Information technology – lecture 4

Elements of computer programming. Programming languages

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Programming languages

There are multitude of programming languages and several ways of categorising them depending on their characteristics. Without going much into details we will distinguish the classifications:

- From the point of view of the complexity of instructions:
  - Low-level programming languages : assembly languages
  - High-level programming languages : C, C++, Java, etc.
- From the point of view of the usage patterns:
  - System programming languages: (C, C++, Fortran, Java, Ada) – associated with the tags like: efficiency safety, static type control.
  - Scripting languages: (Python, Ruby, Tcl, Guile, Ch) – associated with the tags like: rapid prototyping, flexibility, advanced introspection features

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High-level programming languages paradigms

- Imperative programming – language example Octave, C. Characterized by sequential execution of instructions, use of variables that represent memory locations, use of assignment statement to change the values of these variables.
- Functional programming – language example Lisp, Haskel. Based on mathematical concept of function. Computation is expressed in term of the evaluation of functions. No variables and no assignment statements. Repetition expressed in terms of recursive function calls.
- Logic programming – language example PROLOG. Based on principles of symbolic logic.

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Programming languages for numerical simulations

Some languages are considered as better suited for writing numerical simulation codes. However picking the right language is a difficult thing often depending on non-technical issues (like available human resources in terms of programmers or local experts).
As most to the numerical algorithms utilize vector and matrix abstractions one important factor when evaluating a language is to what extend the language support direct use of these abstractions. Support for vector and matrices can be either built-in into a language (Matlab, Octave, Fortran) or can be provided by a set of libraries.
Some popular choices are: Ada, C, C++, Fortran (both 77 and 90 and above), Matlab, Octave, Python, Ch.

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Python

What is Python

- Scripting, object-oriented, rapid prototyping, general purpose language
- Quite popular for writing scientific codes, especially when supported by C/C++/Fortran extension libraries
- Extensible and embeddable in applications

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Selected Python features

- Portability – UNIX, Windows, Mac, BeOS, VMS, Cray, ...
- Compiles to interpreted byte code
- Automatic memory management through reference counting
- Many GUI libraries
- Several extension modules (NumPy for numerics)

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Mathematical software

Mathematical software is software used to model, analyse, or calculate numeric, symbolic, or geometric data.(wikipedia)

Application areas:

- Symbolic mathematics – computer algebra systems
- Statistics
- Geometry
- Numerical analysis

Categories of software:

- applications, e.g. GeoGebra
- interactive platforms, e.g. Scilab, Sage
- problems solving environments (PSE), e.g. Diffpack
- software libraries, e.g. GNU Scientific Library, Trilinos

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Selected software packages

Alphabetical list:

- Diffpack
- Maple
- MathCad
- Mathematica
- Matlab
- Maxima `http://maxima.sourceforge.net/`
- Octave `http://www.gnu.org/software/octave/`
- R `http://www.r-project.org/`
- Sage `http://www.r-project.org/`
- Scilab `http://www.scilab.org/`

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Software taxonomies

Licensing:

- Open Source
- Proprietary

Scope:

- Symbolic computations
- Numerical computations

Operating mode:

