

ORFEO TOOLBOX: A COMPLETE SOLUTION FOR MAPPING FROM HIGH RESOLUTION SATELLITE IMAGES

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ABSTRACT:

One of the main objectives of the Orfeo Toolbox (OTB) is the definition and the development of tools for the operational exploitation of the future sub-metric optic and radar images (rapid mapping, tridimensional aspects, change detection, texture analysis, pattern matching, optic and radar complementarities). The purpose of the OTB is to capitalize a methodological know-how in order to adopt an incremental development approach aiming to efficiently exploit the results obtained by research studies. OTB is interesting for all people working in the remote sensing imagery community. Releasing it under an open source licence, CNES hopes to benefit from contributions of many specialists to help grow the practical use of satellite imagery.

1 INTRODUCTION

Besides the Pleiades (PHR) and Cosmo-Skymed (CSK) systems developments forming ORFEO, a dual French-Italian system for Earth Observation, the ORFEO Accompaniment Program was set up, to prepare, accompany and promote the use and the exploitation of the images derived from these sensors.

The creation of a preparatory program is needed because of :

- the new capabilities and performances of the ORFEO systems for mapping applications (high resolutions, access capability, data quality, possibility to acquire simultaneously in optic and radar);
- the implied need of new methodological developments: new processing methods, or adaptation of existing ones.

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On figure 1, a generic structure for generating maps from satellite data is presented. Several steps are required before the map generation itself and several inputs are necessary to obtain valuable results. Hence, the pipeline structure is well adapted for this problem.

Section 2 explains the *raison d'être* of the ORFEO Toolbox library and its features are detailed in section 3. As some of the features are based on external libraries, we mention them in section 4. These external libraries play a key role in the validation of the proposed features and the global validation step is illustrated in section 5. Finally, the computing aspect which cannot be neglected are detailed in section 6.

2 ORFEO TOOLBOX

In this context, CNES decided to develop the *ORFEO ToolBox* (OTB) (The ORFEO Toolbox Software Guide, 2008), a set of algorithms encapsulated in a software library. The purpose of the OTB is to capitalize a methodological know-how in order to adopt an incremental development approach aiming to efficiently exploit the results obtained in the frame of methodological R&D studies.

Indeed, there is often a gap between published algorithms in conferences or journals and algorithms which are used for real applications. Algorithms presented at conferences may work well on small data set or with some settings which need in-depth knowledge of the theory. On the opposite, functional applications need to work on any data set (often huge) without the knowledge of an image processing expert. To be able to bridge this gap practical implementations of algorithms published in the literature need to be available.

Free availability of such implementations play also an important part for the development of reproducible research. It is also very valuable for researchers and students to have access to a complete implementation of previously published algorithms. For researchers, this enables them to compare their results with these previous algorithms. For PhD students it is often a valuable starting point to develop their new methods.

All the developments are based on FLOSS (Free/Libre Open Source Software) or existing CNES developments.

3 WHAT CAN WE DO WITH OTB?

When the purpose is to use high resolution satellite images for fast mapping, several preprocessing steps are necessary before the mapping itself. The goal of OTB is to enable the user to process satellite images from different sources (satellite, image provider) with different levels of preprocessing (orthorectification, radiometric corrections). OTB proposes the basic function-

