The CImg Library

C++ Template Image Processing Toolkit

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Presentation layout

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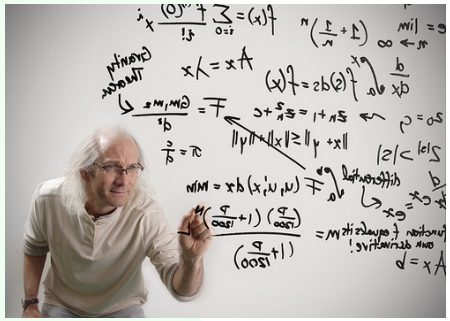
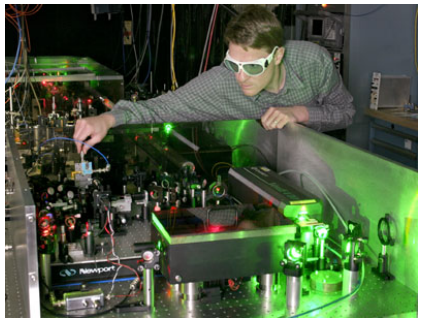
Diversity of People and Applications

- Fact 1 : The image processing research world is **wide.**
  Many different people compose it, each with a different scientific background :



Mathematicians



Physicists

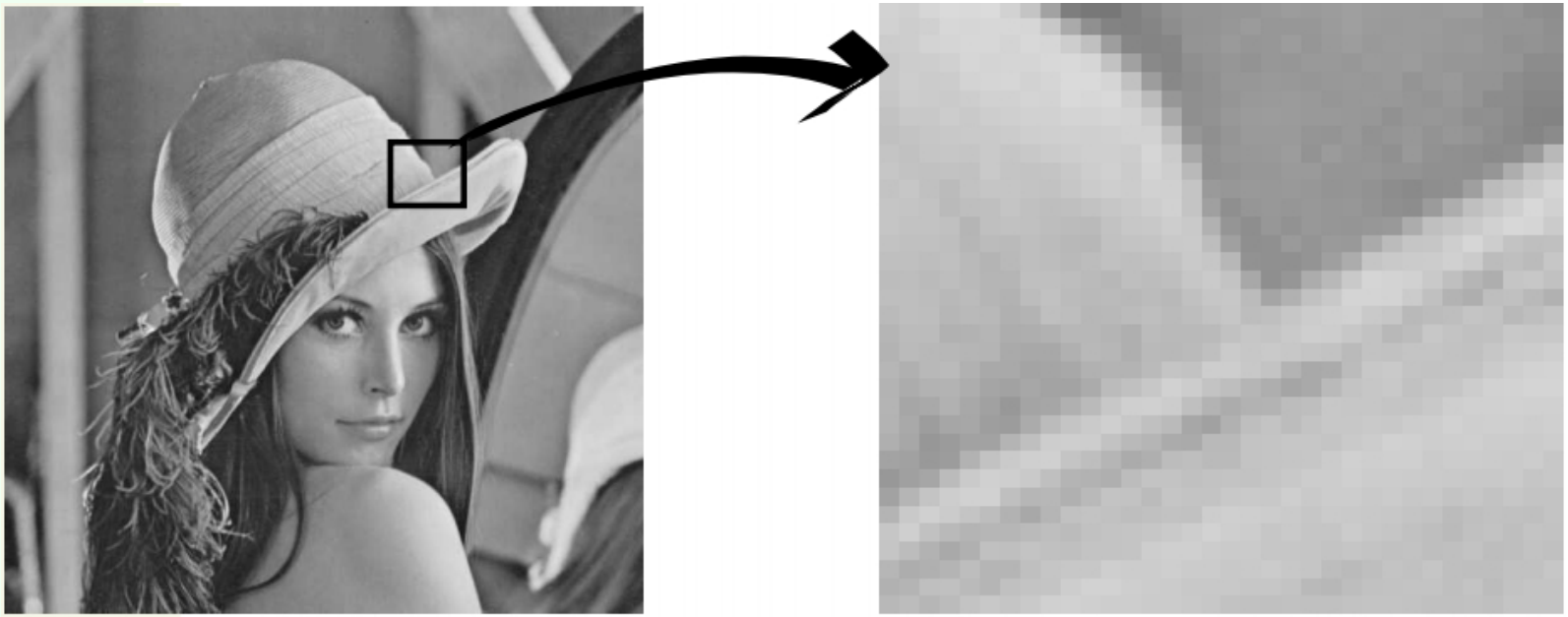
Computer geeks

Biologists ...

- Fact 2 : They all work on images, trying to solve many different problems, involving **a wide diversity of image data.**
  Photography, medical imaging, astronomy, robot vision, fluid dynamics, etc...

Diversity of Image Data

- Fact 3 : Digital images are **generic objects by nature**.



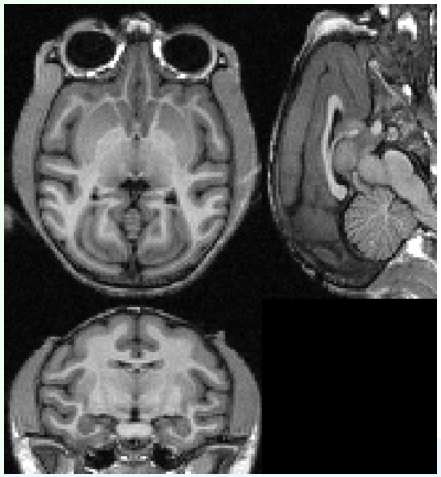
- On a computer, image data are usually stored as discrete arrays of values (pixels or voxels), But the **diversity** of acquired images is important.

