All that begins . . .

السلام عليكم

peace be upon you

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

OSCAE.Initiative
(Open Source Computer Aided Engineering)

Open Source Computer-Aided Engineering (OSCAE)

Tools for Engineers

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May 2018

Outline

- **FreeCAD** is a parametric 3D modeler. Parametric modeling allows you to easily modify your design by going back into your model history and changing its parameters. FreeCAD is open source (LGPL license) and completely modular, allowing for very advanced extension and customization.

  FreeCAD is multiplatfom, and reads and writes many open file formats such as STEP, IGES, STL and others.

  http://www.freecadweb.org/

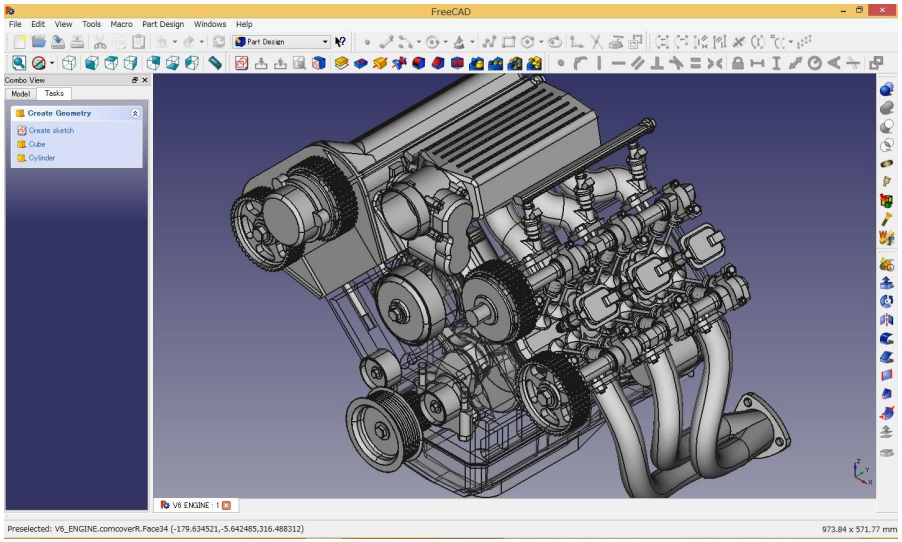

Figure 1: FreeCAD.

- **BRL-CAD** is a powerful cross-platform open source solid modeling system that includes interactive geometry editing, high-performance ray-tracing for rendering and geometric analysis, image and signal-processing tools, a system performance analysis benchmark suite, libraries for robust geometric representation, with more than 20 years of active development.

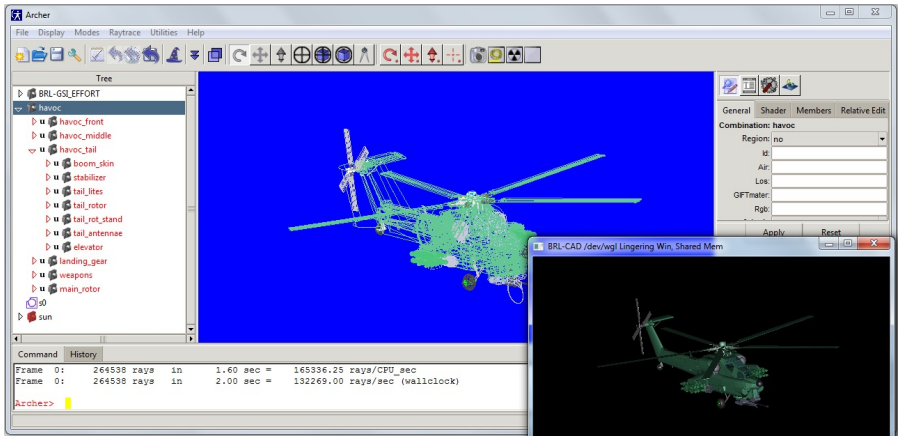

Figure 2: BRL-CAD.

http://brlcad.org/

- **VariCAD** is not “free” nor “open source” but listed here nonetheless because it is about the best CAD system for mechanical engineering works on Linux. It is cross platform, compact, fast, easy to use, and provides everything necessary for mechanical design. The system contains:
  - 2D Drawing and Editing
  - 3D Modeling, Assemblies and Groups
  - Calculations of 2D Sections or 3D Objects
  - Optional Support of Parameters, Geometrical Constraints
  - Shells Modeling, Pipelines, Wires
  - Crash Tests (Interferences)
  - Surface Development (Sheet Metal Unbending)
  - Mechanical Part Libraries and Symbol Libraries

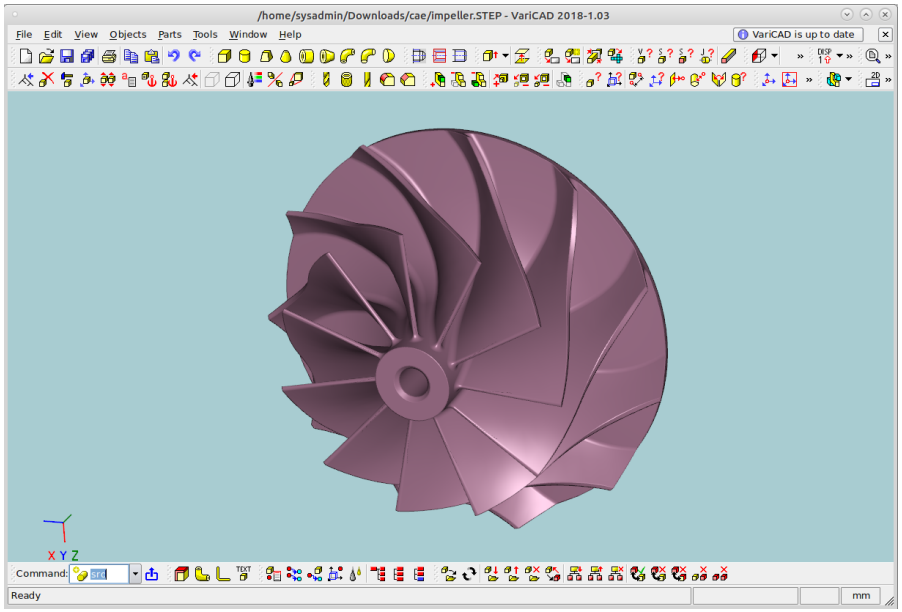

Figure 3: VariCAD.

- **QCAD** is a free, open source application for computer aided drafting (CAD) in two dimensions (2D). With QCAD you can create technical drawings such as plans for buildings, interiors, mechanical parts or schematics and diagrams. QCAD works on Windows, Mac OS X and Linux. The source code of QCAD is released under the GPL version 3 (GPLv3), a popular Open Source license.

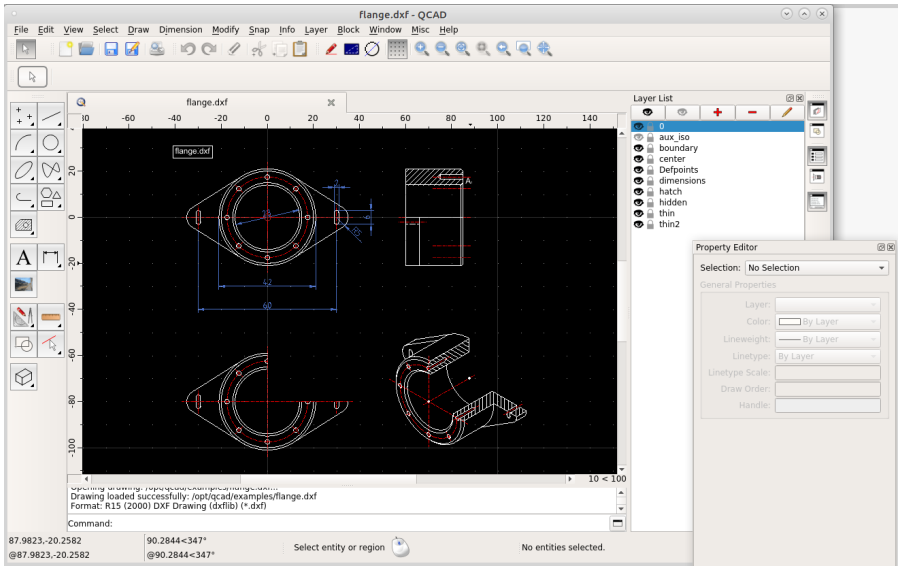

Figure 4: QCAD.

http://www.qcad.org/en/

- **Blender** is the free open source 3D content creation suite, available for all major operating systems under the GNU General Public License. It models, shades, animates, renders, does composite interactive 3D graphics.

