

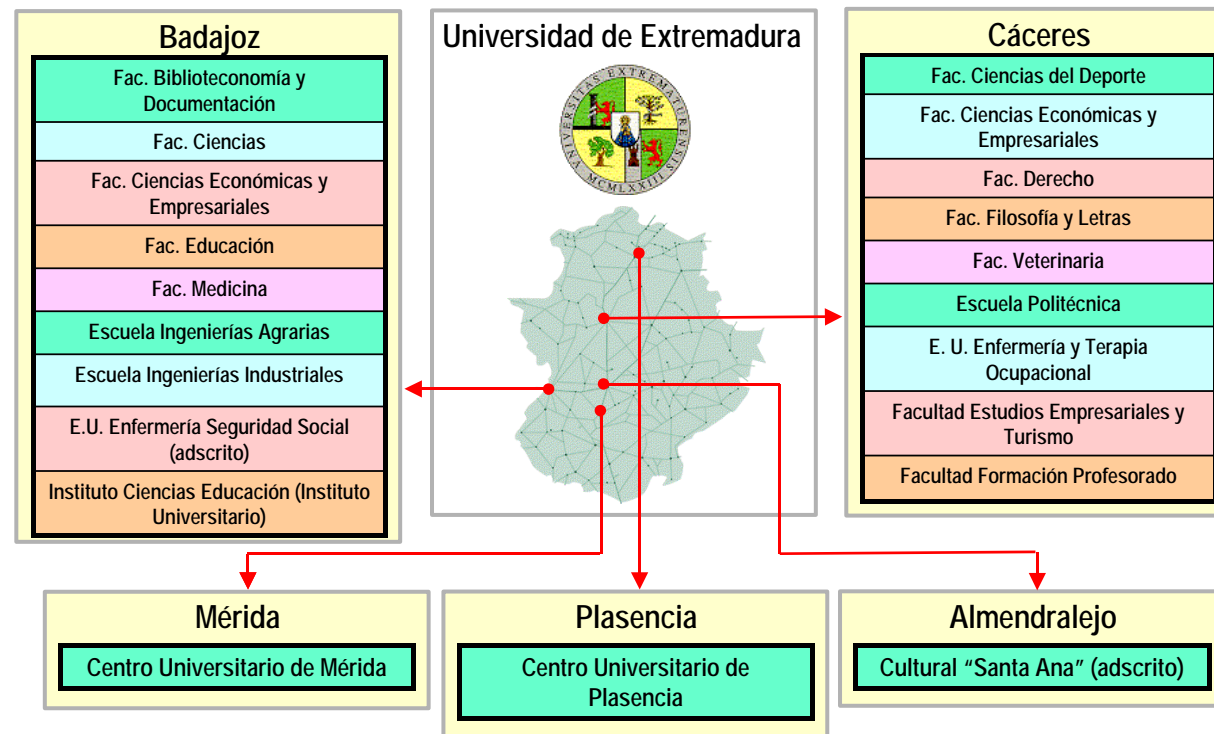
# WP7: Training on Parallel Computing

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# Institution and Laboratory

- The University of Extremadura was founded in 1973.
- Located in the south-west of Spain, it currently has over 15.000 students distributed between different campuses.



# Institution and Laboratory



- The Escuela Politécnica de Cáceres is one of the main schools of the University of Extremadura, with more than 3000 students.
- The main degrees are in Computer Engineering (Bs, Ms and PhD).
- The HyperComp research group is in the Department of Technology of Computers and Communications.



# Institution and Laboratory

- The city of Cáceres was recognized as a UNESCO World Heritage site in 1985.
- It is one of the most well-preserved monumental cities in Europe, with many attractions despite its small size.



Tolomeo Final Meeting

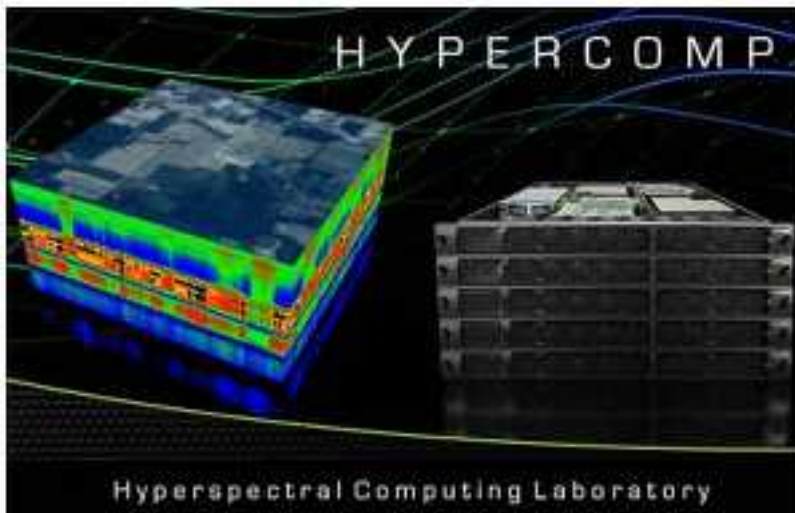


Rio de Janeiro, 20-22 October 2014

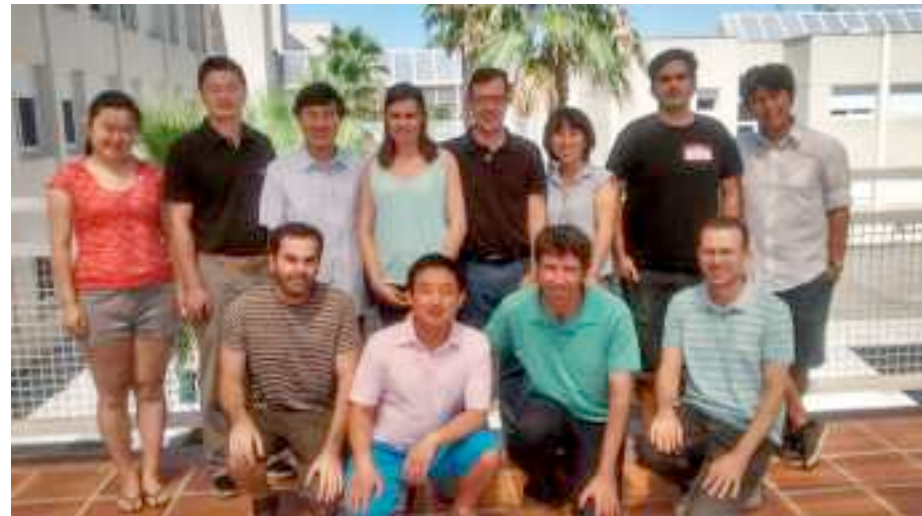
# Institution and Laboratory



- The hyperspectral computing laboratory (HyperComp) at the University of Extremadura, is a young and dynamic research group.
- It is currently made up of 13 researchers (2 professors, 3 postdocs, 5 PhD students, and 3 visiting researchers).
- The group has reported high scientific production in recent years.