Diversity of Image Data

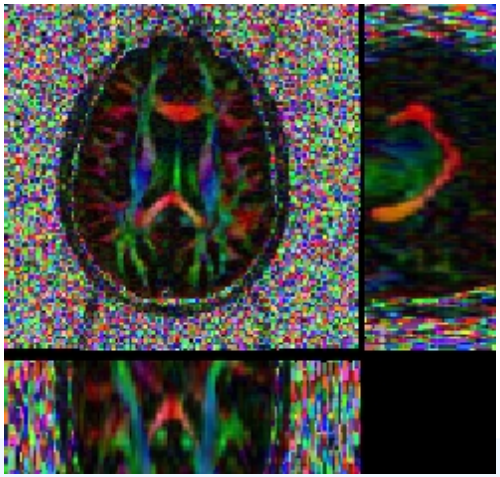
$2D \rightarrow [0, 255]$

$2D \rightarrow [0, 255]^3$

$(2D + t) \rightarrow [0, 255]^3$



$3D \rightarrow [0, 16383]$



$3D \rightarrow \mathbb{R}^6$

$(2D + t) \rightarrow [0, 16384]$

Diversity of Image Data

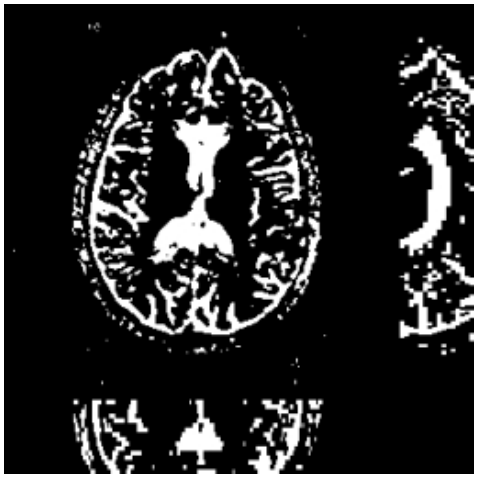
- Acquired digital images may be of different types :
  - Domain dimensions : $2D$ (static image), $2D + t$ (image sequence), $3D$ (volumetric image), $3D + t$ (sequence of volumetric images), ...
  - Pixel dimensions : Pixels can be scalars, colors, $N - D$ vectors, matrices, ...
  - Pixel value range : depends on the sensors used for acquisition, can be N-bits (usually 8,16,24,32...), sometimes (often) float-valued.
  - Type of sensor grid : Square, Rectangular, Octagonal, Graph, ...

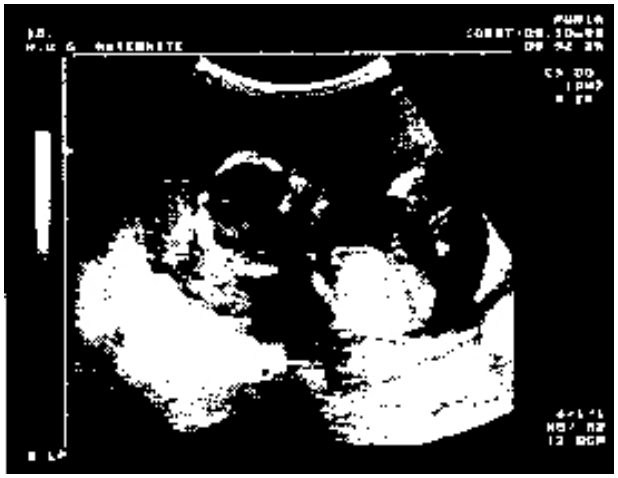
- All these different image data are digitally stored using dedicated file formats :
  - PNG, JPEG, BMP, TIFF, TGA, DICOM, ANALYZE, AVI, MPEG, ...

Image Processing Algorithms

- Fact 4 : Usual image processing algorithms are mostly **image type independent.**
- e.g. : Binarization of an image $I : \Omega \to \Gamma$ by a threshold $\epsilon \in \mathbb{R}$.

$$\tilde{I} : \Omega \to \{0, 1\} \quad \text{such that} \quad \forall p \in \Omega, \quad \tilde{I}(p) = \begin{cases} 0 & \text{if } \|I(p)\| < \epsilon \\ 1 & \text{if } \|I(p)\| >= \epsilon \end{cases}$$





- Implementing an image processing algorithm should be as much independent as possible of the image format and coding.

Question

How to help those **various people** implementing **image processing algorithms** working on **generic images** in an **easy way** ?

CImg and G'MIC Philosophy

- Based on these facts, we designed **CImg** and **G'MIC**, two lightweight image processing toolboxes fitting these constraints :

Easy to install, easy to take control. Two different scales of uses (C++ and script).

Generic enough for managing a wide variety of data types. (template-based).

Provides useful, classical and must-have algorithms and tools.

Extensible frameworks by nature.

Easy to spread from/to any computer (portable to various architectures and OS).

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Presentation layout

The CImg Library : Overview

- What ? : Small C++ library aiming to **simplify the development of image processing algorithms** for generic-enough datasets.
- For whom ? : For Researchers and Students in Image Processing and Computer Vision, having basic notions of C++.
- How ? : Defines a **minimal set** of templated C++ classes able to manipulate and process image datasets.
- Since when ? : Started in late 1999, hosted on Sourceforge since December 2003 *(about 1200 visits and 100 downloads/day)*.

http://cimg.sourceforge.net/

- **Easy to get :** CImg is distributed as a .zip package (≈ 12.7 Mo) containing the library code (≈ 40.000 loc), examples of use, documentations and resource files.
- **Easy to use :** Using CImg requires only the include of a single C++ header file. No complex installation, no pre-compilation :

```
#include "CImg.h"                    // Just do that...
using namespace cimg_library; // ..Ready to go !
```

- **Easy to understand :** It defines only four C++ classes :

```
CImg<T>, CImgList<T>, CImgDisplay, CImgException
```

Image processing algorithms are methods of these classes :

```
CImg<T>::blur(), CImgList<T>::insert(),
CImgDisplay::resize(), ...
```

- **CImg Motto : KIS(I)S, Keep it Small and (Insanely) Simple.**

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CImg is generic-enough for most cases :

- CImg implements static genericity using C++ templates.
  KISS philosophy : One template parameter only !
  $\Longrightarrow$ the type of the image pixel (bool, char, int, float, ...).
- A `CImg<T>` instance can handle hyperspectral volumetric images (4D = width×height×depth×spectrum).
- A `CImgList<T>` instance can handle sequences or collections of 4D images.

$\Longrightarrow$ CImg covers actually a lot of the image data types found in real world applications, while defining straightforward structures that are **still understandable by non computer-geeks**.