- WYSWIG, GUI
- traditional programming, CLI

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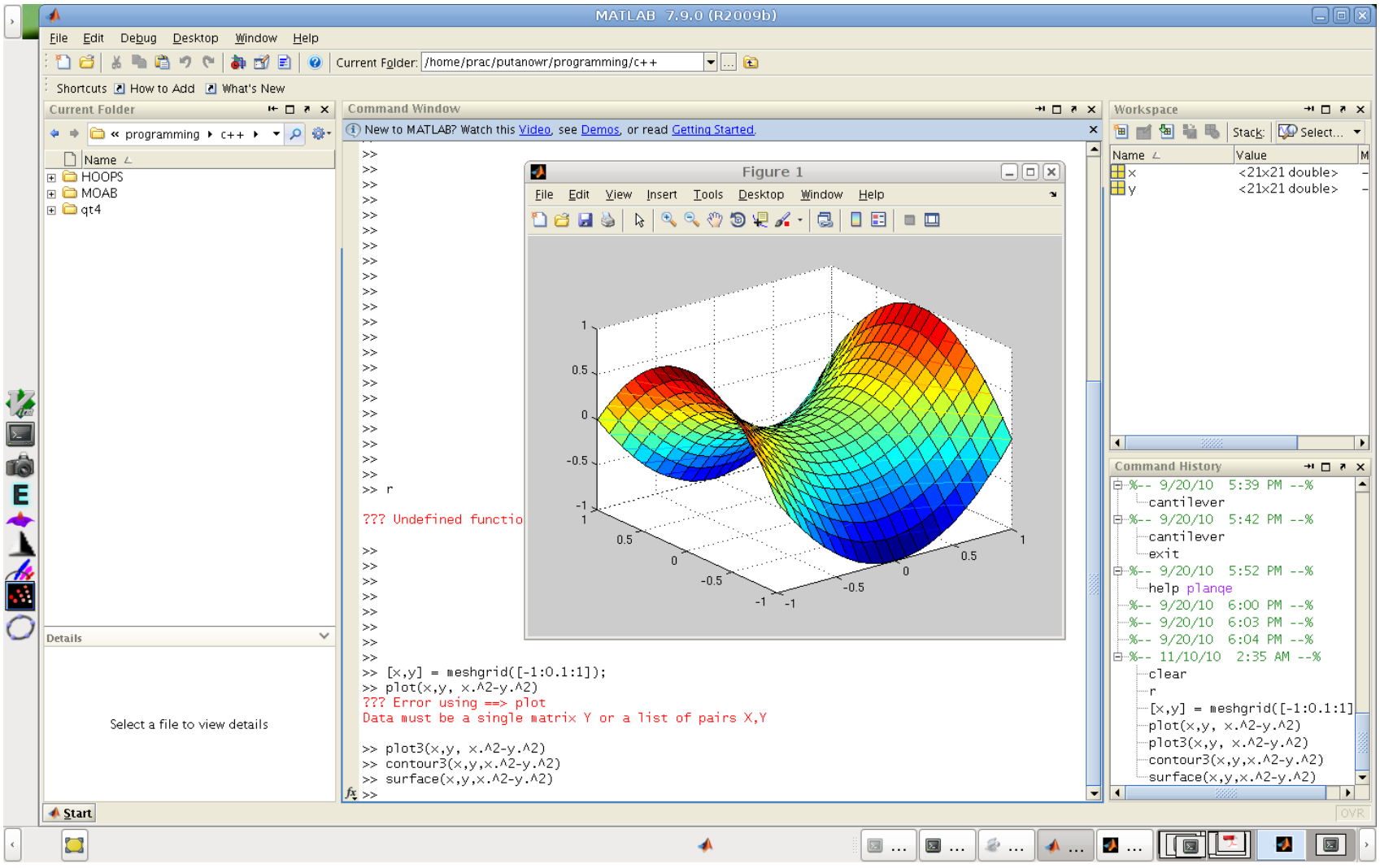
Matlab



