Functional disconnectivity among brain areas in AD and SCH causes alterations in the interaction patterns of electroencephalographic (EEG) signals generated in different regions of the neural cortex, as well as changes in the stability of neural networks formed from these patterns. The main objective of this PhD thesis is to study and apply new methods of local activation, neural coupling, and parameters derived from complex network theory. Our aim is to detect the alterations that AD and SCH cause in the interaction patterns between EEG signals generated in different regions of the cerebral cortex, focusing on the stability of the connectivity among EEG electrodes. The second objective is the extraction, selection, and classification of EEG features to be able to study these pathological patterns. These two main objectives converge in a third objective, which is to find new biomarkers that simplify the complex detection of SCH and AD.

Keywords – Schizophrenia; Alzheimer's disease; electroencephalography; connectivity stability; graph theory.

Characterization of Neuronal Activity in Alzheimer's Disease Based on Complex Network Theory

Saúl José Ruiz-Gómez

Abstract – Alzheimer's disease (AD) is a progressive neurodegenerative disorder associated with cognitive, behavioural, and functional alterations. The prevalence of AD exponentially grows with age after 60. In this regard, increased life expectancy makes AD a major public health issue. Accordingly, an early detection of AD, in its phase of Mild Cognitive Impairment (MCI), is essential to optimize its treatment. Analysis of neurophysiological recordings, such as electroencephalogram (EEG), are suggested to reflect essential information about the functional and structural deficiencies associated with these neuropathologies. Therefore, the main objective of this PhD Thesis is the assessment and application of new methods of neural coupling as well as novel parameters derived from complex network theory. Our purpose is to detect those brain alterations associated with AD and MCI.

Keywords – Alzheimer's disease; Mild Cognitive Impairment; electroencephalography; effective connectivity; graph theory.

Job Satisfaction, Wellbeing at Work and Health Status in Nurses from a Spanish Public Health Service

Jacob González-Gancedo

Abstract – Motivation and job satisfaction are nowadays related to quality of work. In this sense, low levels of both variables could be negative for the performance of workers, for their own health and for their relationships with the environment and people. This is relevant because this quality is associated, on the one hand, with the security and wellbeing of patients and nurses and, on the other hand, with the professional development of workers. In this sense, the onset hypothesis from this Thesis is that demotivation and job dissatisfaction can negatively affect the health and safety of nurses as well as the quality of the cares provided to patients. We will try to study motivation and job satisfaction in nurses in order to quantitatively assess these variables in a sociosanitary context. Additionally, we will try to

investigate the relationship between these variables and health status in nurses. For this task, a descriptive, crossectional, correlational and comparative study will be performed. The subjects of study will be the complete population of active nurses in the selected hospitals from Castilla y León during the data compilation. After obtaining the necessary permissions from the ethic and research committees, the data compilation will be carried out through validated and anonymous questionnaires, adapted to an on-line version. The final questionnaire will be composed by a group of sociodemographic questions and the General Health Questionnaire (GHQ-28), the Overall Job Satisfaction Scale (NTP 394) and Utrecht Work Engagement Scale (UWES-17). The study of motivation and job satisfaction and their relationship with sociodemographic data, as well as with the characteristics of the working environment could offer useful information to organizations in order to adopt preventive measures and to improve the quality of cares.

Keywords – Job Satisfaction, motivation, nursing, quality of cares, health status.

Variance-Stabilizing Transformation of Non-Central Chi Data with an Application to Nonstationary Noise Estimation in Accelerated Parallel MRI Acquisitions

Tomasz Pieciak

Abstract – The noise is an inherent part of every magnetic resonance imaging (MRI) acquisition. Since the noise component in MRI data cannot simply be assumed as additive Gaussian distributed, the advanced and computationally intensive statistical models are usually employed. These models take signal-dependency of the noise into account, and they became the fundamental part of modern adaptive noise-driven image processing and analysis of the MRI data. In this work, the author presents a new computational framework to estimate spatially variant noise patterns from non-central Chi (nc-χ) distributed data using a variance-stabilizing transformation (VST). The VST changes a signal-dependent nature of noise into a signal-independent one. Consequently, complicated nc-χ models are no longer necessary as they can be replaced by the algorithms assuming that the variance-stabilized noise is additive and Gaussian distributed. The author obtained new VSTs for nc-χ distributed random variable and proposed new spatially variant noise estimation algorithm from a single non-stationary distributed nc-χ image. Firstly, the asymptotic VST for squared nc-χ random variable (i.e., nc-χ2 random variable) was analytically derived. This transformation is reversible and it does not require the numerical optimization procedure. Secondly, the author parameterized the asymptotic VST and defined an optimization cost

function using variance-stabilized nc-χ2 central moments. The proposal allows stabilizing the variance in nc χ2 signal in a more efficient way than current models from the literature, especially for low signal-to-noise ratio (SNR). As a proof of concept, spatially variant noise estimation algorithms were employed for accelerated parallel MRI acquisitions. We showed that Gaussian-compliant methods proceeded by the VST can be arranged to estimate noise patterns from a non-stationary nc-χ distributed data and they provide better results than those without the stabilization step.
Keywords – Non-stationary noise; non-central Chi; VST; Gaussian homomorphic filtering; spatially variant noise estimation.

Groupwise Non-Rigid Registration on Multiparametric Abdominal DWI Acquisitions for Robust ADC Estimation: Comparison with Pairwise Approaches and Different Multimodal Metrics

Santiago Sanz-Estébanez

Abstract – Registration of diffusion weighted datasets remains a challenging task in the process of quantifying diffusion indexes. Respiratory and cardiac motion, as well as echo-planar characteristic geometric distortions, may greatly limit accuracy on parameter estimation, especially for the liver. This work proposes a methodology for the non-rigid registration of multiparametric abdominal diffusion weighted imaging by using different well-known metrics under the groupwise paradigm. A three-stage validation of the methodology is carried out on a computational diffusion phantom, a watery solution phantom and a set of voluntary patients. Diffusion estimation accuracy has been directly calculated on the computational phantom and indirectly by means of a residual analysis on the real data. On the other hand, effectiveness in distortion correction has been measured on the phantom. Results have shown statistical significant improvements compared to pairwise registration being able to cope with elastic deformations.
Keywords – ADC estimation; Multiparametric diffusion weighted images; Groupwise registration; Diffusion phantoms; Motion compensation

ADC Measurement Accuracy in Quantitative Diffusion Phantoms Using Reduced Field-Of-View and Multi-Shot Acquisitions

Iñaki Rabanillo

Abstract – Diffusion MRI (dMRI) is typically performed using single-shot Echo Planar Imaging (ssEPI). However, the long echo-trains in ssEPI result in significant image distortion in the presence of static B0 field inhomogeneties. Several techniques have been proposed for reducing the echo-train length in dMRI in order to reduce image distortions compared to ssEPI. Reduced-Field-of-View (rFOV) imaging has been demonstrated in regions such as the spinal cord and pancreas. Multi-shot EPI (msEPI) is based on an interleaved segmented k-space acquisition that enables full FOV dMRI with reduced distortion (upon correction of inter-shot phase inconsistencies). Both rFOV and msEPI have been shown to provide high quality diffusion weighted images. However, their ability to provide accurate quantitative diffusion measures has not been fully characterized. In this study we conduct controlled experiments in two recently proposed quantitative diffusion phantoms to compare the apparent diffusion coefficient (ADC) measured from three diffusion sequences: ssEPI, rFOV and msEPI.

Keywords – Magnetic resonance, diffusion, ADC, multi-shot.

Machinery Monitoring and Predictive Maintenance Through Signal Processing of Acoustical and Mechanical Vibrations

Ruben Ruiz-Gonzalez

Abstract – Agro-industrial machinery monitoring and maintenance are widely recognized as crucial tasks in the fields of agriculture and industry. This PhD dissertation is set to tackle these two problems. In particular, signal processing techniques are applied to acoustical and mechanical vibration signals, acquired respectively by microphones or accelerometers, in order to achieve the monitoring and predictive maintenance of agro-industrial machinery. The main goals of this dissertation are: (i) the proposal of new methods for the monitoring and predictive maintenance of agro-industrial equipment; (ii) the proposal of methods for locating the sources of vibrations; (iii) the proposal of methods for flow rate estimation in agricultural sprayers; and (iv) the exploration of the underlying mechanisms for the

generation of vibrations. As the reader might have noticed, this is a highly multidisciplinary thesis; in which physics, acoustics, and mechanics all play an important role, as well as signal processing techniques do. So far, three main milestones have been accomplished: (i) fault diagnosis and speed monitoring of several rotary components in agricultural harvesters; (ii) 3D fault localization, within the machine structure, using multiple sensors distributed along the chassis of the machine; and (iii) monitoring of the flow rate in agricultural sprayers by means of microphone sensors. Past, current and follow-up research and deployment in this line of research may lead to a simplification of the wiring and a reduction in the number of sensors required in machinery monitoring, as well as to fast and low-cost maintenance inspections.

Keywords – Agro-industrial machinery; acoustical and mechanical vibrations; predictive maintenance (PdM); monitoring; fault diagnosis; 3D source localization; flow rate estimation; signal processing.

