Regional Program STIC-AmSud
2016 Project Proposal (Research – Innovation)

Basic Form

- This form, and the associated CVs, must be filled in English. Before filling the form, please read carefully the bases published in the STIC-AmSud site (http://sticmathamsud.org/).
- This form must be sent in **.pdf** by email to the STIC-AmSud Secretariat (contacto@sticmathamsud.org) by the project's International Coordinator.

A. General Information

A1	Project title
	Image reconstruction from compressed measurements: application to hyperspectral and medical imaging

A2	Acronym
	HyperMed

A3	Research domain
	Image and signal processing applied to compressive medical and hyperspectral imaging

A4	Project goals
	The goal of this project is to develop novel compressive acquisition modes in medical and hyperspectral imaging. These new frameworkswill be based on the integration of the following elements: 1. Sparse signal processing (design of compressive acquisition schemes, of image reconstruction methods and multi-temporal image processing). 2. Applications to compressed ultrasound and quantitative acoustic microscopy imaging techniques. 3. Applications to compressed hyperspectral imaging.

A5	Abstract
	Introduced in 2006, the compressed sensing (CS) theory guarantees an exact recovery of specific signals from fewer measurements than the number predicted by the Nyquist limit. This guarantee is obtained for sparse signals (or having a sparse representation in a given basis or frame) and is based on incoherent measurements that generalize the concept of samples in the standard sampling scheme. Since its introduction in 2006, CS has received much attention from the scientific community as shown by the impressive number of journal papers, conferences and workshops on this topic. In particular, it has been shown that several applications can benefit from CS, such as image and video processing, communications, radar, biology or astronomy. Despite solid theoretical background, its application to practical image processing problems (such as those related to hyperspectral and medical imaging addressed in this project) remains an open research problem. This project will be the opportunity to gather researchers from different communities, i.e., medical imaging, hyperspectral imaging and statistical signal processing, with the main objective of bringing CS closer to hyperspectral and medical imaging by developing new methodological approaches meeting the practical constraints specific to each application.

A6	Scientific coordinators at each institution			
	South America A		South America B	
	Institution	Pontificia Universidad Catolica del Peru	Institution	Universidad Industrial de Santander
	Project coordinator	Ph.D. Paul Rodriguez	Project coordinator	Ph.D. Henry Arguello
	Address	Av. Universitaria 1801 San Miguel, Lima 32 Lima, Peru	Address	Carrera 27 Calle 9 Ciudad Universitaria LP 333 Bucaramanga, Colombia
	Phone/Fax	+511 626 2000 ext 4681	Phone/Fax	+57-7-6344000 Ext. 2676
	Email	prodrig@pucp.edu.pe	Email	henarfu@uis.edu.co
	France A		France B	
	Institution	Institut de Recherche en Informatique de Toulouse (IRIT)	Institution	
	Project coordinator	Pr. J.-Y. Tourneret	Project coordinator	
	Address	ENSEEIHT, 2 rue Camichel 31071 Toulouse Cedex 7, France	Address	
	Tel/Fax	+33 5 34 32 22 24	Tel/Fax	
	Email	jean-yves.tourneret@enseeiht.fr	Email	

A7	Other participating institutions	
	In South America	**In France**

A8	List of expected participants (name and affiliation and status : junior, senior)
	IRIT: Seniors Dr. Adrian Basarab (Medical Imaging) Pr. Jean-Yves-Tourneret (Signal processing) Juniors PhD students who might participate to the project Nora Ouzir, working on dictionary learning for medical imaging Julien Lesouple, working on compressed sensing techniques for navigation UIS: Seniors Dr. Henry Arguello (Hyperspectral imaging) Juniors Claudia V. Correa, working on compressive spectral imaging PUCP: Seniors Dr. Paul Rodriguez (Signal Processing) Junior Master students who might participate to the project Jorge Quesada, working on convolutional sparse representations Gustavo Silva, working on convolutional sparse representations

A9	International Project Coordinator (to be chosen among the Scientific Coordinators mentioned in A6)
	Pr. J.-Y. Tourneret

B. Project Details

B1. Project guidelines

The fundamentals of digital signal processing rely on the well-known Shannon sampling theory. This theory states that to recover exactly a bandlimited signal, the sampling rate has to be larger than the Nyquist rate, equal to twice the maximum signal frequency (or more generally twice the difference between the maximum and the minimum signal frequencies). In a number of applications, respecting Shannon theorem requires a huge amount of acquired data (and/or a large number of sensors). Therefore, one conventional approach consists in acquiring all the data and compressing it afterwards. From a practical viewpoint, compressed sensing (CS) theory provides a solution to a basic question: is it possible to acquire only the part of the data that will be kept after the compression step? Introduced in 2006, the CS paradigm guarantees an exact recovery of specific signals from fewer measurements than the number predicted by the Nyquist limit. This guarantee is obtained for sparse signals (or having a sparse representation in a given basis or frame) and is based on incoherent measurements that generalize the concept of samples in the standard sampling scheme. Since its introduction in 2006, CS has received much attention from the scientific community as shown by the impressive number of journal papers, conferences and workshops on this topic. In particular, it has been shown that several applications can benefit from CS, such as image and video processing, communications, radar, biology or astronomy.

The three main concepts of CS applied to image acquisition are

- *Sparsity*. The images to be acquired should have a sparse representation in a given basis. In other words, the images should be compressible via transforms such as wavelet or DCT.

- *Incoherent sampling*. Contrary to standard sampling, a measurement in the sense of CS contains information about several image pixels. Ideally, each measurement should be a linear combination of all the image pixels with random weights. The idea behind this random choice of the measurements is to introduce noise-like interferences in the sparse representation of the signal to be recovered.

- *Image reconstruction*. A non-linear numerical optimization technique is needed in order to recover the image of interest from sparse measurements. Generally, this numerical optimization algorithm is trying to make the best compromise between minimizing a data fidelity term and exploiting the sparsity of the image to reconstruct.

Despite the solid theoretical background of CS, its application to practical image processing problems (such as those related to hyperspectral and medical imaging addressed in this project) remains an open research problem. Several questions are still open and will be investigated in this project in collaboration between the research teams involved. More precisely, the problems investigated in this project include

- Determining the optimal sparse representation by taking into account the *a priori* knowledge about the physical phenomena related to the image modalities.
- Designing the optimal incoherent patterns coupling the sampling requirements imposed by CS with the physical characteristics of the imaging systems.

- Finding the optimal reconstruction strategy adapted to the sparse representations and measurement patterns used in a given imaging application.
- The use of the CS measurements in image processing applications prior to the reconstruction of fully sampled images.

Therefore, the project targets methodological research in statistical modeling, development of signal and image processing algorithms, and the evaluation of these algorithms in specific applications related to hyperspectral and medical imaging. This project will be the opportunity to gather researchers from different communities, i.e., medical imaging, hyperspectral imaging and statistical signal processing.

B2. Project description

Goals

The main objective of this project is to bring CS closer to hyperspectral and medical imaging by developing new methodological approaches meeting the practical constraints specific to each application.

Methodology

Sparse signal processing and compressed acquisition schemes

Sparsity is at the core of the methodological aspects that will be developed in this project. The key idea is that many natural signals and images can be reconstructed faithfully from a much smaller number of transformed coefficients than the original number of samples (i.e., samples acquired according to the Nyquist theorem). The choice of the transformation, which defines the new representation space, is of course important. Two strategies will be investigated in this project

- Signal representations can be constructed using predefined bases such as wavelets, curvelets or contourlets. These representations have emerged and have enabled the design of powerful algorithms for signal processing and information extraction. For instance, the importance of these representations has led to powerful wavelet-based image denoising or compression methods [Mall-99].
- In addition to signal representations constructed from fixed predefined bases, the use of adaptive transforms learnt from the data is also interesting. These transforms can be obtained from so-called dictionary learning methods that are receiving a considerable attention in the literature [Tosi-11].