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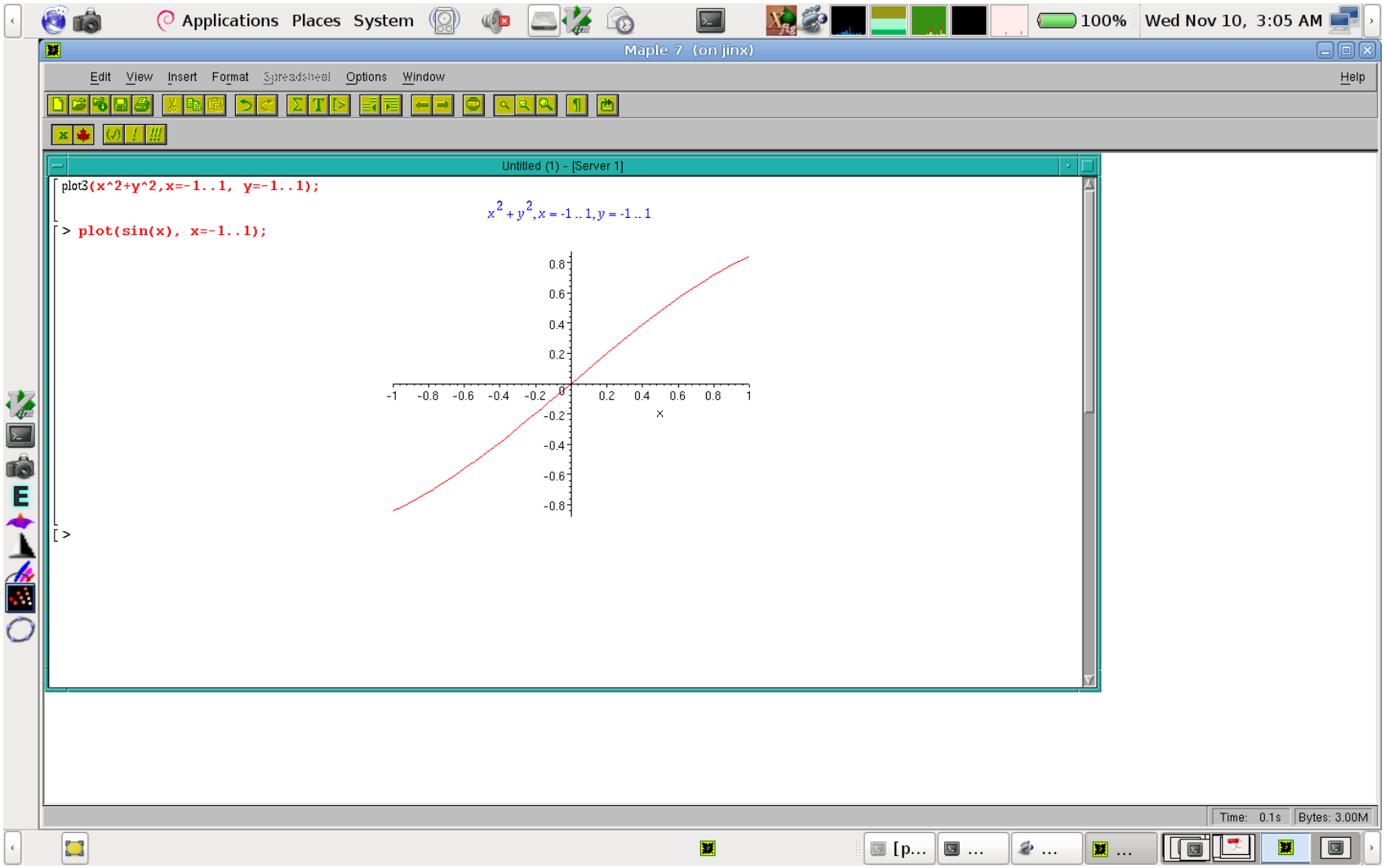
Maple



