Earth observation image processing with the ORFEO ToolBox

Remote sensing real image processing

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Part of the presentation is derived for a tutorial given by J. Inglada and E. Christophe at IGARSS:"Pragmatic Remote Sensing" .

IPOL workshop 2012

Why?

Common problems

- Reading images
- Accessing metadata
- Implementing state of the art algorithms → Reproducible research

⇒ to be able to extract the most information, we need to use the best of what is available: data, algorithms,. . .

What is Orfeo Toolbox (OTB)?

In the frame of CNES ORFEO Program

Goal

Make the development of new algorithms and their validation easier

- C++ library: provide many algorithms (pre-processing, image analysis) with a common interface
- Open-source: free to use, to modify, you can make your own software based on OTB and sell it
- Multiplatform: Windows, Linux, Unix, Mac

End of the story : 2011 - Launch of Pleiades 1A

Crédits : Pléiades 1A - CNES 2012

A bit of History

Everything begins (2006)

- Started in 2006 by CNES (French Space Agency), funding several full-time developers
- Targeted at high resolution images (Pleiades) but with application to other sensors
- 4 year budget, over 1,000,000€ recently renewed for 3 additional years

Moving to user friendly applications (2008)

- Strong interactions with the end-user community highlighted that applications for non-programmers are important
- Several applications for non programmers (with GUI) since early 2008
- Several training courses (3/5-day courses) given in France, Belgium, Madagascar, UNESCO, Hawaii. . .

A bit of history (2)

Monteverdi (2009)

- Modular software with GUI → Access to some of OTB filters
- Use first for technical courses (*Capacity Building*)
- User feedback : great interest for this type of tool

Interoperability (2011)

- Framework **OTB-Applications**
- Plugin based architecture
- one code → multiple targets
- Example : Quantum GIS plugins (*via* Sextante)
- In parallel : continue to add new algorithms added in the C++ library

Why doing that?

Is it successful so far?

- OTB user community growing steadily (programmers and application users)
- Presented at IGARSS and ISPRS in 2008, special session in IGARSS (2009,2010,2011)
- CNES is planning to extend the budget for several more years
- Value analysis is very positive (cf. Ohloh): re-using is powerful

Why make a multi-million dollar software and give it for free?

- CNES is not a software company
- One goal is to encourage research: it is critical for researchers to know what is in the box
- CNES makes satellites and wants to make sure the images are used
- if more people have the tools to use satellite images, it is good for CNES

How?

How to reach this goal?

Using the best work of others: do not reinvent the wheel

Many open-source libraries of good quality

- ITK: software architecture (streaming, multithreading), many image processing algorithms
- Gdal/Ogr: reading data format (geotiff, raw, png, jpeg, shapefile, . . .)
- OpenJPEG: reading and writing of large data in jpeg2000 format
- Ossim: sensor models (Spot, RPC, SAR, . . .) and map projections
- 6S: radiometric corrections
- and many other: libLAS (lidar data), Edison (Mean Shift clustering), libSiftFast (SIFT), Boost (graph), libSVM (Support Vector Machines)

⇒ all behind a common interface

Components available

Currently

- Most satellite image formats
- Geometric corrections
- Radiometric corrections
- Change detection
- Feature extraction
- Segmentation
- Classification

Huge documentation available

- Software Guide (+700 pages pdf), also the online version
- CookBook online version OTB recipes
- Doxygen: documentation for developers

A powerful architecture

Modular

- Easy to combine different blocks to do new processing

Scalable

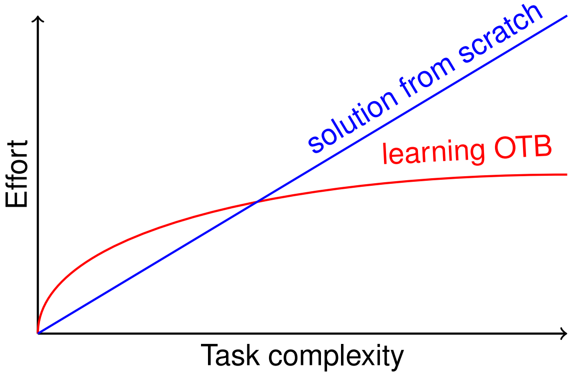
- Streaming (processing huge images on the flow) transparent for the user of the library
- Multithreading (using multicore CPUs) also

But a steep learning curve for the programmer

Advanced programming concepts

- Template metaprogramming (generic programming)
- Design patterns (Factory, Functors, Decorators, Smart Pointers, ...)