A projection matrix $\mathbf{\Psi}$ is used to represent the image of interest $\mathbf{f}$ in the transformed domain using the relation $\mathbf{f} = \mathbf{\Psi\theta}$, where $\mathbf{\theta}$ is a sparse vector. A sensing matrix $\mathbf{H}$ is then used to form the compressed sensing (CS) measurements $\mathbf{y} = \mathbf{H\Psi\theta} + \mathbf{n}$, where $\mathbf{n}$ is the additive noise modeling representation errors. Different classes of imagers have been considered in the literature leading to different structures of the sensing matrix $\mathbf{H}$. In this project, we will consider compressive spectral imagers based on spatial coding (such as the coded aperture snapshot spectral imager (CASSI) [Waga-08] [Arg-2014]) or on spectral coding (such as the spatio spectral encoded compressive spectral imager (SSCSI [Lin-14]).

Image reconstruction

The classical way of reconstructing the unknown image from CS measurement is to solve the following inverse problem

$$\text{argmin}_{\boldsymbol{\theta}} ||\mathbf{H}\boldsymbol{\Psi}\boldsymbol{\theta} - \mathbf{y}||_2 + \tau\, \varphi(\boldsymbol{\theta})$$

where $\varphi(\boldsymbol{\theta})$ is an appropriate regularization term. Several regularization will be investigated in this project including the l_1 or l_p norms.

Design of the sensing matrix

The design of the sensing matrix $\mathbf{H}$ is important and can have a significant on the performance of the reconstruction algorithm. HyperMed will try to answer the following question: how to design the structure of the compressive imaging matrix to ensure that it preserves the information contained in medical or hyperspectral images? A strategy for optimizing the pseudorandom structure of the sensing matrix will be developed. It will take into account on one hand the constraints related to the application and on the other hand the structure needed to optimize the image reconstruction process.

Analysis of multi-temporal images

We propose in this last workpackage to take advantage of the work conducted in video processing to extract information from multi-temporal images. Video background modeling is a ubiquitous pre-processing step in several computer vision applications, used to detect moving objects in digital videos. There are several models for this task based on mixtures of Gaussians, subspace learning, fuzzy logic or robust PCA. While in the past ten years this area has been very active, both in number of publications and in leading competing methods, it is becoming apparent that the robust PCA (RPCA) model, which includes the principal component pursuit (PCP) method has becomes the state-of-the-art approach in terms of accuracy and computational complexity (e.g., due to recent advances in incremental / online approaches) [Bouw-14,17].

In its original formulation, PCP is defined as the optimization problem

$$\text{argmin}_{\mathbf{L},\mathbf{S}} ||\mathbf{L}||_N + ||\mathbf{S}||_1 \;\; s.t.\, \mathbf{D} = \mathbf{L} + \mathbf{S} \qquad (1)$$

where the matrix **D**, with m rows and n columns, is the observed video of n frames, each of size m = Nr×Nc×nDims (number of rows, columns and dimensions of each frame), $||\cdot||_N$ is the nuclear norm, $||\mathbf{S}||_1$ is the l_1-norm of the matrix **S** concatenated in a long vector, the matrix **L** represents the background and the matrix **S** is associated with the foreground or moving objects.

Typical solutions to (1), including the Augmented Lagrange Multiplier (ALM) and inexact ALM (iALM) algorithms [Liu-10][Lin-11], are inherently batch methods, which require a large number of frames to be observed before starting any processing. Furthermore, the computational cost of most batch PCP algorithms is dominated by a partial SVD computation at each outer loop, with a cost of $O(m \times n \times r)$, where $r = \text{rank}(\mathbf{L})$. As a consequence, these types of algorithms are unsuitable for online / real-time processing.

In this project we propose to perform the background estimation in the CS domain. For that purpose we will use the CS measurements as the input to the PCP problem (matrix **D** in (1)). In order to achieve online / real-time processing capabilities, we will solve (1) via the incremental PCP algorithm [Rodr-16] since it can processes one frame at a time, obtaining similar results to standard batch PCP algorithms, while being able to adapt to changes in the background. Moreover, this kind of algorithm has an extremely low memory footprint, and a computational complexity that allows real-time processing.

Given the background estimation (CS domain) further processing can be performed such as motion estimation, object recognition / classification, etc, with the added advantage of applying such methods specifically for the moving objects, for instance see [Otaz-15][Teja-17].

Finding the optimal reconstruction strategy adapted to the sparse representations and measurement patterns used in a given imaging application

Inverse problems with sparsity constrains, such as Basis Pursuit denoising (BPDN), Compressive Sensing (CS) and Convolutional BPDN (CBPDN), usually use the l_1-norm as the penalty function. However such choice leads to a solution that is biased towards zero. Recently, several works [Voro-13, Kowa-14, Sele-14, Bayr-16, Rodr-17] have proposed and assessed the properties of other non-standard penalty functions (most of them being non-convex), which avoid the above mentioned drawback and at the same time are intended to induce sparsity more strongly than the l_1-norm. However these works have been mainly focused on the BPDN problem.

Applications to medical imaging

One originality of this project also consists of gathering people having worked in the area of inverse problems for different signal and image processing applications. More precisely, the Colombian team and part of the French team have been involved in hyperspectral imaging. Another part of the French team has been working in the field of medical imaging but with less knowledge in hyperspectral images. The different modalities that we plan to study in this project are summarized below.

Ultrasound imaging (USI)

Ultrasound imaging (USI) is one of the most popular medical imaging techniques. Image acquisition in real time is the main advantage of USI with respect to other classic medical imaging techniques such as magnetic resonance imaging, nuclear medicine or computed tomography. USI has been established as a technology with a proven impact and potential in clinical settings. However, despite its benefits in terms of cost, size, safety, and ease of use, current US technology is still unable to support the level of sensitivity, specificity and dynamics that some competing technologies offer. Moreover, the recent developments in 3D imaging devices allow large amounts of data to be accessed, whose processing could compromise the real-time specificity of ultrasound imaging. A major objective of our project will be to investigate CS-based methods for faster USI and in particular for real-time 3D USI. It is important to note here that this kind of method has received few attention in the literature [Lieb-12].

Quantitative acoustic microscopy (QAM)

Quantitative acoustic microscopy (QAM) employs very high-frequency ultrasound (>250 MHz) to examine thin (< 10 μm) *ex vivo* tissue sections as well as fresh *ex vivo* bulk tissues. QAM processes raw ultrasound data to produce quantitative, ultra-fine-resolution (< 7 μm) 2D maps of acoustical properties (e.g., speed of sound and acoustic impedance) and mechanical properties (e.g., bulk modulus). QAM provides novel information that is complementary to information provided by other microscopy modalities. QAM can fill an important knowledge gap that currently limits our understanding of the etiology of many diseases. Several limitations prevent the widespread acceptance and use of current commercially available QAM systems. One of them is related to the scanning time, which is directly dependent on the sample size and can range from few minutes to hours. In order to maintain constant experimental conditions for the sensitive thin sectioned samples, the scanning time is an important practical issue. Hence, one of the objectives of this project is to reduce the scanning time by reconstructing QAM images from spatially under sampled measurements, based on the theory of CS.

Applications to hyperspectral imaging

Hyperspectral imaging involves the sensing of a large amount of spatial information across a multitude of wavelengths. Conventional approaches scan adjacent zones of the spectral scene and merge the results to construct a spectral datacube. Push broom spectral imaging sensors, for instance, capture a spectral cube with one focal plane array (FPA) measurement per spatial line of the scene. Spectrometers based on optical band-pass filters sequentially scan the scene by tuning the band-pass filters in different steps. The disadvantage of these techniques is that they require scanning a number of zones linearly in proportion to the desired spatial and spectral resolution.

Compressive spectral imagers (CSI) comprise the new generation of hyperspectral imagers, as they naturally embody the principles of compressive sensing (CS). The remarkable advantage of CSI is that the entire hyperspectral datacube is sensed using just a few measurements, then enabling real-time video-rate acquisition, highly important for sensing dynamic scenes. To make this possible, CSI rely on sparsity, which characterizes the spectral scenes of interest, and incoherence, which shapes the sensing structure. Sparsity indicates that spectral images found in nature can be concisely represented in some basis, with a limited number of coefficients. This is indeed the case in hyperspectral imaging where natural scenes exhibit correlation among adjacent pixels and also across spectral bands. Incoherence refers to the structure of the sampling waveforms used in CS, which, unlike the signals of interest, have a dense representation in the basis.