Abstraction and Characterization of Viable Algedonic Events Within a Cybernetic Communications Protocol

Iñaki Marín-Medina

Abstract – Considerable efforts have been made for the development and implementation of better e-government and management structures in both public and private administrations. At the same time, recent social trends show an increased concern to reduce corruption, embrace transparency, minimise bureaucracy, and maximise efficiency, with a strong emphasis on the privacy and security of all actors involved. Through the use of an original, cybernetics-focused communications protocol, based on Stafford Beer's Viable Systems Theory, we purpose the abstraction of key descriptors regarding algedonic variables of a specific system, to allow for operation control and algedonic, contextual-issue minimisation. The abstraction model is created through characterisation of all viable algedonic events into a dynamic plot. They are based on their effective regulation along time, any weakening or enhancing events which may affect the original subset, and the variation itself. For each possible descriptor, abstraction of the events can then be elaborated into a dynamic relational model, depending on the flow of events within the system.

Keywords – Bureaucracy; cybernetics; communications protocol; e-government, management cybernetics.

AUTOMATIC ANALYSIS OF FUNDUS IMAGES TO AID IN THE DIAGNOSIS AND SEVERITY GRADING OF DIABETIC RETINOPATHY

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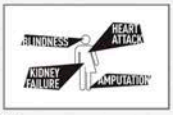
DIABETIC RETINOPATHY

Eye complication of **DIABETES**
- Serious life-long health condition
- Body can't regulate glucose
- There is currently no cure
- Major complications



Causes **reduced vision** or **blindness.**
- Very important in developed countries. **RELEVANT!**

It can be detected by means of retinal image analysis.
Retinal **lesions:**

PROBLEM AND OBJECTIVES

Early detection and monitoring of DR is paramount to **prevent vision loss**
- DR is asymptomatic in its early stages

Diabetic patients should undergo **regular eye examinations**

Growing incidence of diabetes + High cost of examinations + Lack of specialists = Need for automatic diagnostic systems

HYPOTHESIS

It is possible to automatically analyse retinal images in order to detect the early clinical signs of the disease and establish DR severity in a patient

OBJECTIVES

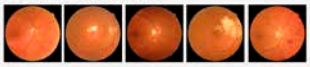
Design and development of automatic methods to aid in the diagnosis of Diabetic Retinopathy
- Detect EXs and RLs in retinal images
- Determine DR severity in a patient

RETINAL IMAGE DATABASE

Collection of **3000** retinal images
- Image capture based on **protocol** proposed by NICE (National Institute for Heath and Care Excellence)

Come from both patients and controls

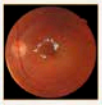
Division
- Train set
- Test set



METHODOLOGY

PRE-PROCESSING
CONTRAST NORMALIZATION, CROPPING, RESIZING, LESION ENHANCEMENT

LOCATION OF STRUCTURES
OPTIC DISC, FOVEA, BLOOD VESSELS



SEGMENTATION
SELECTION OF LESION CANDIDATES

CLASSIFICATION
FEATURE EXTRACTION AND SELECTION, MACHINE LEARNING ALGORITHMS

IMAGE PROCESSING TECHNIQUES
Filtering, Mathematic morphology, Thresholding, etc.

MACHINE LEARNING
Neural networks, Logistic regression, Deep Learning, etc.

INNOVATION AND IMPACT

New annotated **database**
- Follows an image protocol
- Useful for DR-related investigation

Development of **novel automatic methods** useful for health systems to:
- Reduce health costs
- Accelerate detection of DR
- Reduce the workload of specialists

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Retinal Vessels Segmentation in Fundus Images by Improvement of a Multi-Scale Line Detector

Student: Jorge Jiménez García Advisor: María García Gadañón

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Introduction

Diabetic Retinopathy (DR) is a complication of **Diabetes Mellitus (DM).** DR has become one of the most common causes of blindness in developed countries. Moreover, many systemic **cardiovascular diseases (CVDs)** can be investigated using retinal images:

DR
Hypertension
Arteriosclerosis
Other CVDs

Eyes are the windows to your health

Retinal Imaging can be useful in the diagnosis of DR and CVDs. Retina is the only location where blood vessels can be non-invasively imaged.

Retinal Vessels are vascular structures visible in retinal images. Vessels Segmentation in Retinal/Fundus Images is important to determine vascular changes due to DR or cardiovascular diseases.

Problem and Objective

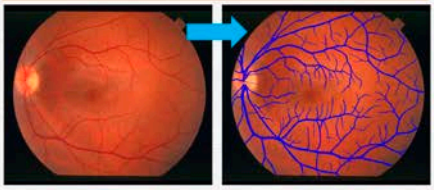
PROBLEM

Diabetes Mellitus is a high prevalence disease:
2010 → 285 M people suffered DM (prevalence 6.4%).
2030 → **440 M people expected to suffer DM worldwide (prev. 7.7%).**
Regular ophthalmic exams that include retinal images are paramount to reduce the risk of blindness due to DR. Automatic methods aimed at DR screening programs are necessary due to the increase of DR prevalence. In this way, general automatic retinal image analysis methods, that include retinal vessels segmentation, are being developed.

OBJECTIVE

The objective of the Final Assignment is to develop accurate retinal blood vessels segmentation algorithms to be included in a general retinal image analysis algorithm.

Retinal Vessels Segmentation

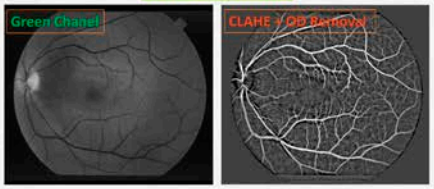


Segmentation of blood vessels is important in retinal image analysis because vessels shapes provide information about vascular changes caused by cardiovascular diseases. Additionally, vessels must be detected prior to detecting Red Lesions (RLs) such as Hemorrhages (HEs) and Microaneurysms (MAs) in DR screening programs.

Methodology

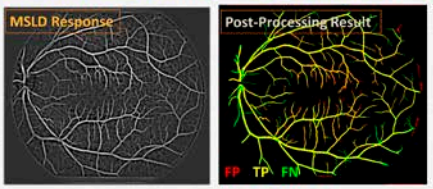
Our approach focused on the improvement of a recent and well known multiscale line detector (MSLD). However, the MSLD method alone has several drawbacks related to the detection of the optic disk (OD) and bright lesions as vessels and to false detections due to low contrast in small vessels. Therefore, novel preprocessing and postprocessing stages were included in the proposed vessel detection algorithm. By including these additional stages, the segmentation accuracy of the MSLD algorithm in the OD boundary increased and small vessels were more precisely segmented.

Preprocessing



Vessels Detection

Segmentation



Results

The algorithm was tested on the DRIVE and STARE public retinal image databases. Segmentation accuracy reached 94.44% on the DRIVE database and 94.77% on the STARE database. Smaller vessels were more accurately detected and the results were also improved in the OD area.

Conclusion

The objective of this Final Assignment was the development of an automatic algorithm for retinal vessel segmentation. The proposed algorithm outperformed the original MSLD and reduced false detections. Therefore, it could be useful in a more general retinal image analysis method in conditions such as DR.

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Swarm Intelligence Methods Applied to P300-Based Brain-Computer Interface Systems Channel Selection

PhD Student: **Víctor Martínez Cagigal** PhD Advisor: **Roberto Hornero Sánchez**

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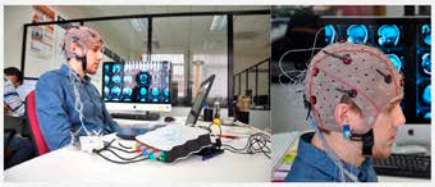
Introduction

Brain-Computer Interfaces (BCIs)

- Allow users to **control applications** with their own brain signals
- Monitor the brain activity using **electroencephalography** (EEG)
- Users intentions can be decoded using control signals



P300 evoked potentials

- **Exogenous** control signals
- Natural **responses to visual stimuli** produced 300ms after their onset
- **Low signal-to-noise ratio** → Multiple repetitions of the same stimulus
- **Curse of dimensionality** is present in real-time → Over-fitting

Problem and Objective

Channel selection procedures are essential to

- **Reduce** the curse of **dimensionality**
- **Reduce** the power **consumption** in wireless EEG caps
- **Increase** the users' **comfort**
- **Increase** the system **performance**

Problem

- **Selection is not trivial** → Intractable exhaustive search (2^N)
- There are no standard methods to perform channel selection
- **Swarm Intelligence** based methods are not yet fully exploited

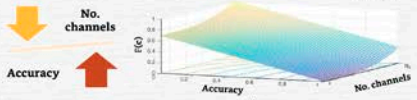
The objective of this study is to compare the performance among **five different SI methods**, based on the social behavior of birds, bees, ants and fireflies, when applied to the **channel selection** in P300-based BCI systems

Cost Function

Multi-objective cost function

- Aggregation approach

$$F(\mathbf{c}) = \omega_a \underbrace{(1 - f_a)}_{\text{max accuracy}} + \omega_c \underbrace{\left(\frac{\sum \mathbf{c} - 1}{N_d - 1}\right)^3}_{\text{min No.ch}}$$

