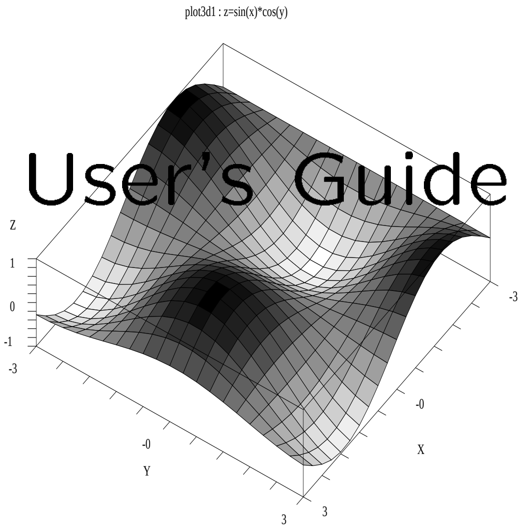
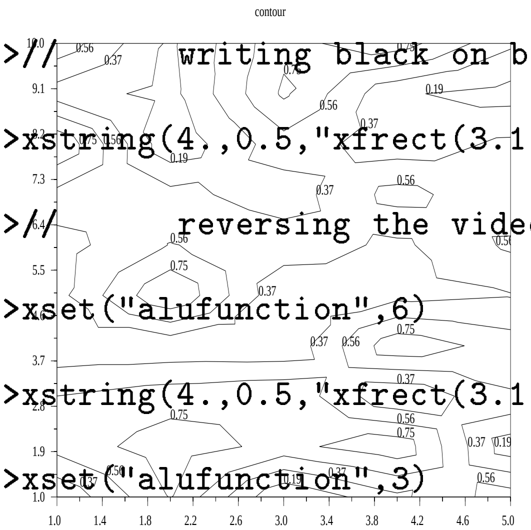
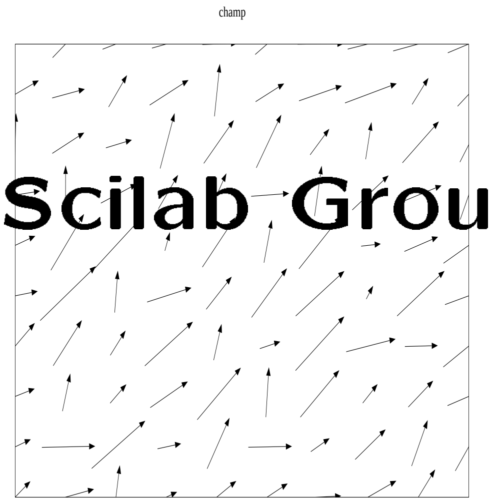
Introduction To Scilab

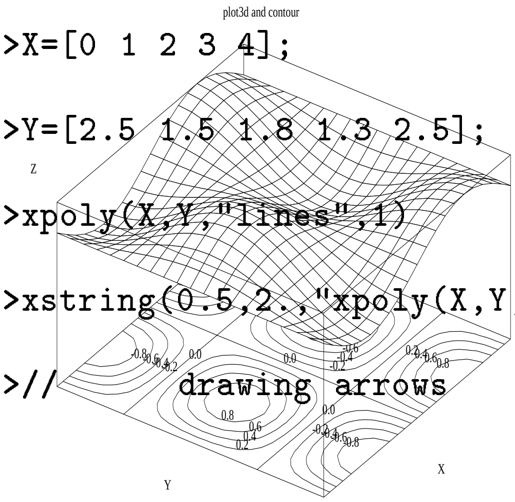
User's Guide

```
-->plot(1:10)

-->xbasc()

-->//      simple rectangle

-->xrect(0,1,3,1)

-->//      filling a rectangle

-->xfrect(3.1,1,3,1)

-->//      writing in the rectangle

-->xstring(0.5,0.5,"xrect(0,1,3,1)")

-->//      writing black on black !

-->xstring(4.,0.5,"xfrect(3.1,1,3,1)")

-->//      reversing the video

-->xset("alufunction",6)

-->xstring(4.,0.5,"xfrect(3.1,1,3,1)")

-->xset("alufunction",3)

-->//      drawing a polyline

-->X=[0 1 2 3 4];

-->Y=[2.5 1.5 1.8 1.3 2.5];

-->xpoly(X,Y,"lines",1)

-->xstring(0.5,2.,"xpoly(X,Y,""lines""

-->//      drawing arrows
```









Scilab Group

INTRODUCTION
TO
ΨLab

Scilab Group

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Chapter 1

Introduction

1.1 What is Scilab

Since the introduction of the "classic" (Fortran) MATLAB by C. Moler in 1982 there have been a number of interactive scientific

software packages which have been developed for system control and signal processing applications.

Developed at INRIA, Scilab which is one of the most elaborate of these packages is freely distributed in source code format (see the file `notice.tex`). and runs in Unix/Xwindow environments. Its libraries and most of the interpreter are written in Fortran for compatibility with numerical librairies. The graphic facilities and the Unix interface are written in C. Scilab is made of three distinct parts: an interpreter, libraries of functions (Scilab procedures) and libraries of Fortran and C routines. These routines (which, strictly speaking, do not belong to Scilab but are interactively called by the interpreter) are of independent interest and most of them are available through Netlib. A few of them have been slightly modified for better compatibility with Scilab's interpreter. A useful tool distributed with Scilab is `intersci` which is a set of routines that allow users to easily add new primitives to Scilab i.e. to add new modules of Fortran or C code into Scilab making it easy to customize.

A key feature of the MATLAB syntax is its ability to handle matrices: basic matrix manipulations such as concatenation, extraction or transpose are immediately performed as well as basic operations such as addition or mutiplication. Scilab's aims are the following: first to use the MATLAB syntax for more complex objects than numerical matrices, (e.g. automatic control people may want to manipulate transfer matrices) and second to be an open interface to numerical libraries (e.g. a specific routine can be either called dynamically from Scilab or included in the package as a new primitive).

Scilab is an interactive, interpreted software package (with a syntax similar to the MATLAB one) which has a number of powerful features:

- lists
- symbolic manipulation of polynomials and polynomial matrices
- symbolic manipulation of linear and non-linear systems
- non-linear calculation: simulation and optimization
- easy interfacing with fortran and C codes

The list structure allows a natural symbolic representation of complicated mathematical objects such as transfer functions and linear systems (see Section 2.6).

Polynomials, polynomials matrices and transfer matrices are also defined and Scilab allows the definition and manipulation of these objects in a natural, symbolic fashion (see Section 2.4). The syntax used for manipulating these matrices is identical to that used for manipulating constant vectors and matrices.

Scilab provides a variety of powerful primitives for the analysis of non-linear systems. Integration of explicit and implicit systems can be accomplished numerically. There exist numerical optimization facilities for non linear optimization (including non differentiable optimization), quadratic optimization and linear optimization.

Scilab has an open programming environment where the creation of functions and libraries of functions is completely in the hands of the user (see Chapter 3). Functions are recognized as data objects in Scilab and, thus, can be manipulated or created as other data objects. For example, functions can be passed as arguments of other functions.

In addition Scilab supports a character string data type which, in particular, allows the automatic creation of functions. Matrices of character strings are also manipulated with the same syntax as ordinary matrices. Finally, Scilab is easily interfaced with Fortran or C subprograms. This allows use of standardized packages and libraries in the interpreted environment of Scilab.

The general philosophy of Scilab is to provide the following sort of computing environment:

- To have data types which are varied and flexible.
- To have a syntax which is natural and easy to use.
- To provide a reasonable set of primitives which serve as a basis for a wide variety of calculations.
- To have an open programming environment where new primitives are easily added.
- To support library development through "toolboxes" of functions devoted to specific applications (linear control, signal processing, networks analysis, non-linear control, etc.)

The objective of this introduction manual is to give the user an idea of what Scilab can do. On line documentation on all Scilab functions is available.

1.2 Software Organization

Scilab is divided into a set of directories. The main directory `SCIDIR` contains the files `scilab.star` (startup file), the copyright file `notice.tex`, and the file `configure` (see(1.3)). The subdirectories are the following:

- `bin` is the directory of the executable files. The executable code of Scilab, `scilex`, is there. In particular, this directory contains Shell scripts for managing or printing Postscript/LaTeX files produced by Scilab
- `demos` is the directory of Scilab demos. The file `alldems.dem` allows to add a new demo which can be run by clicking in "demo". This directory contains the codes corresponding to various demos. They are often useful for inspiring new users. Note

that running a graphic function without input parameter provides an example of use for this function (for instance `plot2d()` displays an example for using `plot2d` function).