The remarkable discovery behind CS is that it is possible to design sensing protocols capable of capturing the essential information content in sparse signals with just a small number of compressive measurements. The signals of interest are then accurately reconstructed from the small number of compressive measurements by numerical optimization. Hence, one of the objectives of this project is to study the switch from spectral scanning sensing mechanisms to compressive snapshot sensing mechanisms, in order to reduce the time required to capture hyperspectral imagery, thus enabling the sensing of dynamic scenes with rich spectral information, by reconstructing them from highly under sampled linear measurements, using the CS theory.

References

[Mall-99] S. Mallat, A wavelet tour of signal processing, 2nd ed. Academic press, 1999.

[Tosi-11] I. Tosic and P. Frossard, Dictionary learning, IEEE Transactions on Signal Processing, vol. 28, no. 2, pp. 27–38, 2011.

[Waga-08] A. A. Wagadarikar, R. John, R. Willett, and D. Brady, Single disperser design for coded aperture snapshot spectral imaging, Appl. Opt., vol. 47, no. 10, pp. B44– B51, 2008.

[Arg-14]] H. Arguello and G. R. Arce, Colored coded aperture design by concentration of measure in compressive spectral imaging, IEEE Transactions on Image, Processing, vol. 23, no. 4, pp.1896 - 1908, 2014

[Lin-14] X. Lin, Y. Liu, J. Wu and Q. Dai, Spatial-spectral encoded compressive hyperspectral imaging, ACM Transactions on Graphics, vol. 33, no. 6, 233, 2014.

[Lieb-12] H. Liebgott, A. Basarab, D. Kouame, and D. Friboulet, Compressive sensing in medical ultrasound, IEEE International Ultrasonics Symposium, 2012.

[Bouw-14] T. Bouwmans and E. Zahzah, Robust PCA via principal component pursuit: A review for a comparative evaluation in video surveillance, Computer Vision and Image Understanding, vol. 122, pp. 22–34, 2014.

[Bouw-17] T. Bouwmans, A. Sobral, S. Javed, S. Jung, and E. Zahzah, Decomposition into low-rank plus additive matrices for background/foreground separation: A review for a comparative evaluation with a large-scale dataset, Computer Science Review, vol. 23, pp. 1 – 71, 2017.

[Rodr-16] P. Rodriguez and B. Wohlberg, Incremental principal component pursuit for video background modeling, J. of Math. Imag. and Vis., vol. 55, no. 1, pp. 1–18, 2016.

[Liu-10] G. Liu, Z. Lin, and Y. Yu, Robust subspace segmentation by low-rank representation., Int. Conf. Mach. Learn. (ICML), pp. 663–670, 2010.

[Lin-11] Z. Lin, M. Chen, and Y. Ma, The augmented lagrange multiplier method for exact recovery of corrupted low-rank matrices, arXiv:1009.5055v2, 2011.

[Otaz-15] R Otazo, E Candès and D. K. Sodickson, Low rank plus sparse matrix decomposition for accelerated dynamic MRI with separation of background and dynamic components, Magnetic

Resonance in Medicine, vol. 73 (3), pp. 1125-1136, 2015.

[Rodr-17] E. Tejada and P. Rodríguez, Moving Object detection in videos using Principal Component Pursuit and Convolutional Neural Networks, submitted to International Conference on Computer Vision (ICCV), Oct. 2017.

[Voro-13] S. Voronin and H. Woerdeman, A new iterative firm-thresholding algorithm for inverse problems with sparsity constraints, Applied and Computational Harmonic Analysis, vol. 35, no. 1, pp. 151 – 164, 2013.

[Kowa-14] M. Kowalski, Thresholding rules and iterative shrinkage/thresholding algorithm: A convergence study, IEEE International Conference on Image Processing (ICIP), pp. 4151–4155, Oct. 2014.

[Sele-14] I. Selesnick and I. Bayram, Sparse signal estimation by maximally sparse convex optimization, IEEE Transactions on Signal Processing, vol. 62, no. 5, pp. 1078–1092, March 2014.

[Bayr-16] I. Bayram, On the convergence of the iterative shrinkage/thresholding algorithm with a weakly convex penalty, IEEE Transactions on Signal Processing, vol. 64, no. 6, pp. 1597–1608, March 2016.

[Rodr-17] P. Rodríguez, "A Two-term Penalty Function for Inverse Problems with Sparsity Constrains", submitted European Signal Processing Conference (EUSIPCO), (Kos Island, Greece), August 2017.

[Duch-08] J. Duchi, S. Shalev-Shwartz, Y. Singer, and T. Chandra, Efficient projections onto the l1-ball for learning in high dimensions, Int'l Conf. on Machine Learning, pp. 272–279, 2008.

[Cond-16] L. Condat, "Fast projection onto the simplex and the 1 ball," Mathematical Programming, vol. 158, no. 1, pp. 575–585, 2016.

[Yang-10] J. Yang, K. Yu, and T. Huang, "Supervised translation-invariant sparse coding," in IEEE Conference on Computer Vision and Pattern Recognition (CVPR), June 2010, pp. 3517–3524.

[Zeil-10] M. Zeiler, D. Krishnan, G. Taylor, and R. Fergus, Deconvolutional networks, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 2528–2535, 2010.

[Riga-13] R. Rigamonti, A. Sironi, V. Lepetit, and P. Fua, Learning separable filters, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 2754–2761, 2013.

[Siro-15] A. Sironi, B. Tekin, R. Rigamonti, V. Lepetit, and P. Fua, Learning separable filters, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 37, no. 1, pp. 94–106, Jan. 2015.

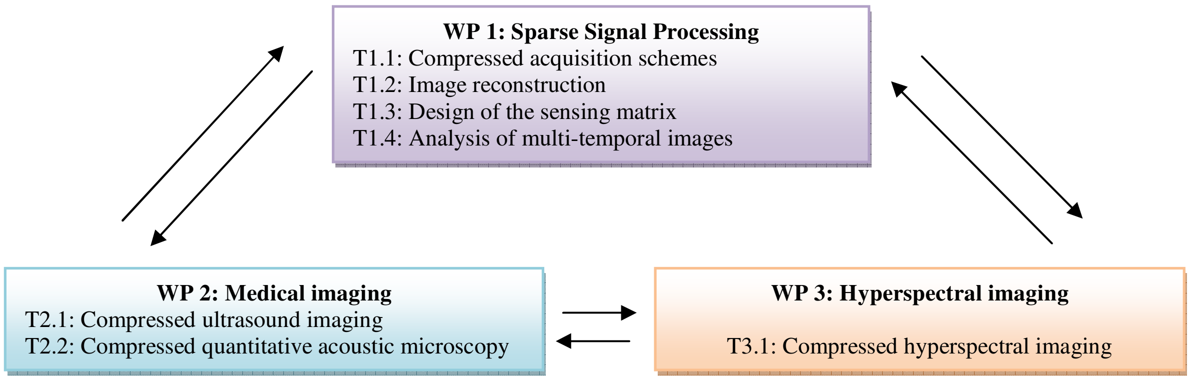
[Naka-15] Y. Nakatsukasa, T. Soma, and A. Uschmajew, Finding a low-rank basis in a matrix subspace, A. Math. Program, pp. 162-325, 2017.

[Rodr-16] P. Rodriguez, Alternating optimization low-rank expansion algorithm to estimate a linear combination of separable filters to approximate 2d filter banks, IEEE Asilomar Conference on Signals, Systems and Computers, Nov. 2016.

[Silv-17] G. Silva, J. Quesada, P. Rodríguez and B. Wohlberg, Fast Convolutional Sparse Coding with Separable Filters, IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), (New Orleans, LA, USA), March 2017.

Project tasks

We propose to structure the HyperMed project into three workpackages with high interactions, each of them divided in several tasks, as highlighted by the schematic view below.



T1.1. Compressed acquisition schemes			
Participants:	UiS (coordinator)	IRIT	PUCP
Description	Compressed acquisition schemes adapted to each application addressed by HyperMed will be considered. - Ultrasound imaging. In order to decrease the acquisition time, plane wave emissions will be used, instead of standard focused waves. - Acoustic microscopy. The signal will be sampled at the innovation rate based on the theory of finite rate of innovation. - Hyperspectral imaging. CASSI system will be considered.		
Output:	Technical reports explaining the compressive acquisition framework used by HyperMed.		