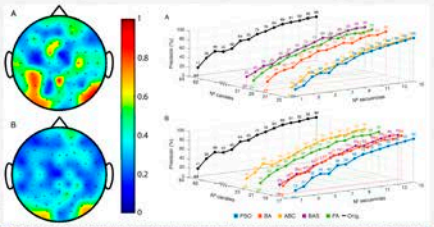


Methods

Swarm Intelligence (SI) optimization

- Complex optimization based on a **collective behavior**
- The **self-organized** systems consist of a **population of simple agents**
- Agents interact among themselves and the environment
- Their **positions are** essentially **solutions** to the problem
- They **tend to move to better positions** based on the cost function

Results



No. times that channels have been selected Final test accuracies versus number of channels and sequences

Conclusions

Channel selection in P300-based BCI systems is essential to avoid over-fitting, to reduce the computational cost and to increase the users' comfort. In this study, five different SI based metaheuristics have been applied to this problem. These methods have been tested with the 'III BCI Competition 2005' dataset II. Results show that all of them are able to achieve similar or even higher accuracies than that obtained without channel selection or using the typical 8-channel set. Moreover, not only the system performance is improved, but also the required number of channels have been reduced to less than the half of the original channel set. These results suggest that SI methods are suitable for use in P300-BCI channel selection procedures.

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USEFULNESS OF DISCRETE WAVELET TRANSFORM IN THE ANALYSIS OF OXIMETRY SIGNALS TO ASSIST IN CHILDHOOD SLEEP APNEA-HYPOPNEA SYNDROME DIAGNOSIS

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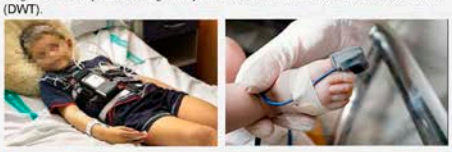
INTRODUCTION

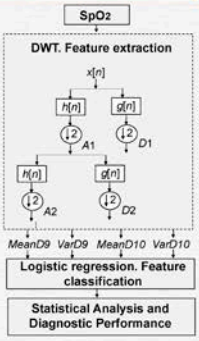
Pediatric sleep apnea hypopnea syndrome (SAHS) is a highly prevalent breathing disorder characterized by a prolonged partial obstruction of the upper airway (hypopnea) and/or intermittent complete cessation (apnea) of airflow during sleep that may cause several negative consequences for the health and development of children. The gold standard for SAHS diagnosis is the overnight polysomnography (PSG), which is highly cost, complex, time demanding, and particularly intrusive for children. Thus, there is a great demand for simplified and reliable alternative techniques. In order to improve early detection of pediatric SAHS, we propose an automated analysis of the blood oxygen saturation (SpO_2) signal from nocturnal oximetry. We hypothesize that wavelet analysis will be useful in the diagnosis of childhood SAHS, due to the recurrence and duration of respiratory events, as well as the abrupt changes they provoke in the SpO_2 signal. Therefore, our goal is to evaluate the diagnostic ability of this signal by means of the discrete wavelet transform (DWT).



METHODS

The methodology is developed into two stages:

1. **Feature extraction.** DWT was computed for each SpO_2 recording. Then, the detail coefficients of the levels 9 (D9, 0.012-0.024 Hz) and 10 (D10, 0.024-0.048 Hz) of the DWT were analyzed. The features extracted were the mean (*MeanD9* and *MeanD10*) and the variance (*VarD9* and *VarD10*) of D9 and D10.
2. **Feature classification.** A logistic regression (LR) model was created with these features to classify the children into SAHS positive or SAHS negative.
3. **Statistical analysis and diagnostic performance.** Mann Whitney U test and ROC curves were applied to assess statistical differences and the diagnostic ability of the methodology.



SUBJECTS AND SIGNALS

A total of 298 SpO_2 signals from children ranging from 0 to 13 years of age composed our dataset. An apnea-hypopnea index (AHI) cutoff of 5 events/h (e/h) was considered as a positive SAHS. This dataset was divided randomly into training (50%) and test (50%) groups.

Table I. Clinical and demographical data in the training and test sets.

Training	All	SAHS negative	SAHS positive
Subjects(n)	149	82	67
Age (years)	6 [4-9]	7 [5-10]	6 [3-9]
Males(n)	88 (59.06%)	51 (62.20%)	37 (55.22%)
BMI (kg/m^2)	18.34 [16.40-23.18]	17.90 [16.35-21.67]	19.03 [16.50-24.22]
AHI (e/h)	-	2.01 [0.95-3.39]	11.09 [7.49-19.59]

Test	All	SAHS negative	SAHS positive
Subjects(n)	149	82	67
Age (years)	7 [4-9]	7 [5-10]	5 [3-9]
Males(n)	78 (52.35%)	40 (48.78%)	38 (56.72%)
BMI (kg/m^2)	18.42 [16.26-22.76]	18.33 [16.30-22.66]	18.42 [16.05-22.80]
AHI (e/h)	-	1.90 [0.97-3.49]	11.13 [7.56-18.41]

RESULTS

Table II. Median, interquartile range and *p*-value of the DWT feature values for SAHS negative and SAHS positive groups in the training set.

	SAHS negative	SAHS positive	*p*-value
MeanD9 (10^{-3})	0.97 [-1.53 - 3.43]	1.21 [-3.11 - 4.96]	0.97
MeanD10 (10^{-4})	-1.71 [-9.47 - 5.21]	3.32 [-1.29 - 1.07]	0.20
VarD9	3.61 [2.97 - 4.41]	5.85 [4.51 - 7.88]	*p*<0.01
VarD10	4.26 [3.43 - 5.18]	6.63 [5.19 - 9.20]	*p*<0.01

Table III. Diagnosis assessment of each single feature and the LR model in the test set.

	Se	Sp	PPV	NPV	LR+	LR-	Acc
MeanD9	37.3	65.9	47.2	56.3	1.09	0.95	53.0
MeanD10	47.8	53.7	45.7	55.7	1.03	0.97	51.0
VarD9	80.6	79.3	76.1	83.3	3.89	0.24	79.9
VarD10	77.6	74.4	71.2	80.3	3.03	0.30	75.8
LR	**79.1**	**84.1**	**80.3**	**83.1**	**4.99**	**0.25**	**81.9**

CONCLUSIONS

- **The variance in both detail levels, *VarD9* and *VarD10*, were significantly higher in the SAHS positive group (*p*<0.01), which suggest that the variability in these bands (0.024-0.049 Hz and 0.012-0.024 Hz) is related with slow variations in the SpO2 signals due to SAHS.**
- **A LR model trained with all the features (*MeanD9*, *MeanD10*, *VarD9* and *VarD10*) reached high diagnostic ability (81.9% Acc) in an independent test set, improving the performance of the best single feature (*VarD9*, 79.9% Acc).**
- **Our results suggest that DWT could be a useful tool for analyzing SpO2 recordings and assisting physicians in the process of achieving a pediatric SAHS diagnosis in high pre-test probability cases.**

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Poincaré Plot Measures to Characterize the Paediatric Sleep Apnoea-Hypopnoea Syndrome Severity in Airflow recordings

Doctoral Student: **Verónica Barroso García** Directors: **Roberto Hornero Sánchez and Gonzalo C. Gutiérrez Tobal**

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INTRODUCTION

The Sleep Apnoea-Hypopnoea Syndrome (SAHS) is a chronic respiratory disorder characterized by recurrent events of apnoea (complete absence of airflow) or hypopnoea (significant airflow reduction) during sleep time. SAHS causes severe medical consequences in paediatric patients suffering from it, like changes in the cardiovascular and central nervous systems, as well as decrease somatic growth and promote nocturnal enuresis, all of which lead to decreases in health and quality of life. Therefore, it requires early detection and treatment. However, the gold standard diagnostic test (polysomnography, PSG) is complex, costly, whit limited availability, and particularly uncomfortable for children. In order to overcome these limitations, we propose the assessment of a new methodology to simplify paediatric SAHS diagnosis. Our hypothesis is that the variability analysis is able to characterize SAHS severity in airflow (AF) recordings from children. Accordingly, our objective is to evaluate the evolution of variability in single-channel AF signal as SAHS severity increases in children by mean of the geometric measures of Poincaré Plot.

SUBJECTS AND SIGNALS

The population under study consists of 501 pediatric subjects which were suspected of suffering from SAHS. All of them performed the PSG in the Pediatric Sleep Unit at the Comer Children's Hospital of the University of Chicago. AF signal used in the study is that registered by the thermistor during the realization of PSG. The sampling frequency of AF is 100 Hz. The apnoea-hypopnoea index (AHI) cutoff are 1, 5, and 10 events per hour (e/h).