- `doc` is the directory of the Scilab documentation: LaTeX, dvi and Postscript files. This documentation is `SCIDIR/doc/intro/intro.tex`. See also the manual (on-line `help`) in the directory `SCIDIR/man`
- `geci` contains source code and binaries for GeCI which is an interactive communication manager created in order to manage remote executions of softwares and allow exchanges of messages beetwen those softwares. It offers the possibility to exploit numerous machines on a network, as a virtual computer, by creating a distributed group of independent softwares. GeCI is used for the link of Xmetanet with Scilab.
- `imp` is the directory of the routines managing the Postscript files for print.
- `libs` contains Scilab libraries (compiled code).
- `macros` contains the libraries of Scilab functions which are available on-line. New libraries can easily be added (see the Makefile). This directory is divided into a number of subdirectories which contain "Toolboxes" for control, signal processing, etc... Strictly speaking Scilab is not organized in toolboxes : functions of a specific subdirectory can call functions of other directories; so, for example, the subdirectory "signal" is not self-contained but its functions are all devoted to signal processing.
- `man` is the directory containing the manual (Unix manual), divided into submanuals, corresponding to the on-line help and to a LaTeXformat of the Scilab reference manual. The LaTeX code is produced by a translation of the Unix format Scilab manual (see the subdirectory `Man-General`). To get information about an item enter `help item` in Scilab or use the help window facility obtained with help button. To get functions corresponding to a key word enter `apropos key-word` or use apropos in the help window.
- `maple` is the directory which contains the source code of Maple functions which allow the transfer of Maple objects into Scilab functions. For efficiency, the transfer is made through Fortran code generation.
- `routines` is a directory with contains the source code of all the numerical routines. The subdirectory `default` contains the source code of routines which are useful to customize Scilab. In particular "external" routines for ODE/DAE solvers or optimization should be included here (see e.g. the file `fydot.f`, interface Scilab-Fortran for ode simulation). Note that if, for example, you want to solve an ode, the right hand side function can be a Scilab function or a C or Fortran subroutine. This Fortran subroutine can be dynamically linked to Scilab or put into the specific file `fydot.f` of the `default` directory. This function is then inside your version of Scilab.
- `intersci` contains the facility provided for add new Fortran or C primitives to Scilab.
- `scripts` is the directory which contains the source code of shell scripts files.
- `tests` : this directory contains evaluation programs for testing Scilab's installation on a machine. The file "demos.tst" tests all the demos.

- `tmp` : some examples written by users for courses ... have been added in this directory.
- `util` contains some utility functions for calling Scilab as a fortran routine or for making the documentation
- `xless` is a file browsing tool developped at Berkeley University.
- `xmetanet` is the directory which contains `xmetanet`, a graphic display for networks. Type `metanet()` in Scilab to use it.

1.3 Installing Scilab. System Requirements

Scilab is distributed in source code format; binaries for several popular Unix-XWindow systems are also available: Dec Alpha (OSF 3.0), Dec Mips (ULTRIX 4.2), Sun Sparc stations (Sun OS 4.1.3), Sun Sparc stations (Sun Solaris 2.3), HP9000 (HP-UX 9.01), SGI Mips Irix 5.2, IBM-RS6000 (AIX 3.2), PC 486 (Slackware Linux 2.0.2 – XFree86 3.1).

The installation requirements are the following :

- for the source version: Scilab requires approximately 75Mb of disk storage to unpack and install (all sources included). You need X Window (X11R4 or X11R5, C compiler and Fortran compiler (or f2c). If you run X11R4, you also need Athena Widgets libraries libXaw.a and libXmu.a.

- for the binary version: the minimum for running Scilab (without sources) is about 20 Mb when decompressed. The versions for Dec Alpha, Dec Mips, Sun OS, HP9000 and IBM-RS6000 are statically linked and in principle do not require a fortran compiler. The versions for Sun Solaris, SGI and PC Linux are dynamically linked.

The main part of the memory in Scilab is a pile corresponding to the usual Fortran behaviour. In some parts Scilab is using dynamic allocation (in particular for the sparse matrices). We have chosen 2 mega-words (double float) for the size of the pile. Of course with the source code version a user can easily change this size and (decrease or) increase it up to the memory of his computer (parameter `vsiz` in the file `routines/stack.h`).

1.4 Scilab at a Glance. A Tutorial

1.4.1 Getting Started

Scilab is called by typing `scilab` in the directory `SCIDIR/bin` where `SCIDIR` denotes the directory where Scilab is installed. Scilab can be launched in another directory with the same command and a corresponding search path. This shell script runs Scilab in an Xwindow environment (this script file can be invoked with specific parameters). You will immediatly get the Scilab window with the following banner and prompt represented by the `-->` :

```
                          ===========
                          S c i l a b
                          ===========


                 Scilab-2.1  ( 10 February 1995 )
```

```
                  Copyright (C) 1989-95 INRIA


Startup execution:
  loading initial environment

 -->
```

A first contact with Scilab can be made by clicking on `Demos` with the left mouse button and clicking then on `Introduction to SCILAB` : the execution of the session is then done by entering empty lines and can be stopped with the buttons `Stop` and `Abort`.

Several libraries (see the `SCIDIR/scilab.star` file) are automatically loaded.

To give the user an idea of some of the capabilities of Scilab we will give later a sample session in Scilab.

1.4.2 Editing a command line

Before the sample session, we briefly present how to edit a command line. You can enter a command line by typing after the prompt or clicking with the mouse on a part on a window and recall it at the prompt in the Scilab window. At this moment you have the classical Emacs commands at your disposal for modifying a command (Ctrl-<chr> means hold the CONTROL key while typing the character <chr>), for example:

- Ctrl-p recall previous line
- Ctrl-n recall next line
- Ctrl-b move backward one character
- Ctrl-f move forward one character
- Delete delete previous character
- Ctrl-h delete previous character
- Ctrl-d delete one character (at cursor)
- Ctrl-a move to beginning of line
- Ctrl-e move to end of line
- Ctrl-k delete to the end of the line
- Ctrl-u cancel current line
- Ctrl-y yank the text previously deleted
- !prev recall the last command line which begins by prev
- Ctrl-c interrupt Scilab and pause after carriage return. (Only functions can be interrupted). Clicking on the stop button enters a Ctrl-c.

As said before you can also cut and paste using the mouse. This way will be useful if you type your Scilab commands in an editor. Another way to "load" files containing Scilab statements is available with the `File Operations` button.

1.4.3 Buttons

The Scilab window has the following buttons.

- Stop interrupts execution of Scilab and enters in `pause` mode
- Resume continues execution after a `pause` entered as a command or generated by the `Stop` button
- Abort aborts execution after one (or several) `pause`, and returns to top-level prompt
- Restart clears all variables and executes startup files
- Quit quits Scilab
- Kill kills Scilab shell script
- Demos for interactive run of some demos
- File Operations facility for loading functions or data into Scilab, or executing script files. Note the following change w.r.t. the previous release : using this button implied to change the working directory to the directory of the location of the loaded file. This fact could be confusing and the use of this button does not change anymore the working directory.
- Help : invokes on-line help with the tree of the man and the names of the corresponding items. It is possible to type directly `help <item>` in the Scilab window.
- +- : increases or decreases the number of the active window
- Raise Window : exposes the window corresponding to the indicated number and creates one or several windows if necessary
- Set Window : the window corresponding to the indicated number becomes active (and creates one or several windows if necessary)

Note that the command `SCIDIR/bin/scilab -nw` invokes Scilab in the "no-window" mode.

1.4.4 Customizing your Scilab

As usual for many softwares the parameters of the different windows opened by Scilab can be easily changed. The way for doing that is to edit the files contained in the sub-directory X11-defaults. The first possibility is to directly change these files but the same modifications will be needed for the further releases. The right way is to copy the right lines with the modifications in the `.Xdefaults` file of one's own home directory. These modifications are activated by starting again Xwindow or with the command `xrdb .Xdefaults`. Scilab will read the `.Xdefaults` file: the lines of this file will cancel and replace the corresponding lines of X11-defaults.

