PRACE
Winter School
2013

Scientific Visualization

SOME CONCEPTS, TOOLS & LIBRARIES

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Introduction

Audience

- Yourself
- Scientific community
- Students
- Media

Criterion

- Quality
- Speed
- Development time

Usage

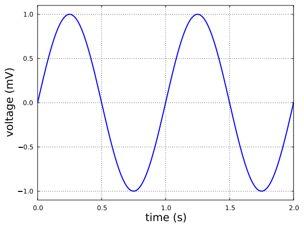
- Runtime visualization
- Final visualization
- Illustration
- Demonstration

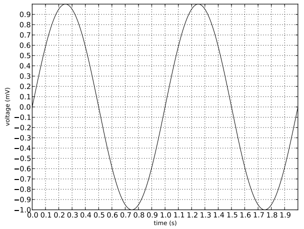
Nature of data

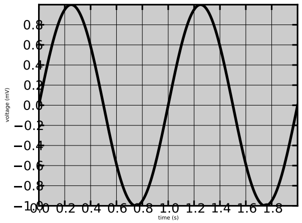
- 2D, 3D, 4D, …
- Continuous, discrete, …
- Numeric, symbolic, …

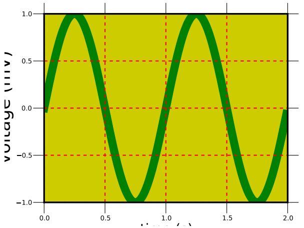
The good, the bad & the ugly...

...and the very ugly



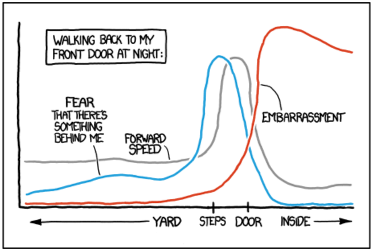






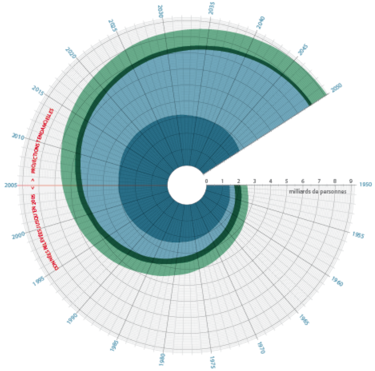
Readibility first

Beauty is an option



WALKING BACK TO MY FRONT DOOR AT NIGHT:
FEAR THAT THERE'S SOMETHING BEHIND ME
FORWARD SPEED
EMBARRASSMENT
YARD
STEPS
DOOR
INSIDE

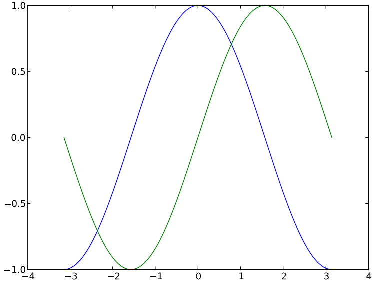
(http://xkcd.com/1064/)

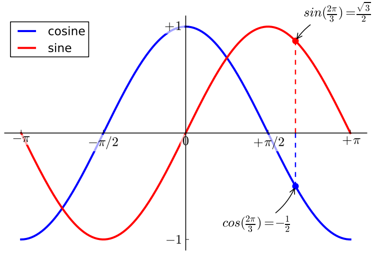


What's the point of this polar axis ?

Do not trust the defaults

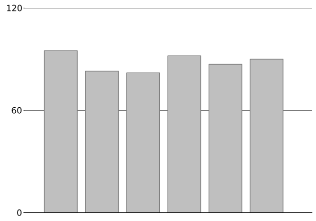
Defaults are never good for a specific case