Steep learning curve



Ask questions

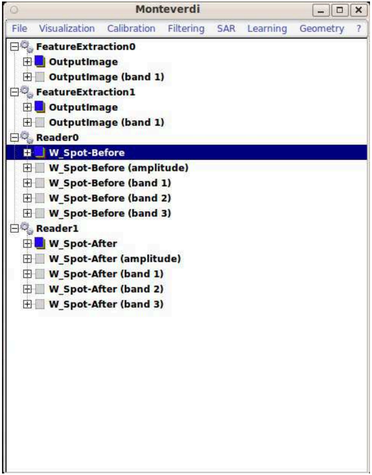
As for everything: easier when you're not alone

- Much easier if you have somebody around to help!
- We didn't know anything not so long ago...
- Not surprising that most software companies now focus their offer on support: help is important

Making it easier for the users: Monteverdi

Module architecture

- Standard input/output
- Easy to customize for a specific purpose
- Full streaming or caching the data
- Graphical pipeline
- Classic : viewer, threshold. . .
- Advanced VHR image analysis : classification, feature extraction, fusion, change detection. . .



FeatureExtraction0
OutputImage
OutputImage (band 1)
FeatureExtraction1
OutputImage
OutputImage (band 1)
Reader0
W_Spot-Before
W_Spot-Before (amplitude)
W_Spot-Before (band 1)
W_Spot-Before (band 2)
W_Spot-Before (band 3)
Reader1
W_Spot-After
W_Spot-After (amplitude)
W_Spot-After (band 1)
W_Spot-After (band 2)
W_Spot-After (band 3)

Making it easier for the users: Monteverdi

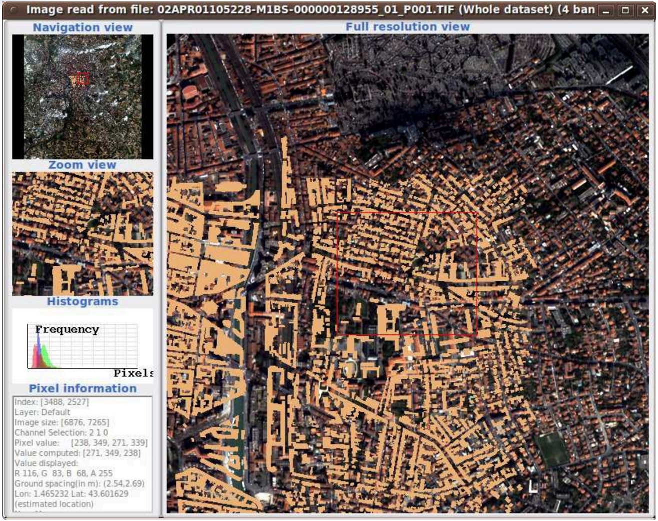


Image read from file: 02APR01105228-M1BS-000000128955_01_P001.TIF (Whole dataset) (4 ban

Pixel information

```
Index: [3488, 2527]
Layer: Default
Image size: [6876, 7265]
Channel Selection: 2 1 0
Pixel value:     [238, 349, 271, 339]
Value computed: [271, 349, 238]
Value displayed:
R 116, G  83, B  68, A 255
Ground spacing(in m): (2.54,2.69)
Lon: 1.465232 Lat: 43.601629
(estimated location)
```

Bindings: access through other languages

Not everybody uses C++!

- Bindings provide an access to the library through other languages
- Python: available
- Java: available with also JVM (Clojure, Scala, etc. . .)
- IDL/Envi: cooperation with ITT VIS to provide a method to access OTB through idl/envi (working but no automatic generation)
- Matlab: ser contribution (R. Bellens from TU Delft)
- Other languages supported by Cable Swig might be possible (Tcl, Ruby. . .)

OTB-Applications

No C++ and no templates please!

- Get benefit of the OTB pipeline architecture from other software(auto magic I/O, streaming, threading, filters. . .)
- Plugin based architecture