T1.2. Image reconstruction			
Participants:	PUCP (coordinator)	IRIT	UiS
Description	Medical or hyperspectral image reconstruction from compressed measurements requires algorithms able to minimize convex or non-convex functions. HyperMed project will address this task by exploring numerical optimization routines, stochastic optimization methods and hybrid techniques combining the advantages of each class of algorithms.		
Output:	Technical reports, journal and conference papers at the end of each year. Image reconstruction software.		

T1.3. Design of the sensing matrix			
Participants:	UiS (coordinator)	PUCP	
Description	Compressed acquisition modeling depends on the actual sensing devices. HyperMed project will explore compressed acquisition schemes in medical and hyperspectral imaging to provide mathematical models that represent the underlying sensing phenomena.		
Output:	Mathematical models for compressed acquisition that will serve as input for image reconstruction (Task 1.2)		

T1.4. Analysis of multi-temporal images			
Participants:	PUCP (coordinator)	IRIT	UiS
Description	Usually, based on the CS reconstruction, further processing (e.g. motion estimation, etc.) is performed. HyperMed project will explore to first perform the background estimation in the CS domain, to then post-process only the moving objects.		
Output:	Technical reports, journal and conference papers at the end of each year. Background modeling software applied to medical and hyperspectral imaging.		

T2.1. Compressed ultrasound imaging			
Participants:	IRIT (coordinator)		
Description	The application of CS framework to US imaging is very challenging and involves knowledge from different fields, from applied mathematics to US instrumentation. Several theoretical and practical outputs from tasks in WP 1 will be used to: - Generate compressed ultrasound measurements; - Reconstruct 2D and 3D ultrasound images from compressed measurements; - Compare the quality of reconstructed images to fully-sampled data.		
Output:	Technical reports, journal and conference papers at the end of each year. Simulation and experimental results of compressed USI.		

T2.2. Compressed quantitative acoustic microscopy			
Participants:	IRIT (coordinator)		
Description	CS methods designed in WP 1 will be applied to biological samples to assess fully and demonstrate clearly the applicability and significance of our methods. QAM imaging studies will be performed using thin sections harvested from cancerous human lymph nodes and using fresh *ex vivo* tissue obtained from normal and glaucomatous rat eyes. QAM data will be made available by Riverside Research.		
Output:	Technical reports, journal and conference papers at the end of each year. Simulation and experimental results of compressed QAM.		

T3.1. Compressed hyperspectral imaging			
Participants:	UiS (coordinator)	IRIT	
Description	The methods developed in WP 1 will be used in compressive imaging sensors to: • Acquire compressive hyperspectral measurements • Reconstruct ground truth spatial and spectral information • Evaluate reconstruction quality with respect to state of the art methods		
Output:	Technical reports, journal and conference papers. Simulation and experimental results of evaluation of the proposed toolbox on compressive spectral imaging sensors.		

Project scope

The project will produce three main reusable technical deliverables:

1. A toolbox of CS algorithms adapted to medical and hyperspectral imaging. This software platform will integrate the methods developed in WP 1 and will include algorithms for designing optimal sampling patterns, statistical modeling and image reconstruction routines.

2. Technical reports on compressed medical imaging. One report per medical imaging modality will be provided, detailing the CS procedure adapted to each specific modality. The reports will include simulation and experimental results, as well as quantitative measurements proving the quality of medical images reconstructed from compressed measurements compared to the standard fully-sampled images.

3. Technical reports on compressed hyperspectral imaging, including a complete framework for practical compressed acquisition, optimization of sensing matrices and image reconstruction from compressed measurement.

Expected results

The results will be published in journal papers and presented in international conferences. A ratio of one journal paper for two conference proceedings will be considered. Given the multidisciplinary nature of the project, a large spectra of journals and conferences will targeted.

Sparse signal processing (WP 1)

2 papers in IEEE Trans. on Image processing

4 conference papers in IEEE Int. Conference on Image Processing, IEEE Int. Conference on Acoustics, Speech and Signal Processing

Medical imaging (WP 2)

2 papers in IEEE Trans. on Medical Imaging, IEEE Trans. on Ultrasonics, Ferroelectrics, and Frequency Control

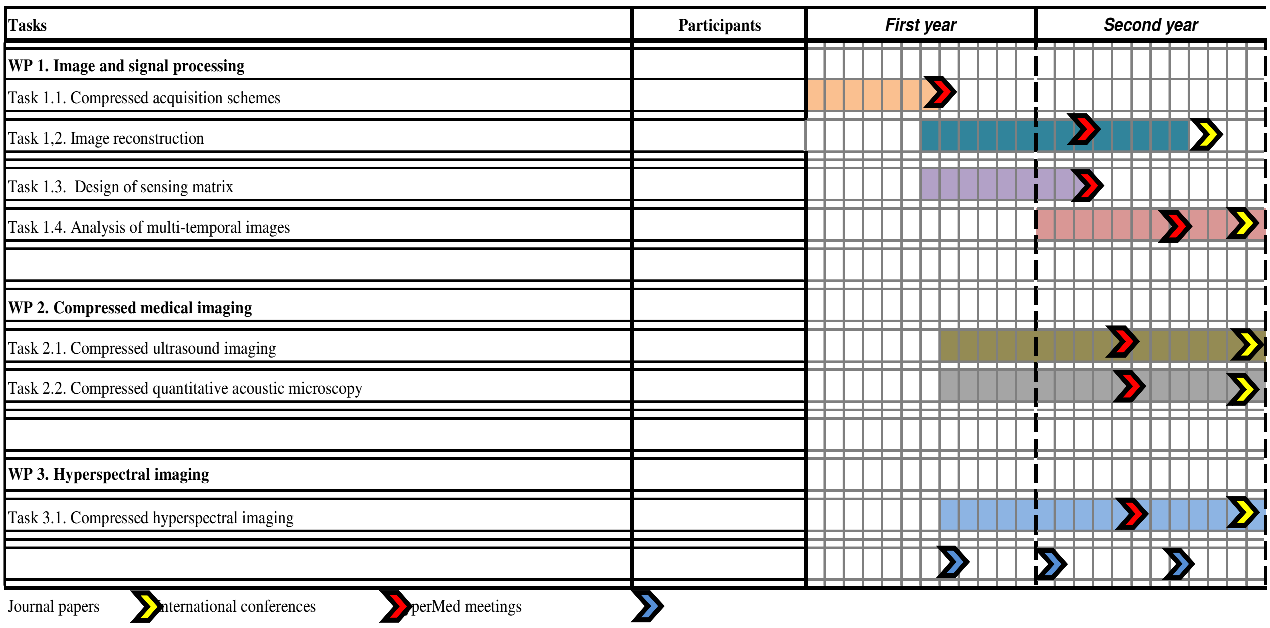
2 conference papers in IEEE Int. Symposium on Biomedical Imaging, IEEE Ultrasonics Symposium

Hyperspectral imaging (WP 3)

1 paper in a renowned journal

1 conference paper in a scientific event

B3. Schedule, with main execution stages



B4. Contributions

Present contributions so as to highlight the role of each partner and the integration among partners.

Statistical signal processing, image reconstruction, inverse problems

Jean-Yves Tourneret has been working intensively on the development of Bayesian methods for image processing applications, with a specific interest for remote sensing images. In particular, he has investigated several methods for the unmixing of hyperspectral images. This unmixing operation is important since several pure components are usually present in a given pixel of a hyperspectral image, due to their limited resolution. Unmixing strategies are based on linear and non-linear models and use Monte Carlo or optimization methods. Jean-Yves Tourneret has acquired a strong knowledge in the area of Markov chain Monte Carlo methods (Gibbs sampler, Metropolis Hastings, particle filters, …) that can be useful for this study. He has also important contributions in the field of change detection for remote sensing images. He has studied interesting strategies exploiting the statistical properties of these images to detect changes between optical and radar images. Finally, He has recently participated to several studies related to the fusion of multi-resolution images, including panchromatic, multispectral and hyperspectral images. Most of the methods used to address these unmixing, change detection and fusion problems solve linear or non-linear inverse problems adapted to these images. The generalization of these methods to the analysis of medical images is one of the objectives of this project.