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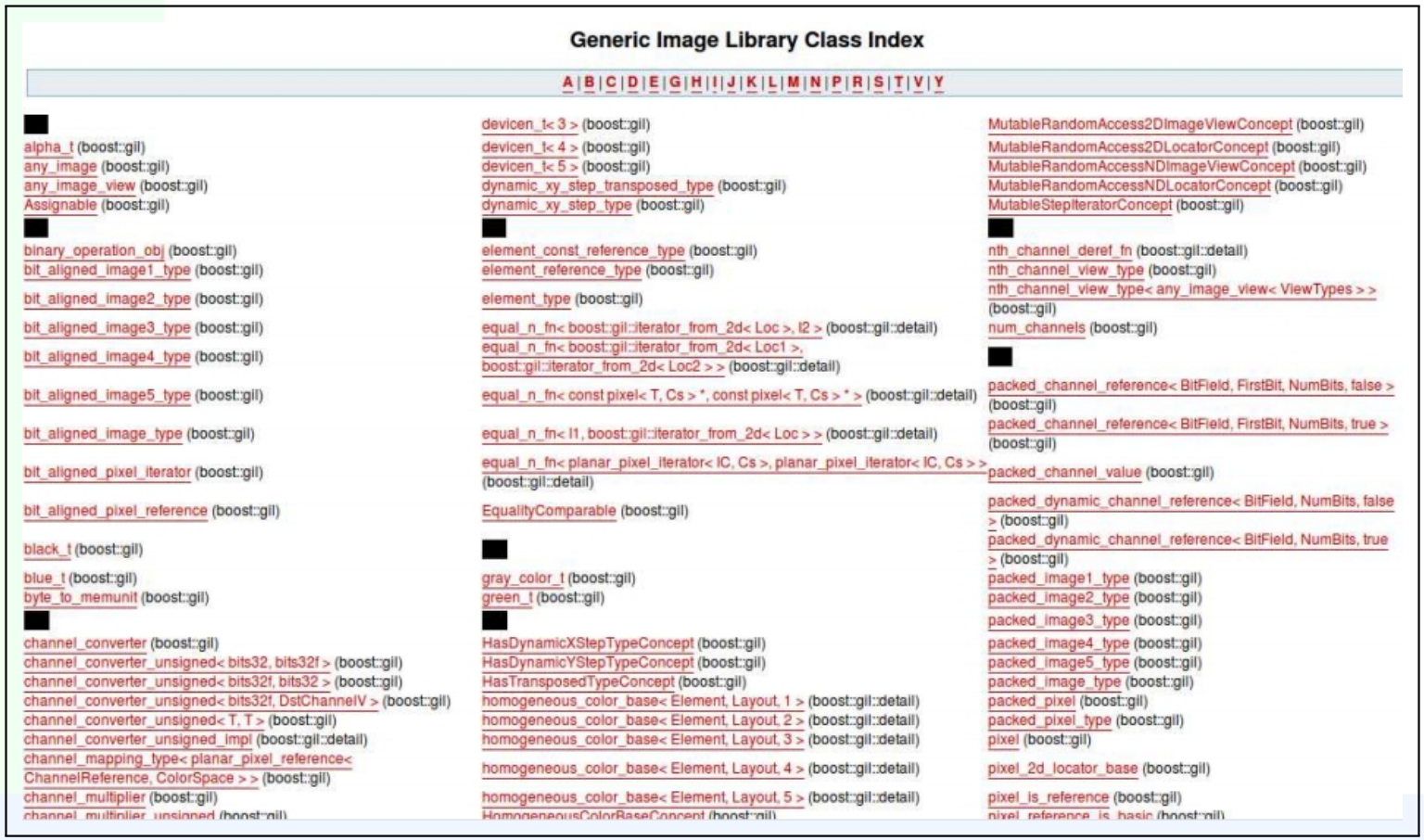
What we wanted to avoid at any price !



Generic Image Library Class Index

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packed_pixel_type (boost::gil)
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pixel_is_reference (boost::gil)
pixel_reference_is_basic (boost::gil)

$\Longrightarrow$ Discouraging for any average C++ programmer !!
(i.e. most of the researchers in Image Processing).

What we actually have !

$\Longrightarrow$ Looks simpler ! ☺

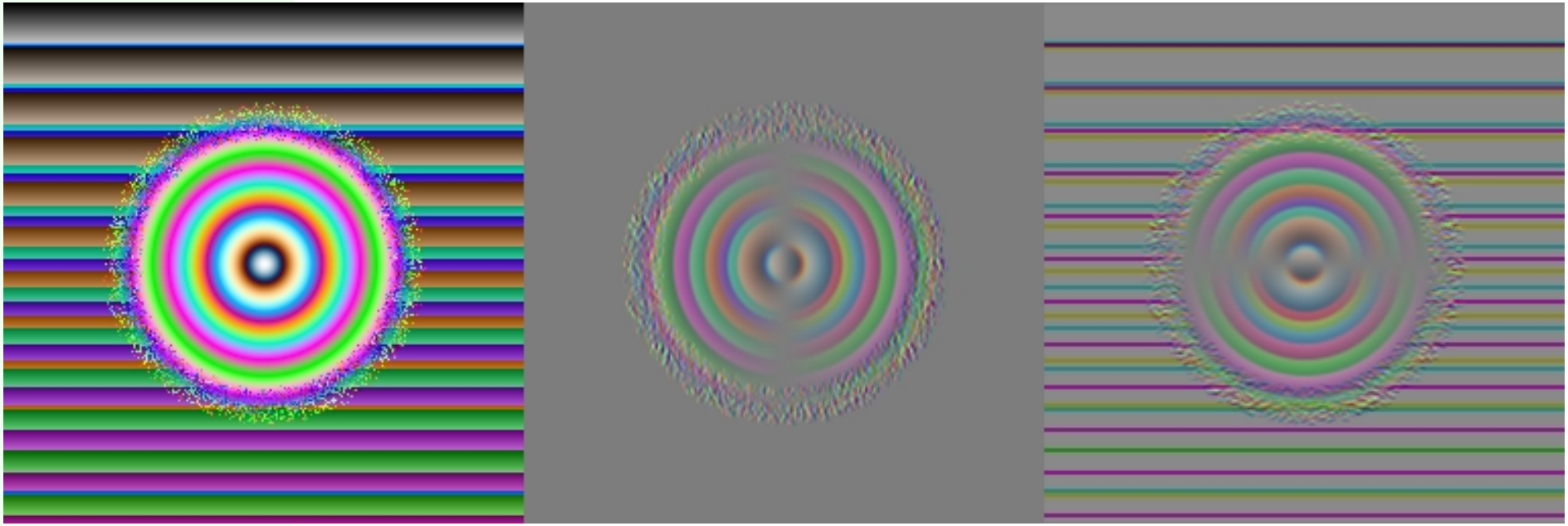
- CImg has algorithms/methods everybody is looking for :
  - Data inputs/outputs : supports a large number of image file formats (e.g. float-valued multi-page tiff files).
  - Usual IP operators : Convolution, gradients, histograms, color conversions, interpolation, geometric transformations, non-linear blur/sharpening, displacement field estimation, FFT, ...
  - Arithmetic operators : Most usual mathematical operations between images are defined (e.g. operator+(), sqrt(),...).
  - Vector / matrix operations : SVD, matrix inversion, linear system solving, eigenvalues, ...
  - Image drawing functions : Lines, polygons, ellipses, text, vector fields, graphs, 3D objects, ...
- All methods and algorithms of CImg are designed to **work flawlessly on 4D images** `CImg<T>`.