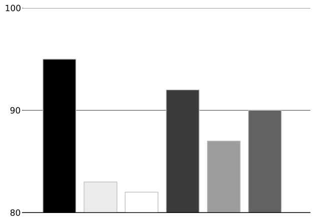




Be fair to your data

Don't hide reality

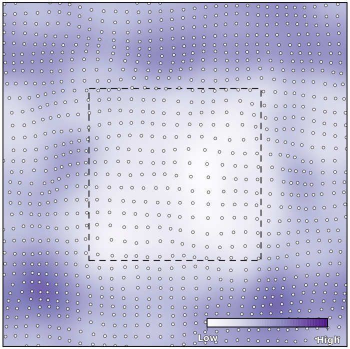




Get the right tool

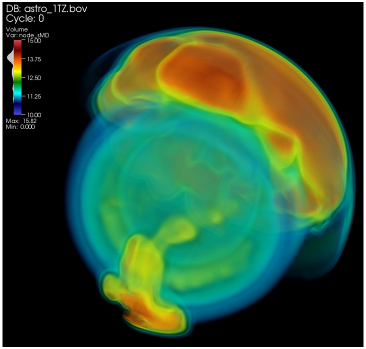
32 000 cores to plot sin(x) may be slightly overkill...

Model of somatosensory cortex



≈ 1 000 points, matplotlib, single core

Supernova simulation



≈ 2 trillion points, VisIt, 32000 cores

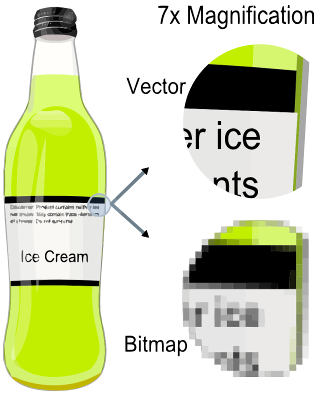
Image formats

Bitmap/Raster Image format

- Matrix of pixels
- Fixed native resolution
- B&W, grayscale, color, HDR
- PNG, JPG, TIFF

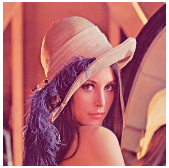
Vector Image format

- Geometrical primitives
- No fixed resolution
- B&W, grayscale, color
- SVG, PDF, PS

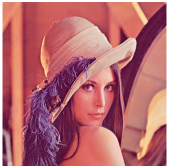


Bitmap Image Compression

Lossless compression (png, bmp, tiff)

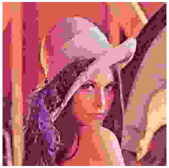

quality=0 (507k)

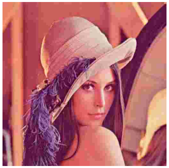
quality=10 (702k)


quality=50 (712k)

quality=100 (717k)

Lossy data compression (jpg)


quality=0 (3k)


quality=10 (7k)

quality=50 (30k)

quality=100 (400k)

Bitmap Image Resolution

DPI (dots per inch)

- 1 inch = 2.54 cm
- 1000x1000 pixels at 250dpi = 4 inches x 4 inches area at most

Figures should be rendered at 600dpi

- Double-column article on A4 paper
  - (21 - 2x2 (≈ margins) - 1 (≈ col. sep.))/2 ≈ 8 cm
  - 8/2.54*600 = 1889 pixels ≈ **2000 pixels wide**
- Single-column article on A4 paper
  - (21 - 2x2 (≈ margins)) ≈ 17 cm
  - 17/2.54*600 = 4015 pixels ≈ **4000 pixels wide**

Drawing software

Vector

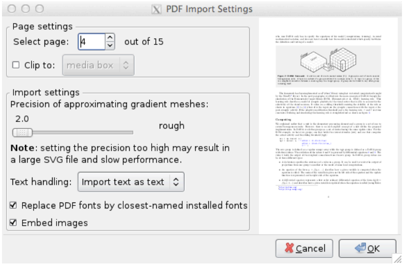
- xfig
  - Old-school and limited font support
  - pdf/svg/eps/bitmap import/export
- inkscape
  - Unix standard
  - pdf/svg/eps/bitmap import/export

Bitmap

- gimp
  - Unix standard
  - bitmap import/export, vector import

Inkscape

www.inkscape.org



PDF Import Settings

Page settings

Select page: 4 out of 15

☐ Clip to: media box

Import settings

Precision of approximating gradient meshes:

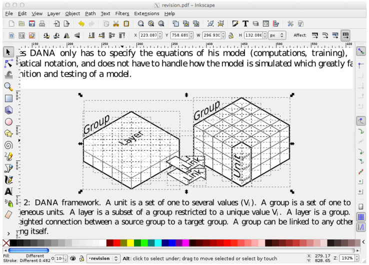
2.0 rough

Note: setting the precision too high may result in a large SVG file and slow performance.