For the last 12 years, Paul Rodriguez has been working on image reconstruction and inverse problems with emphasis on the development of computational efficient algorithms. In particular Dr. Rodriguez has focused on (TV) Total Variation (2005-2013), (PCP) Principal Component Pursuit (2013-onwards) and (CSR) Convolutional Sparse Representation (2016-onwards); as a result of these works, novel optimization algorithms have been introduced to solve the TV, PCP and CSR problems; furthermore, a patent (related to PCP) has been recently awarded to Dr. Rodriguez. Dr. Rodriguez´s experience on background modeling and optimization techniques will benefit HyperMed in development of efficient procedures for the analysis of medical images.

Ultrasound imaging

Despite promising preliminary results, only a few research teams in the world are now working on the application of compressive sampling to US imaging, with IRIT (Dr. A. Basarab) being among the pioneers in this area. The main contribution of IRIT in this area will be: i) to bring to the project its knowledge about the physics of ultrasound and the technical constraints of USI, and ii) to ensure the availability of ultrasound data.

Quantitative acoustic microscopy

Dr. A. Basarab started one year ago a collaborative study with Riverside Research, NYC, USA, who is worldwide leader in medical QAM, disposing of two scanners at 250 MHz and 500 MHz. We demonstrated the potential use of CS to reduce spatial sampling in QAM. The study was accepted for presentation at the Ultrasonic Imaging and Tissue Characterization Symposium in 2017. This collaboration will benefit to HyperMed project by making available QAM data, in general very difficult to obtain, considering the only few existing QAM scanners worldwide and the very specific acquisition conditions.

Hyperspectral imaging

During the last seven years, Dr. Henry Arguello has been working on compressed sensing for hyperspectral imaging. His work has focused on coded aperture-based compressive spectral imaging systems, specifically, on designing the coded aperture patterns for these systems, such that compressed sensing principles are better satisfied. As a result of this work, different coded aperture types have been developed, including: coded apertures for spectral selectivity that recover subsets of spectral bands of interest; coded aperture design for super-resolution; block-unblock and colored coded apertures that enhance reconstruction quality. Dr. Arguello has also worked on spectral image classification from coded aperture compressive measurements, and a computational block/separable reconstruction approach. Dr. Arguello´s experience on hyperspectral imaging will benefit HyperMed in the integration of the proposed methodologies for this particular application.

B5. Regional Aspects

The research projects and work packages proposed by HyperMed cover several aspects running from theoretical developments in signal and image processing to medical and hyperspectral instrumentation. HyperMed project will create multidisciplinary environments where the research will be at the borders among medical and hyperspectral imaging, signal and image processing and practical applications. Mixing different skills in applied mathematics, physics, signal and image processing will provide a major opportunity to tackle many challenges in compressed medical and hyperspectral acquisitions. The young researchers involved in HyperMed, as well as other PhD students from each of the three participating institutions, will have the opportunity to participate both in cutting-edge research and in its application to challenging, specific and real problems. In addition, the collaborative work in the context of HyperMed will create strong links between the fellows and senior researchers that will be maintained long beyond the end of the contract. Such a solid network of professionals is an essential tool for excellent research and successful professional career of the young researchers participating in HyperMed.

B6. Institutions and CVs of coordinators

IRIT - University of Toulouse

IRIT (Institut de Recherche en Informatique de Toulouse) is a research institute in computer science and engineering. It is a joint research unit between CNRS and the University of Toulouse. IRIT has about 700 people including researchers and support staff working on 7 research themes covering different computer science disciplines and fields. Theme one is dedicated to studies in information analysis and synthesis. The group of this theme involved in HyperMed project is called Image Processing and Analysis. It is focused on one hand on statistical signal processing including image restoration and inverse problems and on the other hand on medical imaging.

Universidad Industrial de Santander (UIS)

UIS is a public university whose main campus is located in Bucaramanga, Colombia. It is one of the leading higher education institutions in the country, and is composed by five different colleges: Physical-Mechanical Engineering, Physical-Chemical Engineering, Basic Sciences, Medical Sciences and Humanities. In particular, the college of Physical-Mechanical Engineering, to which Dr. Henry Arguello is affiliated, offers 7 undergraduate, 17 masters, and 4 doctorate programs. Thus, this college covers a wide range of research areas related to the offered programs: Electrical Engineering, Electronics Engineering, Computer Science, Mechanical Engineering, Civil Engineering, Industrial Design, and Industrial Engineering.

Pontificia Universidad Catolica del Peru (PUCP)

PUCP is a private university located in Lima, Peru. PUCP is the leading higher education institution in Peru and one of the leading universities in South-America (ranking number 18, QS World University Rankings 2015-2016). PUCP is home to more than 20,000 undergraduate students and has eleven Schools, among them the School of Science and Engineering (SoCE). The SoCE-PUCP offers several undergraduate engineering and science related programs (fourteen in total), such as Electrical Engineering, Mechanical Engineering, Civil Engineering, Industrial Engineering, etc., as well as graduate programs (most of them are master level). Dr. Rodriguez is affiliated with the Department of Electrical Engineering as well as with the Master program on Digital Signal and Image Processing.

CV – Jean-Yves TOURNERET

1/ Personal data

Name: Jean-Yves Tourneret
Birth date: August 7, 1965
Professional address (with telephone and e-mail):
ENSEEIHT, 2 Rue Camichel, 31071 Toulouse cedex 7 France
Tel +33 5 34 32 22 24
E-mail: jean-yves.tourneret@enseeiht.fr
Current job title and size of the research group:
Full Professor in Computer Science at University of Toulouse**,** Research activities in statistical signal and image processing in IRIT UMR CNRS 5505 Laboratory (more than 700 people), Toulouse, France.

2/ Highest obtained degree (with indication of place and date)

1998 Habilitation to conduct researches, March 1998, University of Toulouse, France.
1992 PhD Thesis, University of Toulouse, France.

3/ Professional activity in the last 5 years

2002 Full professor, University of Toulouse
1993 Assistant Professor, University of Toulouse

4/ Other duties/ positions

None

5/ Awards, fellowships and external recognition

- Member of the Signal Processing Theory and Methods (SPTM) committee of the IEEE Signal Processing Society (2001-2007, 2010-2015).
- Associate editor for the IEEE Transactions on Signal Processing (2008-2011, 2015-present) and for the EURASIP journal on Signal Processing (2013-present)
- Best paper award, H. Wendt, P. Abry, S. McLaughlin et J.-Y. Tourneret, "Bayesian Estimation for the Local Assessment of the Multifractality Parameter of Multivariate Time Series", Proc. of 24th Conf. on Sig. Proc. (EUSIPCO'16), Budapest, Hungary, Aug. 29 – Sept. 2, 2016.
- Best Student paper award for one of my students, Chao LIN for the paper C. Lin, A. Giremus, C. Mailhes and J. Y. Tourneret, "Beat-to-beat P and T Wave Delineation in ECG Signals Using a Marginalized Particle Filter", Proc. of 19th Conf. on Sig. Proc. (EUSIPCO'12), Bucharest, Romania, Aug. 27-31, 2012.
- Best paper award for the paper Y. Altmann, N. Dobigeon, S. McLaughlin and J.-Y. Tourneret, "Unsupervised nonlinear unmixing using Gaussian processes," Proc.of IEEE GRSS Workshop on Hyperspectral Image and SIgnal Processing: Evolution in Remote Sensing (WHISPERS), Gainsville, Florida, June 25-28, 2013.
- IEEE Senior Member : March 2008.

6/ Ongoing funded research projects with dates, titles, sources of funding

2016-2017 Asymmetric generalized Gaussian distributions for image processing, CNES funding, 50kEuros, PI.

2016-2017 Development of machine learning techniques for the classification of data flows, Thales Alenia Space funding, 30 kEuros.