- Methods of `CImg<T>` can be pipelined to write complex image processing pipelines in few lines :

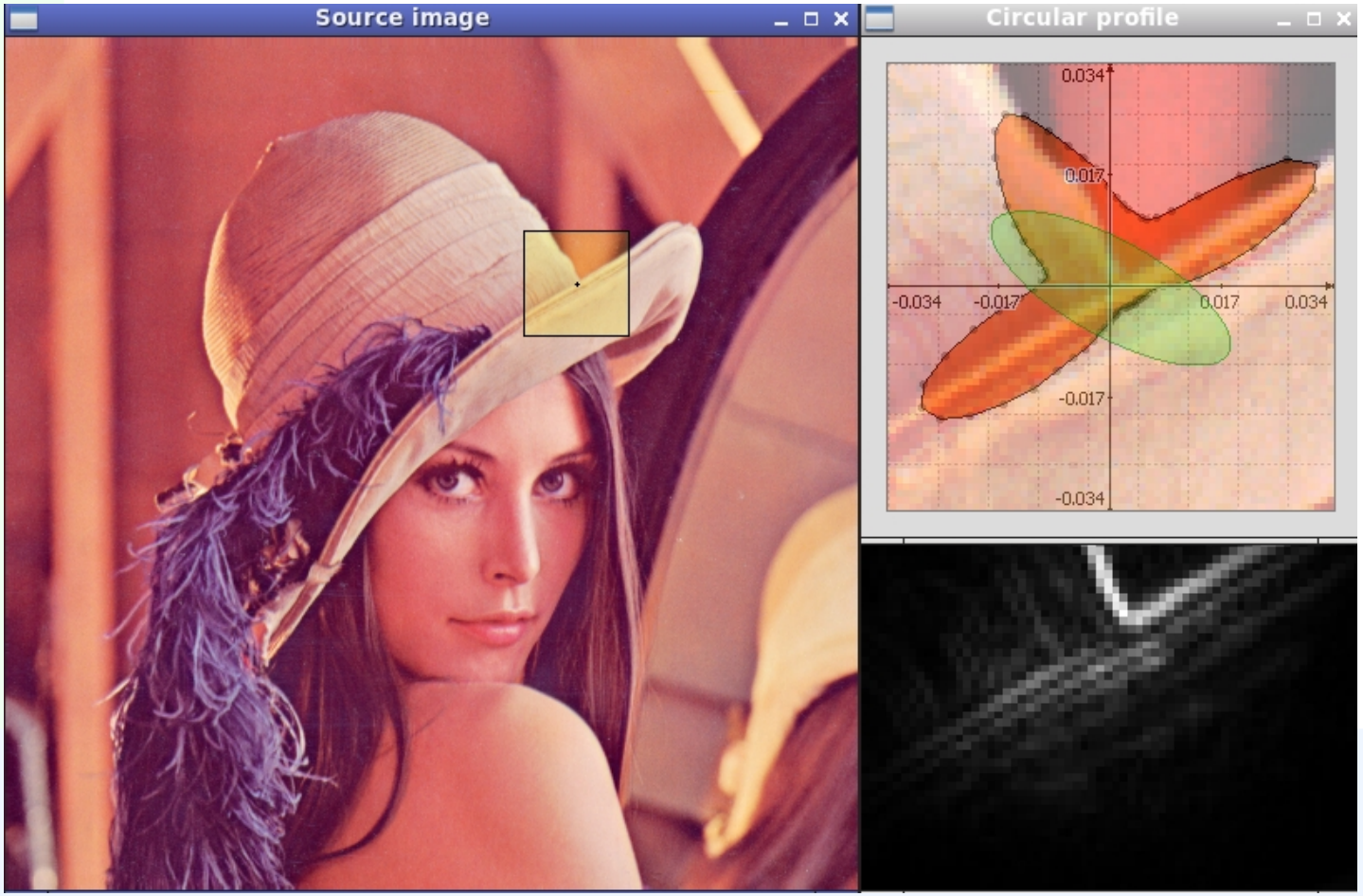
```
#include "CImg.h"
using namespace cimg_library;
int main() {

  // Load 521x512 lena color image.
  CImg<> img("lena.bmp");

  // Do some weird pipelines.
  img.RGBtoYCbCr().channel(0).quantize(10,false).
  map(CImg<>(3,1,1,3).rand(0,255).resize(10,1,1,3,3));
  // Display result.
  img.display("My nice image");
}
```

- CImg owns a mathematical expressions evaluator :

```
#include "CImg.h"
using namespace cimg_library;
int main() {

  // Construct 256x256 color image.
  CImg<> img(256,256,1,3);

  // Fill pixel values from a formula.
  img = "X=x-w/2;Y=y-h/2;D=sqrt(X^2+Y^2);"
        "if(D+u*20<80,abs(255*cos(D/(5+c))),"
        "10*(y%(20+c)))";

  // Display result.
  (img,img.get_gradient("xy")).display();
}
```



- CImg has a lot of methods to draw things on images, as well as a class (`CImgDisplay`) to display images on windows and interact with the user.