Tolomeo Final Meeting



Rio de Janeiro, 20-22 October 2014

# HyperComp research



- Development of algorithms for remotely sensed hyperspectral image analysis (spectral unmixing, classification, target detection, compressive sensing).
- Efficient implementation of algorithms for remote sensing data processing in different high performance computing architectures (GPUs, FPGAs, multi-core platforms, Beowulf clusters, distributed systems and grids, cloud computing, etc.)
- Development of software tools for analysis and processing of remotely sensed data:
  - HyperMix (spectral unmixing, specifically developed in TOLOMEO)
  - Hyperspectral repository (free repository of hyperspectral data)
  - Web map processing server (classification of Google Maps data)

# WP7: Initial Forecast



<b>Work package number</b>	7	<b>Start date or starting event:</b>	Month 4
<b>Work package title</b>	Training on parallel computing		
<b>Beneficiary/Partner</b>	UEX		
<b>Organisation short names</b>	INPE, PUC-RIO, UNIPV, CNES, LUH		
<b>Objectives</b>			
To train users and researchers to improve the computational efficiency of the tools developed by the TOLOMEO project and to train the partners to improve the tool design including parallel processing capabilities using different techniques and platforms, such as those based on the efficient exploitation of multiple processing cores available in modern desktop computers, and also resorting to widely available and low-cost specialized hardware in desktop computers (GPUs).			
<b>Description of work</b>			
Task 7.1 – <i>On-line and on-site training sessions for researchers</i> : design and implementation of training tools to understand parallel computing and introduce it into the TOLOMEO tool improvement and optimization procedure.			
Task 7.2 – <i>Library of parallel computing routines</i> : design and implementation of a library of (sub)routines useful for implementing parallel computing in the open platform used for the development of the TOLOMEO tools within the other WPs.			
<b>Deliverables</b>			
D7.1: Training materials for parallel computing training sessions both on-line and on-site.			
<b>Researchers involved</b>			
ESR “K”, ESR “N”			

# WP7: Secondments



- The following table summarizes the secondments carried out which are directly or indirectly related with WP7. Net we provide a summary and description of each of these secondments.

Researcher	From	To	Start Date	End date	Duration
Renata Sampaio da Rocha Ruiz	INPE	UEX	09-05-12	08-08-12	3 months
José Renato García Braga	INPE	UEX	02-02-14	02-05-14	3 months
Victor Andrés Ayma Quirita	PUC	UEX	05-03-14	28-09-14	7 months
Paulo Roberto da Silva Ruiz	INPE	UEX	13-04-14	12-07-14	3 months
Luis Ignacio Jiménez Gil	UEX	PUC	17-08-13	18-09-13	1 month
Luis Ignacio Jiménez Gil	UEX	PUC	15-02-13	12-05-13	3 months
Luis Ignacio Jiménez Gil	UEX	PUC	01-09-14	30-11-14	4 months
Sergio Bernabé García	UEX	PUC	17-08-13	18-09-13	1 month



# WP7: Secondments



- Renata Sampaio da Rocha Ruiz was seconded from INPE to UEX from May 9<sup>th</sup>, 2012 to August 8<sup>th</sup>, 2012 (3 months).
- The activities related to the WP resulting from this secondment were focused on the implementation of a technique for estimating the number of endmembers for linear spectral mixture analysis (LISA) in the HyperMix tool.
- The result on the WP tool from this secondment was the implementation of a technique for estimating the number of endmembers for linear spectral mixture analysis (LISA) model in HyperMix.
- A comparison with other techniques for estimating the number of endmembers in hyperspectral data was also conducted.

# WP7: Secondments

- The tasks carried out by Renata Sampaio da Rocha Ruiz in HyperComp can be summarized as follows:

Months	May			June				July				August			
Week/ Tasks	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4
A	■	■													
B		■	■	■	■										
C					■	■	■								
D							■	■	■						
E									■	■	■				
F												■	■		

A – Presentation of previous research; B – Analysis of existing algorithms and their GPU implementations; C – First attempt to develop computationally efficient algorithms; D – Adaptation to other problems; E – Experimental evaluation; F – Final report.

# WP7: Secondments

- The following table shows the processing times (in seconds) and the speedups achieved for the GPU implementations of a new method for estimating the number of endmembers from remotely sensed hyperspectral scenes, as implemented in an NVIDIA GTX 580 GPU architecture.
- Two standard hyperspectral scenes have been used in the comparisons: AVIRIS Cuprite and AVIRIS World Trade Center (WTC).
- In both cases, real-time analysis results were obtained, which represents an important achievement:

	<b>Cuprite</b>	<b>WTC</b>
<b>Time CPU</b>	22.3	75.8
<b>Time GPU</b>	1.22	3.16
<b>Speedup</b>	18.28	2.99

# WP7: Secondments



- José Renato García Bragawas seconded from INPE to UEX from February 2<sup>nd</sup>, 2014 to May 2<sup>nd</sup>, 2014 (3 months).
- The activities related to the WP resulting from this secondment were focused on the development of a new FPGA implementation of an algorithm to reduce the dimensionality of data from hyperspectral images.
- The result on the WP tool from this secondment is expected to be the inclusion of this computationally efficient method in the HyperMix tool when it is fully developed.
- Due to the additional requirements introduced by FPGA hardware architectures, this objective could not be completed so far but we are working towards the full inclusion of FPGA and GPU platforms.

# WP7: Secondments

- The tasks carried out by José Renato García Braga in HyperComp can be summarized as follows:

Months	February			March				April				May			
Week/ Tasks	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4
A	■														
B		■	■	■	■	■	■								
C							■	■	■	■	■				
D											■	■	■	■	

A – Presentation of previous research activities to HyperComp group.

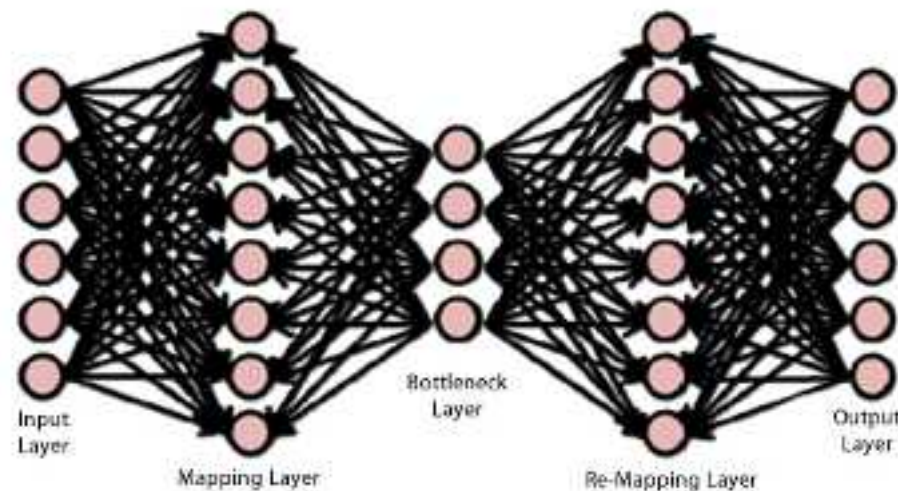
B – Study and evaluation of non-linear principal component analysis (NLPCA) for dimensionality reduction in hyperspectral images.

C – Implementation of NLPCA method in FPGA architectures.

D – Development of final report and preparation of a publication.