	All	Training group	Test group
Subjects (n)	501	250	251
Age (years)	6.21 ± 3.41	6.02 ± 3.19	6.40 ± 3.62
Males (n)	314 (62.67%)	160 (64%)	154 (61.35%)
BMI (kg/m²)	19.63 ± 7.37	19.35 ± 7.02	19.92 ± 7.70
AHI (e/h)	8.26 ± 17.20	7.30 ± 16.80	9.22 ± 17.56
AHI ≥ 1 (n)	367 (73.25%)	170 (68%)	197 (78.49%)
AHI ≥ 5 (n)	180 (35.93%)	83 (33.2%)	97 (38.65%)
AHI ≥ 10 (n)	104 (20.76%)	48 (19.2%)	56 (22.31%)

METHODOLOGY

FEATURE EXTRACTION

An analysis of first-order difference plots, which are scatter diagrams centered on the origin that represent displaced subsequences of the original time series: (x[i+2]-x[i+1]) vs. (x[i+1]-x[i]), will be carry out by mean of the geometric measures of Poincaré Plot

Poincaré Plot Measures:

A. Ellipse Fitting Technique

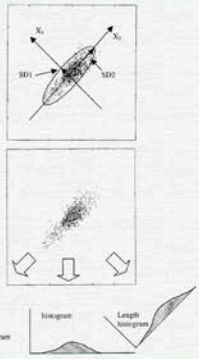
- Standard Deviation SD1: measure the dispersion of the points around the X_1 axis reflecting the short-term variability
- Standard Deviation SD2: measure the dispersion of the points around the X_2 axis reflecting the long-term variability
- Total Standard Deviation of Poincaré Plot (SDRR): reflect the total variability of plot
- Ellipse area (A): this measure is characterized by SD1 and SD2 and also reflect the total variability

B. Histogram Technique

- Histogram: the histogram of the Poincaré plot points projected onto the X axis (or the Y axis). This view provides summary information on the overall characteristics
- Width histogram: the histogram of the Poincaré plot points projected along the direction of the line-of-identity. Mathematically, it is the distribution of X_1 and provides summary information on the short-term characteristics
- Length histogram: this histogram is obtained by projecting the Poincaré plot points perpendicular onto the line-of-identity. The histogram is described mathematically by the distribution of X_2 and portrays the long-term characteristics

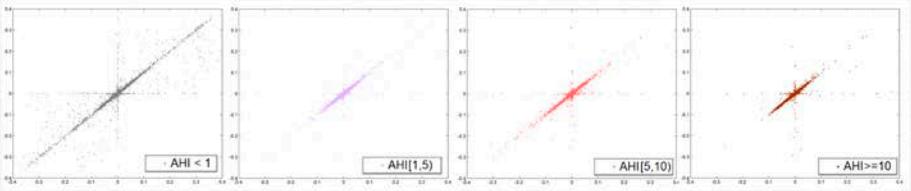
C. Ratios and Correlation Coefficient

- Correlation Coefficient of Poincaré Plot: measure the linear correlation between (x[i+2]-x[i+1]) and (x[i+1]-x[i]). This measure can be expressed in terms of the SD1 and SD2
- Ratio SD1/SD2 or SD2/SD1: relation between the dispersion of the points around the X_1 and dispersion of the points around the X_2



PRELIMINARY RESULTS

- First-order difference plots were plotting according to SAHS severity degree.
- Our preliminary results showed decreasing variability in AF as AHI is higher. The reduction of the data dispersion were clearly experienced among AHI<1, AHI [5,10), and AHI ≥ 10 groups.
- This results suggest that apnoea-hypopnoea events cause changes in variability of AF signal. Hence, Poincaré Plot measures could be useful to help diagnose the degree of SAHS severity in children.



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CHARACTERIZATIONOF NEURAL SUBSTRATES IN SCHIZOPHRENIA AND ALZHEIMER'S DISEASE BY MEANS OF COMPLEX NETWORK THEORY

PhD student: **Pablo Núñez Novo** PhD advisors: **Jesús Poza Crespo and Roberto Hornero Sánchez**

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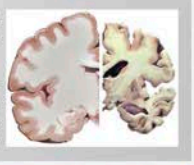
SCHIZOPHRENIA

Schizophrenia (SCH) is a mental disorder characterized by a cluster of symptoms and signs that differ among subjects, including, but not limited to, hallucinations and delusions, reduced motivation and impairment in cognitive processing

SCH has an incidence of 15.2/100,000 persons per year, and a significant contribution to the global burden of disease. SCH commonly has its onset in early adulthood and approximately 2/3 of affected individuals have persisting symptoms

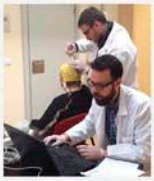
ALZHEIMER'S DISEASE

Alzheimer's disease (AD) is a progressive, fatal neurodegenerative disorder characterized by deterioration in cognition and memory, as well as a number of neuropsychiatric and behavioral symptoms



AD is the most common form of dementia, being responsible for approximately two thirds of cases of dementia among the elderly. Hence, AD is very common and, consequently, a major public health issue

PROBLEM



Alzheimer's disease and schizophrenia are pathologies that share some characteristics like their high prevalence and a high social and personal cost

EEG captures the summation of neural oscillations in the brain and their synchronization

HYPOTHESIS

Functional disconnectivity among brain areas in AD and SCH causes alterations in the interaction patterns of EEG signals generated in different regions of the neural cortex, as well as changes in the stability of neural networks formed from these patterns

The **main objective** of this PhD thesis is to study and apply new methods of **local activation, neural coupling and parameters derived from complex network theory.**. Our aim is to detect the alterations that AD and SCH cause in the interaction patterns between EEG signals generated in different regions of the cerebral cortex

METHODOLOGY

The characterization of neural function can be studied from different points of view according to the different hierarchies of organization

LOCAL ACTIVATION	INTERACTION	NETWORK
		
Level of activation of individual clusters of neurons	Statistical dependence between two electrodes.	Analyze the brain as a graph of connections between electrodes

CONNECTIVITY STABILITY

EEG PROCESSING	CONNECTIVITY	STABILITY
		
Extract time-frequency information and obtain relevant features	Obtain connectivity measures between pairs of electrodes at different time windows	Measure connectivity stability differences between groups

RELEVANCE AND INNOVATION

This PhD thesis combines local activation, functional connectivity and network theory techniques in order to help in the diagnosis of pathologies with a high economic and social cost

The thesis will focus on a novel research line: connectivity stability. This line is enjoying a rise in popularity, which will increase the impact of the research

New biomarkers for AD and SCH may be found, which would help simplify an early diagnosis of these pathologies. This would help alleviate the burden of caregivers and relatives

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CHARACTERIZATION OF NEURONAL ACTIVITY IN ALZHEIMER'S DISEASE BASED ON COMPLEX NETWORK THEORY

PhD Student: **Saúl José Ruiz Gómez** PhD Advisors: **Carlos Gómez Peña and Roberto Hornero Sánchez**

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ALZHEIMER'S DISEASE (AD) AND MILD COGNITIVE IMPAIRMENT (MCI)

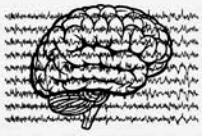
- **Alzheimer's disease (AD)** is a progressive neurodegenerative disorder that provokes cognitive, behavioral and functional alterations
- The **prevalence** of AD exponentially increases with age
- **Mild Cognitive Impairment (MCI)** is a symptomatic pre-dementia stage of AD in which subjects exhibit memory impairment beyond what w… …pected for their age

AD prevalence for two different age groups

Annual rates of progression of MCI and global population to dementia due to AD

ELECTOENCEPHALOGRAPHY (EEG)

- **EEG** is an electrophysiological monitoring method used to **record the brain's spontaneous electrical activity**

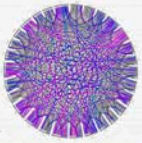


- **Advantages:**
  - ✓ Low-cost
  - ✓ Portability
  - ✓ Good time resolution
  - ✓ Good spatial resolution

PROBLEM AND OBJECTIVE

PROBLEM **Complex detection** of AD and its incipient f…

AD is increasingly being recognized as a **modern epidemic with an enormous impact on the healthcare systems**

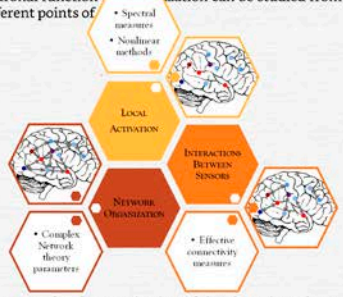


OBJECTIVE **Apply new methods of neural coupling and parameters derived from complex network theory**, to detect the alterations in the brain activity in patients with AD and MCI

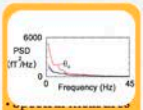
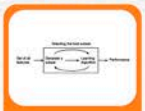
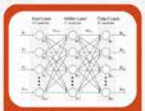
Delimit new biomarkers to help in AD and MCI diagnosis

METHODOLOGY

- Analysis of EEG recordings with advanced methods of signal processing
- Neuronal function … …ization can be studied from three different points of



To carry out the characterization of the alterations that AD and MCI produce in the cerebral activity, **selection of the most relevant characteristics** and **classification and deduction of patterns** should be performed