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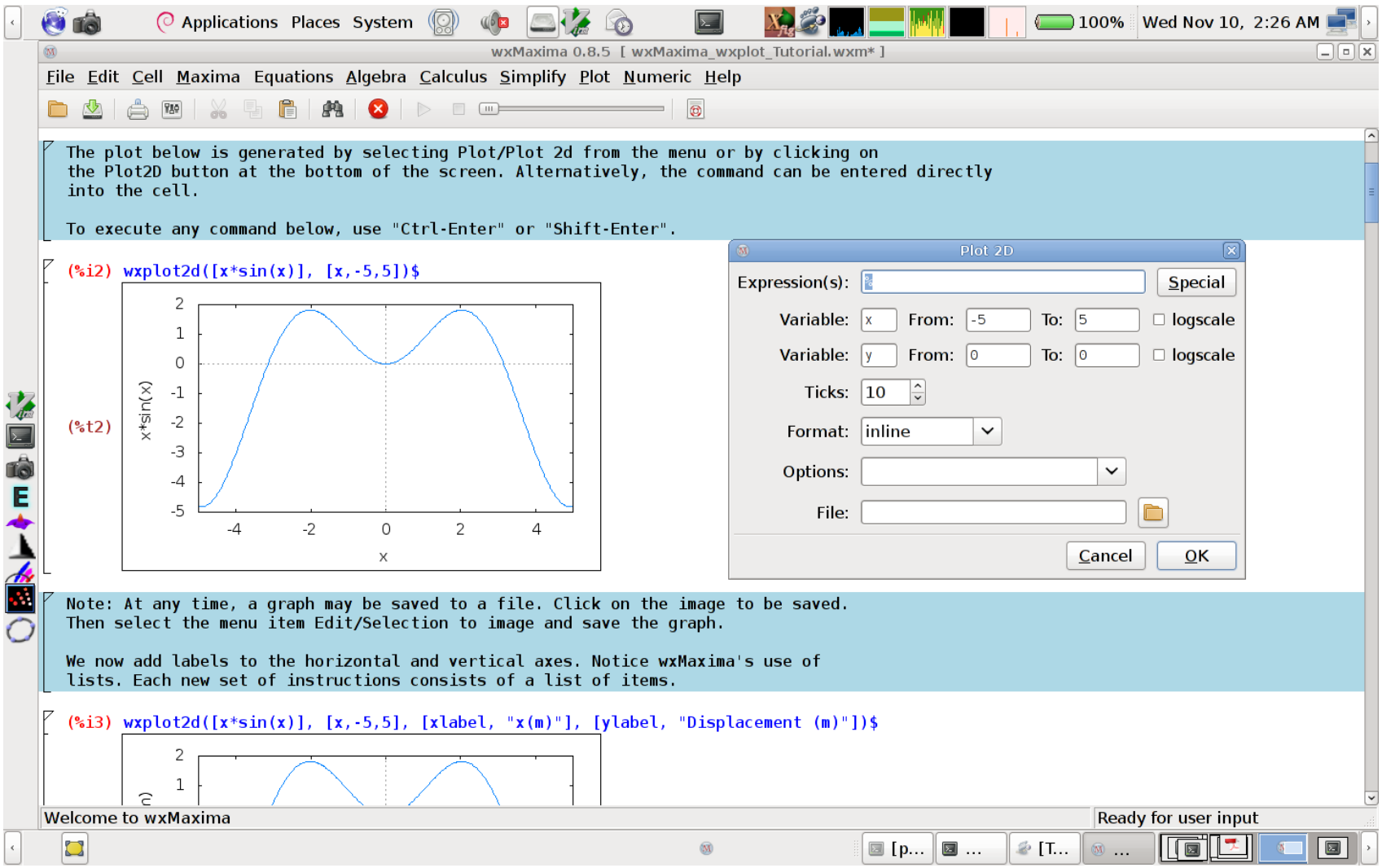
Maxima + wx = wxMaxima