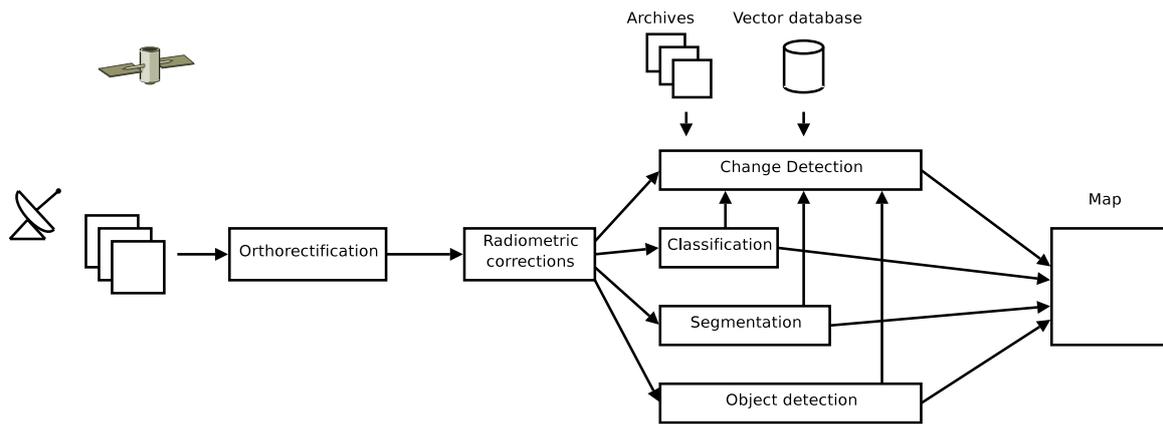


Figure 1: Generic pipeline processing for mapping from satellite images

alities that need to be interconnected to meet the needs of a particular user.

About 3000 C++ classes are already available in the current version of OTB for most of the usual operations on remote sensing images.

- image access: optimized read/write access for almost any of remote sensing image formats, meta-data access, visualization;
- geometric modeling: sensor models, DEM access, cartographic projections, image registration, disparity map estimation;
- filtering: blurring, denoising, enhancement;
- feature extraction: interest points, alignments, lines;
- image segmentation: region growing, fast marching, watershed, level sets;
- object extraction: road network extraction, example-based detection;
- classification: K-means, SVM, Markov random fields;
- change detection.

As we can see, the functionalities cover the whole range of image processing, from access to image format to applications like change detection.

Segmentation is a basic task in image processing. On figure 2 an example is given for the fast marching algorithm initiated from three different seeds directly on the luminance image.

On figure 3, the registration between an optical and a radar image of the same area is illustrated. A good registration is a compulsory stage before being able to exploit jointly information from both images (Inglada and Giros, 2004). The deformation model is done by a centered affine transform which is able to introduce translation, rotation and scaling effects. The similarity metric cannot be a simple correlation due to the completely different acquisition process between the two sensors: mutual information is used instead (Maes et al., 1997).

Most current high resolution optical sensors (Spot 1 to 5, Quickbird, the coming Pleiades), have a high resolution panchromatic band and a multispectral band with a lower resolution (typically



Figure 2: Segmentation example: from three different seeds. The fast marching algorithms generates three different areas.

by a factor of four). A pan-sharpening step is necessary to obtain an image with four spectral bands with the highest resolution. Several pan-sharpening methods are available in OTB. One example is illustrated in figure 4.

Image classification from examples is a very useful task. Support Vector Machine can produce a good classification models from few examples (Weston and Watkins, 1998). On figure 5, an example of classification by SVM is illustrated. On the multispectral image, few regions of interest are selected to train the SVM. Then the entire image is classified.

One common application of satellite images is the change detection between two images, either to detect the effects of natural disasters or to update vector database (Poulain et al., 2008). Figure 6 presents the application on flooding on the South of England using SPOT images. Many other change detectors have been implemented in the toolbox using statistical similarity measures, as for instance the one presented in (Inglada and Mercier, 2007).

Finally, direct objects or network extraction can also be developed. Figure 7 presents a real-time road extraction algorithm (Christophe and Inglada, 2007).

All these features are available in OTB, but not all were developed internally. The library is based on several external libraries.

4 USING THE (GREAT) WORK OF OTHERS

When developing a complex library, thorough validation of the algorithms is always a very delicate part. To be able to provide well tested algorithm with limited resources, OTB is based on numerous, carefully chosen, open-source libraries. For each domain, we select the library which has a broad base of users (the library is well tested) and which is compatible in terms of licence