Wrappers

- CLI interface
- GUI interface (QT)
- Python API
- QGIS plugins

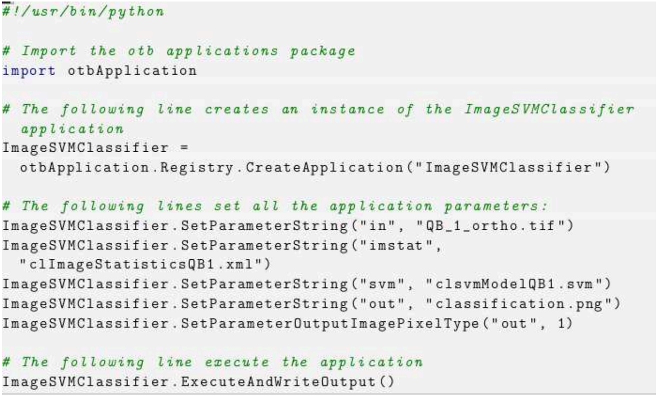
Code!

```
#include "otbImage.h"
#include "otbImageFileReader.h"
#include "otbStreamingImageFileWriter.h"
#include "itkCannyEdgeDetectionImageFilter.h"
#include "itkRescaleIntensityImageFilter.h"

int main(int argc, char * argv[])
{
  typedef double                        PixelType;
  typedef otb::Image<PixelType>         ImageType;

  typedef unsigned char                 OutputPixelType;
  typedef otb::Image<OutputPixelType> OutputImageType;

  typedef otb::ImageFileReader<ImageType> ReaderType;
  ReaderType::Pointer reader = ReaderType::New();

  reader->SetFileName(argv[1]);

  typedef itk::CannyEdgeDetectionImageFilter
  <ImageType, ImageType> FilterType;
  FilterType::Pointer filter = FilterType::New();

  filter->SetInput(reader->GetOutput());
```

I want some more (code)

```
typedef itk::RescaleIntensityImageFilter
  <ImageType, OutputImageType> RescalerType;
  RescalerType::Pointer rescaler = RescalerType::New();

  rescaler->SetOutputMinimum(0);
  rescaler->SetOutputMaximum(255);

  rescaler->SetInput(filter->GetOutput());

  typedef otb::StreamingImageFileWriter<OutputImageType> WriterType;
  WriterType::Pointer writer = WriterType::New();

  writer->SetFileName(argv[2]);

  writer->SetInput(rescaler->GetOutput());

  writer->Update();

  return EXIT_SUCCESS;
}
```

Calling applications from Python



```
#!/usr/bin/python

# Import the otb applications package
import otbApplication

# The following line creates an instance of the ImageSVMClassifier
  application
ImageSVMClassifier =
  otbApplication.Registry.CreateApplication("ImageSVMClassifier")

# The following lines set all the application parameters:
ImageSVMClassifier.SetParameterString("in", "QB_1_ortho.tif")
ImageSVMClassifier.SetParameterString("imstat",
  "clImageStatisticsQB1.xml")
ImageSVMClassifier.SetParameterString("svm", "clsvmModelQB1.svm")
ImageSVMClassifier.SetParameterString("out", "classification.png")
ImageSVMClassifier.SetParameterOutputImagePixelType("out", 1)

# The following line execute the application
ImageSVMClassifier.ExecuteAndWriteOutput()
```

OTB access - Applications, Monteverdi. . .

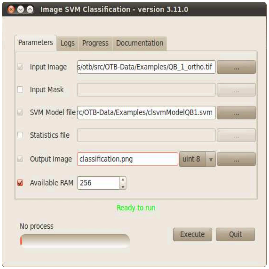


Image SVM Classification - version 3.11.0

☑ Input Image s/otb/src/OTB-Data/Examples/QB_1_ortho.tif

□ Input Mask

☑ SVM Model file: rc/OTB-Data/Examples/clsvmModelQB1.svm

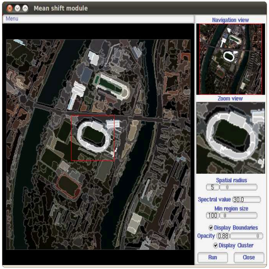
□ Statistics file

☑ Output Image: classification.png, uint 8

☑ Available RAM: 256

Ready to run

No process


Mean shift module

Spatial radius: 5

Spectral value: 30.0

Min region size: 100

☑ Display Boundaries

Opacity: 0.88

☑ Display Cluster

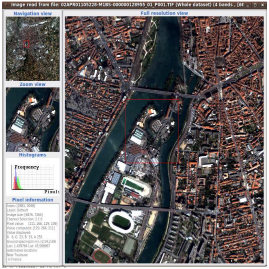


Image read from file: 02APR01105228-M1BS-000000128955_01_P001.TIF (Whole dataset) (4 bands , [6€

Index: [2681, 3048]
Layer: Default
Image size: [6876, 7265]
Channel Selection: 2 1 0
Pixel value: [211, 266, 129, 109]
Value computed: [129, 266, 211]
Value displayed:
R 6, G 23, B 33, A 255
Ground spacing(in m): (2.54,2.69)
Lon: 1.439764 Lat: 43.588967
(estimated location)
Near Toulouse
in France