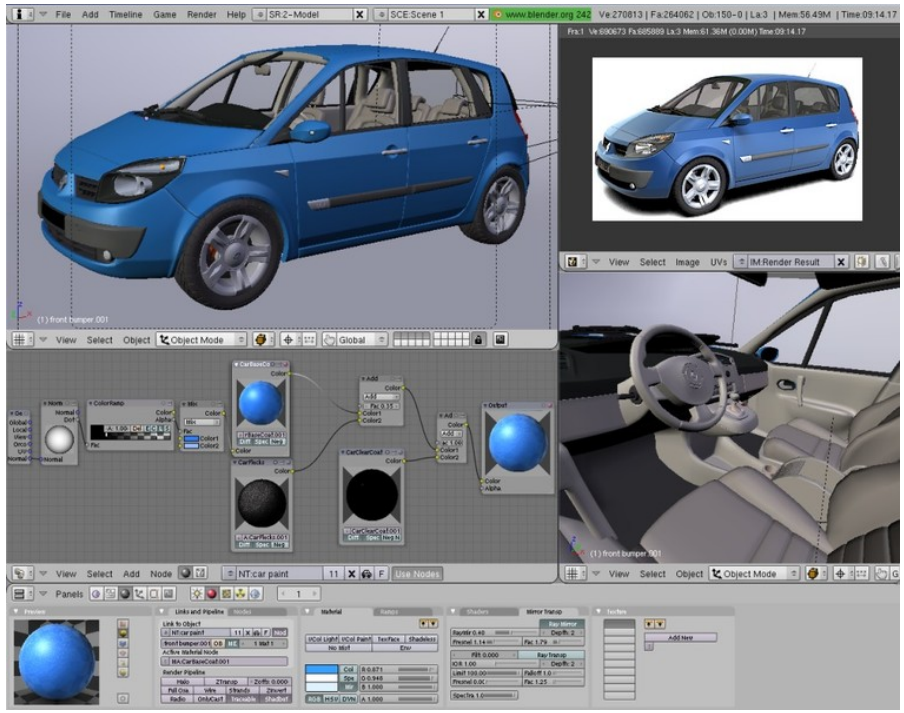

Figure 5: Blender.

http://www.blender.org/

- **Salome** is a software that provides a generic platform for Pre- and Post-Processing for numerical simulation. CAE solvers like **Code_Aster** and **Code_Saturne** can be easily integrated into this platform. Some of Salome platform capabilities are:
  - Create/modify, import/export in multiple formats (IGES, STEP, BREP), using CAD operations like extrusions, cut...
  - Mesh CAD models, edit mesh, check mesh quality, import/export mesh (MED, UNV, DAT, STL)
  - Handle physical properties and quantities attached to geometrical items
  - Display computation results (scalar, vectorial)

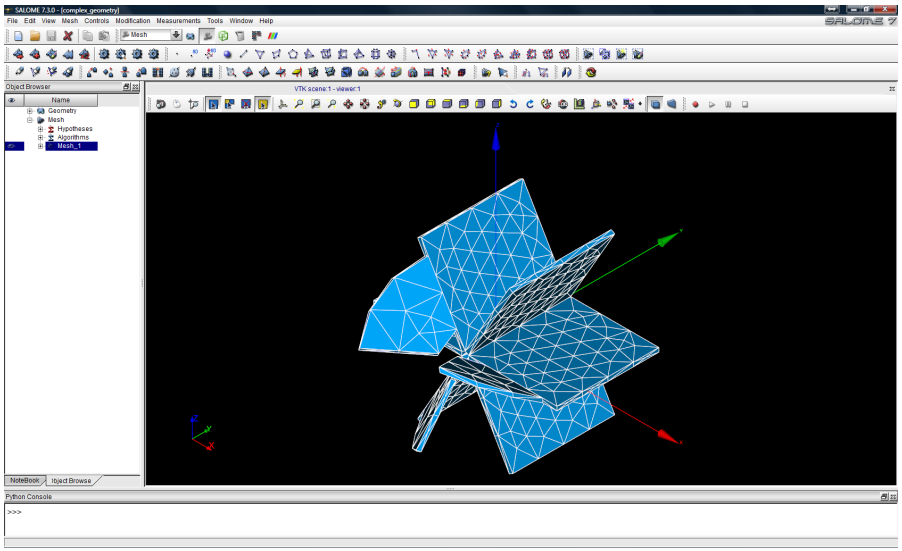

Figure 6: Salome as pre-processor.

- **gmsh** is an automatic 3D finite element grid generator with a built-in CAD engine and post-processor. gmsh is built around four modules:
  - geometry,
  - mesh,
  - solver and
  - post-processing.

  The specification of any input to these modules is done either interactively using GUI or in ASCII text files using gmsh's own scripting language.

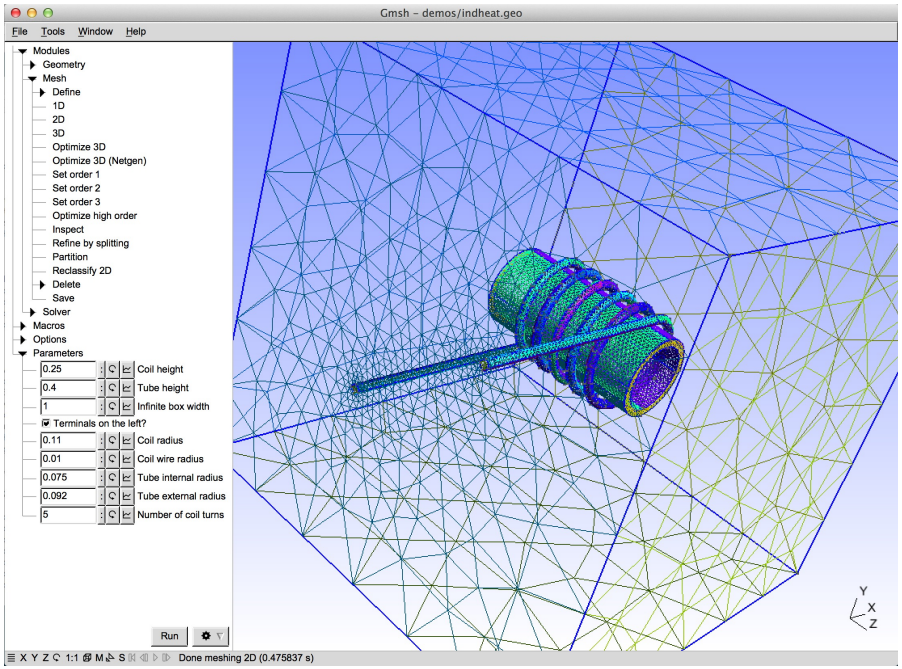

Figure 7: Gmsh.

http://www.geuz.org/gmsh/

- **Netgen** is a multi-platform automatic mesh generation tool written in C++ capable of generating meshes in 2- and 3-D. It generates triangular or quadrilateral meshes in 2D, and tetrahedral meshes in 3D. The input for 2D is described by spline curves, and the input for 3D problems can be defined by Constructive Solid Geometry (CSG), the standard STL file format, or BRep/IGES/STEP when compiled with OpenCascade support.

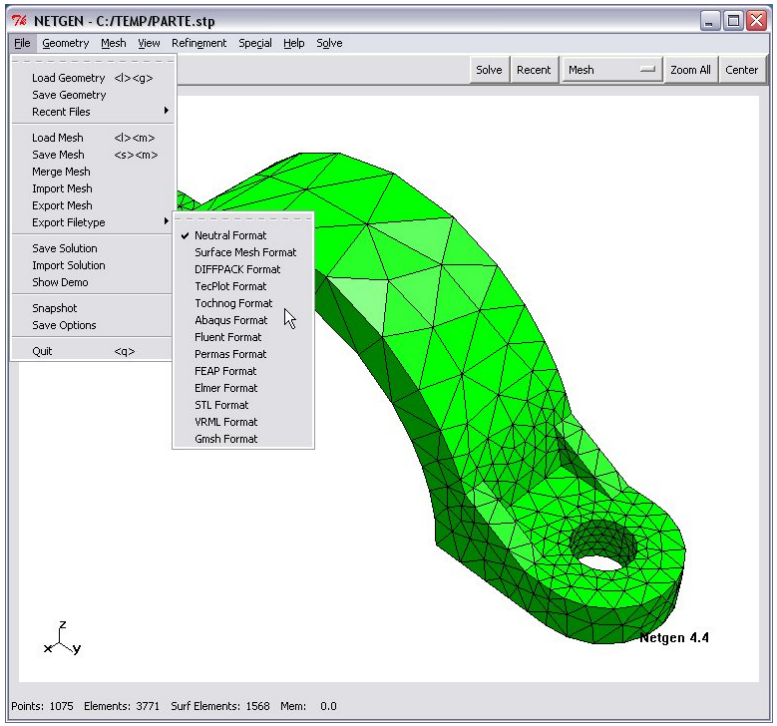

Figure 8: Netgen.

http://sourceforge.net/apps/mediawiki/netgen-mesher/index.php?title=Main_Page

- **Code_Aster** is an Open Source software package for Civil and Structural Engineering finite element analysis and numeric simulation in structural mechanics originally developed as an in-house application by the French company EDF.

  It was released as free software under the terms of the GNU General Public License, in October 2001.

