

# VIRTUAL PROCESSING SOFTWARE FOR DISTRIBUTED ANALYSIS OF HIGH-RESOLUTION REMOTE SENSING DATA

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## ABSTRACT

In this paper we address a prospective look at the problem of computational simulation for different distributed tasks related to analysis of multispectral data obtained with the use of remote sensing systems as required for end-user-oriented environmental monitoring, urban assessment/planning and natural resources management. This virtual processing software for analysis of multispectral remote sensing imagery employs and unifies some previously developed enhancement, reconstruction, segmentation, classification, quantification and dynamical post-processing methodologies in a simulation tool referred to as the Geophysics Dynamic Laboratory (GDL). Simulation examples are reported to illustrate the usefulness of the elaborated GDL software for algorithmic-level analysis of high-resolution multispectral remote sensing imagery.

*Index Terms*— Remote Sensing, Image Classification

## 1. INTRODUCTION

Considerable progress has been made generally in the application of remote sensing (RS) techniques, to both research and operational problems for environmental monitoring, urban assessment/planning and natural resources management. Reports of such work may be found in journals such as *Geoscience and Remote Sensing* (IEEE, USA), *Remote Sensing of the Environment* (USA) and the *International Journal of Remote Sensing* (UK), as well as in discipline-specific publications such as the *Hydrological Sciences Journal* (UK) and through the *Proceedings of International Conferences in Remote Sensing* (e.g., those organized regularly by IEEE). Modern applied theory of image processing for environmental monitoring, urban assessment/planning and natural resources management is now a mature and well-developed research field, presented and detailed in many works ([1] thru [4] and the references therein are only some indicative examples).

Although the existing theory offers a manifold of statistical and descriptive regularization techniques to tackle with the particular environmental monitoring problems, in many applications areas there still remain some unresolved crucial theoretical and data processing problems.

One of those unsolved problems is particularly related to the extraction, enhancement and space-time analysis of environmental characteristics (e.g., wetland, forest, grassland, rangeland) for applications in natural resource management (modelling and planning) and end-user computing aspects that incorporate the high-precision filtering techniques for evaluation and prediction of the dynamic behaviour of the particular extracted environmental processes. To solve this problem, three principal tasks must be analysed:

1) Imaging techniques – This is the data collection stage. High-resolution multispectral imaging of a particular geophysical zone can be obtained using remote sensing active techniques such as microwave (RADAR) [5], laser (LIDAR) [6] or acoustic (SONAR) [7].

2) Geophysical characteristics mapping – Information extraction procedures [3] are applied based on multispectral image segmentation and classification (supervised or unsupervised). This stage generates the geophysical signature map of the environmental characteristics to be analysed [7].

3) Dynamic analysis of signature maps – This is the digital multispectral image post-processing technique that provides the space-time performance and evolution of the environmental characteristics analysed. This is a filtering and analysis methodology [9].

## 2. MULTISPECTRAL IMAGING

Multispectral imaging is a technology originally developed for space-based imaging. Multispectral remote sensing (MRS) images are the main type of images acquired by RS radiometers. Usually, MRS systems have from 3 to 7 radiometers; each one acquires one digital image (also called scene) in a small band of visible spectra, ranging 450 nm to 690 nm, called red-green-blue (RGB) regions [10].

For different purposes, combinations of spectral bands can be used. They are usually represented with red (R), green (G) and blue (B) channels. This is referred to as True-Color RS imagery [10]. The wavelengths for the spectral bands are as follows (the values are approximated, exact values depends on the particular MRS instruments [7])

- 1) Blue: 450-520 nm.
- 2) Green: 520-600 nm.
- 3) Red: 600-690 nm.

### 3. GEOPHYSICS DYNAMIC LABORATORY

Taking into consideration the three stages described in Section 2, a virtual processing software for analysis of MRS images is developed, which employs and unifies some previously developed enhancement, reconstruction, segmentation, classification, quantification and dynamical post-processing methodologies in a simulation tool referred to as the Geophysics Dynamic Laboratory (GDL), using distributed computing techniques to improve time processing.

Figure 1 shows the graphical user interface of the GDL software.

#### 3.1. First stage: MRS imaging techniques

At this level of study we adopt the previously developed high-resolution radar imaging technique to the problem of geophysical mapping and multi-stage post-processing. The particular adopted technique is the robustified and multispectral version of the fused Bayesian-Regularization (RFBR) method [5] for high-resolution reconstruction of the power spatial spectrum patten (SSP) of the wavefield scattered from the remotely sensing scene, incorporating the analysis of the MRS imaging method based on matched filtering.

Since this is in essence a nonlinear numerical inverse problem, the proposition is to alleviate the problem ill-posedness by robustification of the Bayesian estimation strategy [5] via performing the non adaptive approximations of the reconstructive operators that incorporate the non trivial metrics considerations for designing the proper solution space and different regularization constraints imposed on a solution. Pursuing such an approach the RFBR method is proposed in the form adapted to the problems of MRS mapping.