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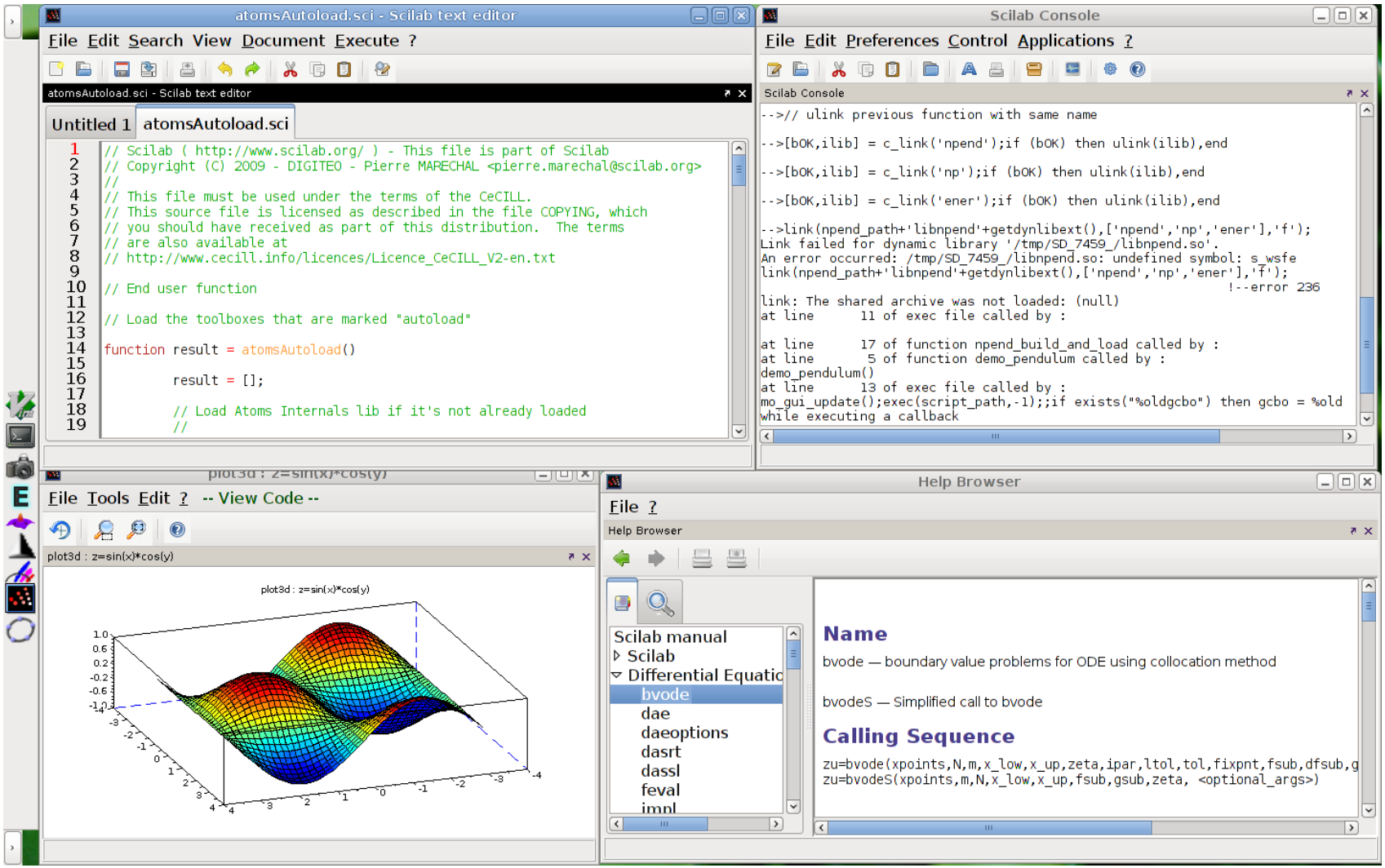
Scilab