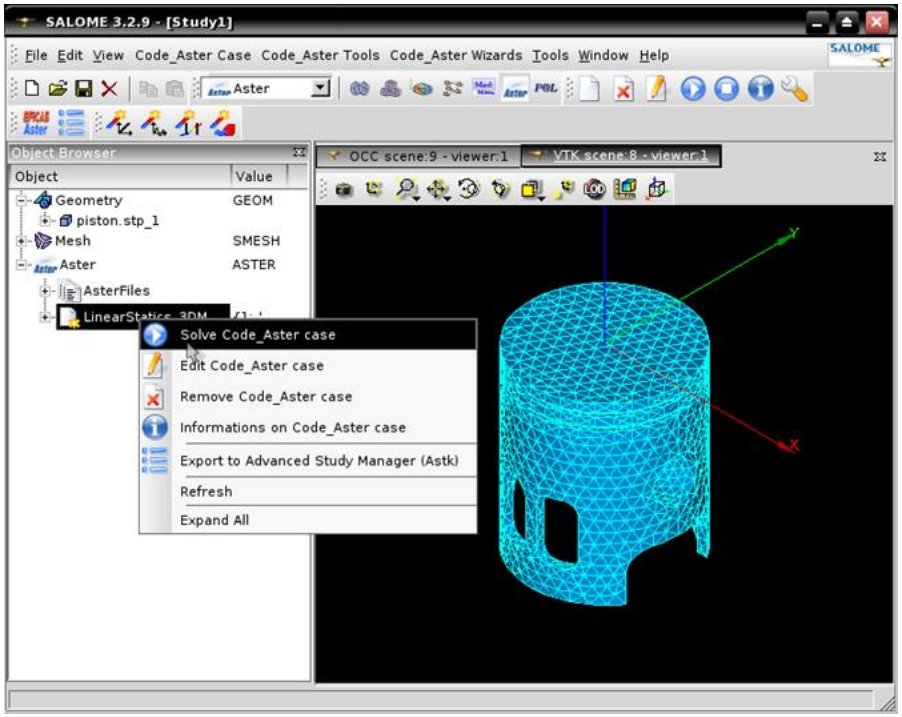

Figure 9: Code_Aster.

http://www.code-aster.org/V2/spip.php?rubrique2

- **Z88Aurora** is a free finite element software package for static calculation in Mechanical Engineering. Beside linear static analysis you can use it for large displacement analysis, stady state thermal analysis and natural frequency analysis.

  Z88Aurora is made up of three components:

  - FE-Preprocessor,
  - FE-Solver and
  - FE-Postprocessor.

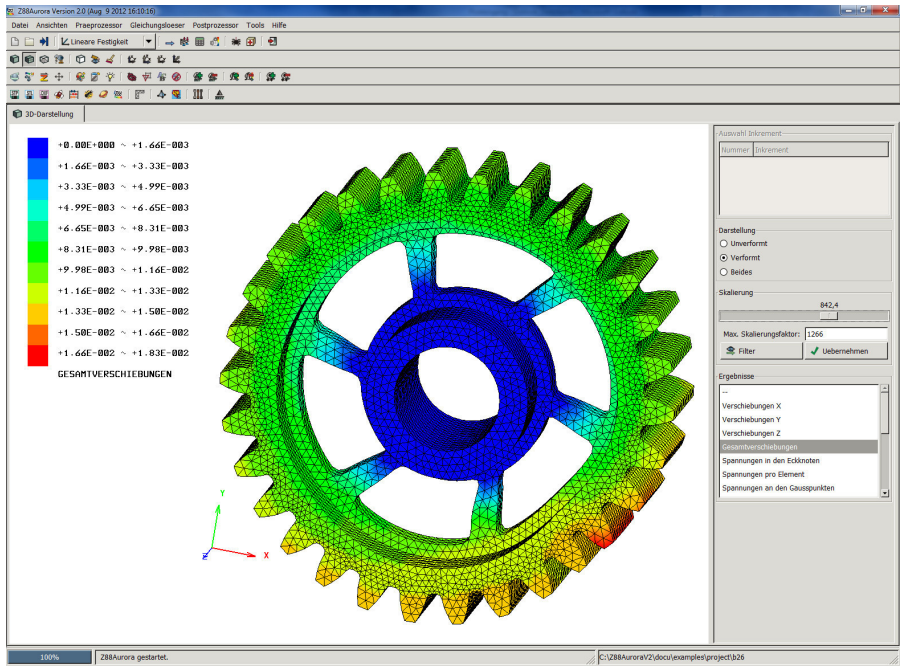

Figure 10: Z88 Aurora.

http://www.z88.uni-bayreuth.de/z88aurora/wasistz88_e.htm

- **Elmer** is an open source multiphysical simulation software developed by CSC. Elmer development was started 1995 in collaboration with Finnish Universities, research institutes and industry.

  Elmer includes physical models of fluid dynamics, structural mechanics, electromagnetics, heat transfer and acoustics, for example. These are described by partial differential equations which Elmer solves by the finite element method.

  http://www.csc.fi/english/pages/elmer

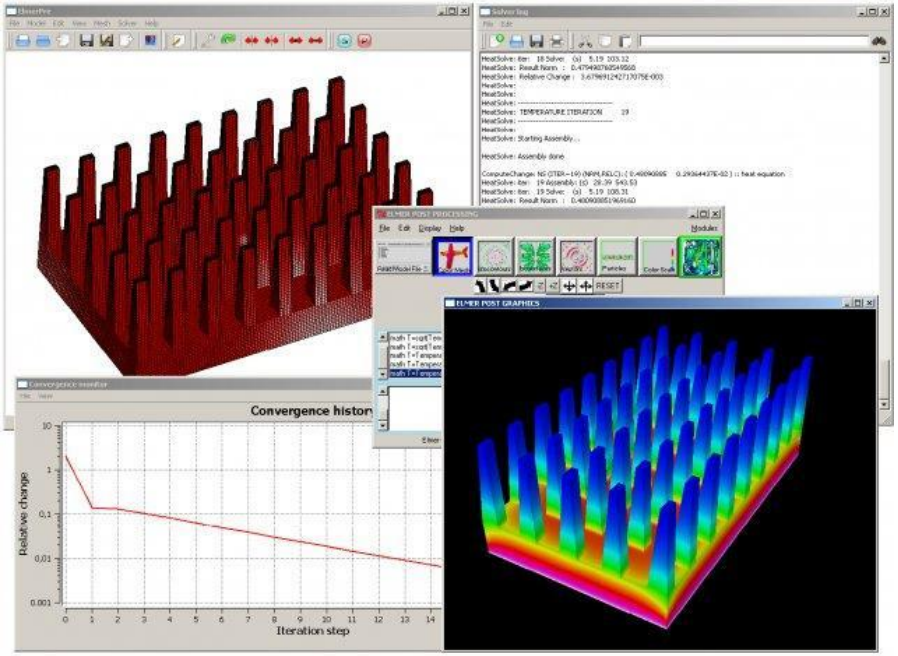

Figure 11: Elmer.

- **OpenFOAM** (**Open Field Operation And Manipulation**) is a C++ toolbox for the customisation and extension of numerical solvers for continuum mechanics problems, including CFD. Standard Solvers include: basic CFD, incompressible flows, compressible flows, multiphase flows, particle-tracking flows, combustion, heat transfer, molecular dynamics, direct simulation Monte Carlo, electro-magnetics, solid dynamics, etc.

http://www.openfoam.com/

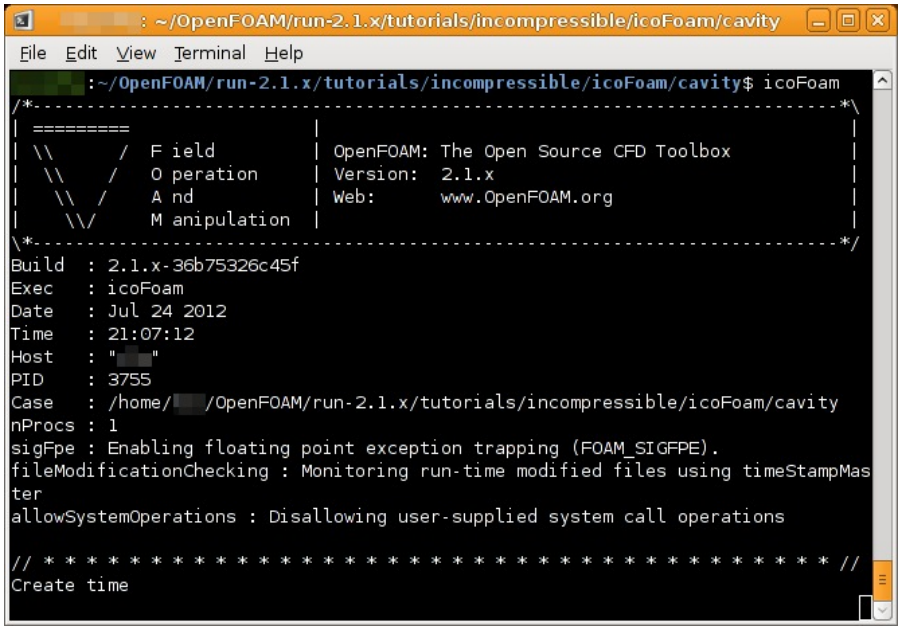

Figure 12: OpenFOAM.