7/ Projects approved in the least 5 years

Several projects in the frame of the TeSA laboratory for industrial partners such as CNES, Thales Alenia Space, Rockwell Collins …

8/ Publications

8.1 – Highlight the most important publications related to the project theme

P. Chen, J. D. B. Nelson and J.-Y. Tourneret, "Towards a Sparse Bayesian Markov Random Field Approach to Hyperspectral Unmixing and Classification," IEEE Trans. Image Process., vol. 26, no. 1, pp. 426-438, Jan. 2017.
F. Costa, H. Batatia, T. Oberlin, C. D'Giano and J.-Y. Tourneret, "Bayesian EEG Source Localization Using a Structured Sparsity Prior," Neuroimage, vol. 144, Part A, pp. 142-152, Jan. 2017.
J. Prendes, M. Chabert, A. Giros, F. Pascal and J.-Y. Tourneret, "A Bayesian Nonparametric Model Coupled with a Markov Random Field for Change Detection in Heterogeneous Remote Sensing Images," SIAM Journal on Imaging Sciences, vol. 9, no. 4, pp. 1889-1921, 2016.
Q. Wei, J. Bioucas-Dias, N. Dobigeon, J.-Y. Tourneret, M. Chen and S. Godsill, "Multi-band Image Fusion Based on Spectral Unmixing", IEEE Trans. Geosci. Remote Sensing, vol. 54, no. 12, pp. 7236-7249, Dec. 2016.
N. Zhao, A. Basarab, D. Kouamé, J.-Y. Tourneret, "Joint Segmentation and Deconvolution of Ultrasound Images Using a Hierarchical Bayesian Model based on Generalized Gaussian Priors", IEEE Transactions on Image Processing, vol. 25, no. 8, p. 3736-3750, 2016.
N. Zhao, Q. Wei, A. Basarab, N. Dobigeon, D. Kouamé, J.-Y. Tourneret, "Fast Single Image Super-resolution using a New Analytical Solution for l_2-l_2Problems", IEEE Transactions on Image Processing, vol. 25 no. 8, p. 3683-3697, 2016.

9/ Theses oriented and post-doctoral fellows supervised

9.1 – Finished/defended in the last 2 years

Facundo Costa (50%), Bayesian M/EEG source localization with possible joint estimation of the skull conductivity, March 2014 to March 2017, Co-advisor: Hadj Batatia (50%) (IRIT, University of Toulouse).
NingNing Zhao (33%), Inverse problems in medical ultrasound images, Oct. 2013 to 20 Oct. 2016, Co-advisors: D. Kouamé (33%) and A. Basarab (33%) (IRIT, University of Toulouse), Chinese Scholarship Council (CSC).
Sébastien Combrexelle (33%), Multifractal analysis for multivariate data with application to remote sensing, Oct. 2013to 12 Oct. 2016, Co-advisors: H. Wendt (IRIT, University of Toulouse, 33%) and Steve McLaughlin (Heriot-Watt University), Funded by DGA/DSTL.
Mohanad Albughdadi (50%), Bayesian joint detection-estimation in functional MRI with automatic parcellation and functional constraints, Sept. 2013 to 16 Sept. 2016, Co-advisor: L. Chaari (IRIT, University of Toulouse, 50%).

9.2 – Ongoing

S. Urbano (2016-2019), J. Lesouple (2015-2018), Nora Ouzir (2015-2018), Fabio Manzoni (2014-2017), Matthieu Legoff (2014-2017), Pierre-Antoine Thouvenin (2014-2017).

CV - Adrian Basarab

1/ Personal data

Name: Adrian Basarab
Birth date: October 6, 1981
Professional address (with telephone and e-mail):
Université Paul Sabatier Toulouse 3, IRIT UMR 5505
118 Route de Narbonne
31062 Toulouse cedex 9 France
Tel +33 5 61 55 68 82
E-mail: basarab@irit.fr
Current job title and size of the research group:
Associate Professor in Computer Science at University of Toulouse**,** Research activities in IRIT UMR CNRS 5505 Laboratory (more than 700 people), Toulouse, France.

2/ Highest obtained degree (with indication of place and date)

2016 Habilitation to conduct researches, A few inverse problems in ultrasound imaging, University of Toulouse
2008 PhD Thesis, Motion estimation in ultrasound imaging, INSA-Lyon

3/ Professional activity in the last 5 years

2016 Associate professor, University of Toulouse
2009 Assistant Professor, University of Toulouse

4/ Other duties/ positions

None

5/ Awards, fellowships and external recognition

Best PhD thesis award (Z. Chen, defended in October 2016), IEEE EMBS France Section, 2017
Winner of "Plane wave imaging challenge in ultrasound imaging", IEEE Ultrasonics Symposium, Tours, 2016
Paul Calas award, French Society of Endodontics, 2016
Best student paper finalist, IEEE Ultrasonics Symposium, Taiwan, 2015
Associate Editor of Digital Signal Processing (Elsevier)

6/ Ongoing funded research projects with dates, titles, sources of funding

2016-2017 French national funding, Ultrasound Medical Imaging: from Theory to Applications, 30 kEuros, Role: Research Scientist
2015-2018 University of Toulouse funding, Cardiac motion estimation, 30 kEuros, Role: PI
2015-2018 University of Toulouse funding, Quantum mechanics and signal processing, 30 kEuros, Role: Research Scientist
2016-2019 French national PhD thesis funding, Cardiac motion estimation, 100 kEuros Role: PhD co-supervisor

7/ Projects approved in the least 5 years

2011-2014 French national funding, Tagged ultrasound imaging, 205 kEuros, Role: Research Scientist
2011-2014 University of Toulouse and Midi-Pyrénées Region funding, Ultrasound image enhancement, 110 kEuros, Role: Research Scientist
2011-2014 French national funding, Intercomparision of clinical dosimetry approches in molecular radiotherapy, 150 kEuros, Role: Research Scientist
2013-2016 French national PhD thesis funding, Sparse signal processing-based beamforming methods in ultrasound imaging, 100 kEuros, Role: PhD co-supervisor
2013-2016 Two Chinese Scholarship Council (CSC) PhD thesis funding, 200 kEuros, Role: PhD co-supervisor

8/ Publications

8.1 – Highlight the most important publications related to the project theme

N. Zhao, A. Basarab, D. Kouamé, J.-Y. Tourneret, "Joint Segmentation and Deconvolution of Ultrasound Images Using a Hierarchical Bayesian Model based on Generalized Gaussian Priors", IEEE Transactions on Image Processing, Vol. 25, no. 8, p. 3736-3750, 2016.
N. Zhao, Q. Wei, A. Basarab, N. Dobigeon, D. Kouamé, J.-Y. Tourneret, "Fast Single Image Super-resolution using a New Analytical Solution for l2-l2Problems", IEEE Transactions on Image Processing, Vol. 25 N. 8, p. 3683-3697, 2016.
Z. Chen, A. Basarab, D. Kouamé, "Reconstruction of Enhanced Ultrasound Images From Compressed Measurements Using Simultaneous Direction Method of Multipliers", IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 63 N. 10, p. 1525-1534, 2016.
Z. Chen, A. Basarab, D. Kouamé, "Compressive deconvolution in medical ultrasound imaging", IEEE Transactions on Medical Imaging, Vol. 35, no. 3, p. 728-737, 2016.
A. Achim, A. Basarab, G. Tzagkarakis, P. Tsakalides and D. Kouamé, "Reconstruction of ultrasound RF echoes modelled as stable random variables", IEEE Transactions on Computational Imaging, Vol. 1, no. 2, p. 86-95, June 2015.

8.2 – Publications in cooperation with the project partners

9/ Theses oriented and post-doctoral fellows supervised

9.1 – Finished/defended in the last 5 years

Zhouye Chen (2013-2016, Co-advisor: Denis Kouamé), Teodora Szasz (2013-2016, Co-advisor: Denis Kouamé), Ningning Zhao (2013-2016, Co-advisors: Denis Kouamé and Jean-Yves Tourneret), Rémi Abbal (2010-2014, Co-advisor: Denis Kouamé), Renaud Morin (2010-2013, Co-advisors: Stéphanie Bidon and Denis Kouamé).

9.2 – Ongoing

Rose Sfeir (2015-2018, Co-advisor: Denis Kouamé), Nora Ouzir (2015-2018, Co-advisor: Jean-Yves Tourneret), Jérôme Michetti (2013-2017, Co-advisors: Denis Kouamé and Franck Diemer).

CV - Henry Arguello

1/ Personal data

Name: Henry Arguello, **Birth date:** July 16, 1976

Professional address (with telephone and e-mail): Carrera 27 Calle 9, Ciudad Universitaria, LP 333, Bucaramanga, Colombia. Telephone: +57-7-6344000 Ext. 2676. E-mail: henarfu@uis.edu.co

Current job title and size of the research group: Professor – Department of Computer Science, Universidad Industrial de Santander. Research group composed of nearly 50 people including: Ph.D., Master's and undergraduate students.