FEATURE EXTRACTION	FEATURE SELECTION	FEATURE CLASIFICATION
		
• Nonlinear methods • Effective connectivity measures • Complex Network th…	• Stepwise logistic Regression • Fast Correlation-Based Filter (FCBF)	• Logistic Regression • Linear Discriminant Analysis (LDA) • Multi-Layer Perceptron Neural …

INNOVATION AND IMPACT

- The **innovation** of this research work is the **use of effective or causal connectivity measures** that provide us with information about the directionality of the information flow
- The development of a **new methodology to identify potential biomarkers of early phases of AD** may have a big scientific and technical impact
- The **reduction of waiting times** in critical medical services and the **reduction of human, material, and economic resources** dedicated to diagnosis in the National Health System can be two indirect consequences of this PhD Thesis

GRUPO DE INGENIERÍA BIOMÉDICA
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Job satisfaction, wellbeing at work and health status in nurses from a Spanish public health service

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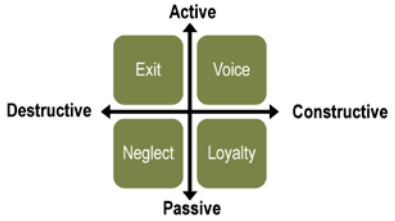
Introduction

Low levels of motivation and job satisfaction can negatively affect the quality of work. Rusbult and Lowery model can offer predictions about this fact: workers' passive and destructive attitudes related to dissatisfaction situations could conduct to negligence. This situation could also affect health. This is relevant in health workers as nurses.



It could also affect nurses´ security. Patients´ health and security could be affected negatively too. Is necessary to analyse and to describe the association of this variables and investigate other determinants.

Objectives

Determine intra and extra personal variables that influence in health status, job satisfaction and motivation levels in nurses of the *Castilla y León* health system. Specifically:

- Synthetize scientific evidence
- Determine the level of these variables in the sample
- Perform a correlational analysis
- Determine sociodemographic influence

Contribution of the research and novelty: This research could suggest guidelines to implement policies related to the health status and quality of cares. Not many previous studies have analyzed these parameters and research has been performed on isolated wards or hospitals. We will try to implement a multicentric approach in *Castilla y León* under Herdbergs's Two Factor theory. The combination of the tools under this theoretical framework is also novel in the region.

Materials and methods

Design: descriptive, crossectional, correlational and comparative study. The data compilation will be carried out through validated and anonymous questionnaires, adapted to an on-line version through LimeSurvey application.

Subjects	Inclusion criteria	Exclusion criteria
• All nurses in selected hospitals	• Active nurses during data compilation	• Nurses on sick leave or in period of unpaid leave.

Tools

GHQ – 28 General Health Questionnaire	NTP 394 Overall Job Satisfaction Scale	UWES – 17 Utrecht Work Engagement Scale
Somatic symptoms	General satisfaction	Vigour
Anxiety and insomnia	Intrinsic satisfaction	Dedication
Social dysfunction	Extrinsic satisfaction	Absorption
Severe depression		

The sampling will be not probabilistic. The data will be analysed with the IBM SPSS V.23. **Proposed analysis**:

Instrumental reliability	Factorial analysis	Descriptive analysis	Linear correlation, comparative analysis
Cronbach's Alpha model	Varimax rotation	Central tendency, dispersion and frequency	Depending on the sample distribution

Ethical considerations: This research respects the declaration of Helsinki, Convention of European Council relative on human rights and biomedicine, and the Universal Declaration of UNESCO on the human genome and human rights and Consejo de Oviedo on human rights and biomedicine. It also respects the *Ley Orgánica 15/1999, de 13 de diciembre, de Protección de Datos de Carácter Personal and the Real Decreto 994/99 del Estado Español; la Ley Nº 67/98 de 26 de octubre*

05.05.2017, Valladolid

Variance-stabilizing transformation of non-central Chi data with an application to nonstationary noise estimation in accelerated parallel MRI acquisitions

Tomasz Pieciak[1,2], Gonzalo Vegas-Sánchez-Ferrero[3,4], Santiago Aja-Fernández[1]

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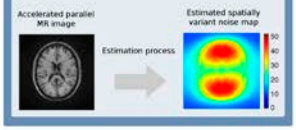
Abstract

The aim of this study is to retrieve spatially variant noise patterns from accelerated parallel MRI data using only a single image. Variance-stabilizing transformations (VSTs) for noncentral Chi (nc-χ) data are derived: (1) an analytic model and (2) a numerical model to improve the performance for low signal-to-noise ratios (SNRs). The VSTs generate Gaussian-like distributed variates from nc-χ data. The noise patterns are estimated then using Gaussian homomorphic filter.



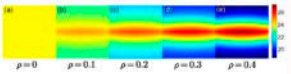
Non-stationary Rician noise

For Cartesian SENSE and Cartesian GRAPPA+SMF, the magnitude signal $M = M(\mathbf{x})$ follows a non-stationary Rician distribution:

$$p(M|A,\sigma) = \frac{M}{\sigma^2}\exp\left(-\frac{M^2+A^2}{2\sigma^2}\right) I_0\left(\frac{AM}{\sigma^2}\right),\ M \geq 0,$$

where:

- $A = A(\mathbf{x})$ is the amplitude signal,
- $\sigma^2 = \sigma^2(\mathbf{x})$ is the underlying noise variance.



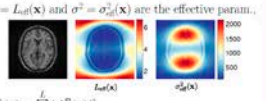
Non-stationary nc-χ noise

For Cartesian GRAPPA+SoS, the composite magnitude signal $M_L = M_L(\mathbf{x})$ can be modelled using a non-stationary nc-χ distribution with *effective parameters*:

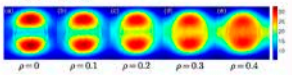
$$p(M_L|A_F,\sigma,L) = \frac{A_F^{1-L}}{\sigma^2} M_L^L \exp\left(-\frac{M_L^2+A_F^2}{2\sigma^2}\right) \times I_{L-1}\left(\frac{A_F M_L}{\sigma^2}\right),\ M_L \geq 0,$$

where:

- $L = L_{\text{eff}}(\mathbf{x})$ and $\sigma^2 = \sigma^2_{\text{eff}}(\mathbf{x})$ are the effective param.,



- $A_F^2(\mathbf{x}) = \sum_{l=1}^{L} |A_l^R(\mathbf{x})|^2$,
- $I_k(\cdot)$ is the modified Bessel function of the first kind and k-th order.



The VST

The VST changes the signal-dependent noise in non-Gaussian data to a signal-independent one. We are interested therefore in a transformation $f_{stab}: \mathbb{R} \mapsto \mathbb{R}$ that leads to a random variable with a constant variance, i.e., $\text{Var}\{f_{stab}(M_L|\sigma, L)\} = 1$.

The first-order Taylor expansion of f_{stab} is given by:

$$f_{stab}(M_L|\sigma, L) = \int^{M_L} \frac{1}{\sqrt{\text{Var}\{M_L|\widetilde{A_F},\sigma,L\}}}\, d\widetilde{A_F}.$$

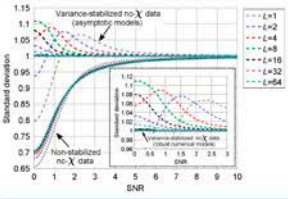
Problem! No closed-form for $\mathbb{E}\{M_L\}$ and $\text{Var}\{M_L\}$.

- **Asymptotic model:**

Let $M_L^2 \sim$ nc-$\chi^2(A_F,\sigma,L)$. The VST is given by:

$$f_{stab}(M_L^2|\sigma, L) = \frac{1}{\sigma}\sqrt{M_L^2 - L\sigma^2}.$$

This model is not optimal for low SNRs!



The VST (continuation)

- **Robust numerical model:**

A vector parameter $\boldsymbol{\Theta} = (\theta_1, \theta_2)$ is introduced:

$$f_{stab}(M_L^2|\sigma, L, \boldsymbol{\Theta}) = \frac{1}{\sigma}\sqrt{\max\{\theta_1^2 M_L^2 - \theta_2 L\sigma^2,\ 0\}}.$$

The vector parameter $\boldsymbol{\Theta}$ must be tuned accordingly to the SNR of the signal, $\text{SNR} = \frac{A_F}{\sqrt{L}\sigma}$:

$$\boldsymbol{\Theta}_{\text{opt}} = \arg\min_{\boldsymbol{\Theta}} J\left(f_{stab}(M_L^2|\sigma, L, \boldsymbol{\Theta})\right).$$

The cost function $J: \mathbb{R}^2 \mapsto \mathbb{R}$ is given then by:

$$J\left(f_{stab}(\cdot|\sigma, L, \boldsymbol{\Theta})\right) = \lambda_1 \cdot \varphi(1 - \text{Var}\{f_{stab}(\cdot|\sigma, L, \boldsymbol{\Theta})\}) + \lambda_2 \cdot \varphi(|\text{Skew}\{f_{stab}(\cdot|\sigma, L, \boldsymbol{\Theta})\}|) + \lambda_1 \cdot \varphi(|\text{ExKurt}\{f_{stab}(\cdot|\sigma, L, \boldsymbol{\Theta})\}|).$$