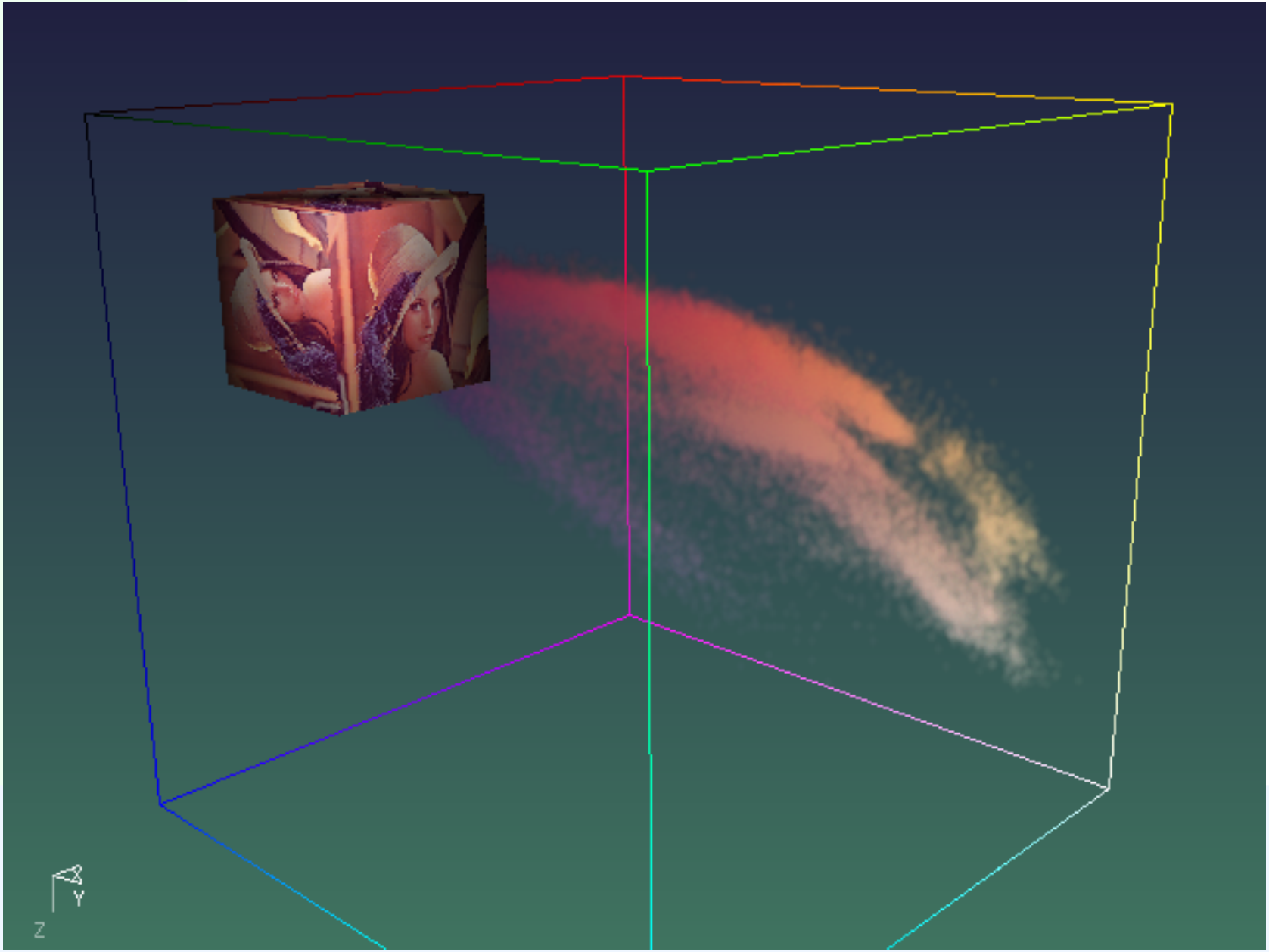


- CImg has its own 3d renderer (kind of mini OpenGL) :

```
#include "CImg.h"
using namespace cimg_library;
int main() {

  // Load 3d object from a .off file.
  CImgList<unsigned int> primitives;
  CImgList<unsigned char> colors;
  const CImg<float> points =
CImg<>::load_off(primitives,colors,"3dhisto.off");

  // Display 3d object in interactive window.
  CImg<unsigned char>(800,600,1,3,128).
      display_object3d("3d
object",points,primitives,colors);
}
```

Usefulness

Usefulness



- You can add your own methods in the `CImg<T>` or `CImgList<T>` classes, without having to modify the library code.

```
#define cimg_plugin "foo.h"
#include "CImg.h"
using namespace cimg_library;
int main() {

  CImg<> img("lena.bmp");
  img.my_method();
}
```

$\Longrightarrow$ Plug-in mechanism !

- Plug-in file `foo.h` contains :

```
CImg<T>& my_method() {
  const CImgList<T> g = get_gradient("xyz");
  (g[0].sqr() + g[1].sqr() + g[2].sqr()).
       sqrt().move_to(*this);
  return *this;
}
```

- Some plug-ins are already distributed within the CImg package : NLmeans, Skeleton, VRML reader, CImg<->Matlab conversion, ...

- The CImg Library code is compiled on the fly.

⇒ The library configuration **is decided by the CImg users**, not by the CImg developers.

- Many existing configuration flags, allow to enable/disable extra functionnalities, provided by external libraries :

```
cimg_use_png, cimg_use_openmp, cimg_use_lapack,
cimg_use_fftw3, cimg_use_opencv, cimg_use_jpeg,
cimg_use_tiff, cimg_use_ffmpeg, cimg_use_zlib,
cimg_use_openexr, ....
```

- CImg is distributed under the CeCILL-C license (permissive, LGPL-like).
- The code of CImg is small and easy to maintain.
  $\rightarrow$ portable library (multi-CPU, multi-OS, multi-compilers).
- The CImg structures are insanely simple
  $\rightarrow$ CImg is easy to integrate and to communicate with other image processing libraries.

$\Longrightarrow$ Isn't it the perfect image processing library ? ☺

Presentation layout

Motivations

- Observation 1 : CImg requires (basic) C++ knowledge.
  Some people don't know C++ but could be interested by the CImg capabilities anyway.
- Observation 2 : When we get new image data, we often want to perform the **same basic operations** on them (visualization, gradient computation, noise reduction, ...).
- Observation 3 : It is not optimal to create C++ code specifically for these minor tasks (requires code edition, compilation time, ..).