2/ Highest obtained degree (with indication of place and date): Ph.D. in Electrical and Computer Engineering – University of Delaware, Newark, DE, USA - 2013

3/ Professional activity in the last 5 years: Professor – Department of Computer Science – Universidad Industrial de Santander, Bucaramanga, Colombia

4/ Other duties/ positions: None

5/ Awards, fellowships and external recognition

- Elevation to IEEE Senior Member – February 2017
- Innovate Award – Challenge: Real-time monitoring of water quality (phenols) in pipelines for discharge and affluents. Ecopetrol-ICP-Unired-UIS – 2016

6/ Ongoing funded research projects with dates, titles, sources of funding

- (2016-2018) Colored coded aperture design for spectral unmixing in compressive spectral imaging of farming produce. Principal investigator.Colciencias-ECOSNORD
- (2016-2017) Mobile app for agricultural technical assistance based on a cloud-computing platform. Co-investigator. Colciencias
- (2016-2017) Efforts for applied research, joint development, incorporation and technology transfer in deep seismic imaging and reliable characterization of seismic anomalies for exploratory problems of Ecopetrol and its business partners. Principal investigator. ECOPETROL
- (2014-2017) Advanced imaging techniques in porous media for the non-intrusive characterization of rock and increase of the recovery factor in heavy crude fields and mature fields of conventional crudes. Co-investigator. ECOPETROL
- (2016-2017) Construction of a high-pressure cell coupled to a spectral measurement system to determine the solubility of naturally occurring molecules in supercritical CO2 from absorbance measurements in UV-VIS spectral range Co-investigator. UIS
- (2016-2017) Grayscale coded aperture optimization to improve the dynamic range of compressive spectral imaging reconstructions. Principal investigator. UIS
- (2016-2017) Design and simulation of an adaptive compressive spectral video sensing system. Principal investigator. UIS
- (2016-2017) Design and simulation of a single pixel compressive computed tomography system. Principal investigator. UIS
- (2015-2017) Design of an X-ray crystallography architecture using coded diffraction patterns. Co-investigator. Colciencias

7/ Projects approved in the least 5 years

- (2016) Real-time monitoring of the phenol concentration in pipelines by means of absorbance measurement in spectroscopy (UV-VIS) for the control of water quality. Principal investigator.
- (2015-2016) Prototype of a center for the analysis of biometric variables of elite athletes with physical, sensory or cognitive limitations. Principal Investigator. Colciencias-Coldeportes
- (2014-2016) Five one-year projects (2 as PI, 3 as Co-PI) related to compressive spectral imaging, funded by UIS.

8/ Publications

8.1 – Highlight the most important publications related to the project theme

- G. R. Arce, D. J. Brady, L. Carin, H. Arguello and D. S. Kittle . "An introduction to compressive coded aperture spectral imaging". IEEE Signal Processing Magazine, USA. Vol. 31, No. 1, pp. 105 - 115, (2014).
- H. Arguello and G. R. Arce. "Colored coded aperture design by concentration of measure in compres- sive spectral imaging". IEEE Trans. on Image Processing. Vol. 23, No. 4, 1896 - 1908, (2014).
- C. V. Correa, H. Arguello, and G. R. Arce. "Spatio-temporal blue noise coded aperture design for multi-shot compressive spectral imaging," Journal of the Optical Society of America JOSA A, Vol. 33, No. 12, 2312 - 2322, (2016).
- H. Rueda, H. Arguello, and G. R. Arce. "Compressive spectral testbed imaging system based on thin-film color-patterned filter arrays," Applied Optics, Vol. 55, No. 33, 9584 - 9593, (2016).
- Ramirez, H. Arguello, G. R. Arce and B. M. Sadler. "Spectral image classification from optimal coded-aperture compressive measurements". IEEE Trans. on Geoscience and Remote Sensing, USA. Vol. 52, No. 6, 3299 - 3309, (2014).

8.2 – Publications in cooperation with the project partners

- O. Espitia, H. Arguello, and J. Y. Tourneret. "High-resolution spectral image reconstruction based on compressed data fusion". IEEE ICIP, Beijing, China (2017).
- Y. Mejia, H. Arguello, F. Costa, J. Y. Tourneret, and H. Batatia. "Bayesian reconstruction of hyperspectral images by using compressed sensing measurements and a local structured prior". IEEE ICASSP, New Orleans, USA (2017).

9/ Theses oriented and post-doctoral fellows supervised

9.1 – MS Theses Finished/defended in the last 5 years: Kareth León (2017); Edson Mojica (2017); Hector Vargas (2016); German Córdoba (2016); Ariolfo Camacho (2016); Nelson Diaz (2015); Diana Galvis (2014); Irene Manotas (2013); Laura Galvis (2013); Sergio Pino (2013); Claudia V. Correa (2013); César Vargas (2012);Hoover F. Rueda (2012); Erwin F. Cardozo (2012).

9.2 – Ongoing Ph.D. Dissertations: Yuri Mejía; Nelson Diaz; Tatiana Gélvez; Héctor Vargas; Ariolfo Camacho; Edson Mojica; Laura Galvis (Coadvisory University of Delaware); Claudia V. Correa (Coadvisory University of Delaware); Hoover F. Rueda (Coadvisory University of Delaware). **Ongoing MS Theses:** Hans Garcia; Elkin Diaz; Carlos Hinojosa; Miguel Marquez; Camilo Noriega; David Boada; Jonathan Monsalve; Samuel Pinilla; Óscar Espitia; Crisóstomo Barajas; Carlos Reyes; Oscar Hurtado.

CV – Paul Rodriguez

1/ Personal data

Name: Paul Rodriguez

Birth date: October 27, 1970

Professional address (with telephone and e-mail):

Av. Universitario 1801, San Miguel, Lima 32, Lima Peru. Telephone: +511-262-2000 Ext. 4681.

E-mail: prodrig@pucp.edu.pe

Current job title and size of the research group:

Full Professor – Department of Electrical Engineering, Pontificia Universidad Catolica del Peru (PUCP). Research group composed of nearly 10 people including: Master's and undergraduate students.

2/ Highest obtained degree (with indication of place and date):

Ph.D. in Electrical Engineering – University of New Mexico, Albuquerque, NM, USA – 2005

3/ Professional activity in the last 5 years:

2014 – onwards: Full Professor – Department of Electrical Engineering Pontificia Universidad Catolica del Peru.

2008-2013: Associate Professor – Department of Electrical Engineering Pontificia Universidad Catolica del Peru.

4/ Other duties/ positions: None

5/ Awards, fellowships and external recognition

- Patent: US 9595112 B2 – Incremental principal component pursuit for video background modeling. March, 2017.
- 2014 National Award for Scientific Production – Concytec (Peru) & Elsevier
- 2014 CUDA Research Center
- 2012 CUDA Teaching Center
- Associate Editor of Transaction on Image Processing (IEEE)

6/ Ongoing funded research projects with dates, titles, sources of funding

- 12/2015-6/2018: Peruvian government funding (169-Fondecyt-2015) – 3D Convolutional Neural Networks for Human Activity Recognition in Digital Videos. USD 140,000. Role: P.I.
- 2016-2017: PUCP funding. Incremental Convolutional Sparse Representation for 3D datasets. USD 50,000. Role: P.I.

7/ Projects approved in the least 5 years

- 2013-2016: Peruvian government funding (179-Fincyt-IB-2013) – Incremental

Principal Component Pursuit. USD 140k. Role: P.I.

- 2014-2016: PUCP funding. Processing Traffic Video Sequences via Principal Component Pursuit. USD 50k. Role: P.I.
- 2014. Nvidia. Cuda Research Center. USD 5k. Role: P.I.
- 2012 Nvidia. Cuda Teaching Center. USD 12k. Role: P.I.