A simple example :

```
Xscilab.color*Scrollbar.background:red
Xscilab*vpane.height: 500
Xscilab*vpane.width:  500
```

in `.Xdefaults` will change the 500x650 window to a square window of 500x500 and the scrollbar background color changes from green to red.

1.4.5 Sample Session for Beginners

We present now some simple commands. A command ends with a semi-colon or a carriage return. At the carriage return all the commands typed since the last prompt are interpreted. The semi-colon before the prompt is optional.

```
-->a=1;

-->A=2;

-->a+A
 ans  =

    3.

-->//Two commands on the same line

-->c=[1 2];b=1.5
 b  =

    1.5

-->//A command on several lines

-->u=1000000.000000*(a*sin(A))**2+2000000.000000*a*b*sin(A)*cos(A)+1000000.000000*(b*cos(A))**2
 u  =

    81268.994

-->u=1000000.000000*(a*sin(A))**2+...
     2000000.000000*a*b*sin(A)*cos(A)+...
     1000000.000000*(b*cos(A))**2
 u  =

    81268.994
```

Give the values of 1 and 2 to the variables `a` and `A`. The semi-colon at the end of the command suppresses the display of the result. Note that Scilab is case-sensitive. Then two commands are processed and the second result is displayed because it is not followed by a semi-colon. The last command shows how to write a command on several lines by using "...". This sign is only needed in the on-line typing for avoiding the effect of the carriage return. The chain of characters which follow the `//` is not interpreted by Scilab (it is a comment line).

```
-->a=1;b=1.5;

-->2*a+b**2
 ans  =

    4.25

-->//We have now created variables and can list them by :

-->who
your variables are...

 ans       b         a         bugmes    %F        %T        TMPDIR
 SCI       xdesslib  utillib   tdcslib   siglib    s2flib    roblib
 percentlib          optlib    scicoslib           metalib   elemlib
 polylib   autolib   armalib   alglib    %z        %s        %nan
 %inf      %t        %f        %eps      %io       %i        %e
 %pi
 using    2891 elements  out of 1000000.
          and      34 variables out of     499
```

We get the list of previously defined variables `a b c A` together with the initial environment composed of the different libraries and some specific "permanent" variables.

Below is an example of an expression which mixes constants with existing variables. The result is retained in the standard default variable `ans`.

```
-->sqrt([4  -4])
 ans  =

!   2.    2.i !
```

Calling a function (or primitive) with a vector argument. The response is a complex vector.

```
-->p=poly([1 2 3],'z','coeff')
 p  =
```

```
               2
    1 + 2z + 3z

-->//p is the polynomial in z with coefficients 1,2,3.

-->//p can also be defined by :

-->s=poly(0,'s');p=1+2*s+s^2
 p  =

              2
    1 + 2s + s
```

A more complicated command which creates a polynomial.

....

```
-->M=[p, p-1; p+1 ,2]
 M  =

!             2          2 !
!   1 + 2s + s     2s + s  !
!                          !
!             2            !
!   2 + 2s + s     2       !

-->det(M)
 ans  =

         2    3   4
    2 - 4s - 4s - s
```

Definition of a polynomial matrix. The syntax for polynomial matrices is the same as the one for matrices of constants. Calculation of the determinant of the polynomial matrix by the `det` function.

....

```
-->z=poly(0,'z');

-->f=[1/s     ,(s+1)/(1-s)
      s/p     ,   s^2     ]
 f  =
```

```
!   1              1 + s  !
!   -              -----  !
!   s              1 - s  !
!                         !
!                   2     !
!       s          s      !
!   ---------      -      !
!             2           !
!   1 + 2s + s     1      !
```

Definition of a matrix of rational polynomials. The internal representation of `f` is a list `list('r',num,den)` where `num` and `den` are two matrix polynomials.

. . . .

```
-->pause

-1->pt=return(s*p)

-->pt
 pt  =

            2   3
    s + 2s + s
```

Here we move into a new environment using the command `pause` and we obtain the new prompt `-1->` which indicates the level of the new environment (level 1). All variables that are available in the first environment are also available in the new environment. Variables created in the new environment can be returned to the original environment by using `return`. Use of `return` without an argument destroys all the variables created in the new environment before returning to the old environment. The `pause` facility is very useful for debugging purposes.

. . . .

```
-->f21=f(2,1);v=0:0.01:%pi;frequencies=exp(%i*v);

-->response=freq(f21(2),f21(3),frequencies);

-->plot2d(v',abs(response)',[-1],'011',' ',[0,0,3.5,0.7],[5,4,5,7]);

-->xtitle(' ','radians','magnitude');
```

Definition of a rational polynomial by extraction of an element of the matrix `f` defined above. This is followed by the evaluation of the rational polynomial at the vector of complex frequency values defined by `frequencies`. The evaluation of the polynomial is done by the primitive `freq`. `numer(f21)` is the numerator polynomial and `denom(f21)` is the denominator polynomial. The visualization of the resulting evaluation is made by using the command `plot2d` (see Figure 1.1).

....

```
-->w=(1-s)/(1+s);f=1/p
 f  =

        1
    ---------
              2
    1 + 2s + s

-->horner(f,w)
 ans  =

              2
    1 + 2s + s
    ----------
        4
```

The function `horner` allows the user to make a (possibly symbolic) change of variables for a polynomial (for example, to perform the bilinear transformation as seen above).

....

```
-->A=[-1,0;1,2];B=[1,2;2,3];C=[1,0];

-->Sl=syslin('c',A,B,C);

-->ss2tf(Sl)
 ans  =

!     1         2    !
!   -----     -----  !
!   1 + s     1 + s  !
```

Definition of a linear system in state-space representation. The function `syslin` defines here the continuous time (`'c'`) system `Sl` with state-space matrices (`A,B,C`). The function `ss2tf` transforms `Sl` into transfer matrix representation.

....

```
-->s=poly(0,'s');

-->R=[1/s,s/(1+s),s^2]
 R  =

!                    2 !
!   1       s       s  !
!   -     -----     -  !
!   s     1 + s     1  !

-->Sl=syslin('c',R);

-->tf2ss(Sl)
 ans  =


       ans(1)   (state-space system:)

 lss

       ans(2) = A matrix =

! - 0.5  - 0.5 !
! - 0.5  - 0.5 !

       ans(3) = B matrix =

! - 1.    1.    0. !
!   1.    1.    0. !

       ans(4) = C matrix =

! - 1.    0. !

       ans(5) = D matrix =

!               2 !
!   0    1     s  !

       ans(6) = X0 (initial state) =

!   0. !
!   0. !

       ans(7) = Time domain =

 c
```

Definition of the rational matrix `R`. `Sl` is the continuous-time linear system with (improper) transfer matrix R. `tf2ss` puts `Sl` in state-space representation with a polynomial `D` matrix. Note that linear systems are represented by special lists (with 7 entries).

. . . .

```
-->sl1=[Sl;2*Sl+eye]
 sl1  =

!                        2  !
!   1           s        s  !
!   -         -----      -  !
!   s         1 + s      1  !
!                           !
!                         2 !
!   2 + s      2s        2s !
!   -----     ----      --- !
!     s       1 + s      1  !

-->size(sl1)
 ans  =

!   2.    3. !

-->size(tf2ss(sl1))
 ans  =

!   2.    3. !
```

`sl1` is the linear system in transfer matrix representation obtained by the parallel inter-connection of `Sl` and `2*Sl +eye`. The same syntax is valid with `Sl` in state-space representation.

. . . .

```
-->deff('[Cl]=compen(Sl,Kr,Ko)',[ '[A,B,C,D]=abcd(Sl);';
       'A1=[A-B*Kr ,B*Kr; 0*A ,A-Ko*C]; Id=eye(A);';
       'B1=[Id     ,0*Ko; Id  ,-Ko   ];';
       'C1=[C ,0*C];Cl=syslin(''c'',A1,B1,C1)' ])

-->comp(compen)
```

On-line definition of a function, called `compen` which calculates the state space representation (`Cl`) of a linear system controlled by an observer with gain `Ko` and a controller with gain `Kr`. Note that matrices are constructed in block form using other matrices. The function `compen` is then compiled by `comp`.