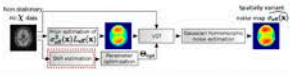
The r-th raw moment for f_{stab} trans. nc-χ^2 RV:

$$m_r = \int_0^\infty f_{stab}^r(\widetilde{M_L^2}|\sigma, L, \boldsymbol{\Theta})\, \underbrace{p(\widetilde{M_L^2}|A_F,\sigma,L)}_{\text{PDF of nc-}\chi^2\text{ RV}} d\widetilde{M_L^2}$$

Spatially variant noise estimation

Gaussian homomorphic filter:

$$\widehat{\sigma_{\text{eff}}(\mathbf{x})} = \sqrt{2}\exp\left\{\text{LPF}_{\sigma_c}\left\{\log\left|\widetilde{L}(\mathbf{x})\right|\right\} + \frac{\gamma}{2}\right\}.$$



Noise estimation results

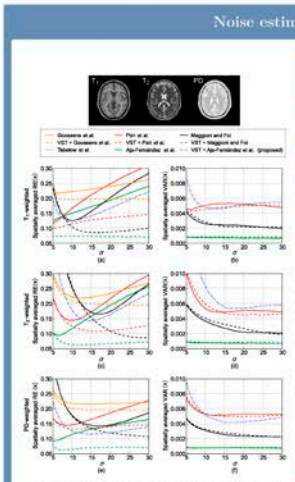


Figure 1: Noise estimators for synthetic GRAPPA+SoS data

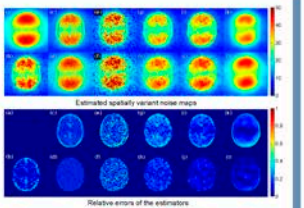


Figure 2: Synthetic GRAPPA+SoS data: (a) *Ground truth*, (b) Tabelow, (c) std. dev. along samples, (d) VST+std. dev. along samples, (e) Goossens, (f) VST+Goossens, (g) Pan, (h) VST+Pan, (i) Maggioni, (j) VST+Maggioni, (k) Aja-Fernández, (l) **proposed**.

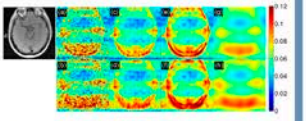


Figure 3: *In vivo* GRAPPA+SoS data: (a) Goossens, (b) VST+Goossens, (c) Pan, (d) VST+Pan, (e) Maggioni & Foi, (f) VST+Maggioni & Foi, (g) Aja-Fernández, (h) **proposed**.

GROUPWISE NON-RIGID REGISTRATION ON MULTIPARAMETRIC ABDOMINAL DWI ACQUISITIONS FOR ROBUST ADC ESTIMATION: COMPARISON WITH PAIRWISE APPROACHES AND DIFFERENT MULTIMODAL METRICS

S. Sanz-Estébanez, O. Peña-Nogales, R. de-Luis-García,
S. Aja-Fernández and C. Alberola-López
Laboratorio de Procesado de Imagen, Universidad de Valladolid, Spain

ABSTRACT

Registration of diffusion weighted datasets remains a challenging task in the process of quantifying diffusion indexes. Respiratory and cardiac motion, as well as echo-planar characteristic geometric distortions, may greatly limit the accuracy in parameter estimation, specially in the liver. This work proposes a methodology for the non-rigid registration of multiparametric abdominal diffusion weighted imaging by using different well-known metrics under the groupwise paradigm. A three-stage validation of the methodology is carried out in a computational diffusion phantom, a watery solution phantom and a set of voluntary patients. Diffusion estimation accuracy has been directly calculated on the computational phantom and indirectly by means of a residual analysis on the real data. On the other hand, effectiveness in distortion correction has been measured on the phantom. Results have shown statistical significant improvements compared to pairwise registration being able to cope with elastic deformations.

INTRODUCTION

◦ Apparent diffusion coefficient (ADC) is sensitive to displacement of water molecules, giving evidences about cellular organization and cell permeability [1] in different tissues.
◦ Robust ADC estimation becomes non-trivial, as an exponential signal dropout is observed when the magnetic diffusion gradient strength (the so-called *b-values*) increases.

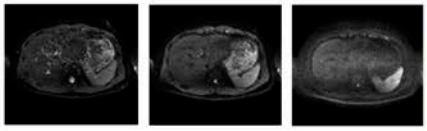


Figure 1: Axial slices of DWI acquisition in a healthy volunteer with *b-values* of 0, 100 and 1000 s/mm^2 (from left to right).

◦ Several confounding factors may greatly affect ADC estimation on the liver; artifacts are very likely to appear during imaging due to respiratory and cardiac motion.
◦ Ultrafast sequences, i.e. echo planar imaging (EPI), suffer from geometric distortions as well as local signal dropouts due to magnetic field inhomogeneities.
◦ Registration schemes of multiparametric (multiple *b-values*) acquisitions have proven to alleviate the effects of these confounding factors.
◦ Groupwise approaches find optimal parameter set using a common reference built out of the whole image space, so that template bias is not present.

METHODS

Groupwise registration of different *b-value* images for robust ADC estimation on the liver. Monoexponential decay model for the DWI images:

$$S(b) = S_0 e^{-b \cdot \mathrm{ADC}} \tag{1}$$

where S represents the image for each *b-value* and S_0, the image without diffusion gradient.

For the registration scheme, a gradient-descent/ascent procedure is performed for the optimization. Non-rigid deformation model based on 2D B-spline [2] FFDs:

$$\mathbf{T}(\mathbf{x}) = \sum_{j,k} B_L(u_j(x_1)) B_L(u_k(x_2)) \boldsymbol{\theta}_{j,k} \tag{2}$$

Performance assessment of different multimodal metrics formulated under groupwise and pairwise paradigms:

◦ **Variance of the local entropy** (VLE). Local entropy [3] should be preserved along the whole image set. Hence, the pixel-wise metric can be considered as the sum of squared differences of the local entropy images $S_{\mathcal{N}}$:

$$S_{\mathcal{N}}(\mathbf{I}(\mathcal{N}(\mathbf{x}))) = \frac{-1}{|\mathcal{N}|} \sum_{\mathbf{x}' \in \mathcal{N}} p(I(\mathbf{x}')) \ln(p(I(\mathbf{x}'))). \tag{3}$$

◦ **Entropy of the distribution of intensities** (EDI) [4]:

$$H(\mathbf{x}) \simeq \frac{-1}{N} \sum_{n=1}^{N} \log[p(I_n(T_n(\mathbf{x})))] \tag{4}$$

with $p(I_n(T_n(\mathbf{x})))$ a Parzen window estimation of the pixel intensity distribution. This metric favours those solutions in which pixel intensities are well concentrated in the intensity space.

◦ **Modality independent neighbourhood descriptor** (MIND): an image descriptor, built from within-patch distances D_p and variance estimates V:

$$\mathrm{MIND}(I, \mathbf{x}, r) \propto \exp\left(\frac{D_p(I, \mathbf{x}, \mathbf{x}+r)}{V(I, \mathbf{x})}\right). \tag{5}$$

Afterwards, simple monomodal measures built from MIND differences are used as pixel-wise metric, as described in [5].
◦ **Normalized cross-correlation** (NCC):

$$H(\mathbf{x}) = \frac{1}{N} \sum_{n=1}^{N} \frac{< I_n(T_n(\mathcal{P}(\mathbf{x}))), \mu(I(\mathcal{P}(\mathbf{x})) >^2}{< I_n(T_n(\mathcal{P}(\mathbf{x}))) >< \mu(I(\mathcal{P}(\mathbf{x})) >} \tag{6}$$

where $\mu(\mathbf{x}) = \frac{1}{N} \sum I_n(T_n(\mathbf{x}))$ and $\overline{I(\mathcal{P}(\mathbf{x}))}$ represents the operator over a predefined patch $\mathcal{P}$ as defined in [6].

ACKNOWLEDGEMENTS

This work was partially supported by the Spanish Ministerio de Ciencia e Innovación under Research Grant TEC2013-44194-P, the European Regional Development Fund (ERDF-FEDER) under Research Grant TEC2014-57428- R and the Spanish Junta de Castilla y León under Grant VA069U16.

RESULTS

Three-fold validation procedure:

- Synthetic experiment on 4D extended cardio-torso (XCAT) computational phantom [7]. Different apnea levels have been simulated and a synthetic deformation field is added for EPI distortion simulation.
- MRI experiment consisting of a pre-design watery solution phantom in order to test the ability of the methods for distortion correction.
- MRI acquisitions on a sample of four healthy volunteers. Axial SENSE DWI and T2 weighted Turbo Spin Echo sequences acquired on a Philips Achieva 3T scanner.

◦ Accuracy in motion compensation and distortion correction measured within the XCAT phantom by means of error distributions on ADC estimation. U-tests have shown significant differences between groupwise and pairwise approaches. EDI and MIND metrics exhibit best, albeit similar performance, specially when compared to the original data ($p < 10^{-9}$).