Text handling: Import text as text

☑ Replace PDF fonts by closest-named installed fonts

☑ Embed images



revision.pdf - Inkscape

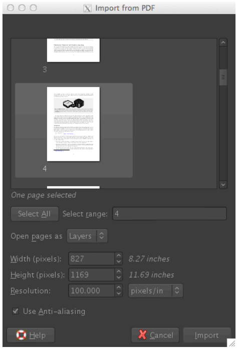
…s DANA only has to specify the equations of his model (computations, training), …atical notation, and does not have to handle how the model is simulated which greatly fa… …ition and testing of a model.

…2: DANA framework. A unit is a set of one to several values (V_i). A group is a set of one to …eneous units. A layer is a subset of a group restricted to a unique value V_i. A layer is a group. …ighted connection between a source group to a target group. A group can be linked to any othe… …ng itself.

An Open Source vector graphics editor, with capabilities similar to Illustrator, CorelDraw, or Xara X, using the W3C standard Scalable Vector Graphics (SVG) file format.

Gimp

www.gimp.org


Import from PDF

One page selected

Select All | Select range: 4

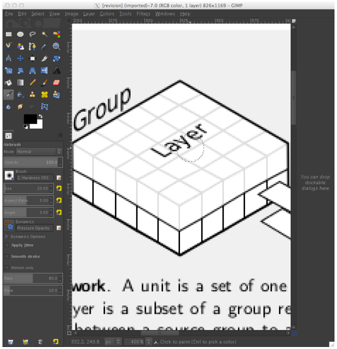
Open pages as: Layers

Width (pixels): 827 — 8.27 inches

Height (pixels): 1169 — 11.69 inches

Resolution: 100.000 pixels/in

☑ Use Anti-aliasing


[revision] (imported)-7.0 (RGB color, 1 layer) 826x1169 – GIMP

Airbrush — Mode: Normal — Opacity 100.0 — Brush 2. Hardness 050 — Size 20.00 — Aspect Ratio 0.00 — Angle 0.00 — Dynamics: Pressure Opacity — Rate 80.0 — Flow 10.0

332.2, 249.8 px 400 % Click to paint (Ctrl to pick a color)

Gimp can be used as a simple paint program, an expert quality photo retouching program, an online batch processing system, a mass production image renderer, an image format converter, etc.

Drawing tools

Bitmap

- ImageMagick
  - convert between image formats as well as resize an image, blur, crop, despeckle, dither, draw on, flip, join, re-sample
- ffmpeg (`ffmpeg.org`)
  - record, convert and/or stream audio and/or video.