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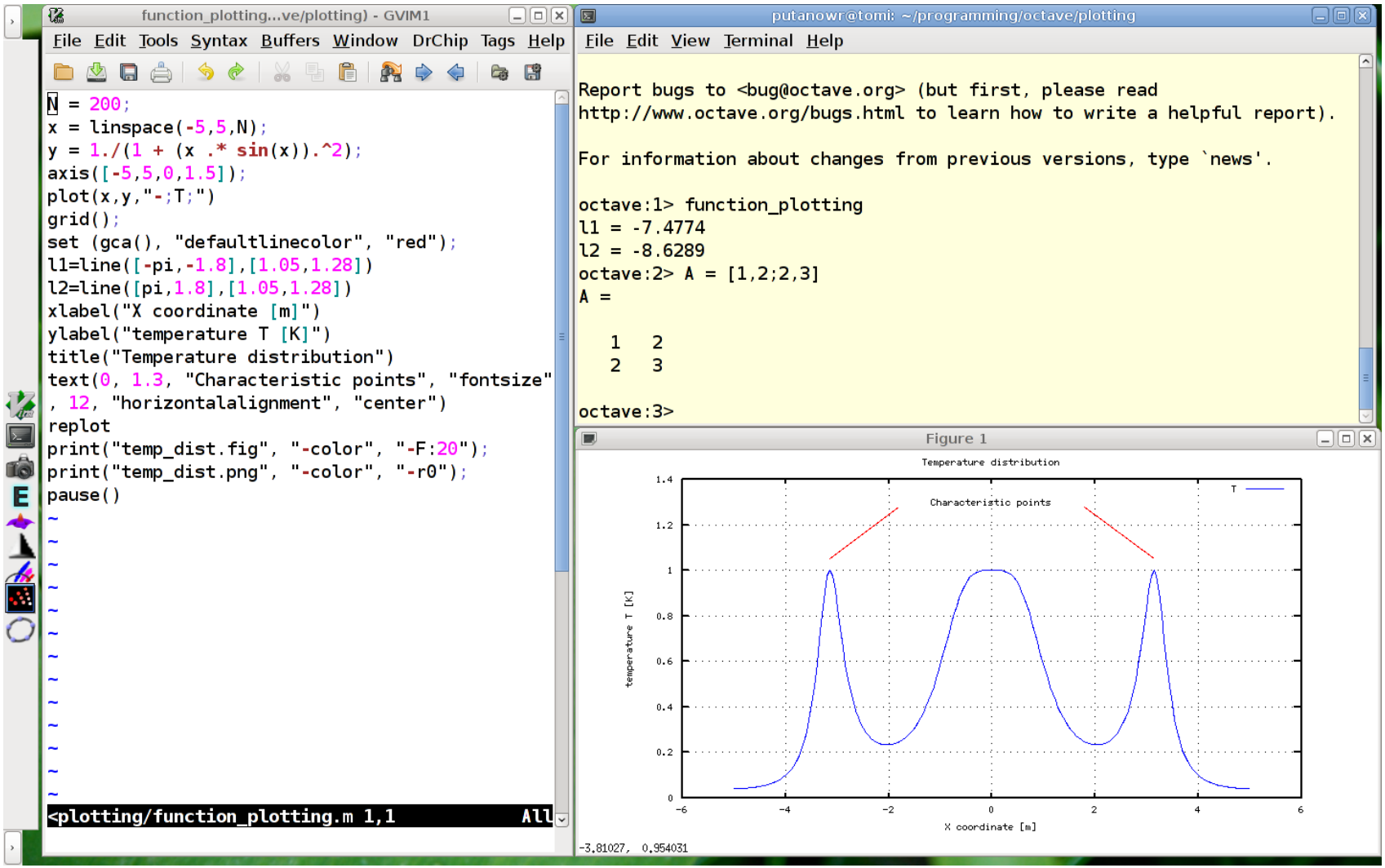
Octave



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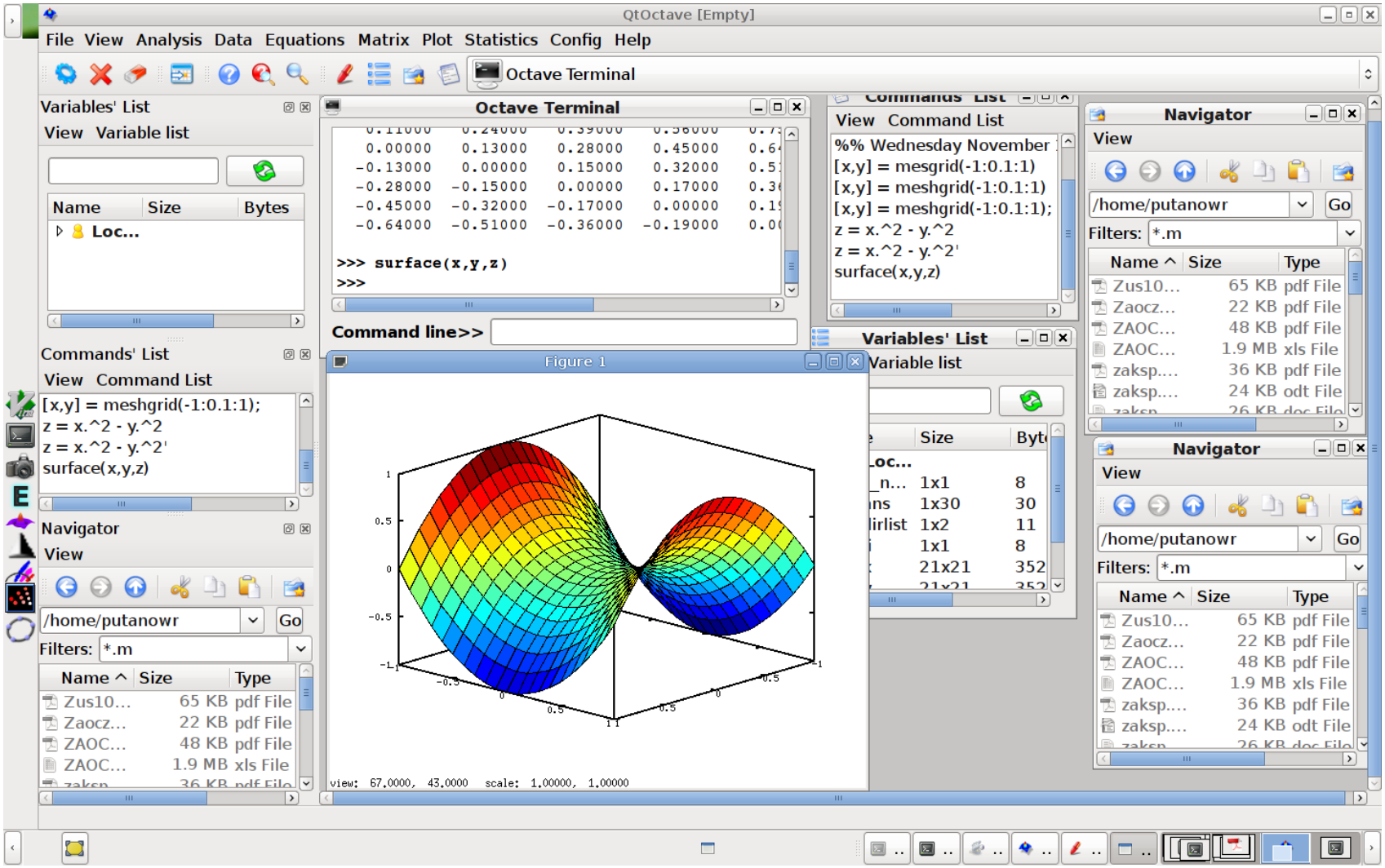
Octave + Qt = QtOctave