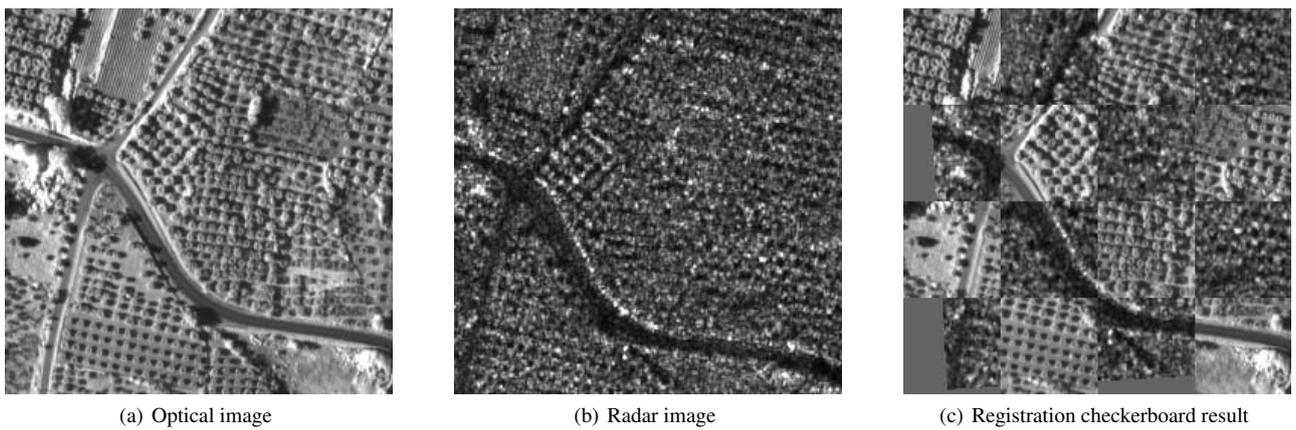


Figure 3: Registration: the optical and the radar images represent the same area with a deformation. A six parameters transform is computed (translation, rotation, scaling) using the mutual information as a similarity measure.

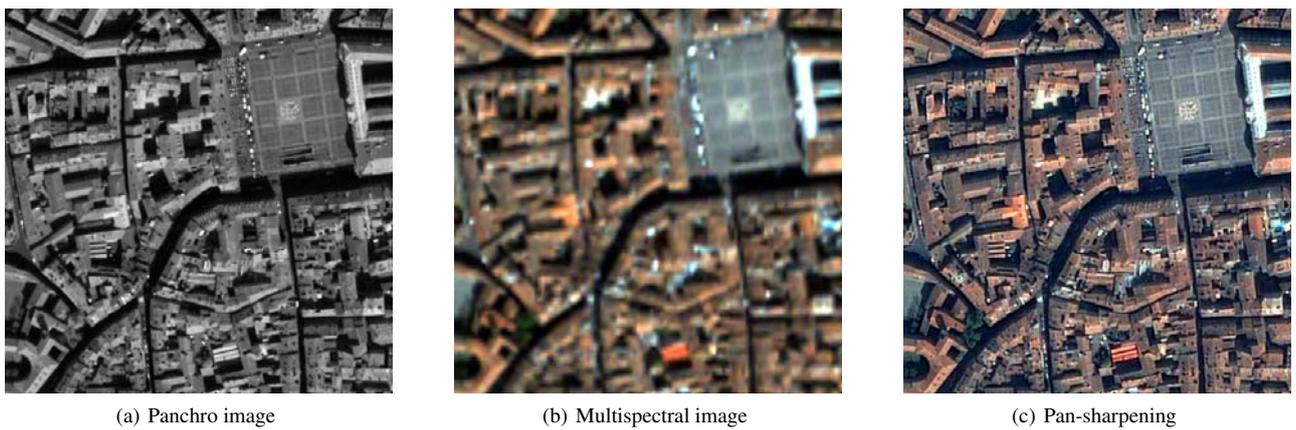


Figure 4: Pan-sharpening example: high resolution of the panchromatic image is introduced in the multispectral image to obtain a multispectral high resolution image with a basic method.