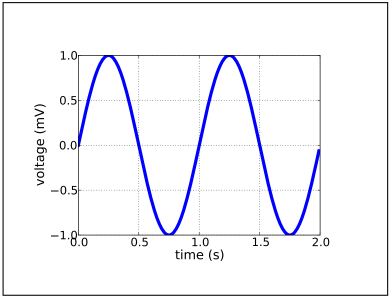
Vector

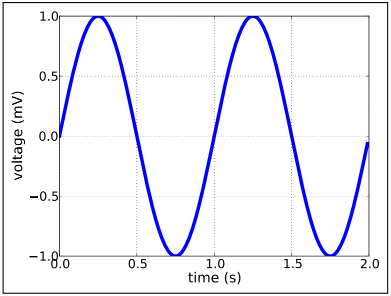
- pdfjam
- pdfcrop
- graphviz
- tikz

pdfcrop

www.tug.org/texlive

```
$ pdfcrop figure.pdf figure.pdf
```

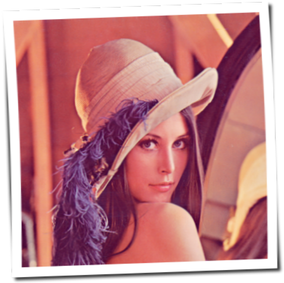




ImageMagick

www.imagemagick.org

```
$ convert lena.png +polaroid polaroid.png
```

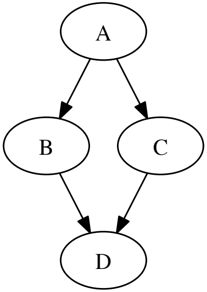


More effects at www.fmwconcepts.com/imagemagick/index.php

graphviz

www.graphviz.org

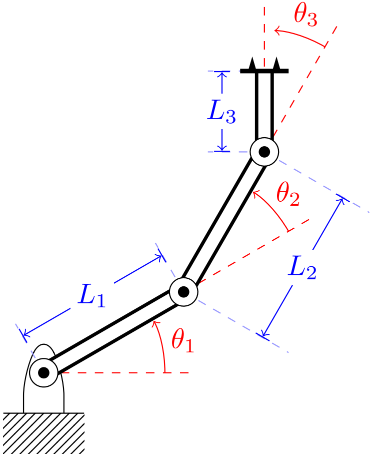
```
graph.dot:
 digraph G { A->B; A->C; B->D; C->D }

$ dot graph.dot -Tpdf -o graph.pdf
```



Tikz

www.texample.net/tikz

```
% Define commands for links, joints and such
\def\link{\draw [double distance=1.5mm,
                  very thick] (0,0)--}
\def\joint{%
   \filldraw [fill=white] (0,0) circle (5pt);
   \fill[black] circle (2pt);
}
\def\grip{%
   \draw[ultra thick](0cm,\dg)--(0cm,-\dg);
   \fill (0cm, 0.5\dg)+(0cm,1.5pt) --
         +(0.6\dg,0cm) -- +(0pt,-1.5pt);
   \fill (0cm, -0.5\dg)+(0cm,1.5pt) --
         +(0.6\dg,0cm) -- +(0pt,-1.5pt);
}
\def\robotbase{%
   \draw[rounded corners=8pt]
          (-\dw,-\dh)-- (-\dw, 0) --
      (0,\dh)--(\dw,0)--(\dw,-\dh);
   \draw (-0.5,-\dh)-- (0.5,-\dh);
   \fill[pattern=north east lines]
          (-0.5,-1) rectangle (0.5,-\dh);
```



Plotting tools

Free

- gnuplot
  `www.gnuplot.info`
- matplotlib
  `matplotlib.sourceforge.net`
- R
  `www.r-project.org`
- mayavi
  `mayavi.sourceforge.net`

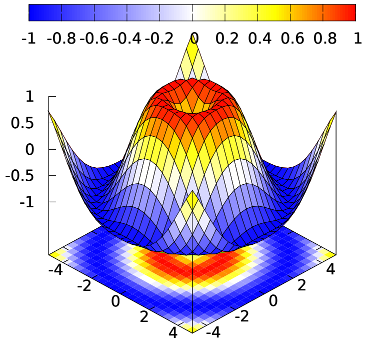
Not so free

- grapher (mac only)
  `wikipedia.org/wiki/Grapher`
- maple
  `www.maplesoft.com`
- matlab
  `www.mathworks.com`
- mathematica
  `www.wolfram.com`

gnuplot

www.gnuplot.org

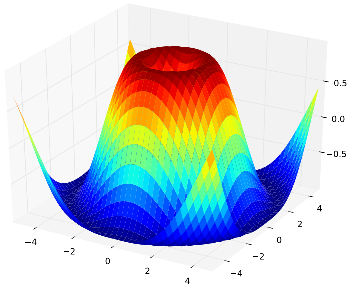
```
set style line 100 lt -1 lw 0.1
set pm3d
set pm3d at b
set palette defined ( 0 "blue", .5 "white", \
                  .75 "yellow", 1 "red")
set colorbox horiz user origin .1,.9 size .8,.04
set view 55,45
set nokey
set hidden3d
set isosamples 25
set term pdf size 3in,3in
set output 'surface-gnuplot.pdf'
set xrange [-5:+5]
set yrange [-5:+5]
set zrange [-1:+1]
set multiplot
splot sin(sqrt(x*x+y*y)) with dots
set pm3d
set pm3d solid hidden3d 100
splot sin(sqrt(x*x+y*y)) with lines
unset multiplot
```