- **Code_Saturne** solves the Navier-Stokes equations for 2D, 2D-axisymmetric and 3D flows, steady or unsteady, laminar or turbulent, incompressible or weakly dilatable, isothermal or not, with scalars transport if required. Several turbulence models are available, from Reynolds-Averaged models (a.k.a. RANS models) to Large-Eddy Simulation models.

  It was released under the terms of the GNU General Public License in 2001.

  http://www.code-saturne.org/

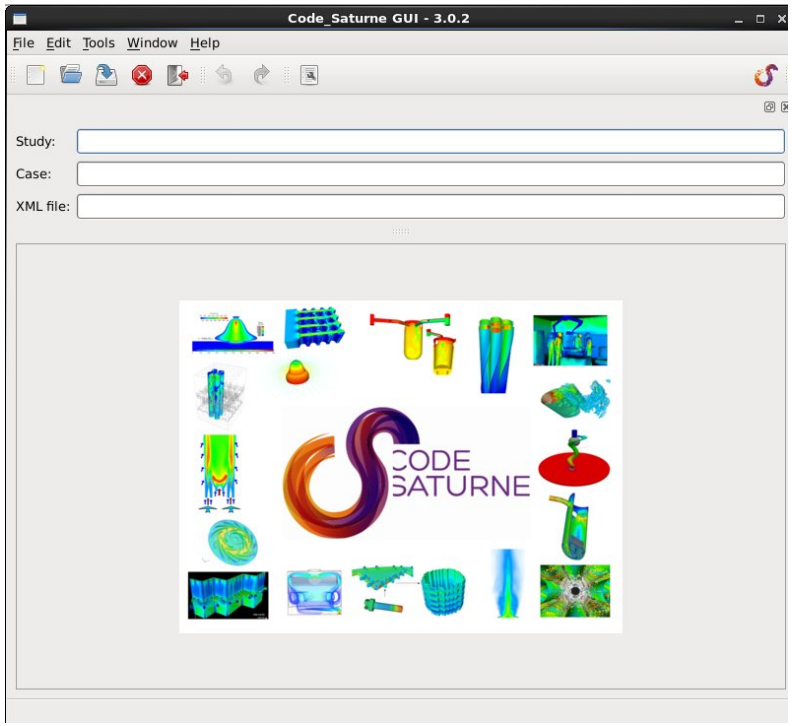

Figure 13: Code_Saturne GUI.

- **Dolfyn** is an open source CFD code initiative originated in Noord-Brabant, the Netherlands. The goal of dolfyn is to promote, introduce and teach the use of modern numerical simulation techniques in general and the use of CFD in particular.

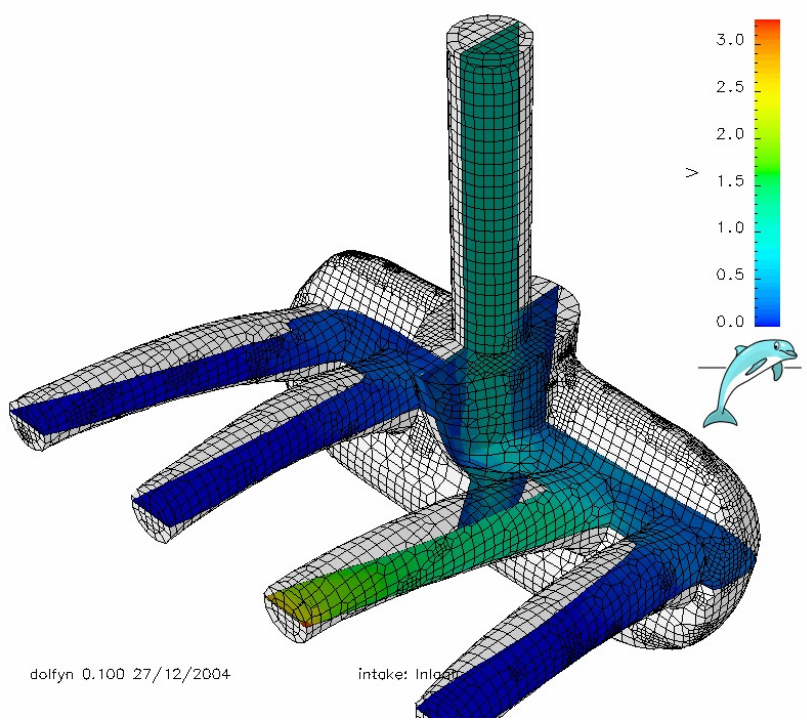

Figure 14: Dolfyn.

http://www.dolfyn.net/

- **OpenFVM** was developed to simulate the flow in complex 3D geometries using the finite volume method. Its mesh can be unstructured and contain control volumes with arbitrary shape. The code has two implementations:
  - serial (using LASpack), and
  - parallel (using PETSc).

  Both implementations use the open source tool **gmsh** for pre- and post-processing.

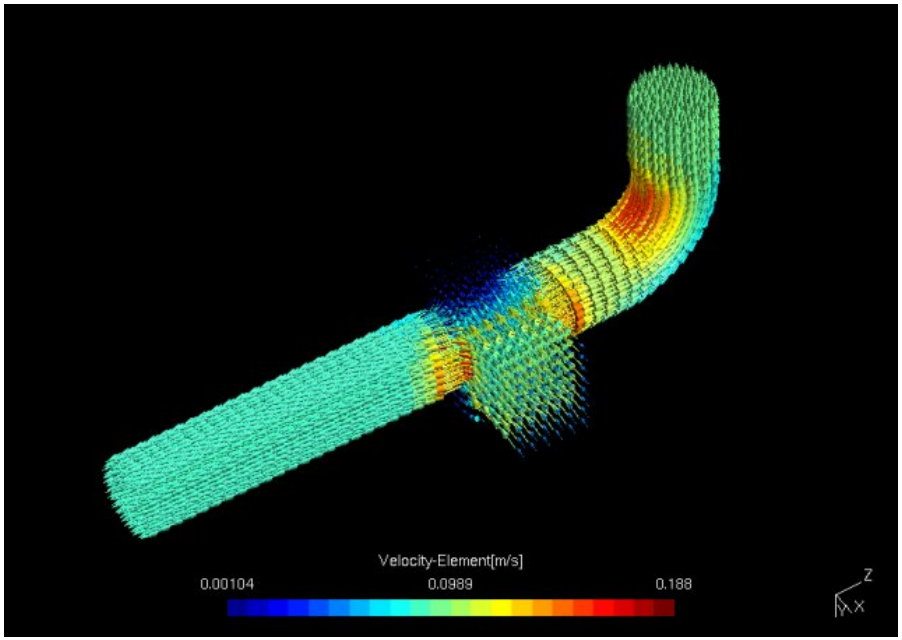

Figure 15: OpenFVM.

http://openfvm.sourceforge.net/

- **Salome** is an open-source software that provides a generic platform for Pre- and Post-Processing for numerical simulation.
  Salome Platform capabilities are:
  - Create/modify, import/export in multiple formats (IGES, STEP, BREP), using CAD operations like extrusions, cut...
  - Mesh CAD models, edit mesh, check mesh quality, import/export mesh (MED, UNV, DAT, STL)
  - Handle physical properties and quantities attached to geometrical items
  - Perform computation using one or more external solvers (coupling)
  - Display computation results (scalar, vectorial)
  - Manage studies (create, save, reload)

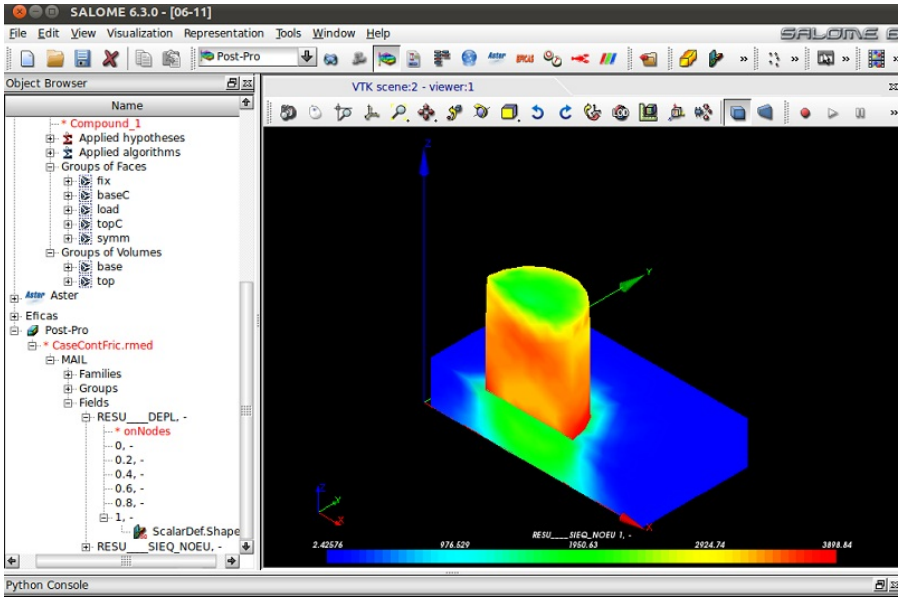

Figure 16: Salome as post-processor.