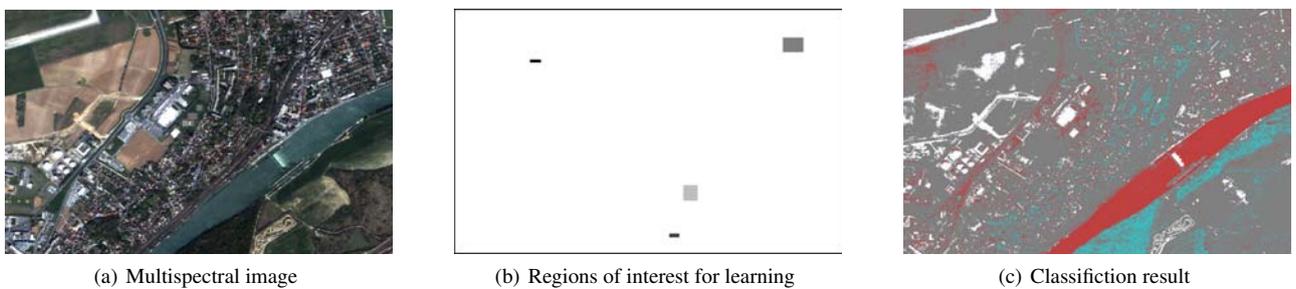


Figure 5: Support Vector Machine example: on a multispectral image, four areas of interest are defined. These area are the base for the SVM learning step. Then all pixels are classified.

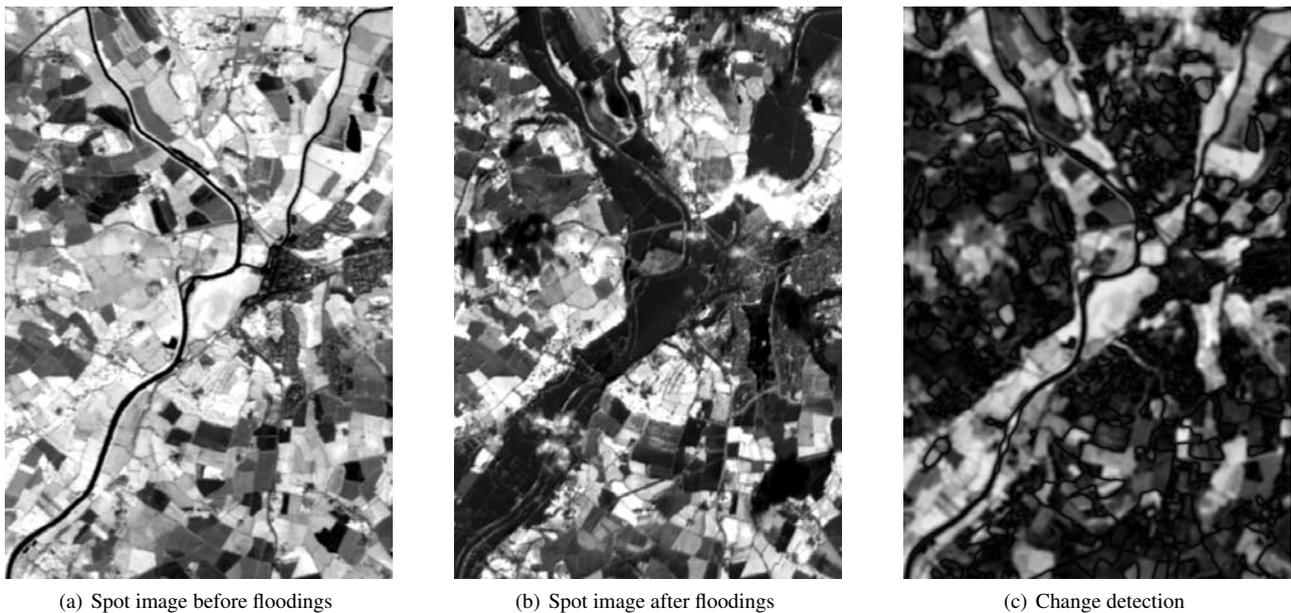


Figure 6: Change detection example on two SPOT5 images from before and during floodings in the north of England with a mean difference change detector.

Libraries	Functionalities
ITK	Architecture, Segmentation Registration
libsvm	Support Vector Machines
boost	Graph representation
ossim	Sensor models, DEM handling
6S	Radiometric corrections
Gdal	Image formats
dxflib	DXF format
OpenJPEG	JPEG 2000 format

Table 1: Open source libraries and functionalities used in OTB

requirements (open source). Access to these libraries is then integrated in the framework of OTB.