matplotlib

matplotlib.sourceforge.net

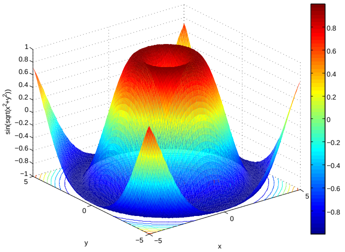
```
from pylab import *
from mpl_toolkits.mplot3d import Axes3D

ax = Axes3D(fig)
T = np.arange(-5, 5, 0.25)
X, Y = np.meshgrid(T,T)
Z = np.sin(np.sqrt(X**2 + Y**2))
ax.plot_surface(X, Y, Z, rstride=1, cstride=1, cmap='jet')
```



matlab

www.mathworks.com

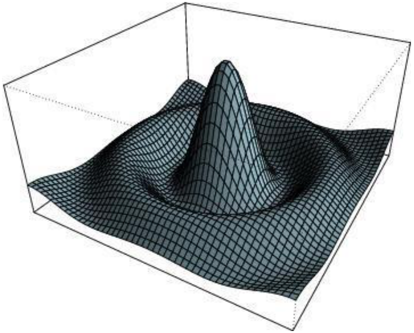
```
[x,y]=meshgrid(-5:0.1:5,-5:0.1:5);
surfc(x,y,sin(sqrt(x.^2+y.^2)),
            'EdgeColor','none')
colorbar
xlabel('x')
ylabel('y')
zlabel('sin(sqrt(x^2+y^2))')
```



R

www.r-project.org

```
x <- seq(-10, 10, length = 50)
y <- x
rotsinc <- function(x,y)
{
   sinc <- function(x)
   {
      y <- sin(x)/x ; y[is.na(y)] <- 1; y
   }
   10 * sinc( sqrt(x^2+y^2) )
}
sinc.exp <- expression(z == Sinc(sqrt(x^2 + y^2)))

z <- outer(x, y, rotsinc)

par(bg = "white",mfrow=c(1,2),mar=rep(1.5,4))
persp(x, y, z, theta = 30, phi = 30,
     expand = 0.5, col = "lightblue",
     ltheta = 120, shade = 0.75,
     xlab = "X", ylab = "Y", zlab = "Z")
```



Drawing/plotting libraries

2D (points, lines, bezier curves, etc.)

- cairo (`www.cairo.org`, c/c++/python)
- agg (`www.antigrain.com`, c+/c++)
- gnuplot (c/c++/python), 2d/2.5d
- matplotlib (python), 2d/2.5d
- d3 (`d3js.org`, javascript)

3D

- OpenGL (`www.opengl.org`, c/python)
- VTK (c/c++/python, not for the faint of heart)
- mayavi.mlab (python)

Visualization tools

Free

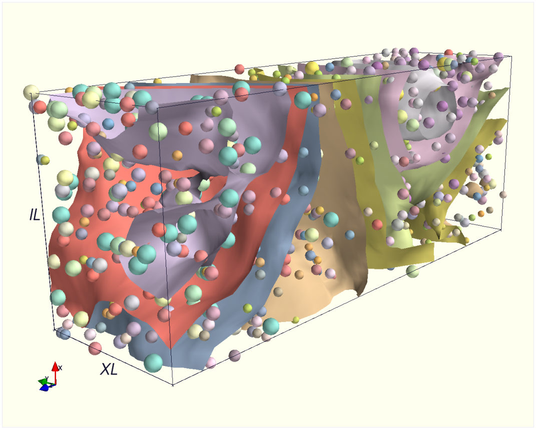
- Mayavi
  `mayavi.sourceforge.net`
- VisIt
  `matplotlib.sourceforge.net`
- Paraview
  `www.scilab.org`

Not so free

- matlab
  `www.mathworks.com`
- mathematica
  `www.wolfram.com`
- etc.