# WP7: Secondments

- The NLPCA method uses a self-associative neural network to achieve the reduction in dimensionality of the data.
- The self-associative neural network has the form of a multi-layer perceptron (MLP) using the error backpropagation algorithm during the training phase.
- The architecture of MLP is shown below:



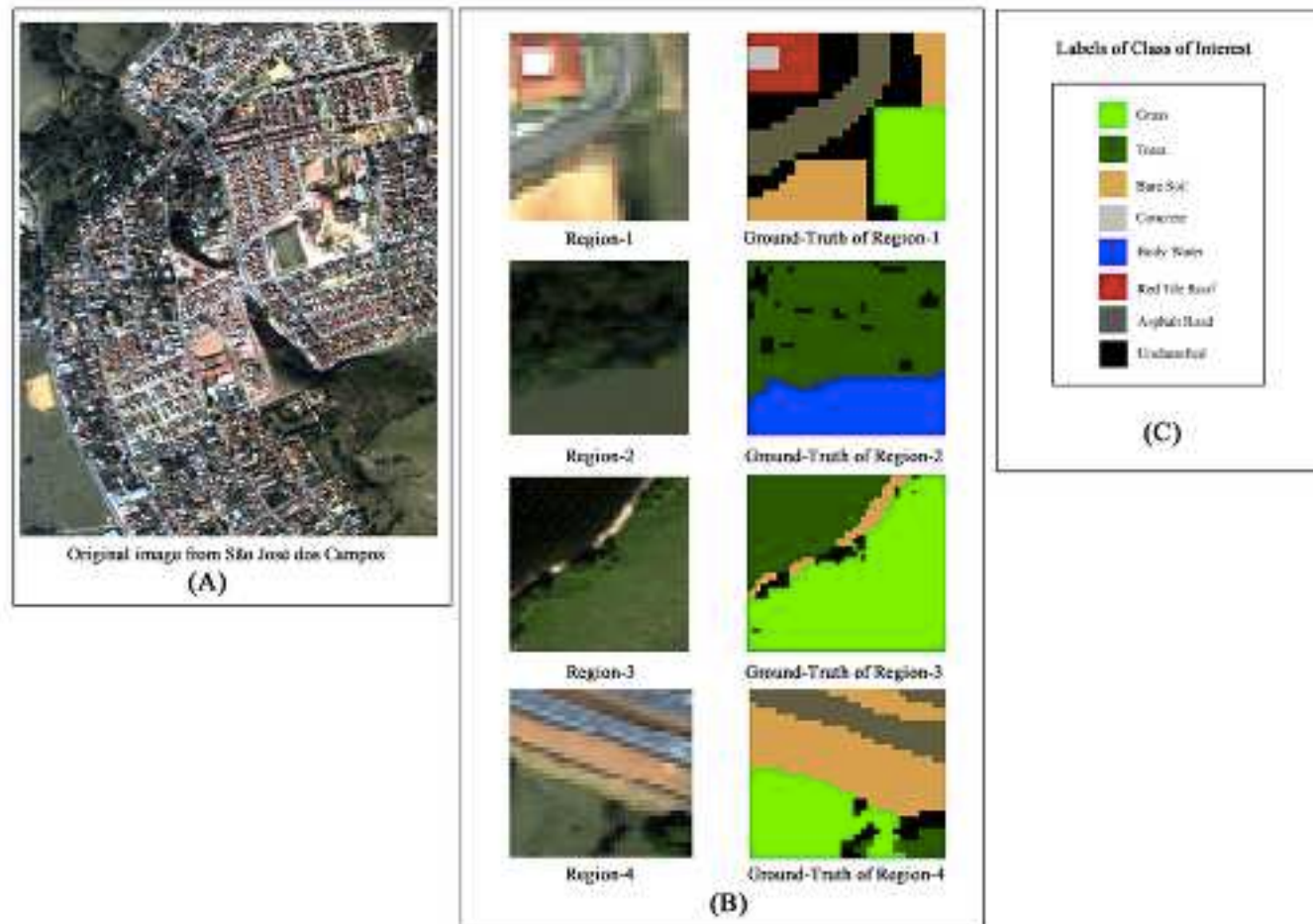
# WP7: Secondments



- The model of FPGA used to implement the NLPCA method is a Virtex 2 Pro that is in a reconfigurable hybrid system (CRAY XD1).
- To address the problem of finding a optimal or nearly optimal architecture for the neural network, an algorithm called multiple particle collision (MPCA) is used is a new meta-heuristic applied to find an optimal or near-optimal architecture for the neural network.
- Both NLPCA and MPCA methods and were programed in software and hardware (in FPGA) to perform the data reduction and subsequent data classification.
- The evaluation was conducted with a scene collected over São José dos Campos, with several regions of interest.

# WP7: Secondments

Image of São José dos Campos (A), 4 regions of interest together with ground-truth (B,C)





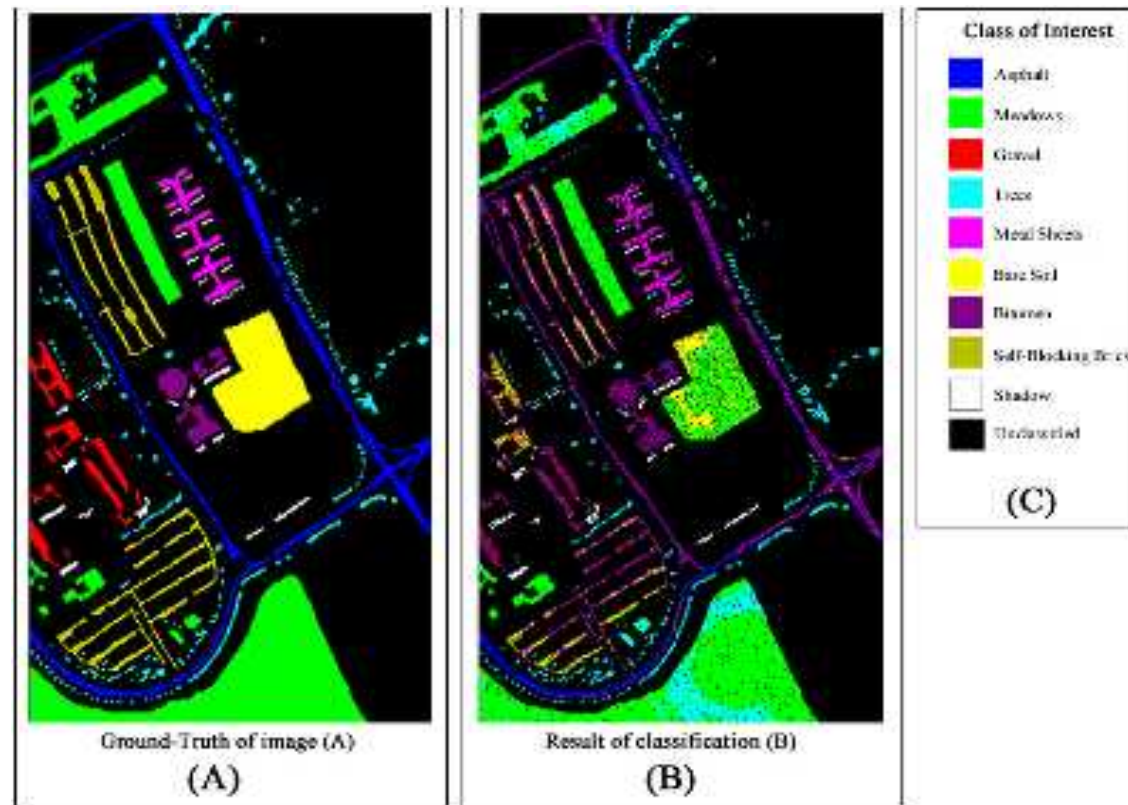
# WP7: Secondments

- The classification results obtained after data reduction using NLPCA (in software and in hardware) are shown in the following table, where a classifier (SVM) was used for classification purposes.
- The overall accuracy (OA), average accuracy (AA) and kappa statistic (K) are reported.
- The results indicate that it is feasible to execute the NLPCA method in FPGA architectures.