....

```
-->A=[1,1 ;0,1];B=[0;1];C=[1,0];Sl=syslin('c',A,B,C);

-->Cl=compen(Sl,ppol(A,B,[-1,-1]),...
                     ppol(A',C',[-1+%i,-1-%i])');

-->f=Cl(2),spec(f)
 f  =

!   1.    1.    0.    0. !
! - 4.  - 3.    4.    4. !
!   0.    0.  - 3.    1. !
!   0.    0.  - 5.    1. !
 ans  =

! - 1.       !
! - 1.       !
! - 1. + i   !
! - 1. - i   !
```

Call to the function `compen` defined above where the gains were calculated by a call to the primitive `ppol` which performs pole placement. The resulting `f` matrix is displayed and the placement of its poles is checked using the primitive `spec` which calculates the eigenvalues of a matrix. (The function `compen` is defined here on-line by `deff` as an example of function which receive a linear system (`Sl`) as input and returns a linear system (`Cl`) as output. In general Scilab functions are defined in files and loaded in Scilab by `getf`).

....

```
-->//Saving the environment in a file named : myfile

-->save('myfile')

-->//Request to the host system to perform a system command

-->unix_s('rm myfile')

-->//Request to the host system with output in this Scilab window

-->unix_w('date')
Thu Nov 23 16:28:43 MET 1995

-->
```

Relation with the Unix environment and an error message: command is not interpretable by the system since the variable `q` is unknown.

....

```
-->foo=['      subroutine foo(a,b,c)';
     '      c=a+b';
     '      end'  ];

-->unix_s('\rm foo.f')

 !--error 10000
sh : rm: foo.f: No such file or directory
at line      23 of function unix_s                    called by :
unix_s('\rm foo.f')


-->write('foo.f',foo);

-->unix_s('make foo.o')

-->link('foo.o','foo')

-->deff('[c]=myplus(a,b)',...
   'c=fort(''foo'',a,1,''r'',b,2,''r'',''out'',[1,1],3,''r'')')

-->myplus(5,7)
 ans  =

    12.
```

Definition of a column vector of character strings defining a Fortran subroutine. The routine is compiled (needs a compiler), dynamically linked to Scilab, and interactively called by the function `myplus`.

....

```
-->deff('[ydot]=f(t,y)','ydot=[a-y(2)*y(2) -1;1 0]*y')

-->a=1;comp(f);y0=[1;0];t0=0;instants=0:0.02:20;

-->y=ode(y0,t0,instants,f);

-->plot2d(y(1,:)',y(2,:)',[-1],'011',' ',[-3,-3,3,3],[10,2,10,2])

-->xtitle('Van der Pol')
```

Definition of a function which calculates a first order vector differential `f(t,y)`. This is followed by the definition of the constant `a` used in the function and the function is compiled. The primitive `ode` then integrates the differential equation defined by `f(t,y)` for $y(0) = \langle 1;0\rangle$ at $t = 0$ and where the solution is given at the time values $t = 0, .02, .04, \ldots, 20$. The result is plotted in Figure 1.2 where the first element of the integrated vector is plotted against the second element of this vector.

....

```
-->m=['a' 'cos(b)';'sin(a)' 'c']
 m  =

!a       cos(b)  !
!                !
!sin(a)  c       !

-->m*m'
     !--error    43
not implemented in scilab....


-->deff('[x]=%cmc(a,b)',['[l,m]=size(a);[m,n]=size(b);x=[];';
  'for j=1:n,y=[];';
  'for i=1:l,t='' '';';
  'for k=1:m;';
  'if k>1 then t=t+''+(''+a(i,k)+'')*''+''(''+b(k,j)+'')'';';
  'else t=''('' + a(i,k) + '')*'' + ''('' + b(k,j) + '')'';';
  'end,end;';
  'y=[y;t],end;';
  'x=[x y],end,'])

-->m*m'
 ans  =

!(a)*(a)+(cos(b))*(cos(b))  (a)*(sin(a))+(cos(b))*(c)  !
!                                                       !
!(sin(a))*(a)+(c)*(cos(b))  (sin(a))*(sin(a))+(c)*(c)  !
```

Definition of a matrix containing character strings. By default, the operation of symbolic multiplication of two matrices of character strings is not defined in Scilab. The (on-line) function definition for `%cmc` defines the multiplication of matrices of character strings (note that the double quote is necessary because the body of the `deff` contains quotes inside of quotes). The `%` which begins the function definition for `%cmc` allows the definition of an operation which did not previously exist in Scilab, and the name `cmc` means "chain multiply chain". This example is not very useful: it is simply given to show how operations can be defined on complex data structures.

....

```
-->deff('[y]=calcul(x,method)','z=method(x),y=poly(z,''x'')')

-->deff('[z]=meth1(x)','z=x')

-->deff('[z]=meth2(x)','z=2*x')

-->calcul([1,2,3],meth1)
 ans  =

                2   3
  - 6 + 11x - 6x + x

-->calcul([1,2,3],meth2)
 ans  =

                  2   3
  - 48 + 44x - 12x + x
```

A simple example which illustrates the passing of a function as an argument to another function. Scilab functions are objects which may be defined, loaded, or manipulated as other objects such as matrices or lists.

....

```
-->quit
```

Exit from Scilab.

....

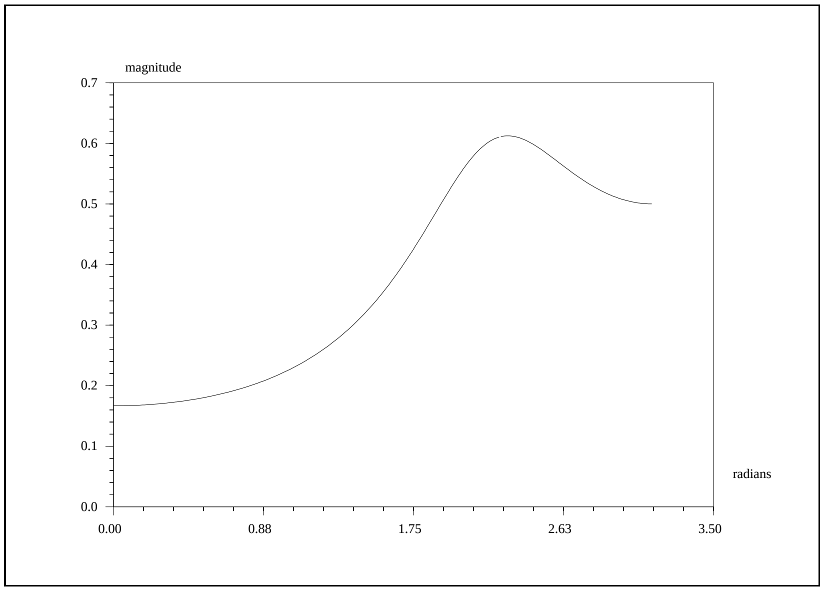

Figure 1.1: A Simple Response

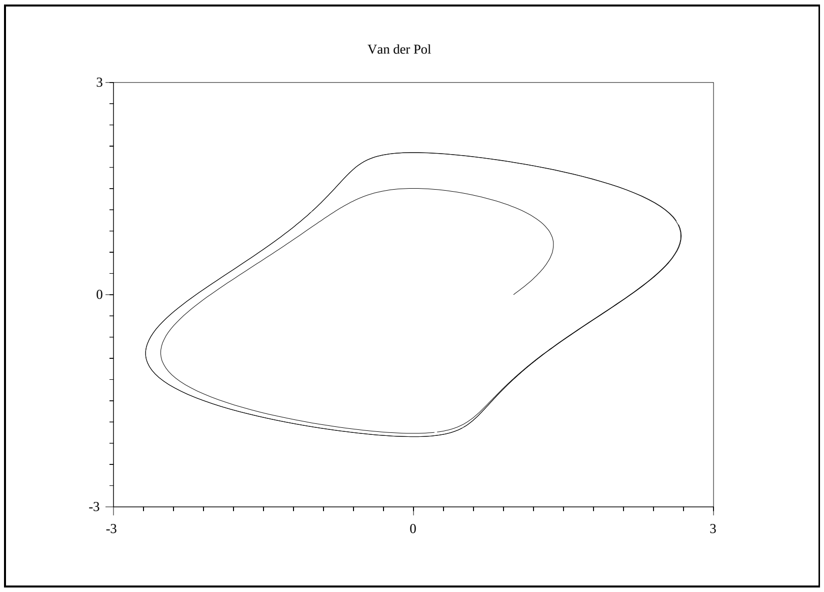

Figure 1.2: Phase Plot

Chapter 2

Data Types

Scilab recognizes several primitive data types. Scalar objects are constants, booleans, polynomials, strings and rationals (quotients of polynomials). These objects in turn allow to define matrices which admit these scalars as entries. Other basic objects are lists and functions. Only constant and boolean sparse matrices are defined. The objective of this chapter is to describe the use of each of these data types.