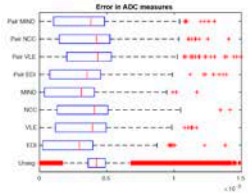


Figure 2: Error on ADC estimation for proposed groupwise and pairwise metrics.

◦ Quantitative analysis, over the MRI phantom, of the overlapping (Dice coefficient) between foregrounds from the registered DWI and the undistorted T2w sequences. No significant differences were found in Dice coefficient distributions between groupwise metrics and its pairwise counterpart. However, Kruskal-Wallis test found significant differences within groupwise metrics ($p = 0.0027$) and with the original data ($p < 10^{-6}$).
◦ For the volunteer data, a goodness-of-fit analysis will measure the discrepancies between registered data and the monoexponential diffusion model in Eq. 1. No differences were found in RSS distributions.

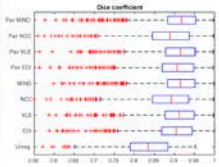


Figure 3: Dice Coefficient distributions for foregrounds of DWI and T2w sequences.

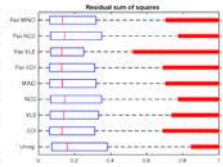


Figure 4: Residual sum of squares distributions obtained from ADC estimation.

CONCLUSIONS

◦ Non-rigid registration framework for motion compensation on multiparametric abdominal DWI acquisitions. Groupwise approaches can deal with signal intensity changes and also correct for geometrical distortions.
◦ Metric choice is also an important issue for outlier removal. However, acquisition parameters and estimation model have had greater impact than the alignment itself, regardless of the metric.

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ADC Measurement Accuracy in Quantitative Diffusion Phantoms using Reduced Field-Of-View and Multi-Shot Acquisitions

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Purpose

Diffusion MRI (**dMRI**) is typically performed using single-shot Echo Planar Imaging (**ssEPI**). However, the long echo-trains in ssEPI result in significant image distortion in the presence of static B0 field inhomogeneities. Several techniques have been proposed for reducing the echo-train length in dMRI in order to reduce image distortions compared to ssEPI. Reduced-Field-of-View (**rFOV**) imaging has been demonstrated in regions such as the spinal cord [1] and pancreas [2]. Multi-shot EPI (**msEPI**) is based on an interleaved segmented k-space acquisition that enables full FOV dMRI with reduced distortion (upon correction of inter-shot phase inconsistencies) [3]. Both rFOV and msEPI have been shown to provide high quality diffusion weighted images. However, their ability to provide accurate **quantitative diffusion** measures has not been fully characterized. In this study we extend the work from Banerjee et al [4] by conducting controlled experiments in two recently proposed quantitative diffusion phantoms to compare the apparent diffusion coefficient (**ADC**) measured from three diffusion sequences: ssEPI, rFOV and msEPI.

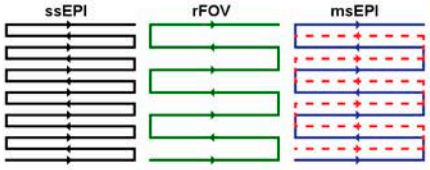


Figure 1: Example of k-space trajectories for single-shot EPI (A), reduced Field of View (B) and interleaved multi-shot EPI (C).

Methods

Two phantomes were used to test the sequences:

- The National Institute of Standards and Technology (NIST) and ISNA-**QIBA diffusion phantom** [5].
- **Diffusion phantom based on acetone-water mixtures** with a wider range of ADC values [6].

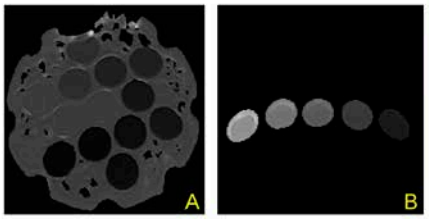


Figure 2: Example of ADC maps of both the QIBA Phantom (A) and the Acetone-Water Phantom (B) obtained from the ssEPI reference acquisition.

Scans were acquired on a 3.0T system (MR 750, GE Healthcare, Waukesha, WI) using dual spin-echo sequences to minimize Eddy current distortions. Because of size differences, the QIBA phantom was images using an 8-channel head coil, while the acetone-water phantom was imaged using a Nova 32-channel coil (Nova Medical, Wilmington, MA). The parameters were set as follows:

- **ssEPI**: FOV=24x24cm, matrix=128x128, slice thickness=6mm, in-plane: 1.9x1.9mm^2, TR/TE=4000/84, single average, b-values={50,150,300,500,800,1000} s/mm^2.
- **rFOV**: rFOV={60%,30%}, in-plane: 1.9x1.9mm^2,b-values={50,150,300,500,800,1000} s/mm^2, slice thickness={6mm,3mm}, averages={1,2}.
- **msEPI**: shots=4, single average, b-values={50,150,300,500,800,1000} s/mm^2, slice thickness={6mm,3mm}, in-plane: {1.25x1.25mm,0.94x0.94mm}^{2}.

For each b-value, three orthogonal directions were acquired and then averaged in magnitude. From the combined images, **ADC maps** were computed using non-linear-least-squares fitting to a mono-exponential signal model. From the fitting results, a mean ADC value was obtained from a single slice in each of the vials for each acquisition. Finally, **linear regression analysis** was performed to compare ADC from rFOV and msEPI to the reference ADC from ssEPI.

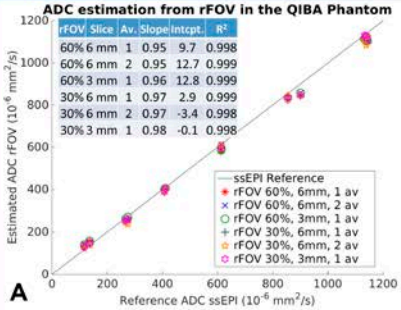
Discussion and Conclusions

1. Both rFOV and msEPI are able to provide **accurate ADC maps** compared to the ssEPI reference.
2. **rFOV** seems to **underestimate** the **ADC** for cases of low SNR in the presence of high ADC, likely due to **noise floor effects** on the fitting.
3. **msEPI** appears to have **higher variability** in ADC measurement, which may be due to **residual ghosting artifacts**.

Results

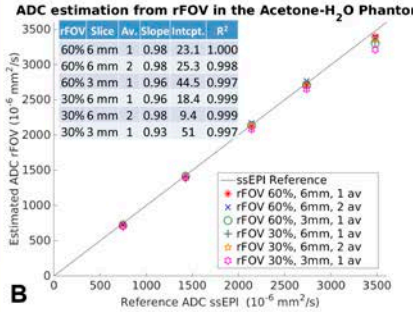
ADC estimation from rFOV in the QIBA Phantom

rFOV	Slice	Av.	Slope	Intcpt.	R^2
60%	6 mm	1	0.95	9.7	0.998
60%	6 mm	2	0.95	12.7	0.999
60%	3 mm	1	0.96	12.8	0.999
30%	6 mm	1	0.97	2.9	0.999
30%	6 mm	2	0.97	-3.4	0.998
30%	3 mm	1	0.98	-0.1	0.998



ADC estimation from rFOV in the Acetone-H_2O Phantom

rFOV	Slice	Av.	Slope	Intcpt.	R^2
60%	6 mm	1	0.98	23.1	1.000
60%	6 mm	2	0.98	25.3	0.998
60%	3 mm	1	0.96	44.5	0.997
30%	6 mm	1	0.96	18.4	0.999
30%	6 mm	2	0.98	9.4	0.999
30%	3 mm	1	0.93	51	0.997



ADC estimation from msEPI in the QIBA Phantom

In plane	Slice	Slope	Intcpt.	R^2
1.25x1.25 mm^2	6 mm	0.93	20.7	0.994
0.94x0.94mm^2	6 mm	0.91	39.5	0.992
1.25x1.25mm^2	3 mm	0.93	20.7	0.994

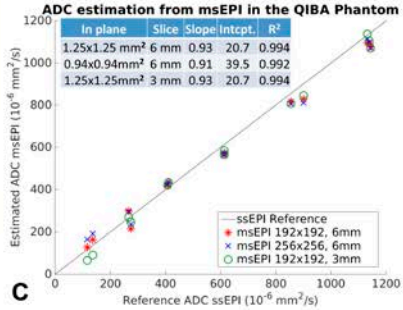


Figure 3: ADC measures for rFOV (A) and msEPI (B) in the QIBA phantom, as well as for rFOV in the acetone-water phantom (C) were compared to ADC measures from ssEPI. The slope, intercept and R2 parameters from a linear regression analysis are shown for all the cases.

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Acknowledgments

The authors acknowledge MICIN for grants TEC2013-44194P and TEC 2014-57428, Junta de Castilla y León for grant 18GHK, the NIH (K24 DK102595) and GE Healthcare for research support. The first author acknowledges MINECO for FPI grant BES-2014-069524.