- **ParaView** is an open-source, multi-platform data analysis and visualization application. ParaView users can quickly build visualizations to analyze their data using qualitative and quantitative techniques.

  The data exploration can be done interactively in 3D or programmatically using ParaView's batch processing capabilities.

http://www.paraview.org/

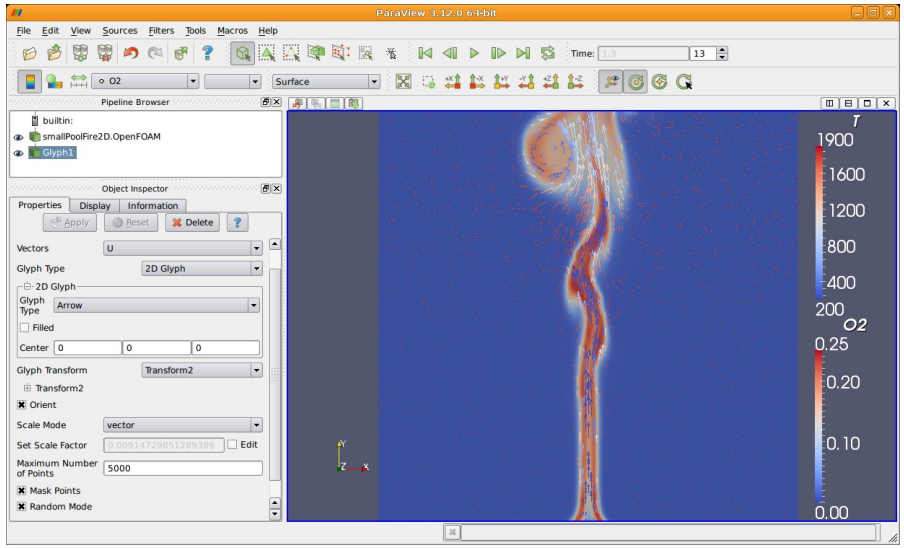

Figure 17: ParaView.

- **VisIt** is a free interactive parallel visualization and graphical analysis tool for viewing scientific data. It can be used to visualize scalar and vector fields defined on 2- and 3-D structured and unstructured meshes.

  VisIt was designed to handle very large data set sizes in the terascale range and yet can also handle small data sets in the kilobyte range.

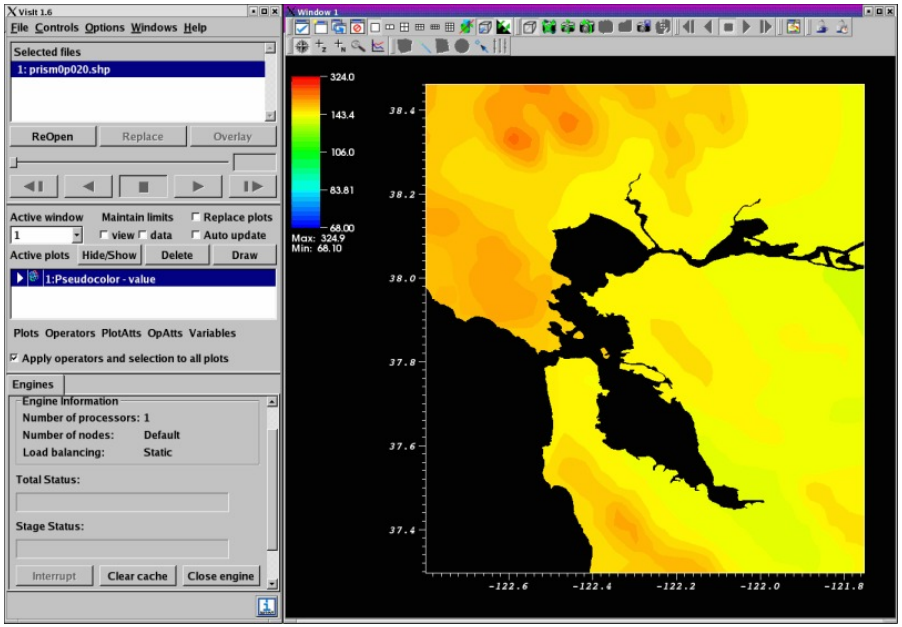

Figure 18: VisIt.

https://wci.llnl.gov/codes/visit/

- **GNU Octave** is a high-level language, primarily intended for numerical computations.

  It provides a convenient command line interface for solving linear and nonlinear problems numerically, and for performing other numerical experiments using a language that is mostly compatible with Matlab. It may also be used as a batch-oriented language.

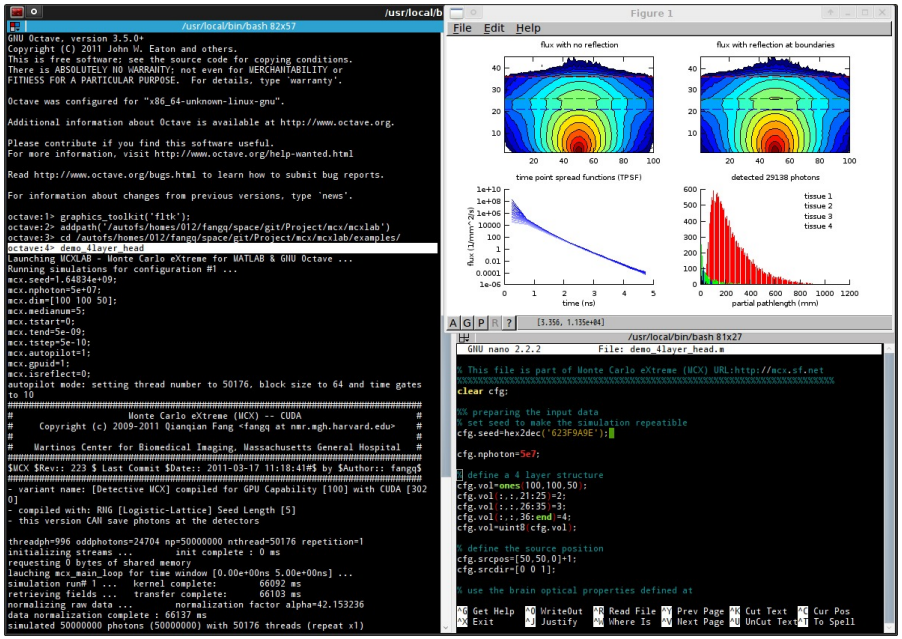

Figure 19: GNU Octave.

http://www.gnu.org/software/octave/

- **Scilab** is a scientific software package for numerical computations providing a powerful open computing environment for engineering and scientific applications.

  It's almost similar to Matlab, but not quite!

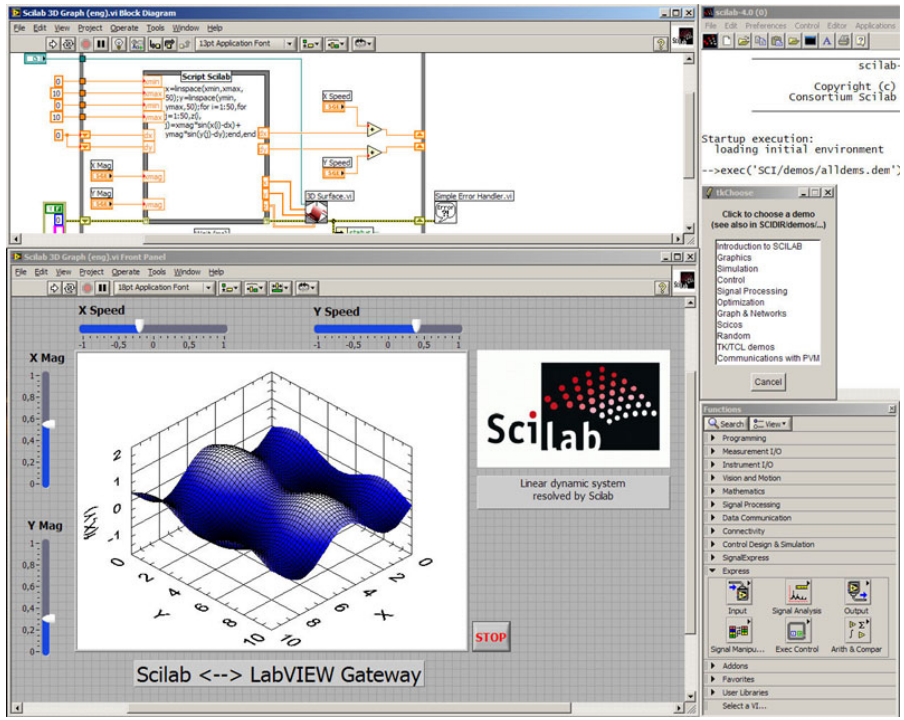

Figure 20: Scilab.

http://www.scilab.org/

- **Maxima** is system for the manipulation of symbolic and numerical expressions, including differentiation, integration, Taylor series, Laplace transforms, ordinary differential equations, systems of linear equations, polynomials, and sets, lists, vectors, matrices, and tensors.