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Scalar product: C versus Octave program

```c
#include <stdio.h>

#define DIM 3
int main() {
  char *fname = "vect.dat";
  FILE *fh = fopen(fname, "r");

  double u[DIM];
  double v[DIM];
  int i;

  for (i=0; i<DIM; i++) {
    fscanf(fh, "%lf", u+i);
  }
  for (i=0; i<DIM; i++) {
    fscanf(fh, "%lf", v+i);
  }
  double s=0;
  for (i=0; i<DIM; i++) {
    s += u[i]*v[i];
  }
  printf("Scalar product of u and v: %g\n", s);
  return 0;
}
```

```
fname = 'vect.dat';
fh = fopen(fname, 'r');
dim = 3;
u = fscanf(fh, '%lf', dim);
v = fscanf(fh, '%lf', dim);
s=0;
for i=1:dim
  s+=u(i)*v(i);
end
printf('Scalar product of u and v: %g', s);
```

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Scalar product: Octave versus Octave program

```
1  fname = 'vect.dat';
2  fh = fopen(fname, 'r');
3  dim = 3;
4  u = fscanf(fh, '%lf', dim);
5  v = fscanf(fh, '%lf', dim);
6  s=0;
7  for i=1:dim
8    s+=u(i)*v(i);
9  end
10 printf('Scalar product of u and v: %g', s);
```

```
1  fname = 'vect.dat';
2  A = load('vect.dat');
3  u = A(1:3);
4  v = A(4:6);
5  s = dot(u,v);
6  printf('Scalar product of u and v: %g\n', s
```

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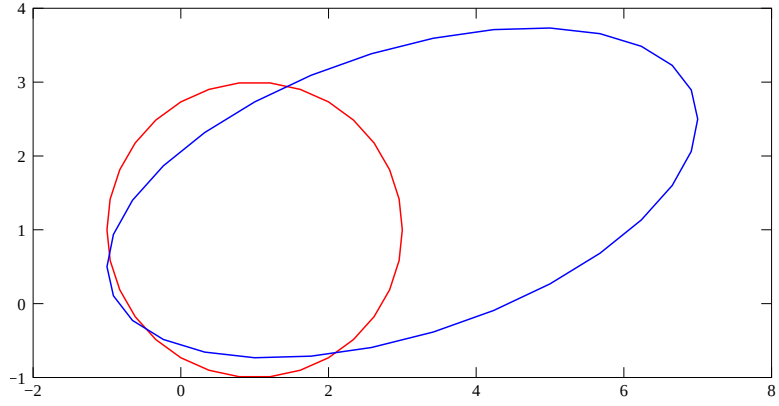
Case study: affine transformation in 2D