8/ Publications

8.1 – Highlight the most important publications related to the project theme

4. P. Rodríguez, B. Wohlberg "Incremental Methods for Robust Local Subspace Estimation", chapter in "Handbook of Robust Low-Rank and Sparse Matrix Decomposition", CRC Press, pp. 284 -320, May 2016.
5. P. Rodríguez, B. Wohlberg "Incremental Principal Component Pursuit for Video Background Modeling", Springer Journal of Mathematical Imaging and Vision, vol. 55, issue 1, pp. 1-18, May 2016.
6. Y. Hu, K. Sirlantzis, H. Howells, N. Ragot, P. Rodriguez, "An online background subtraction algorithm deployed on a nao humanoid robot based monitoring system." submitted, Robotics and Autonomous Systems, 2016.
7. P. Rodriguez, B. Wohlberg, "Translational and rotational jitter invariant incremental principal component pursuit for video background modeling." IEEE International Conference on Image Processing (ICIP), (Quebec, Canada), pp. 537-541, Set. 2015.
8. P. Rodríguez, B. Wohlberg, "Fast Principal Component Pursuit Via Alternating Minimization", IEEE International Conference on Image Processing (ICIP), (Melbourne, Autralia), pp. 69-73, September, 2013.
9. R. Rojas, J. Ormachea, A. Salo, P. Rodríguez, K. Parker, B. Castañeda, "Crawling Waves Speed Estimation Based on the Dominant Component Analysis Paradigm", accepted, Ultrasonic Imaging, Nov. 2014.

8.2 – Publications in cooperation with the project partners

9/ Theses oriented and post-doctoral fellows supervised

9.1 – MS Theses Finished/defended in the last 5 years: Daniel Paredes (2014), caterina Espejo (2013), Renan Rojas (2012), Ricardo Sanchez (2012).

Ongoing MS Theses: Jorge Quesada, Gustavo Silva, Enrique Tejada.

B7. Additional information

List all the complementary fundings expected or already obtained.

Experience of the coordinators in similar projects.

Present main activities and their relationship with the project's main goal.

Perspectives of continuing collaboration after project financing is over.

B8. International referees

Suggest names of at least 3 international referees to evaluate the project. These researchers should not be connected to people in the project.

1- André Ferrari, university of Nice, France, ferrari@unice.fr

2- Steve McLaughlin, university of Heriot-Watt, Scotland, s.mclaughlin@hw.ac.uk

3- José Bioucas Dias, Instituto Superior Tecnico, University of Lisboa, Portugal, bioucas@lx.it.pt

Names of referees who should not review this project in your opinion (optional)

1-

2-

B9. Public and private support obtained related to the project:

Previous project STIC AMSUD / MATH AMSUD? NO

If YES, indicate the code, the year and the name of the project:

Other public support in the past (ECOS, COFECUB, CNRS, European Union, etc.):
ECOS Project C16M01 entitled "Colored aperture design for compressive spectral unmixing in farming product images", in collaboration with the university of Bucaramanga (Colombia), 2014-2017.

Other private support in the past:

Prospects for public or private support in the future:

C. Project Budget

Project title: Image reconstruction from compressed measurements: application to hyperspectral and medical imaging

Participating institutions: **IRIT, UiS, PUCP**

The STIC-AmSud program **funds travel expenses** (air tickets and *per diem*) to researchers in research missions and workshops.

C1. First year (2018)

Planned missions – Year 1

Researcher	Status (student, junior, senior)	Institution	Origin	Destination	Planned date	Duration (max. 30 days)	Estimated cost of the trip (€)	Estimate of total *per diem* (€)	Trip and Mission funding institution[1]	Mission objectives
J.-Y. Tourneret	Senior	IRIT	Toulouse	Lima	1st semester	10	1200	1500	CNRS	<u>Coordination meeting and Workshop</u>: • Detailed planning • Specification of data acquisition • Setting up infrastructure (web) for data exchange and collaborative work • Presentation of partners prior work on compressed medical and hyperspectral imaging, image reconstruction, statistical modeling, inverse problems • collaborative work on observation models and joint characteristics of medical and hyperspectral images
A. Basarab	Senior	IRIT	Toulouse	Lima	1st semester	10	1200	1500	CNRS	
J. Lesouple	Junior	IRIT	Toulouse	Lima	1st semester	10	1200	1500	CNRS	
H. Arguello	Senior	UiS	Bucaramanga	Lima	1st semester	10	600	1500	COLCIENCIAS	
C. Correa	Junior	UiS	Bucaramanga	Lima	1st semester	10	600	1500	COLCIENCIAS	

[1] **Each institution will pay for the trip and per diem of its own researchers.**

P. Rodriguez	Senior	PUCP	Lima	Toulouse	2nd semester	10	1200	1500	CONCYTEC	<u>Coordination meeting and Workshop on compressed acquisitions in medical and hyperspectral imaging</u> • presentation of results of compressive matrix design • Preliminary results of compressed acquisitions and image reconstruction • Validating interim-report
Jorge Quesada	Junior	PUCP	Lima	Toulouse	2nd semester	10	1200	1500	CONCYTEC	
H. Arguello	Senior	UiS	Bucaramanga	Toulouse	2nd semester	10	1200	1500	COLCIENCIAS	
C. Correa	Junior	UiS	Bucaramanga	Toulouse	2nd semester	10	1200	1500	COLCIENCIAS	

CONSOLIDATED BUDGET: Year 1

Funding requested to the STIC-AmSud Program
Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem*)	TOTAL
MAEDI France			
CNRS France	**3600**	**4500**	**8100**
INRIA France			
Institut Mines-Télecom France			
MINCYT Argentina			
CAPES Brazil			
CONICYT Chile			
CONACYT Paraguay			
CONCYTEC Peru	**2400**	**3000**	**5400**
ANII Uruguay			
MPPEUCT Venezuela			
SENESCYT Ecuador			
COLCIENCIAS Colombia	**3600**	**6000**	**9600**
Total requested funding to STIC-AmSud			
Other funding[2]			
TOTAL			

Do you have additional funding sources for this project[3]? (if so please specify the amount and source (s)).

[2] Specify in additional page.
[3] Reserved for CNRS researchers

C2. Second year (2019)

Second year funding depends on approval of intermediate progress report.

Planned missions – Year 2

Researcher	**Status (student, junior, senior)**	**Institution**	**Origin**	**Destination**	**Planned date**	**Duration (max. 30 days)**	**Estimated cost of the trip (€)**	**Estimate of total *per diem* (€)**	**Trip and Mission funding institution**[4]	**Mission objectives**
J.-Y. Tourneret	Senior	IRIT	Toulouse	Bucaramanga	4th semester	10	1200	1500	CNRS	<u>Final meeting</u> • Presentation of compressive sensing results in hyperspectral and medical imaging • Compiling final report and technical documentation • Planning future work
A. Basarab	Senior	IRIT	Toulouse	Bucaramanga	4th semester	10	1200	1500	CNRS	
N. Ouzir	Junior	IRIT	Toulouse	Bucaramanga	4th semester	10	1200	1500	CNRS	
P. Rodriguez	Senior	PUCP	Lima	Bucaramanga	4th semester	10	600	1500	CONCYTEC	
Gustavo Silva	Junior	PUCP	Lima	Bucaramanga	4th semester	10	600	1500	CONCYTEC	

[4] **Each institution will pay for the trip and per diem of its own researchers.**

CONSOLIDATED BUDGET: Year 2

Funding requested to the STIC-AmSud Program
Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem*)	TOTAL
MAEDI France			
CNRS France	**3600**	**4500**	**8100**
INRIA France			
Institut Mines-Télecom France			
MINCYT Argentina			
CAPES Brazil			
CONICYT Chile			
CONACYT Paraguay			
CONCYTEC Peru	**1200**	**3000**	**4200**
ANII Uruguay			
MPPEUCT Venezuela			
SENESCYT Ecuador			
COLCIENCIAS Colombia			
Total requested funding to STIC-AmSud			
Other funding[5]			
TOTAL			

Do you have additional funding sources for this project[6]? (if so please specify the amount and source (s)).

[5] Specify in additional page.
[6] Reserved for CNRS researchers

C3. BUDGET TOTALS

	Year 1	Year 2	Total
Funding requested to MAEDI (France)			
Funding requested to INRIA (France)			
Funding requested to CNRS (France)	8100	8100	**16200**
Funding requested to Institut Mines-Telecom (France)			
Funding requested to MINCYT (Argentina)			
Funding requested to CAPES (Brazil)			
Funding requested to CONICYT (Chile)			
Funding requested to CONACYT (Paraguay)			
Funding requested to CONCYTEC (Peru)	5400	4200	**9600**
Funding requested to ANII (Uruguay)			
Funding requested to SENESCYT (Ecuador)			
Funding requested to MPPEUCT (Venezuela)			
Funding requested to COLCIENCIAS (Colombia)	9600	0	**9600**
Matching funds from the partners			
Other sources			
TOTAL	**23100**	**12300**	**35400**