2.1 Special Constants

Scilab provides special constants `%i`, `%pi`, `%e`, and `%eps` as primitives. The `%i` constant represents $\sqrt{-1}$, `%pi` is $\pi = 3.1415927\cdots$, `%e` is the trigonometric constant $e = 2.7182818\cdots$, and `%eps` is a constant representing the precision of the machine (`%eps` is the biggest number for which $1 +$ `%eps` $= 1$). `%inf` and `%nan` stand for "infinity" and "NotANumber" respectively.

Finally boolean constants are `%t` and `%f` which stand for "true" and "false" respectively. Note that `%t` is the same as `1==1` and `%f` is the same as `~%t`.

These variables are considered as "predefined". They are protected, cannot be deleted and are not saved by the `save` command. It is possible for a user to have his own "predefined" variables by using the `predef` command. The best way is probably to set these special variables in his own startup file `<home dir>/.scilab`.

2.2 Constant Matrices

Scilab considers a number of data objects as matrices. Scalars, vectors, and matrices whose entries are either real or complex are all considered as matrices. The details of the use of these objects are revealed in the following Scilab sessions.

Scalars Scalars are either real or complex numbers. The values of scalars can be assigned to variable names chosen by the user.

```
--> a=5+2*%i
 a         =

    5. + 2.i

--> B=-2+%i;
```

```
--> b=4-3*%i
 b  =

    4. - 3.i

--> a*b
 ans  =

    26. - 7.i

-->a*B
 ans  =

  - 12. + i

--> c=a+b;

-->c
 c  =

    9. - i
```

Note that Scilab evaluates immediately lines that end with a carriage return. Instructions that end in a semi-colon are evaluated but are not displayed on screen. Scilab is case sensitive now (Version 2.0 was not case sensitive).

Vectors The usual way of creating vectors is as follows

```
--> v=[2,-3+%i,7]
 v         =

!   2.  - 3. + i      7. !

--> v'
 ans       =

!   2.       !
! - 3. - i   !
!   7.       !

--> w=[-3;-3-%i;2]
 w         =

! - 3.       !
! - 3. - i   !
!   2.       !
```

```
--> v'+w
 ans       =

! - 1.       !
! - 6. - 2.i !
!   9.       !

--> v*w
 ans       =

    18.

--> w'.*v
 ans       =

! - 6.    8. - 6.i    14. !
```

Notice that vector elements that are separated by commas (or by blanks) yield row vectors and those separated by semi-colons give column vectors. Note also that a single quote is used for transposing a vector (one obtains the complex conjugate for complex entries). Vectors of same dimension can be added and subtracted. The scalar product of a row and column vector is demonstrated above. Element-wise multiplication (.*) and division (./) is also possible as was demonstrated.

Note with the following example the role of the position of the blank:

```
-->v=[1 +3]
 v  =

!   1.    3. !

-->w=[1 + 3]
 w  =

!   1.    3. !

-->w=[1+ 3]
 w  =

    4.

-->u=[1, + 8- 7]
 u  =

!   1.    1. !
```

Vectors of elements which increase or decrease incrementely are constructed as follows

```
--> v=5:-.5:3
 v         =

!   5.    4.5    4.    3.5    3. !
```

The resulting vector begins with the first value and ends with the third value stepping in increments of the second value. When not specified the default increment is one. A constant vector can be created using the `ones` and `zeros` facility

```
--> v=[1 5 6]
 v         =

!   1.    5.    6. !

--> ones(v)
 ans       =

!   1.    1.    1. !

--> ones(v')
 ans       =

!   1. !
!   1. !
!   1. !

--> ones(1:4)
 ans       =

!   1.    1.    1.    1. !

--> 3*ones(1:4)
 ans       =

!   3.    3.    3.    3. !

-->zeros(v)
 ans  =

!   0.    0.    0. !

-->zeros(1:5)
 ans  =

!   0.    0.    0.    0.    0. !
```

Notice that `ones` or `zeros` replace its vector argument by a vector of equivalent dimensions filled with ones or zeros.

Matrices Row elements are separated by commas or spaces and column elements by semi-colons. Multiplication of matrices by scalars, vectors, or other matrices is in the usual sense. Addition and subtraction of matrices is element-wise and element-wise multiplication and division can be accomplished with the `.*` and `./` operators.

```
--> a=[2 1 4;5 -8 2]
 a         =

!   2.    1.    4. !
!   5.  - 8.    2. !

--> b=ones(2,3)
 b         =

!   1.    1.    1. !
!   1.    1.    1. !

--> a.*b
 ans       =

!   2.    1.    4. !
!   5.  - 8.    2. !

--> a*b'
 ans       =

!   7.    7. !
! - 1.  - 1. !
```

Notice that the `ones` operator with two real numbers as arguments separated by a comma creates a matrix of ones using the arguments as dimensions (same for `zeros`). Matrices can be used as elements to larger matrices. Furthermore, the dimensions of a matrix can be changed.

```
--> a=[1 2;3 4]
 a         =

!   1.    2. !
!   3.    4. !

--> b=[5 6;7 8]
 b         =

!   5.    6. !
!   7.    8. !

--> c=[9 10;11 12]
 c         =
```

```
!   9.      10. !
!   11.     12. !

--> d=[a,b,c]
 d         =

!   1.    2.    5.    6.    9.      10. !
!   3.    4.    7.    8.    11.     12. !

--> e=matrix(d,3,4)
 e         =

!   1.    4.    6.    11. !
!   3.    5.    8.    10. !
!   2.    7.    9.    12. !

-->f=eye(e)
 f  =

!   1.    0.    0.    0. !
!   0.    1.    0.    0. !
!   0.    0.    1.    0. !

-->g=eye(4,3)
 g  =

!   1.    0.    0. !
!   0.    1.    0. !
!   0.    0.    1. !
!   0.    0.    0. !
```

Notice that matrix `d` is created by using other matrix elements. The `matrix` primitive creates a new matrix `e` with the elements of the matrix `d` using the dimensions specified by the second two arguments. The element ordering in the matrix `d` is top to bottom and then left to right which explains the ordering of the re-arranged matrix in `e`.

The function `eye` creates an $m \times n$ matrix with 1 along the main diagonal (if the argument is a matrix `e` , m and n are the dimensions of `e`) .

Sparse constant matrices are defined through their nonzero entries (type help `sparse` for more details). Once defined, they are manipulated as full matrices.

2.3 Matrices of Character Strings

Character strings can be created by using single quotes. Concatenation of strings is performed by the `+` operation. Matrices of character strings are constructed as ordinary matrices, e.g. using brackets. A very important feature of matrices of character strings is the capacity to manipulate and create functions. Furthermore, symbolic manipulation of mathematical objects can be implemented using matrices of character strings. The following illustrates some of these features.

```
--> x=1;y=2;z=3;w=4;v=5;

--> a=['x' 'y';'z' 'w+v']
 a         =

!x  y    !
!        !
!z  w+v  !

--> at=trianfml(a)
 at        =

!z  w+v          !
!                !
!0  z*y-x*(w+v)  !

--> evstr(at)
 ans       =

!   3.    9. !
!   0.  - 3. !
```

Note that in the above Scilab session the function `trianfml` performs the symbolic triangularization of the matrix `a`. The value of the resulting symbolic matrix can be obtained by using `evstr`.