4.1 Image processing

The core of the OTB system is coming from ITK which has proven its efficiency for medical image processing. Most of the algorithm for segmentation and registration have been well tested in this context. For the Support Vector Machine (SVM), OTB includes the libsvm library. The graph representation is done using Boost library.

4.2 Specific remote sensing processing

Sensor models, map projections and DEM handling capabilities are provided by ossim. The sensor models are integrated as a special type of ITK transforms which enable an elegant structure for the orthorectifications. Radiometric correction capabilities are provided by 6S. 6S is originally a fortran code that has been automatically translated in C to enable integration into OTB.

4.3 Image format

Most image formats are read through GDAL, enabling OTB to read and write numerous image format. DXF files are handled by dxflib library. For the case of JPEG 2000, as options required by satellite images were not available in JPEG 2000 implementation with compatible licence, CNES participated to the development of OpenJPEG to add these capabilities.

4.4 Great results with minor efforts

As we can see, many functionalities are available, well-tested in the open-source community, and can be integrated to an existing project at marginal cost. When only few options are missing, it is usually quite easy to contribute to the project to add these options.

5 VALIDATION ELEMENTS

OTB is a complex system and needs to be validated both at a computing engineering level and at functionality level. Automation is the key factor for an efficient validation. Every class is coming with some tests to check the non regression and the validity of the results. All these tests are executed every night on 15 different platforms with different compilation options. Impact of modifications on one class is clearly visible on the whole library for the different compilers and compilation options.

A more difficult part, but critical for the OTB user is the validation of the proposed functions from an application point of view. Basically, this is not because a program return a good looking result that the program is correct. For this validation, in-depth knowledge of the functionalities is compulsory. That is why it is particularly important to start with existing and validated developments or to rely on experts for each domain.

6 COMPUTING ASPECTS

6.1 Multiplatform

The library is multiplatform and works under different operating systems (Linux, Unix, Windows, or MacOS) and different architectures (32 or 64 bits) to get rid of hardware constraints. The multiplatform aspect is also very important because it imposes to follow strict design and coding rules thus leading to a robust system less sensitive to particular platform specificities.

6.2 Large data processing

One frequent problem when going from the research algorithm to the real application is the difference in the data size. A satellite



(a) Multispectral image



(b) Road network extraction

Figure 7: Road extraction example combining radiometric and geometric features.

image can reach 1 Giga pixels often in several spectral bands. In this situation, it is unreasonable to load the whole image in the computer memory to process it. This is even truer for high resolution imagery based mapping applications, where, in order to cover the area of interest several satellite scenes are usually used.

Thus, streaming techniques enable to read, process and write the result progressively without having to load the entire image into memory. Most of typical image processing operations work locally and are compatible with streaming. Streaming capabilities are included in OTB transparently for the user, thus enabling an easy processing of huge images.

6.3 Efficient data processing

Since images are divided into separate streams and since most current processors have two, four, or even more, cores, it is tempting to use this capabilities process data in parallel and to save some time. This property is called multithreading. Once again, OTB automatically enables multithreading when it is possible. This is especially valuable to work on clusters where the combination of several processors help to greatly reduce the total processing time. These operations and the repartition on the different computing units is transparent for the OTB user, thus removing most of the burden of multithreaded programming.

7 CONCLUSION

In the mapping and photogrammetry fields the concepts used are often difficult to handle and many users rely on commercial products. However, to truly master the process, a hands on approach is unavoidable.

In this context, OTB allows the user to practice and experiment with real data and real tools and can be used in several situations:

- for engineers: efficient development on new remote sensing applications;
- for engineers: quick evaluation of the performance of a particular algorithm on a specific type of data;
- for researchers: fast prototyping of new algorithms;
- for researchers: library of existing algorithms to compare the results with a new one;
- for professors: teaching of image processing;
- for students: benefit from many heavily-tested algorithms popular in the literature.

The ORFEO Toolbox concerns all people working in the remote sensing imagery community. Releasing it as an open source software, CNES hopes to benefit from the contribution of many specialists to help grow the practical use of satellite imagery.

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