$\Longrightarrow$ G'MIC defines a script language which interfaces the CImg functionalities.

$\Longrightarrow$ No compilation required, all CImg features usable **from the shell**.

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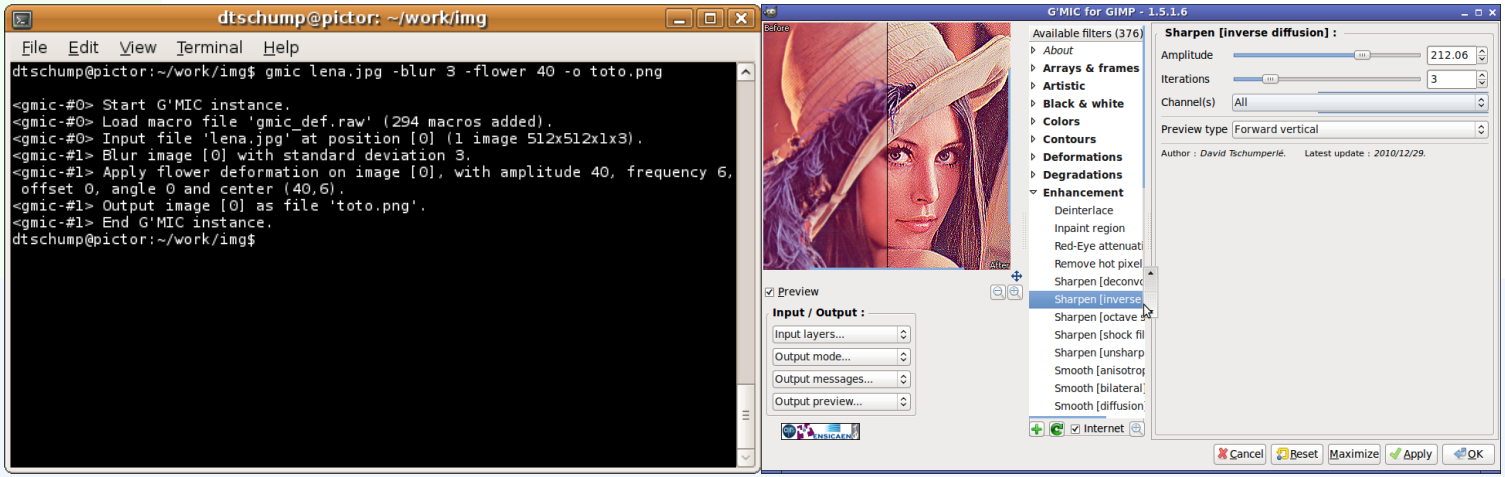
G'MIC : Language properties

- G'MIC manage a list of images (i.e. an instance of `CImgList<T>`).
- Each G'MIC instruction runs an image processing algorithm, or control the program execution : `-blur, -rgb2hsv, -isosurface3d, -if, -endif ...`
- A G'MIC pipeline is executed by calls to CImg methods.
- User-defined functions can be saved as G'MIC script files.
- The G'MIC interpreter can be called from the command line or from any external project (itself provided as a stand-alone library).

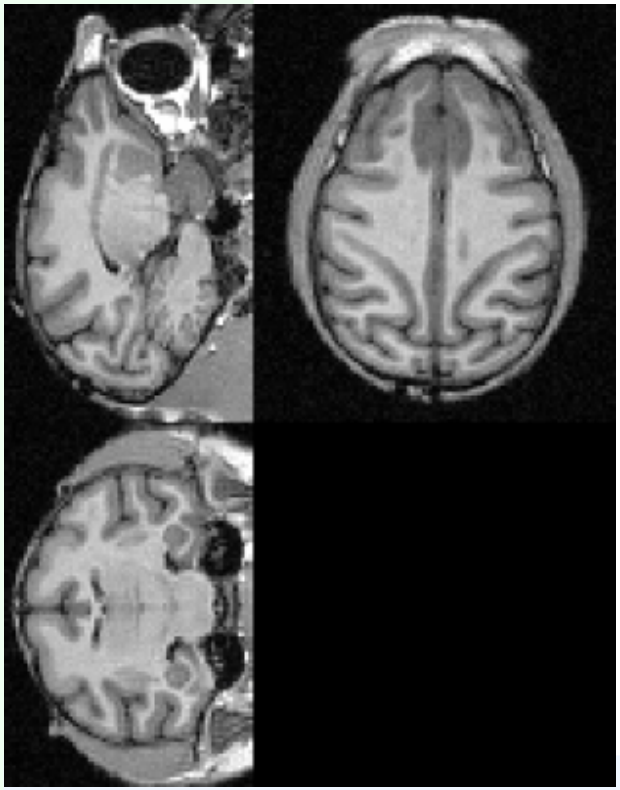


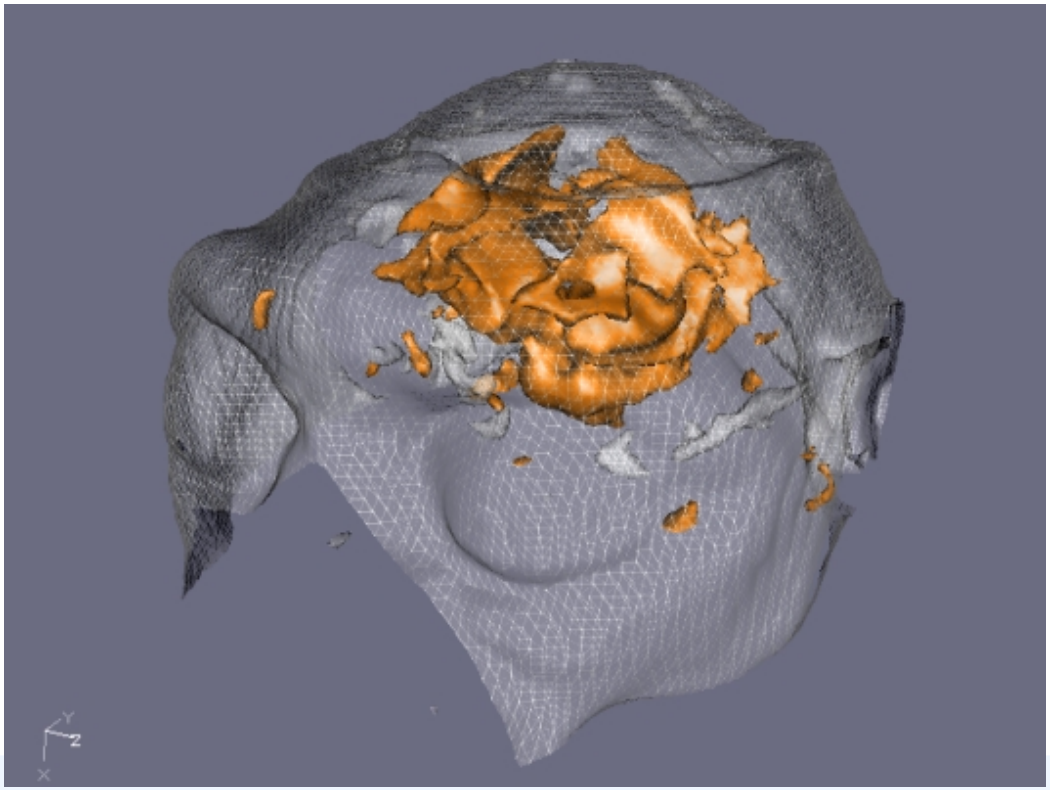
G'MIC : Examples of use (1/6)

```
gmic lena.bmp -blur 3 -sharpen 1000 -noise 30 -+
"'cos(x/3)*30'"
```