Image access

Pléiades data support

- Improve support for Jpeg2000 *via* OpenJPEG[1]
- Metadata access (RPC model) *via* OSSIM[2]
- Metadata access(from DN to reflectance)
- Direct access to other resolution(thanks to Jpeg2000)
- Efficient visualization and navigation in Monteverdi

[1] https://code.google.com/p/openjpeg/

[2] Awesome image Processing

Uncompress Pleiades tiles PHR JPEG2000

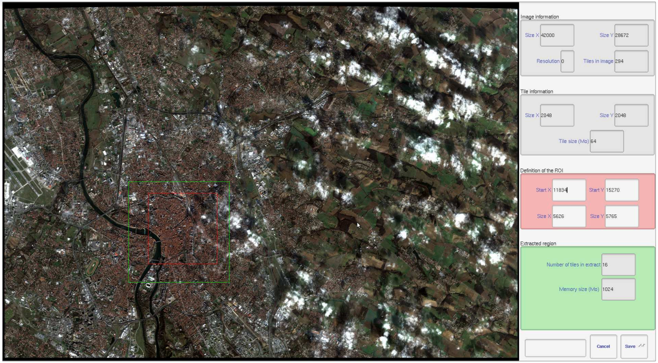


Image information

Size X 42000 Size Y 28672

Resolution 0 Tiles in image 294

Tile information

Size X 2048 Size Y 2048

Tile size (Mo) 64

Definition of the ROI

Start X 11834 Start Y 15270

Size X 5626 Size Y 5765

Extracted region

Number of tiles in extract 16

Memory size (Mo) 1024

Figure: Extraction ROI - Pléiades 50cm

Classification and OBIA

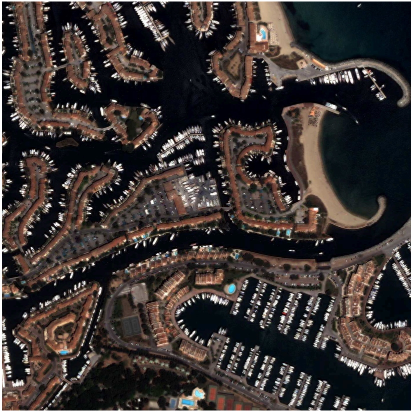
- OBIA : Object Based Image Analysis
- OBIA : lots of methods published
- Labeling objects not pixels
- Improve efficiency of structural approaches

Classification

- Supervised classification based on objects attributes
- SVM for example (but others can be plugged)

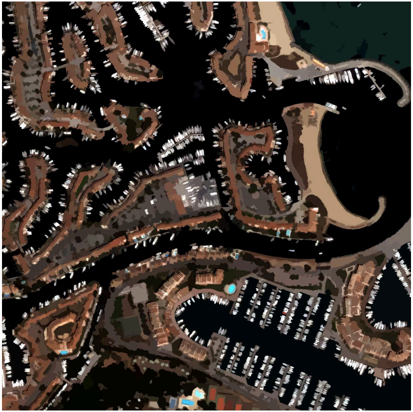
Results

Original image (Massif des Maures - QuickBird pan-sharpening 0.7m)



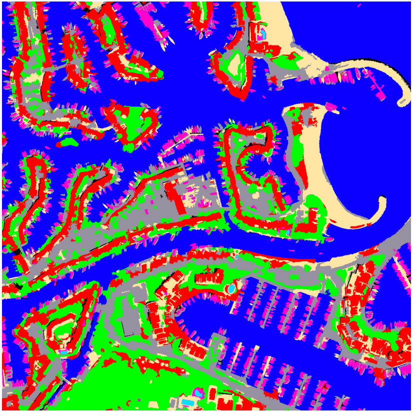
Results

Segmented image (mean-shift here) - Crucial point!



Results

Object based classification (SVM in this case)



OBIA

- Challenge : Large scale analysis with export to SIG
- Performance, ergonomy (vector/raster), streaming, multi-threading
- Different access : C++ classes, applications (supervision → needs a good user interface)

Massive segmentation or nothing

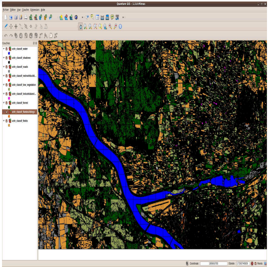
Principe

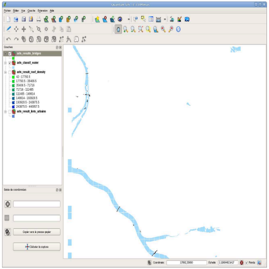
- Large scale segmentation
- Segmentation quality measurement! → Hoover scores
- Efficient and correct segmentation → "Cachez cette tuile que je ne saurait voir"
- Objects manipulation ? Efficient conversion between raster/vector ?