#### 3.2. Second stage: Geophysical signatures extraction

At this stage, we perform the extraction of geophysical characteristics of a particular geographical region through MRS data processing. This enables us to generate electronic maps of geophysical characteristics and create a high-resolution collection atlas of signature maps processed in time for a particular geographical region.

The information extraction procedures are based on image segmentation and classification techniques. We adopt the previously developed Weighted Pixel Statistics (WPS) method. An extensive study was performed in [11] to probe that the accuracy obtained with this classification process is more efficient (both qualitatively and quantitatively) compared with other more computationally intensive algorithm (as the weighted order statistics method [4]).

It is characterized by the mean and variance values of the multispectral geophysical signatures (MGS) to be classified (defined as classes) and the Euclidean distances based on the Pythagorean theorem.

#### 3.3. Third stage: Dynamical analysis of MGS

The last stage is to incorporate the concept of dynamic computing into the electronic maps generation technique to enable the latter to reconstruct the desired environmental imagery taking into account the dynamical behavior (evolution in space and time) of the extracted geophysical characteristics. This provides a background for understanding the future trends in development of intelligent dynamic high-resolution MRS imaging.

The analysis of the dynamical model of MGS maps extracted from a geographic region processed using the data provided by MRS systems generates useful information for environmental monitoring, urban assessment/planning and natural resources management.





Using the MGS signature maps extracted from the MRS reconstructed imagery for a particular geographic zone; the dynamic study of the MGS is performed as described in [9] to obtain the dynamical model of the physical variables and some evolutionary information about the signatures.

### 4. GDL SIMULATION EXPERIMENT

In the reported here preliminary simulation results, the GDL software is employed for MRS image enhancement, hydrological signatures extraction and dynamical analysis using a high-resolution MRS scene.

For the MRS imaging technique using the RFBR method, we considered the SAR with partially (fractionally) synthesized aperture as an MRS imaging system. The signal formation operator was factorized along two axes in the image plane: the azimuth (horizontal axis) and the range (vertical axis). Following the common practically motivated technical considerations we modeled a triangular shape of the MRS range ambiguity function of 3 pixels width, and a  $|\text{sinc}|^2$  shape of the MRS azimuth ambiguity function of 10 pixels width at the zero crossing level.

For the geophysical signatures extraction using the WPS method, three level MGS are selected for this particular simulation process; moreover, unclassified zones must be also considered (2-bit classification) as

-  – MGS relative to the wet zones of the MRS image.
-  – MGS relative to the humid zones of the MRS image.
-  – MGS relative to the dry zones of the MRS image.
-  – Unclassified zones of the MRS map.

Finally, for the dynamical analysis of MGS maps, a collection of 40 MGS maps for the same scene acquired in different discrete time, the dynamical analysis provides a prognosis for the next-step evolution time.