A very important aspect of character strings is that they can be used to automatically create new functions (for more on functions see Section 3.2). An example of automatically creating a function is illustrated in the following Scilab session where it is desired to study a polynomial of two variables `s` and `t`. Since polynomials in two independent variables are not directly supported in Scilab, we can construct a new data structure using a list (see Section 2.6). The polynomial to be studied is $(t^2+2t^3)-(t+t^2)s+ts^2+s^3$.

```
-->getf("macros/make_macro.sci");

-->s=poly(0,'s');

-->t=poly(0,'t');

-->p=list(t^2+2*t^3,-t-t^2,t,1+0*t);

-->pst=makefunction(p)
 pst       =

[p]=pst(t)

-->pst
```

```
 pst       =

[p]=pst(t)

-->pst(1)
 ans       =

             2   3
    3 - 2s + s + s
```

Here the polynomial is represented by the command which puts the coefficients of the variable `s` in the list `p`. The list `p` is then processed by the function `makefunction` which makes a new function `pst`. The contents of the new function can be displayed and this function can be evaluated at values of `t`. The creation of the new function `pst` is accomplished as follows

```
function [newfunction]=makefunction(p)
   n=size(p);
   num=mulf(makestr(p(1)),'1');
   for k=2:n,
      new=mulf(makestr(p(k)),'s^'+string(k-1));
      num=addf(num,new);
   end,
   text='p='+num;
   deff('<p>=newfunction(t)',text),


function [str]=makestr(p)
   n=degree(p)+1,
   c=coeff(p),
   str=string(c(1)),
   x=part(varn(p),1),
   xstar=x+'^',
   for k=2:n,
      ck=c(k),
      if ck<>0 then,
      str=addf(str,mulf(string(c(k)),(xstar+string(k-1))));
      end;
   end,
```

Here the function `makefunction` takes the list `p` and creates the function `pst`. Inside of `makefunction` there is a call to another function `makestr` which makes the string which represents each term of the new two variable polynomial. The functions `addf` and `mulf` are for adding and multiplying strings (i.e. `addf(x,y)` yields the string `x+y`). Finally, the essential command for creating the new function is the primitive `deff`. The `deff` primitive creates a function defined by two matrices of character strings. Here the function `p` is defined by the two character strings `'[p]=newfunction(t)'` and `text` where the string `text` evaluates to the polynomial in two variables.

2.4 Polynomials and Polynomial Matrices

Polynomials are easily created and manipulated in Scilab. Manipulation of polynomial matrices is essentially identical to that of constant matrices. The `poly` primitive in Scilab can be used to specify the coefficients of a polynomial or the roots of a polynomial.

```
--> p=poly([1 2],'s')
 p         =
 
              2
   2 - 3s + s
 
--> q=poly([1 2],'s','c')
 q         =
 
   1 + 2s
 
--> p+q
 ans       =
 
             2
   3 - s + s
 
--> p*q
 ans       =
 
              2    3
   2 + s - 5s + 2s
 
--> q/p
 ans       =
 
     1 + 2s
   -----------
              2
   2 - 3s + s
```

Note that the polynomial `p` has the *roots* 1 and 2 whereas the polynomial `q` has the *coefficients* 1 and 2. It is the third argument in the `poly` primitive which specifies the coefficient flag option. In the case where the first argument of `poly` is a square matrix and the roots option is in effect the result is the characteristic polynomial of the matrix.

```
--> poly([1 2;3 4],'s')
 ans       =
 
              2
 - 2 - 5s + s
```

Polynomials can be added, subtracted, multiplied, and divided, as usual, but only between polynomials of same formal variable.

Polynomials, like real and complex constants, can be used as elements in matrices. This is a very useful feature of Scilab for systems theory.

```
--> s=poly(0,'s')
 s         =

    s

--> a=[1 s;s 1+s^2]
 a         =

!   1     s       !
!                 !
!               2 !
!   s     1 + s   !

--> b=[1/s 1/(1+s);1/(1+s) 1/s^2]
 b         =

!   1           1     !
! ------      ------ !
!   s         1 + s   !
!                     !
!     1       1       !
!    ---     ---      !
!              2      !
!   1 + s     s       !
```

From the above examples it can be seen that matrices can be constructed from polynomials and rationals.

2.5 Boolean Matrices

Boolean constants are `%t` and `%f`. They can be used in boolean matrices. The syntax is the same as for ordinary matrices i.e. they can be concatenated, transposed, etc...

Operations symbols used with boolean matrices or used to create boolean matrices are `==` and `~`.

If `B` is a matrix of booleans `or(B)` and `and(B)` perform the logical `or` and `and`.

```
-->%t
 %t  =

  T

-->[1,2]==[1,3]
 ans  =
```

```
! T F !

-->[1,2]==1
 ans  =

! T F !

-->a=1:5; a(a>2)
 ans  =

!   3.    4.    5. !

-->A=[%t,%f,%t,%f,%f,%f];

-->B=[%t,%f,%t,%f,%t,%t]
 B  =

! T F T F T T !

-->A|B
 ans  =

! T F T F T T !

-->A&B
 ans  =

! T F T F F F !
```

Sparse boolean matrices are generated when, e.g., two constant sparse matrices are compared. These matrices are handled as ordinary boolean matrices.

2.6 Lists, Linear Systems

Scilab has a list data type. The list is a collection of data objects not necessarily of the same type. A list can contain any of the already discussed data types as well as other lists, functions, and libraries. Lists are useful for defining structured data objects. For example, in Scilab linear systems are treated as lists. The basic function which is used for defining linear systems is `syslin`. This function receives as parameters the constant matrices which define a linear system in state-space form or, in the case of system in transfer form its input must be a rational matrix. To be more specific, the calling sequence of `syslin` is either `Sl=syslin('dom',A,B,C,D,x0)` or `Sl=syslin('dom',trmat)`. `dom` is one of the character strings `'c'` or `'d'` for continuous time or discrete time systems respectively. It is useful to note that `D` can be a polynomial matrix (improper systems); `D` and `x0` are optional arguments. `trmat` is a rational matrix i.e. it is defined as a matrix of rationals (ratios of polynomials). Conversion from a representation to another is done by `ss2tf` or `tf2ss`. Improper systems are also treated.

```
-->//list defining a linear system

-->A=[0 -1;1 -3];B=[0;1];C=[-1 0];

-->h=syslin('c',A,B,C)
 h  =


       h(1)   (state-space system:)

 lss

       h(2) = A matrix =

!   0.  - 1. !
!   1.  - 3. !

       h(3) = B matrix =

!   0. !
!   1. !

       h(4) = C matrix =

! - 1.    0. !

       h(5) = D matrix =

    0.

       h(6) = X0 (initial state) =

!   0. !
!   0. !

       h(7) = Time domain =

 c

-->//conversion from state-space form to transfer form

-->hs=ss2tf(h)
 hs  =

        1
    ---------
             2
    1 + 3s + s
```

```
-->size(hs)
 ans  =

!   1.    1. !

-->hs(1)
 ans  =

 r

-->hs(2)
 ans  =

    1

-->hs(3)
 ans  =

              2
    1 + 3s + s

-->hs(4)
 ans  =

 c

-->typeof(hs)
 ans  =

 rational

-->//inversion of transfer matrix

-->inv(hs)
 ans  =

              2
    1 + 3s + s
    ----------
        1

-->//inversion of state-space form

-->inv(h)
 ans  =
```

```
       ans(1)   (state-space system:)

 lss

       ans(2) = A matrix =

     []

       ans(3) = B matrix =

     []

       ans(4) = C matrix =

     []

       ans(5) = D matrix =

              2
    1 + 3s + s

       ans(6) = X0 (initial state) =

     []

       ans(7) = Time domain =

 c

-->//conversion of this inverse

-->ss2tf(ans)
 ans  =

              2
    1 + 3s + s
```

As can be seen by the above Scilab session the list `h` begins with the character string `'lss'` which in this case indicates that the list represents a linear system. The five ensuing list elements are matrices which give the state space description of the linear system and its initial condition ($\dot{x} = Ax + Bu$, $y = Cx + Du$, $x(0) = x_0$). Finally, the last element `'c'` indicates that the list represents a continuous linear system.