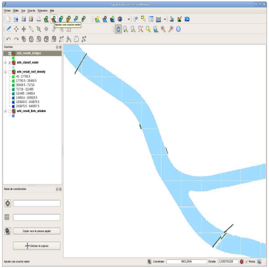
Principles

- Apply segmentation (many algorithms available)
- Vectorized results on each tile (memory management)
- Concatenate vector data and remove tile effects (fusion)

Tiles sucks!


Quantum GIS - 1.3.0-Mimas
Fichier Editer Vue Couche Extension Aide
Couches
arln_classif_water
arln_classif_shadows
arln_classif_roads
arln_classif_redroofsbuild...
arln_classif_low_vegetation
arln_classif_industrialand...
arln_classif_forest
arln_classif_flatbuildings
arln_classif_fields


Quantum GIS - 1.3.0-Mimas
Fichier Editer Vue Couche Extension Aide
Couches
arln_results_bridges
arln_classif_water
arln_result_roof_density
42 - 17793.5
17793.5 - 35406.5
35406.5 - 71716
71716 - 111485
111485 - 149914
149914 - 193928.5
193928.5 - 243875.5
243875.5 - 440957.5
arln_result_ilots_urbains


Quantum GIS - 1.3.0-Mimas
Fichier Editer Vue Couche Extension Aide
Couches
arln_results_bridges
arln_classif_water
arln_result_roof_density
42 - 17793.5
17793.5 - 35406.5
35406.5 - 71716
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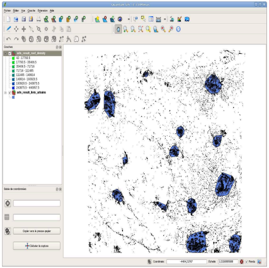
111485 - 149914
149914 - 193928.5
193928.5 - 243875.5
243875.5 - 440957.5
arln_result_ilots_urbains


Quantum GIS - 1.3.0-Mimas
Fichier Editer Vue Couche Extension Aide
Couches
arln_result_roof_density
42 - 17793.5
17793.5 - 35406.5
35406.5 - 71716
71716 - 111485
111485 - 149914
149914 - 193928.5
193928.5 - 243875.5
243875.5 - 440957.5
arln_result_ilots_urbains

Available in 3.14

- Threaded mean-shift algorithm
- Generic filters for tiled based segmentation
- Method for polygons fusion near tiles region
- Fully compatible with OGR

Stereo reconstruction with OTB

- Stereo-rectification of optical images pair based on sensor model
- Complete spectrum of stereo correspondence algorithms has been published
- Block matching, sub-pixel estimation of disparity, median filter. . .
- Use SRTM as initial disparity (DEM)
- What's new? Use/Combine with feature extraction pipeline (common interface)

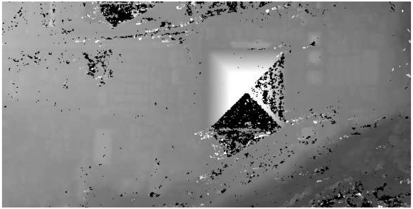


Figure: DEM result from Pleiades stereo pair over the Pyramid of Cheops!

And now?

- ORFEO program - Thematic in-flight commissioning activities until mid-2013
- OTB will continue after the ORFEO program (VHR, SAR, MX,HX. . .)

OTB → On the road to ITKv4

ITK

- 10 years project
- 5M de $ (Leverage)
- From the American Recovery and Reinvestment Act of 2009
- ITKv4 : The next generation 1.5 years project -> Prepare next 10 years

Functionalities

- GPGPU -> massively parallel processing power
- Modularity
- Review, refactoring, new filters. . .
- OTB : Reuse is better than recycling

Where can you find informations?

- `http://www.orfeo-toolbox.org/`
- `http://groups.google.fr/group/otb-users`
- `http://groups.google.fr/group/otb-developers`
- `http://blog.orfeo-toolbox.org/`
- `http://wiki.orfeo-toolbox.org/`

Questions?

ORFEO ToolBox is not a black box