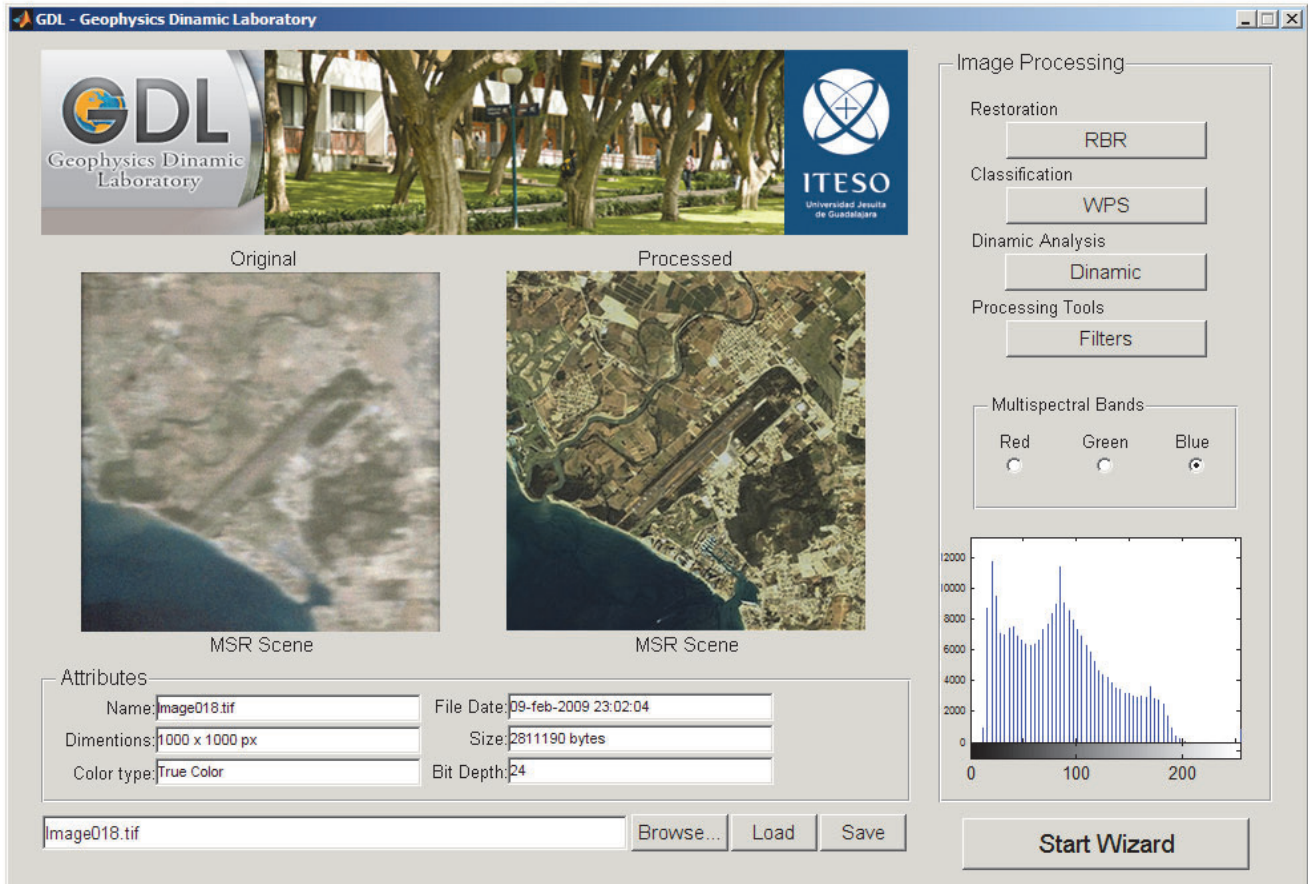


Figure 1. Graphic interface of the virtual GDL intelligent software.

Figure 2 shows the simulated high-resolution ( $10,000 \times 10,000$  pixels) RGB image in TIFF format provided by the MRS system, corresponding to the Banderas Bay in the city of Puerto Vallarta in Mexico [12].

Figure 3 shows the MRS scene reconstructed with the application of the RFBR method.

Figure 4 shows the MGS map extracted from Figure 3 and obtained applying the WPS method for the adopted ordered weight vector. Figure 5 shows the dynamic MGS map for the next-step prediction (map number 41).

## 5. CONCLUDING REMARKS

From the simulation results is possible to confirm that the applied GDL software employs and unifies the previously developed enhancement, reconstruction, segmentation, classification, quantification and dynamical post-processing methodologies in a virtual simulation tool that employs distributed computing techniques to improve the processing time using multispectral and high-resolution data, focused for end-user environmental monitoring, urban assessment/planning and natural resources management applications.

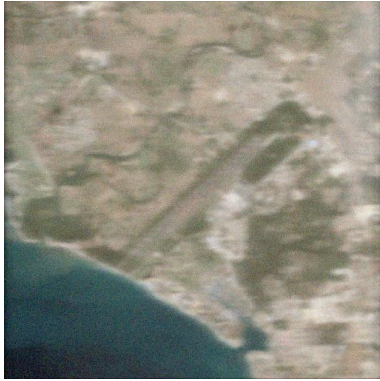
The simulations for the image reconstruction with the use of the RFBR approach was performed for solving the

nonlinear inverse problems of high-resolution reconstruction of the SSP of the remotely sensed scenes via processing the finite-dimensional space-time measurements of the available sensor system signals. The extraction of hydrological MGS maps from a particular MRS region through the WPS method was performed to develop an electronic map atlas. The dynamical post-processing analysis reveals a numerical reconstruction and filtration of different MGS maps in discrete evolution time.

The reported results show the qualitative analysis of the overall performance of the GDL software for geophysical analysis and information retrieval. The quantitative analysis, data interpretation and time processing reduction using distributed computing are a matter of further studies.

## 6. ACKNOWLEDGMENT

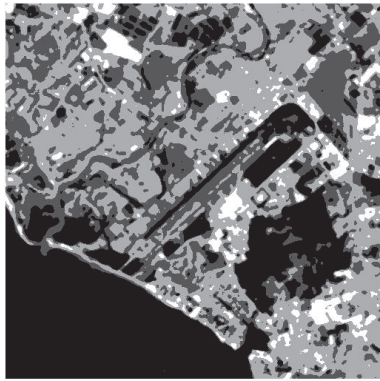
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**Figure 2.** Original simulated MRS scene.



**Figure 3.** Scene reconstructed with the RFBR method.



**Figure 4.** MGS map extracted with the WPS method.



**Figure 5.** MGS dynamic prediction.

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