G'MIC : Examples of use (2/6)

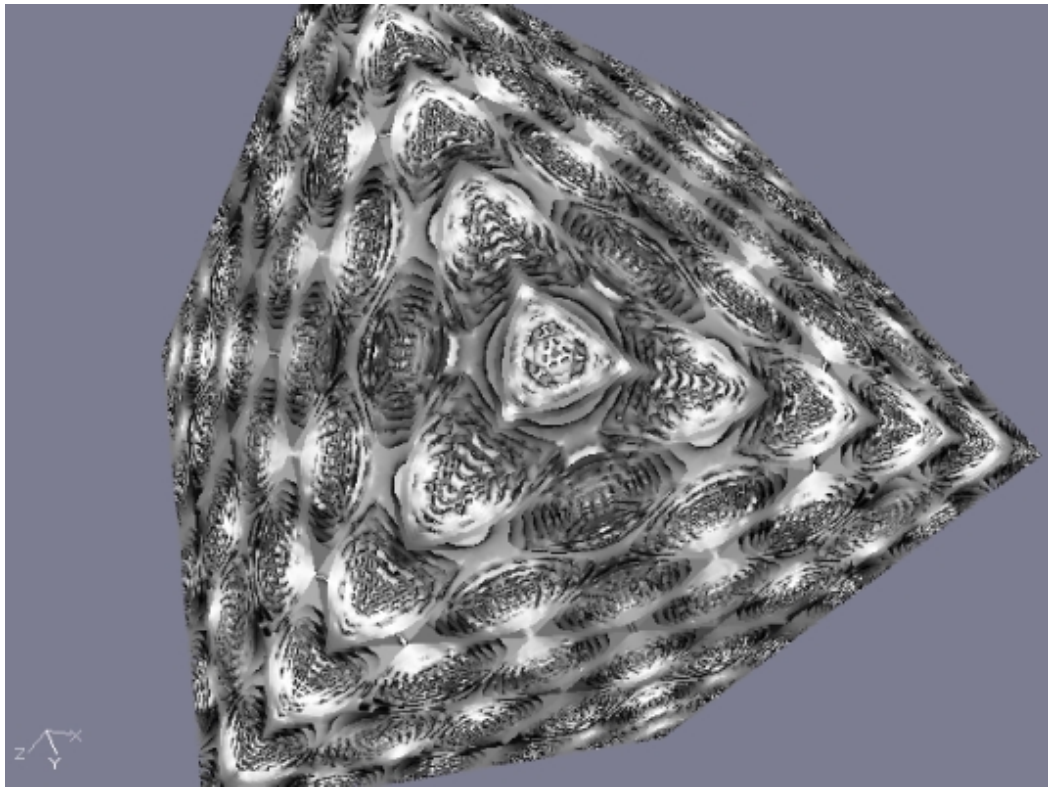
```
gmic reference.inr -flood 23,53,30,50,1,1000 -flood[-2]
0,0,0,30,1,1000 -blur 1 -isosurface3d 900 -opacity3d[-2] 0.2
-color3d[-1] 255,128,0 -+3d
```





G'MIC : Examples of use (3/6)

```
gmic -isosurface3d
"'sin(x*y*z)'",0,-10,-10,-10,10,10,10,128,128,64
```



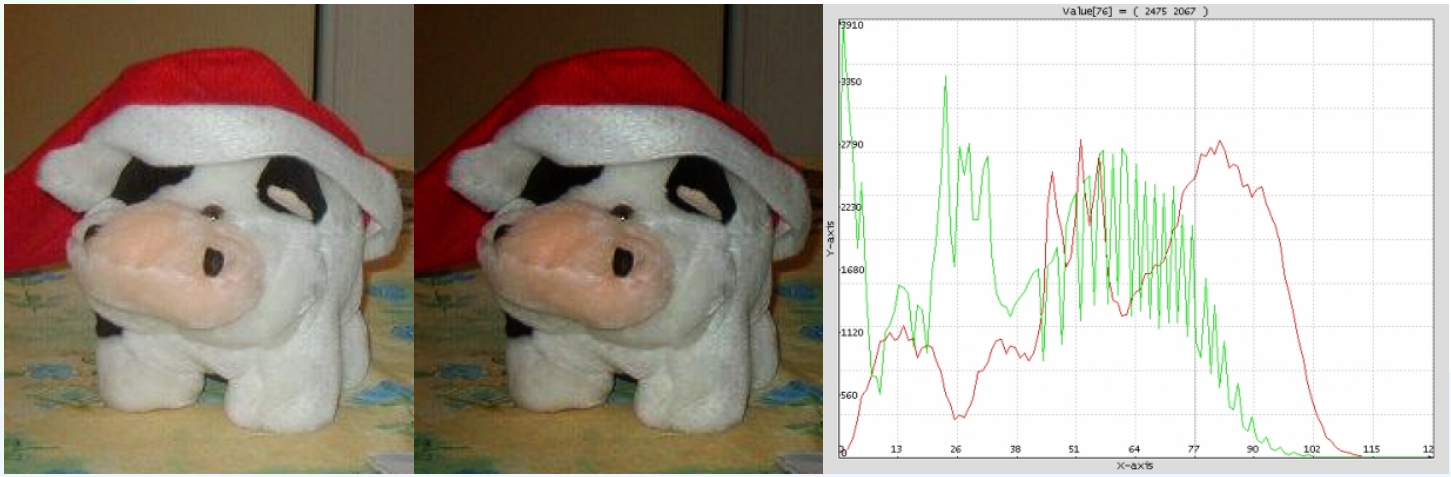
G'MIC : Examples of use (4/6)

```
gmic milla.bmp -f '255*(i/255)^1.7' -histogram 128,0,255 -a c -plot
```