Problem: Write Octave program that illustrates affine transformation of a circle.

$$\hat{x} = ax + by + c$$
$$\hat{y} = ex + fy + g$$



$$\hat{x} = T_{11}x + T_{12}y + T_{13}$$
$$\hat{y} = T_{21}x + T_{22}y + T_{23}$$

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Case study: affine transformation in 2D

```
1  function [XY] = polygon(x,y,R,N)
2    t = linspace(0,2*pi,N+1);
3    XY = zeros(N+1,2);
4    XY(:,1) = x + R*cos(t);
5    XY(:,2) = y + R*sin(t);
6  end
```

```
7  function plot_poly(XY, color)
8    h = line(XY(:,1), XY(:,2));
9    set(h, 'color',color);
10 end
```

```
11 function [NXY] = transform_poly(XY, T)
12   NXY=zeros(size(XY));
13   for i=1:rows(XY)
14     x = XY(i,1);
15     y = XY(i,2);
16     xh = T(1,1)*x + T(1,2)*y + T(1,3);
17     yh = T(2,1)*x + T(2,2)*y + T(2,3);
18     NXY(i,:) = [xh,yh];
19   endfor
20 endfunction
```

```
21 N=30
22 xy = polygon(1,1,2,N);
23 plot_poly(xy,"red");
24 T = [2.0, 0.0, 1.0;
25 0.5, 1.0, 0.0];
26 xy1 = transform_poly(xy, T);
27 plot_poly(xy1,"blue");
28 axis("equal")
29 print("affine.fig")
30 pause()
```

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References

1. Maxima `http://maxima.sourceforge.net/`
2. R `http://www.r-project.org/`
3. Sage `http://www.r-project.org/`
4. Scilab `http://www.scilab.org/`
5. GNU Octave `http://www.gnu.org`
6. GNU Octave. A high-level interactive language for numerical computations, by John W. Eaton, David Bateman, Søren Hauberg, edition 3 for Octave version 3.0.2, Network Theory Ltd, 2008
7. Python `http://www.python.org/`
8. Own materials

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Thank you for your attention

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Scalar product: Octave version 1

```
1  fname = 'vect.dat';
2  fh = fopen(fname, 'r');
3  dim = 3;
4  u = fscanf(fh, '%lf', dim);
5  v = fscanf(fh, '%lf', dim);
6  s=0;
7  for i=1:dim
8    s+=u(i)*v(i);
9  end
10 printf('Scalar product of u and v: %g', s);
```

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Scalar product: Octave version 2

```
1 fname = 'vect.dat';
2 A = load('vect.dat');
3 u = A(1:3);
4 v = A(4:6);
5 s = dot(u,v);
6 printf('Scalar product of u and v: %g\n', s);
```

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Case study: affine transformation in 2D

```
1  function [XY] = polygon(x,y,R,N)
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3    XY = zeros(N+1,2);
4    XY(:,1) = x + R*cos(t);
5    XY(:,2) = y + R*sin(t);
6  end
```

back to the main code

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Case study: affine transformation in 2D

```
7  function plot_poly(XY, color)
8    h = line(XY(:,1), XY(:,2));
9    set(h, 'color',color);
10 end
```

back to the main code

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Case study: affine transformation in 2D

```
11  function [NXY] = transform_poly(XY, T)
12    NXY=zeros(size(XY));
13    for i=1:rows(XY)
14      x = XY(i,1);
15      y = XY(i,2);
16      xh = T(1,1)*x + T(1,2)*y + T(1,3);
17      yh = T(2,1)*x + T(2,2)*y + T(2,3);
18      NXY(i,:) = [xh,yh];
19    endfor
20  endfunction
```

back to the main code

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26 xy1 = transform_poly(xy, T);
27 plot_poly(xy1,"blue");
28 axis("equal")
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30 pause()
```

back to the main code

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