Mayavi

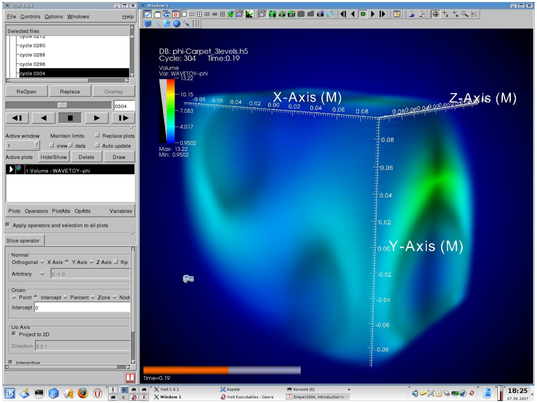
code.enthought.com/projects/mayavi/



MayaVi is a scientific data visualizer written in Python and uses the Visualization Toolkit (VTK) for the visualization.

VisIt

wci.llnl.gov/codes/visit/

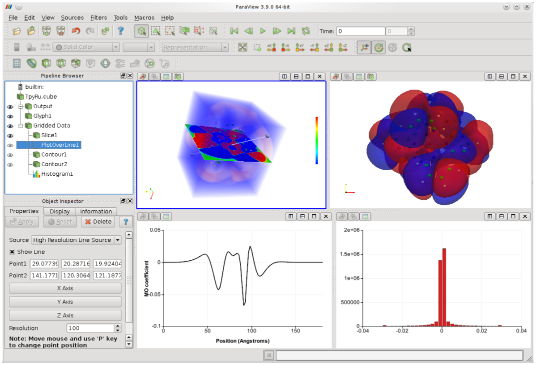


DB: phi-Carpet_3levels.h5
Cycle: 304 Time:0.19
Volume
Var: WAVETOY--phi
13.22
10.15
7.083
4.017
0.9502
Max: 13.22
Min: 0.9502

VisIt is a free interactive parallel visualization and graphical analysis tool for viewing scientific data on Unix and PC platforms.

ParaView

www.paraview.org



builtin:
TpyRu.cube
Output
Glyph1
Gridded Data
Slice1
PlotOverLine1
Contour1
Contour2
Histogram1

Source High Resolution Line Source
Show Line
Point1 29.07739 20.28716 19.92404
Point2 141.1771 120.3064 121.1877
Resolution 100
Note: Move mouse and use 'P' key to change point position

ParaView is an open-source, multi-platform data analysis and visualization application.

First Aid Kit 1

Tools

- ImageMagick (conversion)
- Gimp (bitmap images creation/manipulation)
- Inkscape (vector creation/images manipulation)
- Gnuplot (visualization/illustration, 2d/2.5d)
- Matplotlib (visualization/illustration 2d/2.5d)
- ffmpeg (movie creation/manipulation)

Environment

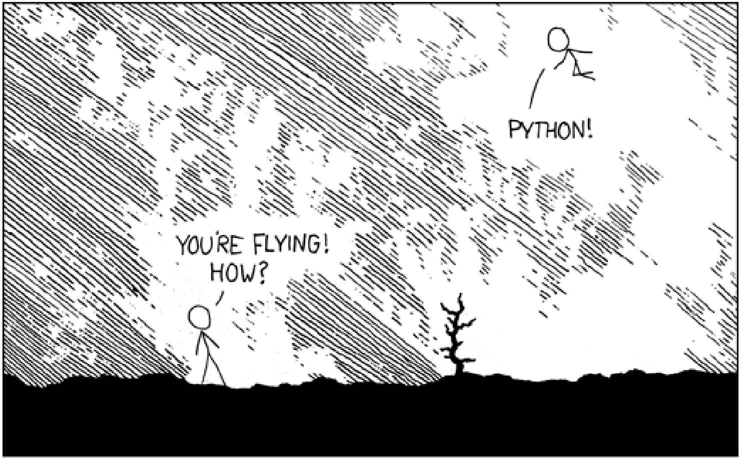
- IPython
  $\rightarrow$ IPython provides a rich toolkit to help you make the most out of using Python.

First Aid Kit 2

Libraries

- Drawing/plotting
  - matplotlib (python, 2d/2.5d)
  - d3 (javascript, interactive, 2d)
  - R (R, 2d/3d)
- Visualization (heavy duty)
  - Mayavi
  - VisIt
  - Paraview

Questions ?



xkcd.com/353/