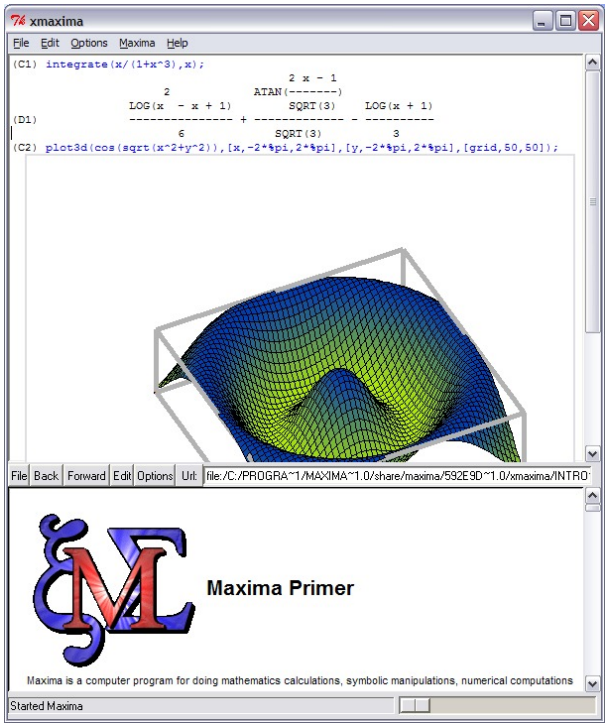

Figure 21: Maxima.

http://maxima.sourceforge.net/

- **SciDAVis** is an open-source cross-platform computer program for interactive scientific graphing and data analysis. SciDAVis can generate different types of 2D and 3D plots (such as line, scatter, bar, pie, and surface plots) from data that is either imported from ASCII files, entered by hand, or calculated using formulas. The built-in analysis operations include column/row statistics, (de)convolution, FFT and FFT-based filters. Curve fitting can be performed with user-defined or built-in linear and nonlinear functions, including multi-peak fitting, based on the GNU Scientific Library.

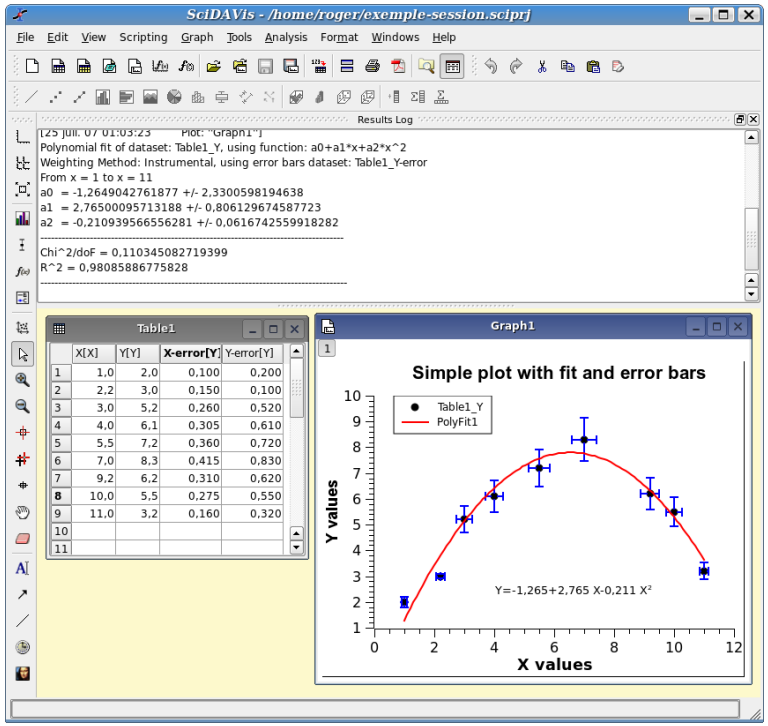

Figure 22: SciDAVis.

- **g3data** is used for extracting data from graphs. In publications graphs often are included, but the actual data is missing. g3data makes the extracting process much easier.

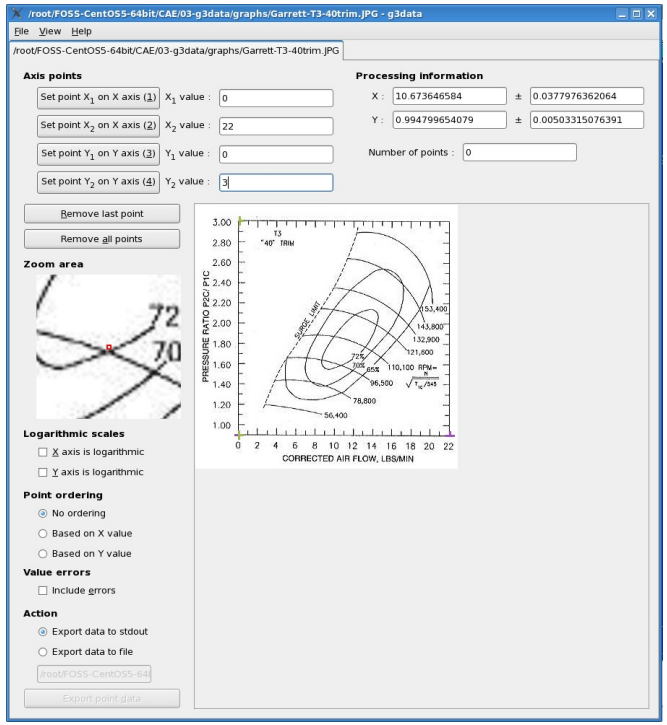

Figure 23: g3data.

http://www.frantz.fi/software/g3data.php

- **GNUplot** is a portable command-line driven interactive data and function plotting utility for UNIX, IBM OS/2, MS Windows, DOS, Macintosh, VMS, Atari and many other platforms.

  It supports many types of plots in either 2D and 3D. It can draw using lines, points, boxes, contours, vector fields, surfaces, and various associated text. It also supports various specialized plot types.

  http://www.gnuplot.info/

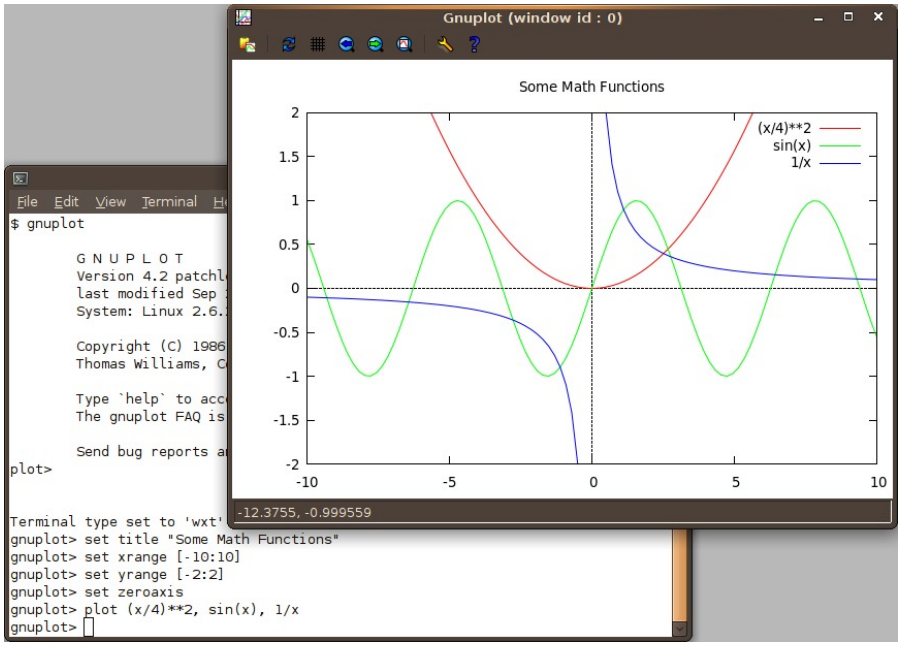

Figure 24: GNUplot.

- **3D Slicer** is an open source software platform for medical image informatics, image processing, and three-dimensional visualization. Built over two decades through support from the National Institutes of Health and a worldwide developer community, Slicer brings free, powerful cross-platform processing tools to physicians, researchers, and the general public.