	Software			Hardware		
	K	OA	AA	K	OA	OA
Region - 1	0.4075	68.95 %	39.87 %	0.4075	68.95 %	39.87 %
Region - 2	0.4996	67.40 %	74.70 %	0.4996	67.40 %	74.70 %
Region - 3	0.6763	85.98 %	59.58 %	0.6763	85.98 %	59.58 %
Region - 4	0.6177	68.95 %	68.95 %	0.6177	68.95 %	68.95 %

# WP7: Secondments

- Classification results were also obtained for other popular scenes in the community, including well-known hyperspectral scenes:



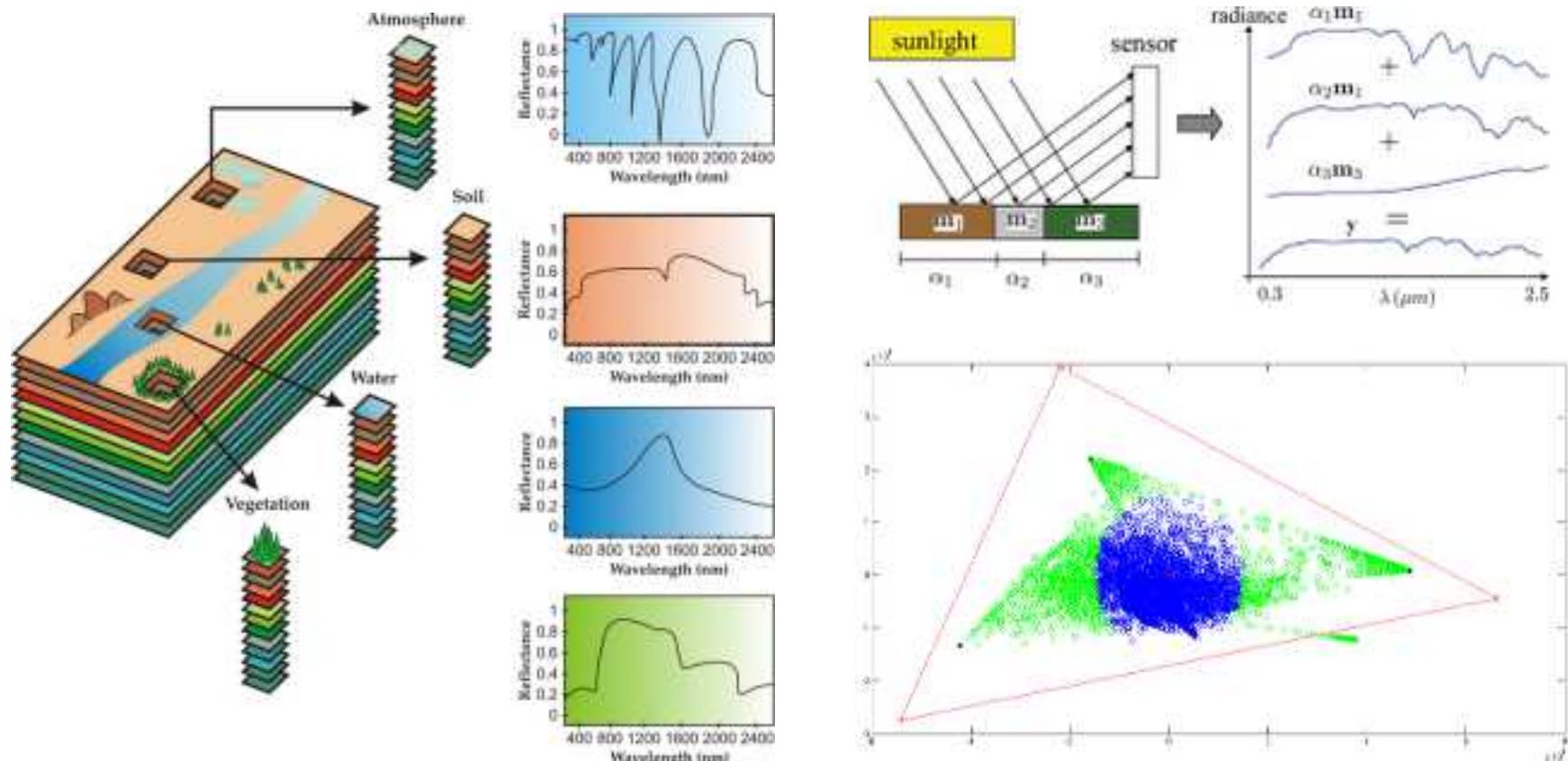
# WP7: Secondments



- Victor Andrés Ayma Quirita was seconded from PUC-Rio to UEX from March 5<sup>th</sup>, 2014 to September 28<sup>th</sup>, 2014 (6 months and 3 weeks).
- The activities related to the WP resulting from this secondment were focused on the development of new efficient implementations of classification algorithms for remote sensing data.
- The result on the WP tool from this secondment is expected to be the inclusion of this computationally efficient methods in the HyperMix tool (and other tools developed by HyperComp, such as web map processing server) when it is fully developed.
- Frameworks (Hadoop and Pig latin) were used for this purpose.

# WP7: Secondments

- A new simplex growing algorithm (SGO) for endmember extraction:



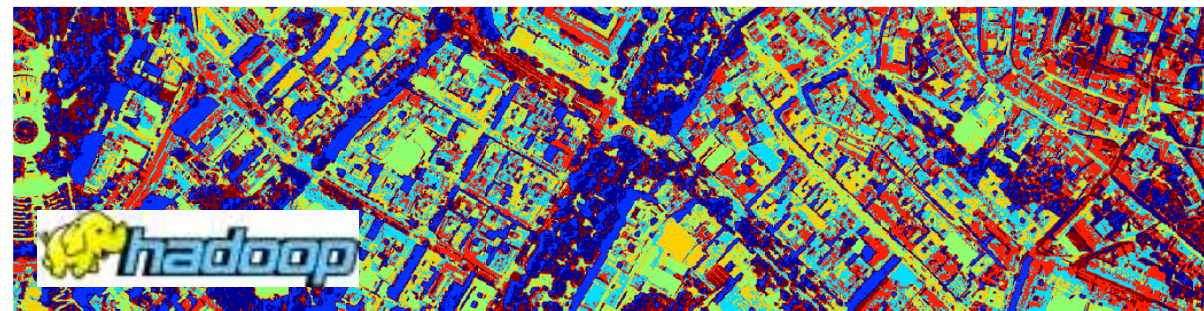
# WP7: Secondments

- Efficient implementation of classification algorithms:



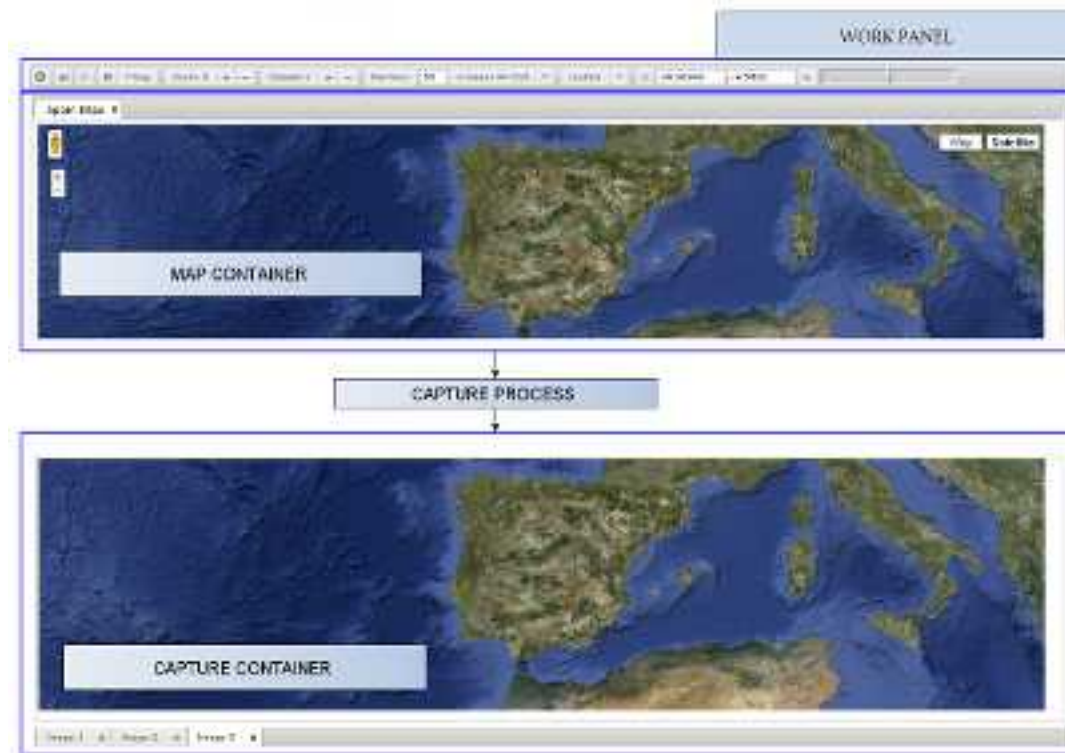
# WP7: Secondments

- Hadoop is a framework that allows for the distributed processing of large data sets across clusters of computers.
- Pig laDn is a platform for analyzing large data sets that consists of a high-level language for expressing data analysis programs.



# WP7: Secondments

- A collaboration has been started between Victor Ayma and a PhD student at University of Extremadura (Juan Mario Haut) in order to integrate these algorithms in the WMPS tool developed by UEx:



# WP7: Secondments



- Paulo Roberto da Silva Ruiz was seconded from INPE to UEX from April 13<sup>th</sup>, 2014 to July 12<sup>th</sup>, 2014 (3 months).
- The activities related to the WP resulting from this secondment were focused on the GPU implementation of a new technique for estimating the number of endmembers in remotely sensed hyperspectral scenes and based on random matrix theory (RMT).
- The result on the WP tool from this secondment is expected to be the inclusion of this computationally efficient method in the HyperMix tool.
- Another goal of this secondment was the comparison of the GPU implementation of RMT with other GPU implementations such as virtual dimensionality (VD) and HySime.



# WP7: Secondments

- The computational resources used in the comparison can be summarized as follows:

## Processor intel core i7 3,06 Ghz quadcore:

- cores: 4;Internal Memory: 4 x 32 KB + 32 KB (L1), 4 x 256 KB (L2), 8 MB (L3);Speed Clock: 3,06 Ghz.12,00 GB memory RAM DDR3

## GPU NVIDIA GeForce GTX 580

- Cores: 512;Speed Clock: 1544 Mhz;Memory DRAM: 1,5 Ghz;



## Software and Programming Language:

- Ubuntu version 10.04 Its;Language C and CUDA;Compilers: GCC (GNU), ICC (INTEL),NVCC (NVIDIA);



# WP7: Secondments

- Algorithm comparison (endmember extraction accuracy):

Sintetic Image	Number of Endmembers		
	VD	Hysime	RMT
Fractal1_noise10	4	4	6
Fractal1_noise30	8	9	9
Fractal1_noise50	8	9	9
Fractal1_noise70	8	9	9
Fractal1_noise90	8	9	9
Fractal1_noise110	9	9	9
Fractal1_nonoise	8	9	9
Fractal2_noise10	5	5	6
Fractal2_noise30	8	9	9
Fractal2_noise50	8	9	9

Real Image	Number of Endmembers		
	VD	Hysime	RMT
Salinas	19	20	16
KSC	24	21	21
Cuprite	19	16	13
Purdue	28	12	15

signal-to-noise ratios (SNRs):  
10:1, 30:1, 50:1, 70:1, 90:1,  
and 110:1

Number of endmenbers: 9

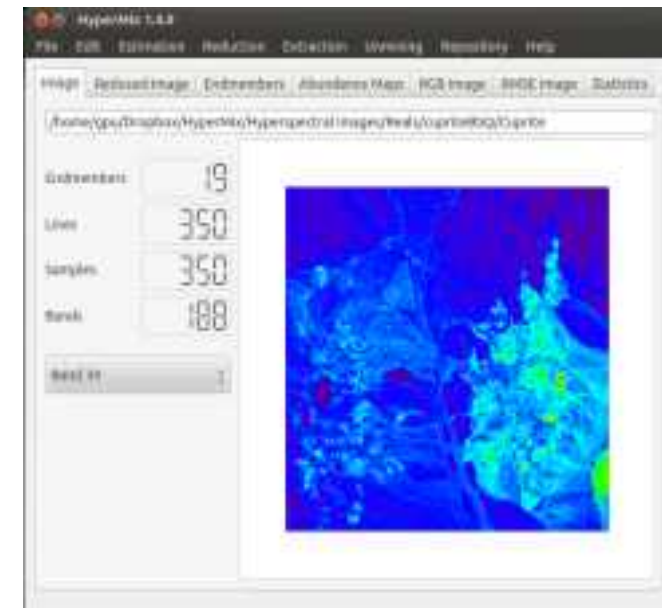
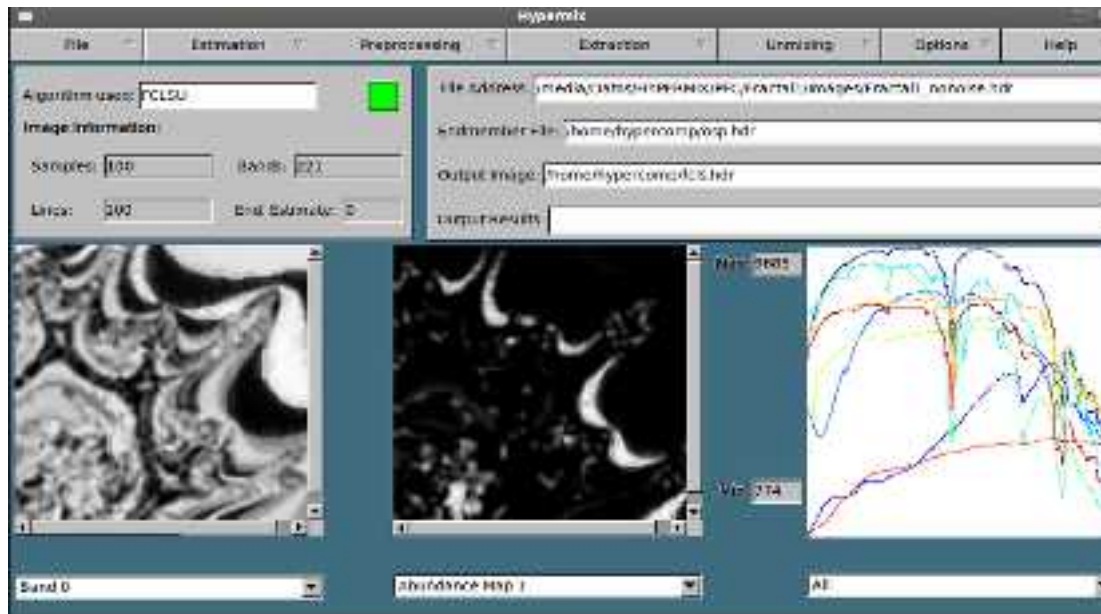
# WP7: Secondments