Machinery monitoring and predictive maintenance through signal processing of acoustical and mechanical vibrations

Application in the Agro-Industrial Field

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Abstract

Agro-industrial machinery monitoring and maintenance are widely recognized as crucial tasks in the fields of agriculture and industry. This PhD dissertation is set to tackle these two problems. In particular, signal processing techniques are applied to acoustical and mechanical vibration signals, acquired respectively by microphones or accelerometers, in order to achieve the monitoring and predictive maintenance of agro-industrial machinery. The main goals of this dissertation are: (*i*) the proposal of new methods for the monitoring and predictive maintenance of agro-industrial equipment; (*ii*) the proposal of methods for locating the sources of vibrations; (*iii*) the proposal of methods for flow rate estimation in agricultural sprayers; and (*iv*) the exploration of the underlying mechanisms for the generation of vibrations. As the reader might have noticed, this is a highly multidisciplinary thesis; in which physics, acoustics, and mechanics all play an important role, as well as signal processing techniques do. So far, three main milestones have been accomplished: (*i*) fault diagnosis and speed monitoring of several rotary components in agricultural harvesters; (*ii*) 3D fault localization, within the machine structure, using multiple sensors distributed along the chassis of the machine; and (*iii*) monitoring of the flow rate in agricultural sprayers by means of microphone sensors. Past, current and follow-up research and deployment in this line of research may lead to a simplification of the wiring and a reduction in the number of sensors required in machinery monitoring, as well as to fast and low-cost maintenance inspections.

Keywords: agro-industrial machinery; acoustical and mechanical vibrations; predictive maintenance (PdM); monitoring; fault diagnosis; 3D source localization; flow rate estimation; signal processing.

Introduction

Machinery monitoring and maintenance are both key tasks in agriculture and industry [1]. Nowadays, these tasks are being carried out by using many diverse techniques [4]. Vibration analysis highlights over the rest for its simplicity and the relative low cost of the necessary sensors. By simply recording acceleration data sequences from one or several points in the chassis of the machines, and after adequately processing them, plenty of information can be obtained about the machinery status or condition. Furthermore, acoustical and mechanical vibrations can also be used for monitoring machinery components and agro-industrial equipment. The PhD thesis here presented tackles some research in this highly multidisciplinary area.

Published articles, presenting some of the research carried out so far in this thesis, can be found in Ruiz-Gonzalez *et al.* [3] and Martínez-Martínez *et al.* [2].

Main Objectives

1. Proposal and assessment of techniques and methods for monitoring and maintaining agro-industrial equipment and machinery.
2. Proposal and assessment of estimation methods for fault diagnosis and monitoring the status and speed of rotating components in agricultural harvesters.
3. Proposal and assessment of methods to locate faulty sources within the whole machine structure.
4. Proposal and assessment of methods for estimating the flow rate through individual nozzles in agricultural sprayers by means of acoustic signal processing.
5. Exploration of the underlying mechanisms for the generation of vibrations using numerical simulations in the aforementioned monitoring and maintenance applications.

Materials and Methods

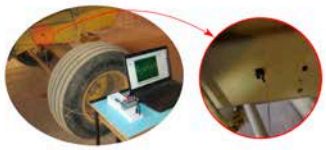

Figure 1: A sample experimental setup for mechanical vibration data acquisition.

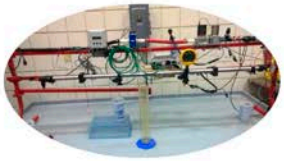

Figure 2: A sample experimental setup for acoustical vibration data acquisition.

Materials

The main materials required to undertake this PhD thesis are: (*i*) agro-industrial machinery, such as harvesters, tractors, and agricultural sprayers; (*ii*) vibration sensors, such as accelerometers and microphones; (*iii*) data acquisition modules; and (*iv*) a laptop computer. Two example setups for data acquisition can be seen in Figure 1 and Figure 2.

Methods

The methodological work-flow employed in this thesis can be briefly summarized in these four stages: (*i*) data acquisition of acoustical and/or mechanical vibration data, (*ii*) proposal of methods by applying signal processing techniques, (*iii*) validation of the proposals through simulations, and (*iv*) validation of the proposals in real environments. This work-flow is not sequential, but iterative; with all stages repeated several times after having gained some further knowledge in the subsequent stages.

Figure 3a schematically shows how the assessment of faulty conditions was conducted in Ruiz-Gonzalez *et al.* [3] for a harvester employing one single accelerometer sensor. Figure 3b illustrates the problem of multiple sources localization, in a 2D scenario for a simpler representation.

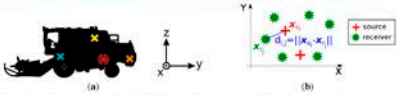

Figure 3: (**a**) Harvester schematic in which the red symbol represents the precise location of the accelerometer sensor on the harvester chassis, the yellow cross represents the location of the engine, the blue cross represents the location of the threshing cylinder, and the orange cross represents the location of the straw chopper. (**b**) Source localization problem for multiple simultaneous sources, in a 2D scenario, where the unknown locations of the sources are to be estimated.

Relevant Results and Conclusions

In the research related to this PhD thesis, the following milestones have been reached so far:

- Accurate estimation of the status of various rotating components in agro-industrial machinery is possible by processing the vibration signal acquired from a single point on the machine structure (Figure 4). The vibration signal can be acquired with a triaxial accelerometer, the orientation of which does not significantly affect the classification accuracy [3]. This monitoring can be even performed while the machines are working in the field, e.g. while harvesting is being done.
- Flow rate through agricultural sprayer nozzles can be estimated accurately *via* acoustic signal processing (Figure 5). A novel signal processing method has been proposed in this line of research.
- Accurate 3D localization of multiple, simultaneously active vibration sources can be achieved when reflections are negligible along the structure of the machinery.

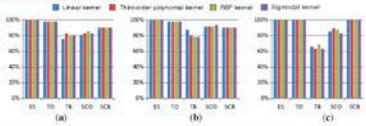

Figure 4: Cross-validation accuracy for each kernel under the following conditions—(*ES*) engine speed, (*TO*) threshing cylinder operation, (*TB*) threshing cylinder balance, (*SCO*) straw chopper operation, and (*SCB*) straw chopper balance—using the sensor channel corresponding to the axes: (**a**) transverse (X); (**b**) longitudinal (Y); and (**c**) vertical (Z).

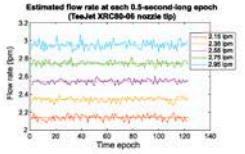

Figure 5: Estimated flow rate through a nozzle tip using real-time acoustic signal processing.

Follow-up Research

- Complete tridimensional (3D) failure localization and identification in multi-path environments.
- Source separation of vibrations so as to improve the accuracy in fault detection and monitoring.
- Numerical simulations to gain insight about generation of acoustical and mechanical vibrations.

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THIS POSTER REFLECTS INFORMATION CURRENTLY PLACED TO BECOME AVAILABLE ON A FUTURE PUBLICATION. RESTRICTIVE CONFIDENTIALITY AGREEMENTS ARE ON EFFECT.

ABSTRACTION AND CHARACTERIZATION OF VIABLE ALGEDONIC EVENTS WITHIN A CYBERNETIC COMMUNICATIONS PROTOCOL

Considerable efforts have been made for the development and implementation of better e-government and management structures in both public and private administrations. At the same time, recent social trends show an increased concern to reduce corruption, embrace transparency, minimise bureaucracy, and maximise efficiency, with a strong emphasis on the privacy and security of all actors involved.

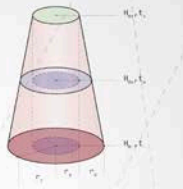
AIM

Through the use of an original cybernetics-focused communications protocol based on Stafford Beer's Viable Systems Theory, we purpose the abstraction of key descriptors regarding algedonic variables of a specific system, to allow for operation control and algedonic, contextual-issue minimisation.

MODEL

The abstraction model is created through caracterization of all viable algedonic events into a dynamic plot. They are based on their effective regulation along time, any weakening or enhancing events which may affect the original subset, and the variation itself.

For each possible descriptor, abstraction of the events can then be elaborated into a dynamic relational model, depending on the flow of events within the system.

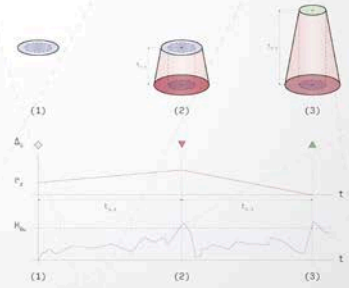


3D representation of a model dynamic plot of a singular event set along time (t_1, t_2, t_3), along the scatter regulation polar axis.

ATLAS

A prototype communications protocol (Atlas) has been developed, which is able to use the abstraction model to obtain and discriminate among the actual variation over specific algedonic events, leading to their characterization into specific status states.

Such states are then detected and managed when the variational output exceeds an appropriate threshold.



3-stage visualization of a singular event set along time and their interactions within Atlas' observe flow: the threshold (H_{th}) manages variational characterization into singular status states on (2) and (3).

CONCLUSIONS

Preliminary results indicate the viability of the protocol to successfully capture, abstract, and provision algedonic descriptors into specific status states. With enough refinement, Atlas should be able to provide insight into complex, non-linear, hysteresis-based algedonic routes, leading to better outcomes when reducing perverse events within systems.

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