is the G'MIC equivalent code to

```
#include "CImg.h"
using namespace cimg_library;
int main(int argc,char **argv) {
const CImg<>
img("milla.bmp"),
hist = img.get_histogram(128,0,255),
img2 = img.get_fill("255*((i/255)^1.7)",true),
hist2 = img2.get_histogram(128,0,255);
(hist,hist2).get_append('c').display_graph("Histograms");
return 0;

}
```

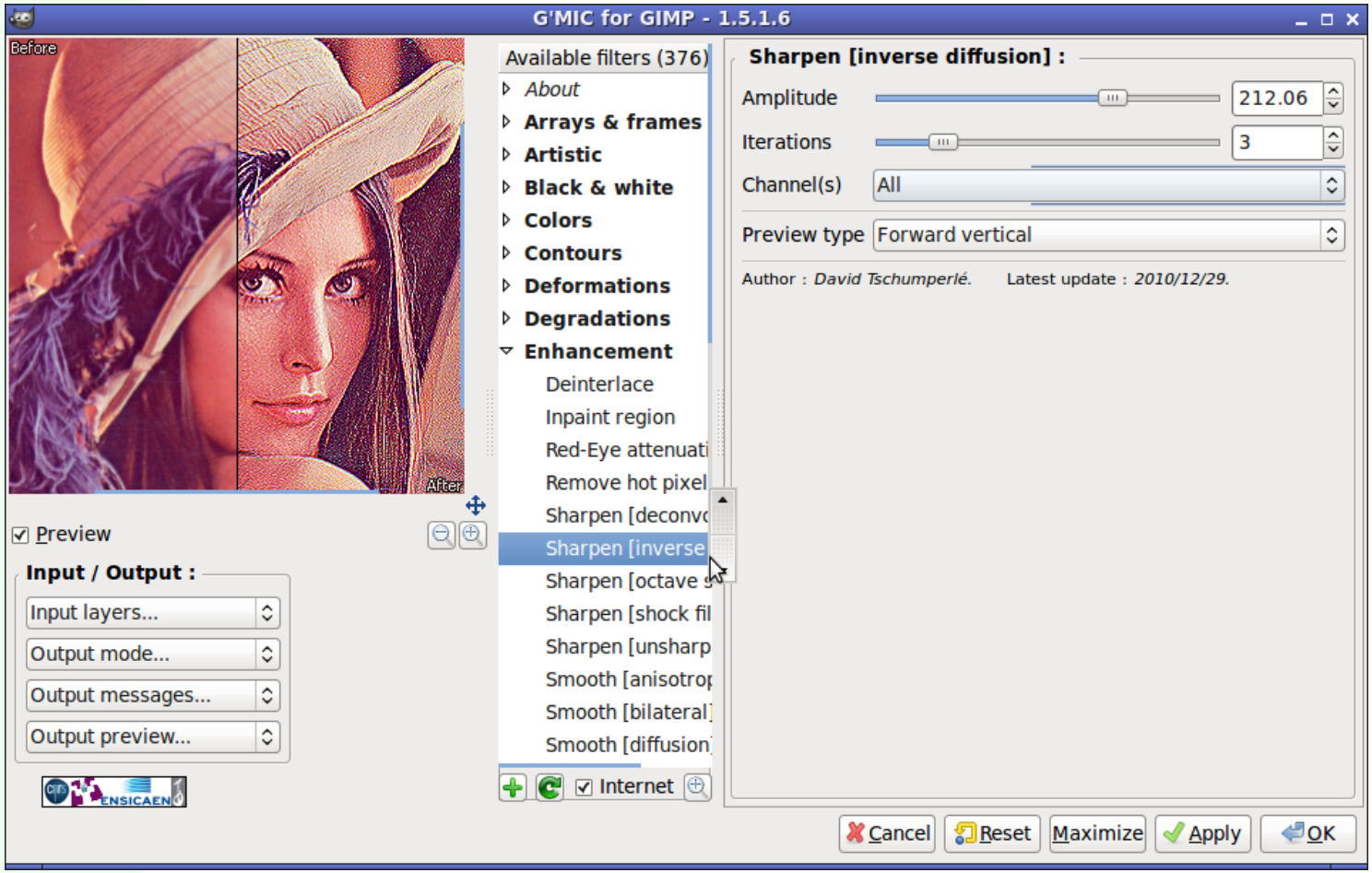


G'MIC : Examples of use (5/6)

```
gmic lena.jpg -pencilbw 0.3 -o gmic_lena1.jpg; gmic lena.jpg
-cubism 160 -o gmic_lena3.jpg
gmic lena.jpg -flower 10 -o gmic_lena4.jpg; gmic lena.jpg
-stencibw 30 -o gmic_lena2.jpg
```

$\Longrightarrow$ A better ImageMagick's "convert" ? ☺

Plug-in G'MIC for GIMP



CImg functionalities available for everyone !

$\Longrightarrow \approx$ 400-500 downloads/day (+600.000 dl since 2008).

Presentation layout

Conclusion and Links

- The CImg Library is a very small and easy-to-use C++ library that eases the coding of image processing algorithms.

  `http://cimg.sourceforge.net/`

- G'MIC is the script-based counterpart of CImg.

  `http://gmic.sourceforge.net/`

- These projects are Open-Source and can be used, modified and redistributed without hard restrictions.
- **Generic** (enough) libraries to do **generic things**.
- **Small**, **open** and **easily embeddable libraries** : can be integrated in third parties applications.

The end

Thank you for your attention.

Time for questions if any ..