- Algorithm comparison (computational performance):

Image	Algorithm	GCC			ICC		
		Processing Time (s)		Speedup	Processing Time (s)		Speedup
		CPU	GPU		CPU	GPU	
Fractal1_noise_10	VD	0,52	0,03	17,33	0,36	0,028	12,86
	Hysime	3,36	0,33	10,18	2,51	0,304	8,26
	RMT	2,51	0,16	15,69	1,96	0,166	11,81
Fractal2_noise_10	VD	0,52	0,029	17,93	0,36	0,028	12,86
	Hysime	3,33	0,33	10,09	2,55	0,31	8,23
	RMT	2,52	0,16	15,75	1,96	0,166	11,81
Salinas	VD	6,17	0,221	27,92	4,48	0,206	21,75
	Hysime	33,15	1,51	21,95	22,78	1,475	15,44
	RMT	24,46	0,93	26,30	17,07	0,93	18,35
KSC	VD	3,84	0,178	21,57	2,84	0,16	17,75
	Hysime	21,01	1,21	17,36	14,51	1,187	12,22
	RMT	15,61	0,67	23,30	10,86	0,69	15,74
Cuprite	VD	4,82	0,228	21,14	3,74	0,21	17,81
	Hysime	26,6	1,37	19,42	18,89	1,37	13,79
	RMT	19,61	0,83	23,63	13,94	0,83	16,80
Purdue	VD	0,93	0,048	19,38	0,72	0,045	16,00
	Hysime	5,42	0,39	13,90	3,84	0,385	9,97
	RMT	3,99	0,19	21,00	2,83	0,186	15,22

# WP7: Secondments

- Luis Ignacio Jiménez Gil has been the developer of HyperMix, the main tool resulting from this workpackage and which will be described later. This tool has been used both for research and training purposes in the context of the work package.



# WP7: Outcomes



- The HyperMix tool has been developed and refined as part of the TOLOMEO project.
- It now includes GPU processing capabilities and automatically detects if a GPU is available in the system and executes the parallel versions of algorithms on-the-fly (this is a completely new feature).
- In addition, several new GPU implementations of a region growing-based segmentation algorithm developed by the team at PUC-Rio have also been developed.
- The speedups obtained by the parallel versions are relevant using images with different numbers of bands.
- Despite being fully available in the TOLOMEO website, the tool still can be improved. In future work, we will perform tests with additional computing platforms and image data.

# WP7: Outcomes



- In summary, the main outcome of the secondments carried out consist of the algorithm implementations performed (many of them included to HyperMix and other TOLOMEO software tools).
- Another important outcome is current ongoing preparation of joint publications (journal articles) involving the seconded researchers and the scientists that participated in the supervision.
- All secondments are expected to result in at least one journal publication, although some of them are in preparation but it is expected that the papers in preparation will be submitted soon.
- Another important outcome of WP7, as specified in the original workplan, has been the development of training activities in parallel computing, specifically in GPU programming and implementations (HyperMix has been instrumental for this).

# WP7: Tools

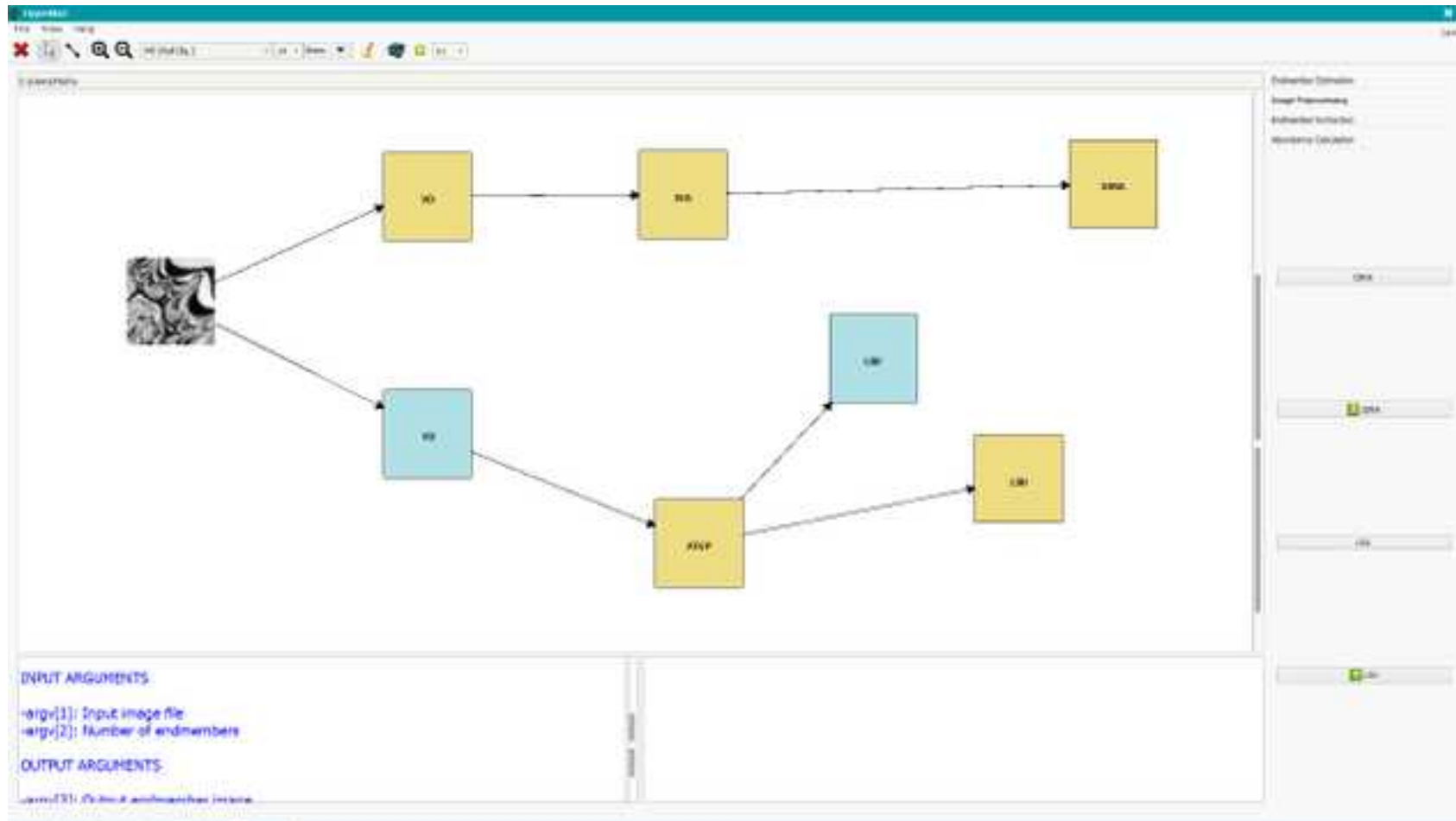


HyperMix allows to execute the complete unmixing chain at once.