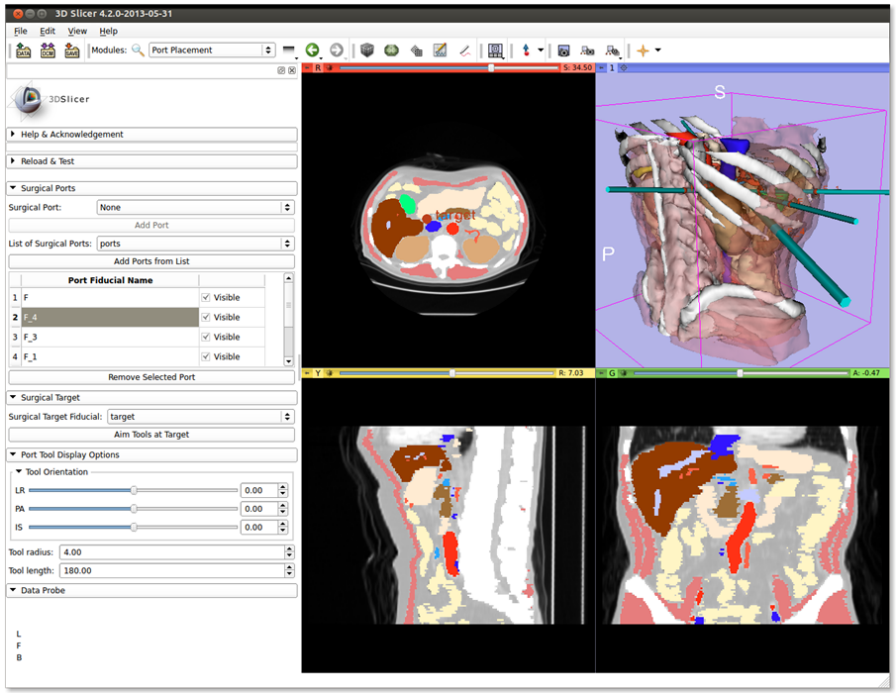

Figure 25: Volume rendering using 3D Slicer.

- **MRIcroGL** is a program designed to display 3D medical imaging. By using your computer's graphics card, it can allow real-time interactive rendering.

Figure 26: MRIcroGL.

http://www.mccauslandcenter.sc.edu/CRNL/tools

- **R** is a programming language and software environment for statistical computing and graphics.

  It is an implementation of the **S** programming language with lexical scoping semantics inspired by Scheme.

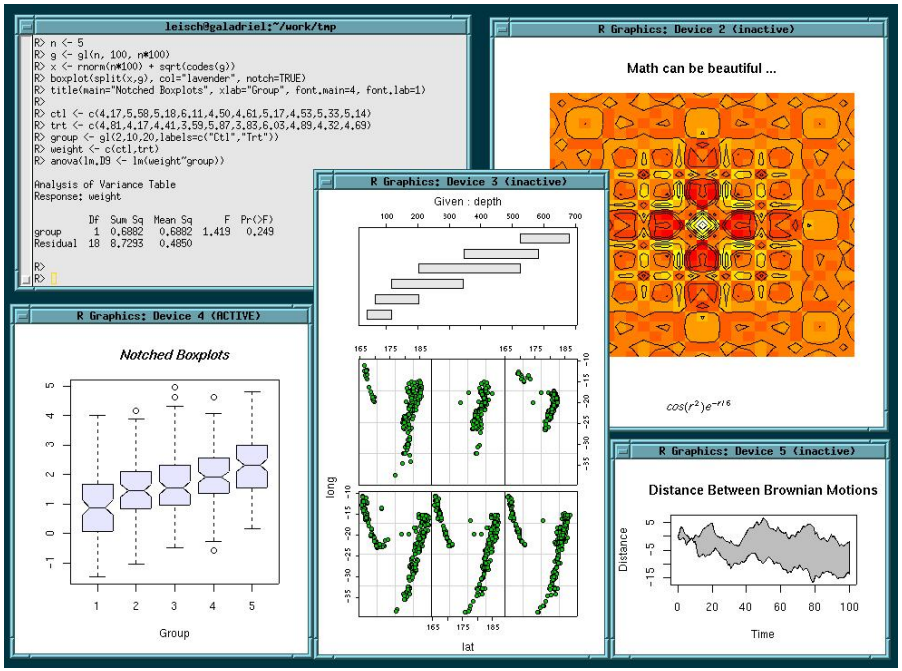

Figure 27: R.

http://www.r-project.org/

- **RStudio** is a powerful and productive Integrated Development Environment (IDE) for R. It's free and open source, and works great on Windows, Mac, and Linux.

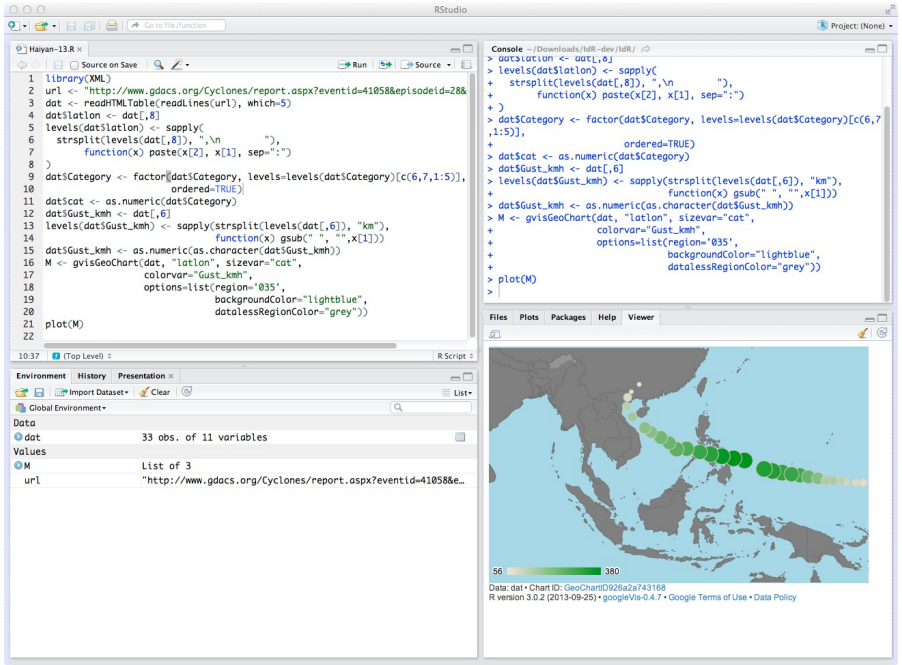

Figure 28: RStudio.

http://www.rstudio.com/

- **GNU PSPP** is a program for statistical analysis of sampled data. It is a free replacement for SPSS, and appears very similar to it with a few exceptions. Features include:
  - Support for over 1 billion cases and 1 billion variables.
  - Syntax and data files which are compatible with those of SPSS.
  - A choice of terminal or graphical user interface.
  - A choice of text, postscript, pdf, opendocument or html output formats.
  - Inter-operability with Gnumeric, LibreOffice, OpenOffice.Org and other free software.
  - Easy data import from spreadsheets, text files and database sources.
  - Portability; runs on many different operating systems

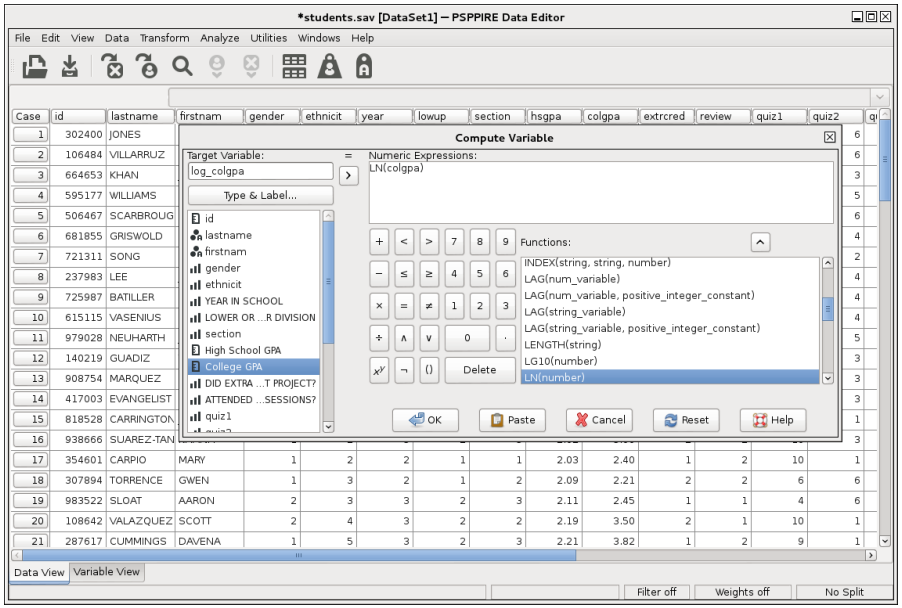

Figure 29: GNU PSPP.

- **GNU Compilers Collection** (GCC) includes front ends for C, C++, Objective-C, Fortran, Java, and Ada, as well as libraries for these languages (libstdc++, libgcj, ...).

  GCC was originally written as the compiler for the GNU operating system. The GNU system was developed to be 100% free software, free in the sense that it respects the user's freedom.

http://gcc.gnu.org/
http://en.wikipedia.org/wiki/GNU_Compiler_Collection

- **MinGW-w64** is an advancement of the original **MinGW** (Minimalist GNU for Windows) project, created to support the GCC compilers on Windows systems. It has forked it in 2007 in order to provide support for 64 bits and new APIs.

https://mingw-w64.org/doku.php
https://sourceforge.net/projects/mingw-w64/files

Figure 30: MinGW-64 for Windows.