The list representation allows manipulating linear systems as abstract data objects. For example, the linear system can be combined with other linear systems or the transfer function representation of the linear system can be obtained as was done above using `ss2tf`. Note that the transfer function representation of the linear system is itself a list. The list consists of four elements: the first element is the character string `'r'`

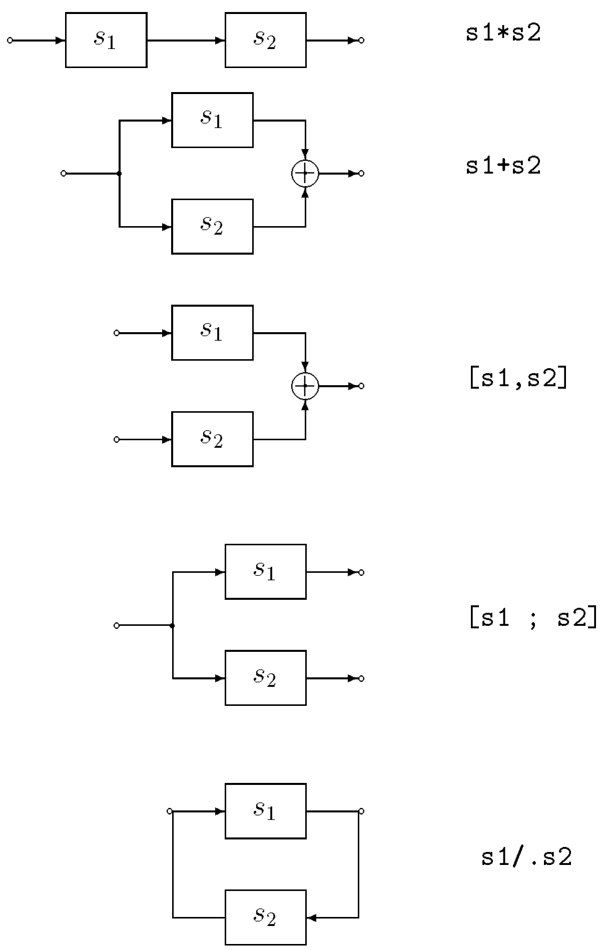

Figure 2.1: Inter-Connection of Linear Systems

which indicates that the list represents a rational polynomial matrix, the second and third elements are the numerator and denominator polynomials, and finally, the fourth element is the character string 'c' which indicates that the transfer function is that of a continuous system. A very useful aspect of the manipulation of systems in Scilab is that a system can be handled as a data object. Linear systems can be inter-connected, their representation can easily be changed from state-space to transfer function and vice versa.

The inter-connection of linear systems can be made as illustrated in Figure 2.1. For each of the possible inter-connections of two systems `s1` and `s2` the command which makes the inter-connection is shown on the right side of the corresponding block diagram in Figure 2.1. Note that feedback interconnection is performed by `s1/.s2`.

The representation of linear systems can be in state-space form or in transfer function form. These two representations can be interchanged by using the functions `tf2ss` and `ss2tf` which change the representations of systems from transfer function to state-space and from state-space to transfer function, respectively. An example of the creation, the change in representation, and the inter-connection of linear systems is demonstrated in the following Scilab session.

```
-->//system connecting

-->s=poly(0,'s')
```

```
 s  =
 
    s
 
-->ft=1/(s-1)
 ft  =
 
      1
    -----
  - 1 + s
 
-->gt=1/(s-2)
 gt  =
 
      1
    -----
  - 2 + s
 
-->ft=syslin('c',ft);
 
-->gt=syslin('c',gt);
 
-->gls=tf2ss(gt);
 
-->ssprint(gls)
 
x = | 2 |x + | 1 |u
 
y = | 1 |x
 
-->hls=gls*ft;
 
-->ssprint(hls)
 
.   | 2  1 |    | 0 |
x = | 0  1 |x + | 1 |u
 
y = | 1  0 |x
 
-->ht=ss2tf(hls)
 ht  =
 
        1
    ---------
              2
    2 - 3s + s
 
-->gt*ft
```

```
 ans  =

      1
   ---------
            2
   2 - 3s + s
```

The above session is a bit long but illustrates some very important aspects of the handling of linear systems. First, two linear systems are created in transfer function form using the primitive `syslin`. This primitive was used to label the systems in this example as being continuous (as opposed to being discrete). The primitive `tf2ss` is used to convert one of the two transfer functions to its equivalent state-space representation which is in list form (note that the function `ssprint` creates a more readable format for the state-space linear system). The following multiplication of the two systems yields their series inter-connection. Notice that the inter-connection of the two systems is effected even though one of the systems is in state-space form and the other is in transfer function form. The resulting inter-connection is given in state-space form. Finally, the primitive `ss2tf` is used to convert the resulting inter-connected systems to the equivalent transfer function representation.

2.7 Functions (Macros)

Functions (also called macros) are a very useful aspect of Scilab. Functions are collections of commands which are executed in a new environment thus isolating function variables from the original environments variables. Functions can be created and executed in a number of different ways. Furthermore, functions can pass arguments, have programming features such as conditionals and loops, and can be recursively called. Functions can be arguments to other functions and can be elements in lists. The most useful way of creating functions is by using a text editor, however, functions can be created directly in the Scilab environment using the `deff` primitive.

```
--> deff('[x]=foo(y)','if y>0 then, x=1; else, x=-1; end')

--> foo(5)
 ans       =

    1.

--> foo(-3)
 ans       =

  - 1.
```

Usually functions are defined in a file using an editor and loaded into Scilab with `getf('filename')` or `getf('filename','c')`. This can be done also by clicking in the `File operation` button. This latter syntax loads the function(s) in `filename` and compiles them. The first line of `filename` must be as follows:

```
function [y1,...,yn]=macname(x1,...,xk)
```

where the `yi`'s are output variables and the `xi`'s the input variables.

For more on the use and creation of functions see Section 3.2.

2.8 Libraries

Libraries are collections of functions which can be either automatically loaded into the Scilab environment when Scilab is called, or loaded when desired by the user. Libraries are created by the `lib` command. Examples of librairies are given in the `SCIDIR/macros` directory. Note that in these directory there is an ASCII file "names" which contains the names of each function of the library, a set of `.sci` files which contains the source code of the functions and a set of `.bin` files which contains the compiled code of the functions. The Makefile invokes `scilab` for compiling the functions and generating the `.bin` files. The compiled functions of a library are automatically loaded into Scilab at their first call.

2.9 Objects

We conclude this chapter by noting that the function `typeof` returns the type of the various Scilab objects. The following objects are defined:

- `usual` for matrices with real or complex entries.
- `polynomial` for polynomial matrices: coefficients can be real or complex.
- `boolean` for boolean matrices.
- `character` for matrices of character strings.
- `uncompiled function` for un-compiled functions.
- `function` for compiled functionds.
- `rational` for rational matrices (or linear systems in transfer matrix representation (`syslin` lists)
- `state-space` for linear systems in state-space form (`syslin` lists).
- `sparse` for sparse matrices.
- `list` for ordinary lists i.e. lists which do not represent linear systems (`syslin` lists).
- `library` for library definition.

Chapter 3

Programming

One of the most useful features of Scilab is its ability to create and use functions. This allows the development of specialized programs which can be integrated into the Scilab package in a simple and modular way through, for example, the use of libraries. In this chapter we treat the following subjects:

- Programming Tools
- Defining and Using Functions
- Definition of Operators for New Data Types
- Debbuging

Creation of libraries is discussed in a later chapter.

3.1 Programming Tools

Scilab supports a full list of programming tools including loops, conditionals, case selection, and creation of new environments. Most programming tasks should be accomplished in the environment of a function. Here we explain what programming tools are available.

3.1.1 Comparison Operators

There exist five methods for making comparisons between the values of data objects in Scilab. These comparisons are listed in the following table.

`==` or `=`	equal to
`<`	smaller than
`>`	greater than
`<=`	smaller or equal to
`>=`	greater or equal to
`<>` or `~=`	not equal to

These comparison operators are used for evaluation of conditionals.

3.1.2 Loops

Two types of loops exist in Scilab: the `for` loop and the `while` loop. The `for` loop steps through a vector of indices performing each time the commands delimited by `end`.

```
--> x=1;for k=1:4,x=x*k,end
 x         =

    1.
 x         =

    2.
 x         =

    6.
 x         =

    24.
```

The `for` loop can iterate on any vector or matrix taking for values the elements of the vector or the columns of the matrix.

```
--> x=1;for k=[-1 3 0],x=x+k,end
 x         =

    0.
 x         =

    3.
 x         =

    3.
```

The `for` loop can also iterate on lists. The syntax is the same as for matrices.