The user can create his own operator chains.

Complexity of the chain is almost unlimited.

# WP7: Tools





# WP7: Tools

The HyperMix tool allows to execute operators which were developed using NVIDIA CUDA language.

Easy way to compare performance improvements that can provide the GPUs for different unmixing chain steps.



# WP7: Tools



HyperMix allows a user to include his/her own algorithms in order to run and check their results allowing to increase the functionality of the tool for hyperspectral and multispectral images.

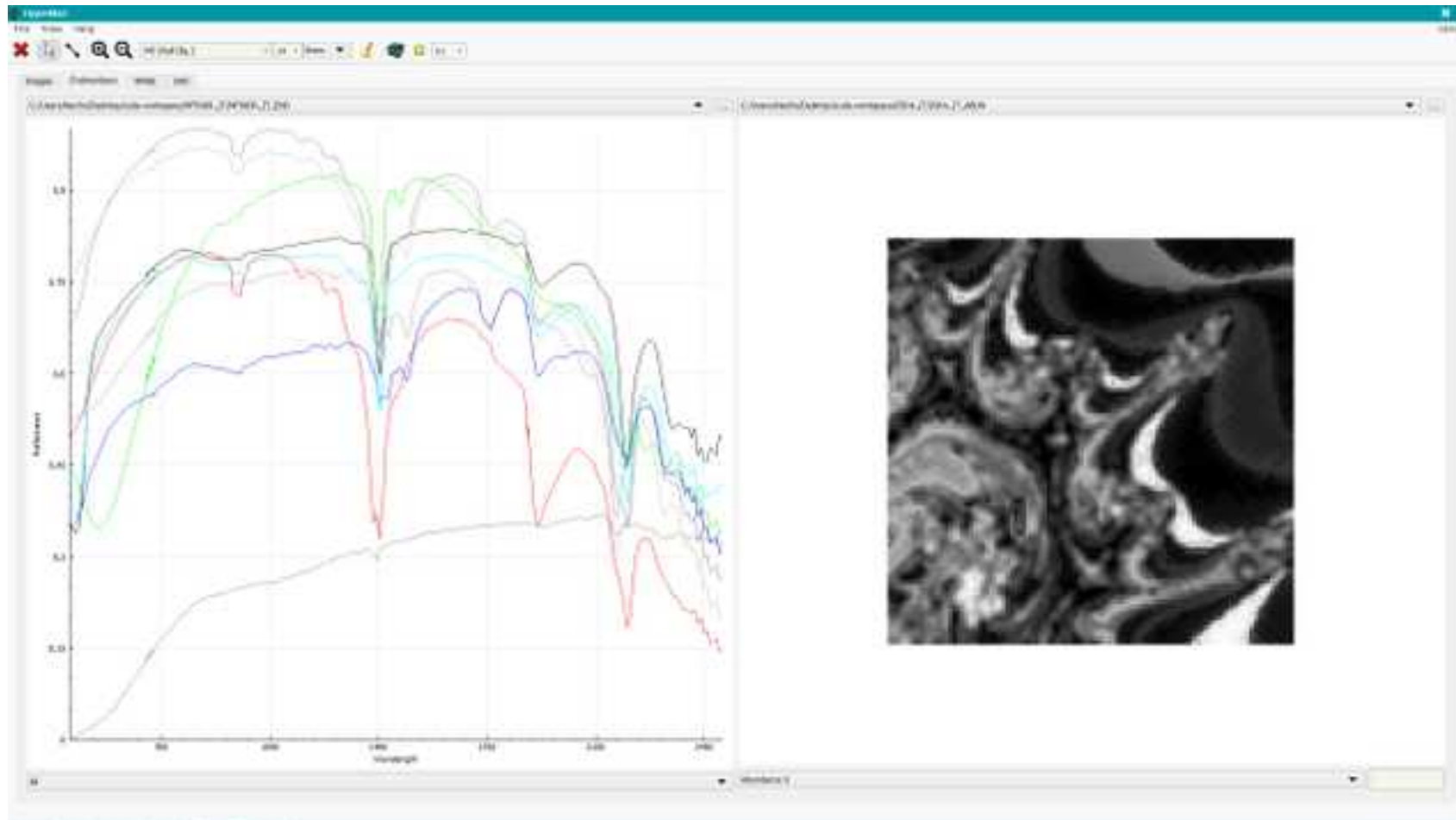
Operators source codes are available with the tool included some methods to handle the hyperspectral and multispectral images properly.