Cross platform scripting languages by seniority:

1. **Perl** is a cross general-purpose programming language with over 30 years of development. It was originally developed for text manipulation and now used for a wide range of tasks including system administration, web development, network programming, GUI development, and more.

   https://www.perl.org/

2. **Python** is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together.

   https://www.python.org

3. **Ruby** is a dynamic, open source programming language with a focus on simplicity and productivity. It has an elegant syntax that is natural to read and easy to write.

   https://www.ruby-lang.org/en/

If you are developing software using compilers, these are some of the major repositories of highly efficient codes you might want to visit:

- **Netlib** is a collection of mathematical software, papers, and databases.
  http://www.netlib.org.
- **TOMS** (Transactions on Mathematical Software) is part of the family of journals produced by the Association for Computing Machinery (ACM). It also publishes machine-readable computer software which is incorporated into the Collected Algorithms of the ACM.
  http://toms.acm.org/.
- **GAMS** (General Algebraic Modeling System) is a high-level modeling system for mathematical programming and optimization. It is tailored for complex, large scale modeling applications, and allows you to build large maintainable models that can be adapted quickly to new situations.
  http://www.gams.com/.
- **PETSc** PETSc, pronounced PET-see (the S is silent), is a suite of data structures and routines for the scalable (parallel) solution of scientific applications modeled by partial differential equations. It employs the MPI standard for parallelism.
  https://www.mcs.anl.gov/petsc/.

- **Dislin:** A high-level plotting library for displaying data as curves, polar plots, bar graphs, pie charts, 3D-color plots, surfaces, contours and maps.
  http://www.mps.mpg.de/dislin/.
- **PLplot** A cross-platform software package for creating scientific plots. To help accomplish that task it is organized as a core C library, language bindings for that library, and device drivers which control how the plots are presented in non-interactive and interactive plotting contexts.
  http://plplot.sourceforge.net/.
- **VTK** (Visualization ToolKit): is an open-source, freely available software system for 3D computer graphics, image processing and visualization. VTK consists of a C++ class library and several interpreted interface layers including Tcl/Tk, Java, and Python.
  http://www.vtk.org/.

- **SciPy:** SciPy (pronounced "Sigh Pie") is a Python-based ecosystem of open-source software for mathematics, science, and engineering. In particular, these are some of the core packages:
  - **SciPy library**: Fundamental library for scientific computing
    https://www.scipy.org/.
  - **NumPy**: Base *N*-dimensional array package
    http://www.numpy.org/.
  - **Matplotlib**: Comprehensive 2D Plotting
    https://matplotlib.org/.
  - **SymPy**: Symbolic mathematics
    http://www.sympy.org/en/index.html.
  - **pandas**: Python Data Analysis Library
    http://pandas.pydata.org/.
  - **IPython**: Enhanced Interactive Console which provides a rich architecture for interactive computing
    http://ipython.org/.

- When Linus Torvalds first developed Linux back in August of 1991, the operating system basically consisted of his **kernel** and some GNU tools. With the help of others Linus added more and more **tools** and **applications**.
- With time, individuals, university students and companies began distributing Linux with their own choice of packages bound around Linus' kernel. This is where the concept of the **distribution**, or distro, was born. Sample distros include
  - RedHat, CentOS, Scientific Linux, Mandriva, SuSe: (rpm, Unix Sys V)
  - Debian, Ubuntu/Kubuntu, CAELinux: (deb, Unix Sys V)
  - Slackware: (tgz, BSD)
- Go visit `http://distrowatch.com/` for all the distros available out there!!
- Check out the various distros available at our local repository at `http://ossm.utm.my/`

- Linux running on servers are capable of offering these services:
  - **Mail Service:** sendmail, postfix
  - **File Service:** NFS, Samba
  - **DNS Service:** BIND
  - **FTP Service:** vsftp, ProFTP
  - **WWW Service:** Apache
  - **Database Service:** MariaDB, PostgreSQL
  - **Caching Proxy Server:** Squid, Squidguard, Dansguardian
  - **Firewall:** NetFilter/iptables
  - **NIDS:** Snort, Snortsam, Ethereal, Etherape, Nessus, Arpwatch, Ettercap
  - **LAMP Server:** Linux+Apache+MariaDB+PHP

- For desktop/laptop workstations, most Linux distros readily come (or easily installable) with the following applications:
  - **Office Suite:** LibreOffice, Scribus
  - **Software Development Kits:** GNU Compilers, GSL, Lapack, BLAS
  - **Multimedia Tools:** K3B, MPlayer, VLC, Audacious, XMMS
  - **Internet Tools:** Firefox, Opera, Konqueror, Thunderbird, Kmail, IRC
  - **Graphics Tools:** Blender, GIMP, ImageMagick
  - **CAE Tools:** OpenFOAM, Code_Aster, Code_Saturne, Gerris, z88 Aurora, GNUplot, FreeCAD, gmsh, Netgen, Octave, Scilab, Maxima, Paraview, VisIt, Dolfyn
  - **Utilities:** Ghostscript, Evince, Calibre, GSview, GV, PDFCreator

- **Linux Apps Server:** Serves user accounts, SSH, VNC services for remote access; CAE applications like Code_Aster, Code_Saturne, Salome, OpenFOAM from FOSS collection and commercial ones like Ansys, Abaqus, Comsol, Matlab etc.
- **Linux Workstation:** Needs client apps to acces Linux Apps Server: SSH client, VNC viewer and/or nx client.
- **Windows Workstation:** Needs client apps to acces Linux Apps Server: PuTTY, VNC viewer and/or nx client.

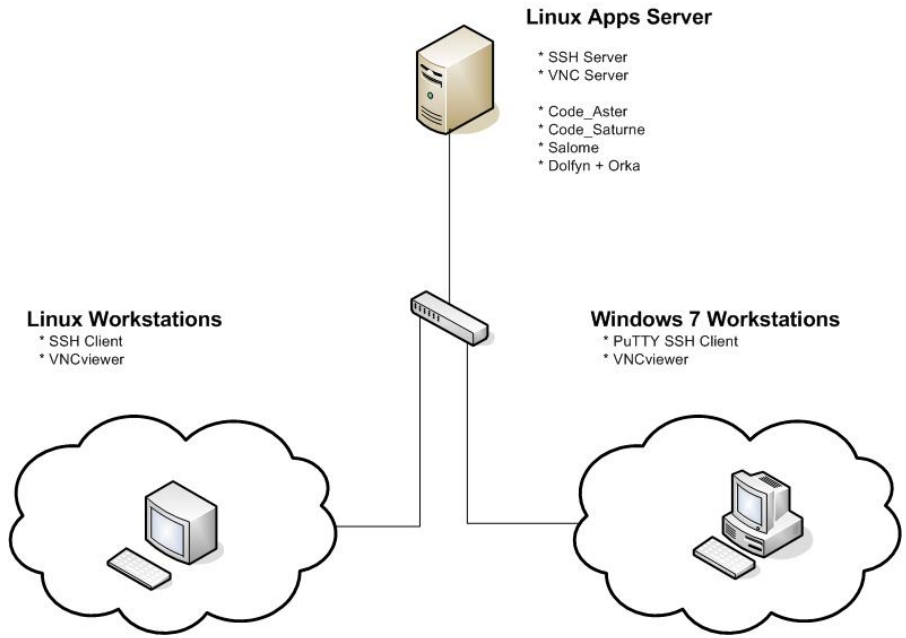

Figure 31: Remote computing concept.

Challenges

Shortfalls of FOSS

- Where do I get started?
- Time consuming
- More difficult to use
- Limited or no support
- Commercial codes have broader range of models for industrial applications

My advice for the first four . . .

- Where do I get started?
- Time consuming
- More difficult to use
- Limited or no support
- Commercial codes have broader range of models for industrial applications

My advice for the first four . . .

is just a click away!

Challenges

Quotes from FOSS USers

- *"The best part of using FOSS is there are lot of freeware in FOSS, and if you have an inhouse FOSS developer or tweaker, it works out cheaper than Licensing."*
- *"We use Blender. It's a powerful 3D modeling/rendering app. We use it in many of the corporate videos we produce. The best part about this kind of software is that there are thousands of people working on tools for it. Every time we turn around someone else has developed some kind of plug in or something that helps things move along. When it comes down to it OSS is really what the internet is about. Communities working to make things faster and better."*

Challenges

Quotes from FOSS USers

- *"FOSS is highly integrable to lots of licensed software and devices too."*
- *"For those of us that directly use OSS, the advantages of using it have to be weighed against the costs of using it. If you have the technical expertise in house to support a project, the cost savings can be significant. If you don't have that in house talent, the cost of ownership can approach or exceed commercially supported systems.*

  In my opinion, convincing people that Open Source is not free can be difficult. In the end, you have to weigh all the options and pick the best solution. Sometimes it is going to be Open Source Software, sometimes it is going to be commercial off-the-shelf software. The real trick is knowing the difference."

. . . and may the **FOSS** be with you.

جزاكم الله خيرا

. . . thank you.

. . . must end

- . . . and I end my presentation with two supplications

رَّبِّ زِدْنِي عِلْمًا

my Lord! increase me in knowledge

(TAA-HAA (20):114)

اَللّٰهُمَّ اِنَّا نَسْئَلُكَ عِلْمًا نَافِعًا

O Allah! We ask You for knowledge that is of benefit

(IBN MAJAH)