# WP7: Tools

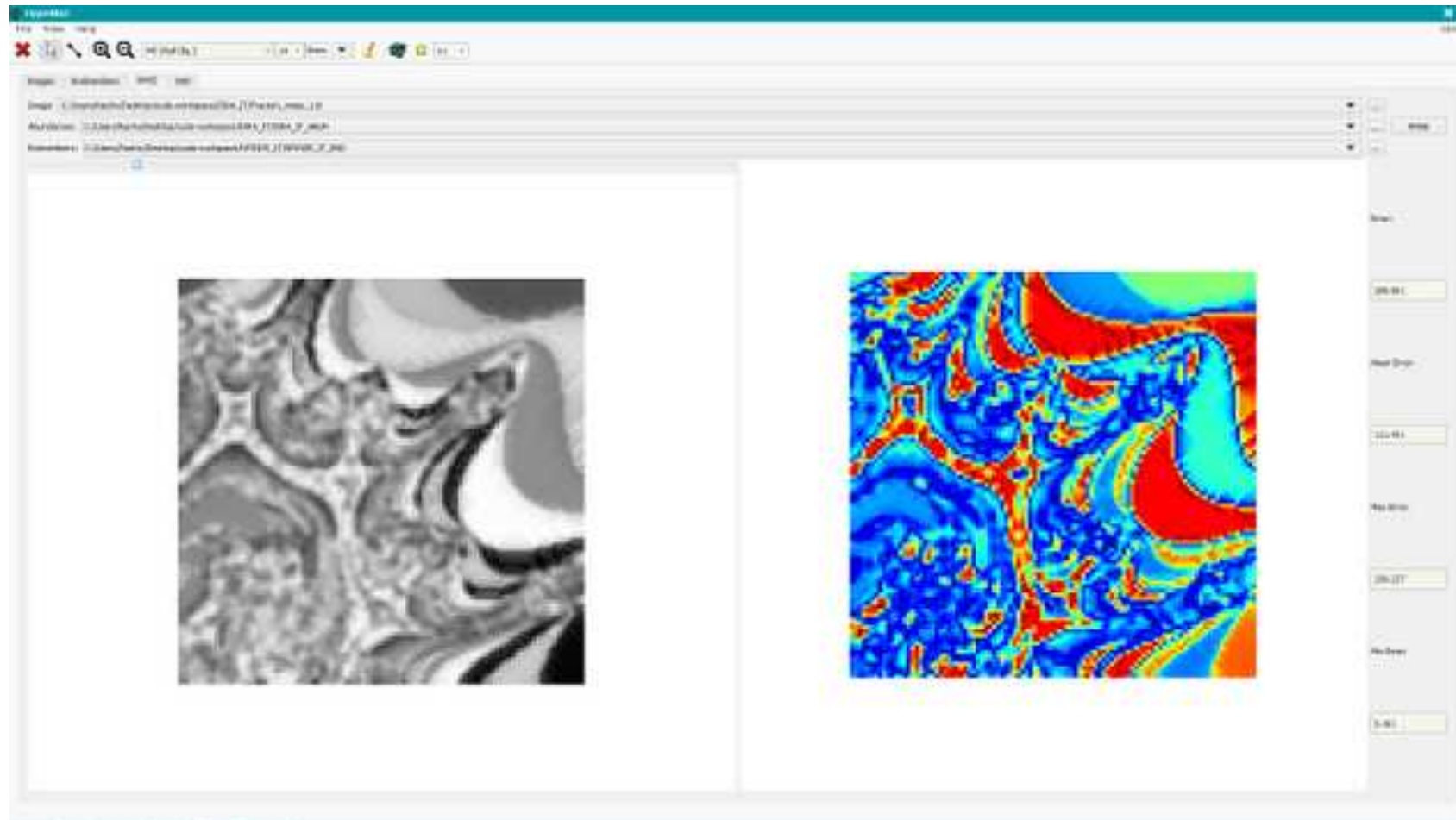


- HyperMix functionality and data visualization:
  - Images
  - Endmembers
  - Abundances
- HyperMix tools for testing the results obtained:
  - Root Mean Square Error (RMSE)
  - Spectral Angle Distance (SAD)

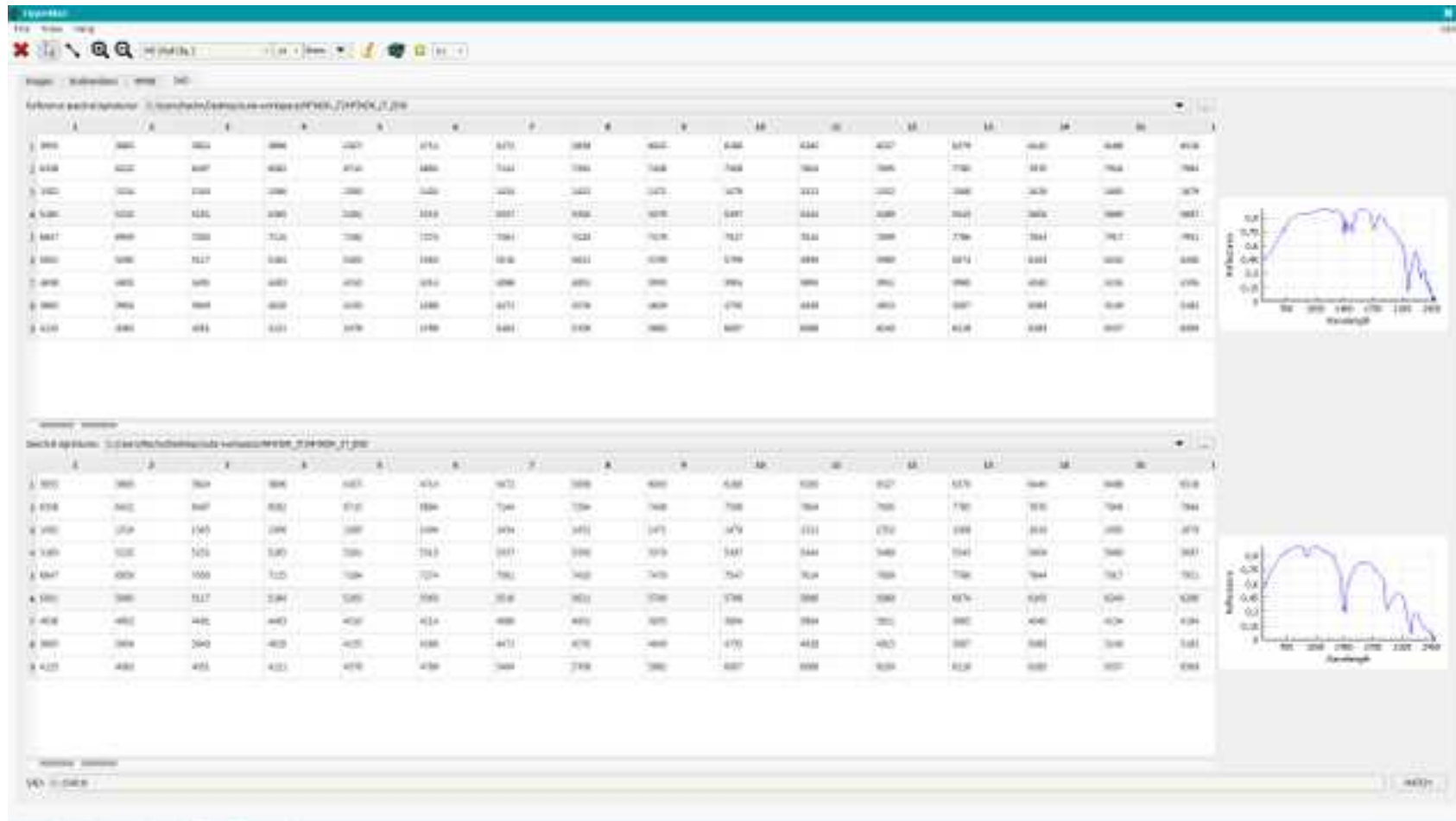
# WP7: Tools



# WP7: Tools



# WP7: Tools



# WP7: Outreach Activities



- L. I. Jimenez, P. N. Happ, R. Q. Feitosa and A. Plaza, “A Parallel Implementation of a Region Growing Segmentation Algorithm for Multispectral and Hyperspectral Images,” *International Workshop on High Performance Computing for Scientific Problems*, Timisoara, Romania, 2013.
- L. I. Jimenez, G. Martin and A. Plaza, “HyperMix: A New Tool for Quantitative Evaluation of Endmember Identification and Spectral Unmixing Techniques,” *IEEE Geoscience and Remote Sensing Symposium (IGARSS'12)*, Munich, Germany, 2012.
- L. I. Jimenez, G. Martin and A. Plaza, “A New Tool for Evaluating Spectral Unmixing Applications for Remotely Sensed Hyperspectral Image Analysis,” *International Conference on Geographic Object-Based Image Analysis (GEOBIA)*, Rio de Janeiro, Brazil, 2012.

# WP7: Outreach Activities



- Renata Ruiz, Paulo Ruiz, Sergio Sánchez, Antonio Plaza, “Using Random Matrix Theory to Determine the Number of Endmembers for Real Time Hyperspectral Unmixing on GPUs,” In preparation.
- José Renato G. Braga, Wanessa da Silva, Sabrina B. Sambatti, Vitor C. Gomes, Antonio J. Plaza, Elcio H. Shiguemori, Haroldo F. C. Velho, “Hyperspectral Image Classification by Neural Network and Non-linear PCA with Hardware Implementation,” In preparation.
- Victor Ayma, Jun Li et al., “A New Simplex Growing Algorithm for Endmember Extraction from Hyperspectral Images,” In preparation.
- Victor Ayma, Mario Haut et al., “Integration of supervised classification strategies in a web maps processing server for efficient analysis of Google Maps data,” In preparation.



# Conclusions



- The initial forecast for the work package (to develop research and training activities in the area of parallel computing for the benefit of the TOLOMEO project) has been achieved.
- A new tool (HyperMix) with a strong component on parallel computing has been developed and refined as part of the project (without the project, the tool would not exist).
- The secondment activities related with the workpackage have been performed very smoothly, with a group of highly talented young researchers that have contributed significantly to the institutions that they visited, from the human and work points of view.
- The number of secondments could be higher, in this case the relevance of the work package activities could be more significant.
- Thanks to Paolo Gamba for his great coordination and support.