The `while` loop repeatedly performs a sequence of commands until a condition is satisfied.

```
--> x=1; while x<14,x=2*x,end
 x         =

    2.
 x         =

    4.
 x         =

    8.
 x         =
```

```
    16.
```

A `for` or `while` loop can be ended by the command `break` :

```
-->a=0;for i=1:5:100,a=a+1;if i > 10  then  break,end; end

-->a
 a  =

    3.
```

3.1.3 Conditionals

Two types of conditionals exist in Scilab: the `if-then-else` conditional and the `select-case` conditional. The `if-then-else` conditional evaluates an expression and if true executes the instructions between the `then` statement and the `else` statement (or `end` statement). If false the statements between the `else` and the `end` statement are executed. The `else` is not required. The `elseif` has the usual meaning and is a also a keyword recognized by the interpreter.

```
--> x=1
 x         =

    1.

--> if x>0 then,y=-x,else,y=x,end
 y         =

  - 1.

--> x=-1
 x         =

  - 1.

--> if x>0 then,y=-x,else,y=x,end
 y         =

  - 1.
```

The `select-case` conditional compares an expression to several possible expressions and performs the instructions following the first case which equals the initial expression.

```
--> x=-1
 x         =
```

```
  - 1.

--> select x,case 1,y=x+5,case -1,y=sqrt(x),end
 y         =

    i
```

It is possible to include an `else` statement for the condition where none of the cases are satisfied.

3.2 Defining and Using Functions

It is possible to define a function directly in the Scilab environment, however, the most convenient way is to create a file containing the function with a text editor. In this section we describe the structure of a function and several Scilab commands which are used almost exclusively in a function environment.

3.2.1 Function Structure

Function structure must obey the following format

```
function [y1,...,yn]=foo(x1,...,xm)
   .
   .
   .
```

where `foo` is the function name, the `xi` are the m input arguments of the function, the `yj` are the n output arguments from the function, and the three vertical dots represent the list of instructions performed by the function. An example of a function which calculates $k!$ is as follows

```
function [x]=fact(k)
  k=int(k);
  if k<1 then,
     k=1;
  end,
  x=1;
  for j=1:k,
     x=x*j;
  end,
```

If this function is contained in a file called `fact.sci` the function is "loaded" into the Scilab environment and is used as follows.

```
--> exists('fact')
 ans       =

    0.

--> getf('../macros/fact.sci')
```

```
--> exists('fact')
 ans        =

    1.

--> x=fact(5)
 x          =

    120.

--> comp(fact)
```

In the above Scilab session, the command `exists` indicates that `fact` is not in the environment (by the 0 answer to `exist`). The function is loaded into the environment using `getf` and now `exists` indicates that the function is there (the 1 answer). The example calculates 5!. Finally, the function is compiled using `comp` for faster execution. Note that compiling `fact` can be realized directly by the command `getf('../macros/fact.sci','c')`.

3.2.2 Loading Functions

Functions are usually defined in files. A file which contains a function must obey the following format

```
function [y1,...,yn]=foo(x1,...,xm)
   .
   .
   .
```

where `foo` is the function name. The `xi`'s are the input parameters and the the `yj`'s are the output parameters, and the three vertical dots represent the list of instructions performed by the function. Inputs and ouputs parameters can be *any* Scilab object (including functions themeselves).

Functions are Scilab objects and should not be considered as files. To be used in Scilab, functions defined in files *must* be loaded by the command `getf(filename,'c')`. If the file `filename` contains the function `foo`, the function `foo` can be executed only if it has been previously loaded by the command `getf(filename,'c')` (where `'c'` is optional). A file may contain several functions. Functions can also be defined "on line" by the command `deff`. This is useful if one wants to define a function as the output parameter of a other function.

Collections of functions can be organized as libraries (see `lib` command). Standard Scilab librairies (linear algebra, control,...) are defined in the subdirectories of `SCIDIR/macros/`.

3.2.3 Global and Local Variables

If a variable in a function is not defined (and is not among the input parameters) then it takes the value of a variable having the same name in the calling environment. This variable however remains local in the sense that modifying it within the function does not alter the variable in the calling environment unless `resume` is used (see below). Functions can be invoked with less input or output parameters. Here is an example:

```
function [y1,y2]=f(x1,x2)
y1=x1+x2
y2=x1-x2


-->[y1,y2]=f(1,1)
 y2  =
    0.
 y1  =
    2.

-->f(1,1)
 ans  =
    2.

-->f(1)
y1=x1+x2;
        !--error     4
undefined variable : x2
at line       2 of function f

-->x2=1;

-->[y1,y2]=f(1)
 y2  =
    0.
 y1  =
    2.

-->f(1)
 ans  =

    2.
```

Note that it is not possible to call a function if one of the parameter of the calling sequence is not defined:

```
function [y]=f(x1,x2)
if x1<0 then y=x1, else y=x2;end



-->f(-1)
 ans  =

  - 1.

-->f(-1,x2)
```

```
       !--error     4
undefined variable : x2

-->f(1)
 undefined variable : x2
at line       2 of function    f     called by :
f(1)

-->x2=3;f(1)

-->f(1)
 ans  =

    3
```

3.2.4 Special Function Commands

Scilab has several special commands which are used almost exclusively in functions. These are the commands

- `argn`: returns the number of input and output arguments for the function
- `error`: used to suspend the operation of a function, to print an error message, and to return to the previous level of environment when an error is detected.
- `warning`,
- `pause`: temporarily suspends the operation of a function.
- `break`: forces the end of a loop
- `return` or `resume` : used to return to the calling environment and to pass local variables from the function environment to the calling environment.

The following example loads a function called `foo` into Scilab which illustrates these commands.

```
-->getf('../macros/foo.sci')

-->foo
 foo      =

[z]=foo(x,y)

--> z=foo(0,1)
error('division by zero');
                          !--error 10000
division by zero
at line       4 of function    foo      called by :
```

```
 z=foo(0,1)


--> z=foo(2,1)

-1-> resume
 z         =

    0.7071068

--> s
 s         =

    0.5
```

In the example we load `foo.sci` and display the contents of the function. The first call to `foo` passes an argument which cannot be used in the calculation of the function. The function discontinues operation and indicates the nature of the error to the user. The second call to the function suspends operation after the calculation of `slope`. Here the user can examine values calculated inside of the function, perform plots, and, in fact perform any operations allowed in Scilab. The `-1->` prompt indicates that the current environment created by the `pause` command is the environment of the function and not that of the calling environment. Control is returned to the function by the command `return`. Operation of the function can be stopped by the command `quit` or `abort`. Finally the function terminates its calculation returning the value of `z`. Also available in the environment is the variable `s` which is a local variable from the function which is passed to the global environment.

3.3 Definition of Operations on New Data Types

It is possible to transparently define fundamental operations for new data types in Scilab. That is, the user can give a sense to multiplication, division, addition, etc. on any two data types which exist in Scilab. As an example, two linear systems (represented by lists) can be added together to represent their parallel inter-connection or can be multiplied together to represent their series inter-connection. Scilab performs these user defined operations by searching for functions (written by the user) which follow a special naming convention described below.

The naming convention Scilab uses to recognize operators defined by the user is determined by the following conventions. The name of the user defined function is composed of four (or possibly three) fields. The first field is always the symbol `%`. The third field is one of the characters in the following table which represents the type of operation to be performed between the two data types.

Third field	
SYMBOL	OPERATION
`a`	`+`
`b`	`;` (row separator)
`c`	`[ ]` (matrix definition)
`d`	`./`
`e`	`()` extraction: `m=a(k)`
`i`	`()` insertion: `a(k)=m`
`k`	`.*.`
`l`	`\` left division
`m`	`*`
`p`	`^` exponent
`q`	`.\`
`r`	`/` right division
`s`	`-`
`t`	`'` (transpose)
`u`	`*.`
`v`	`/.`
`w`	`\.`
`x`	`.*`
`y`	`./.`
`z`	`.\.`

The second and fourth fields represent the type of the first and second data objects, respectively, to be treated by the function and are represented by the symbols given in the following table.

Second and Fourth fields	
SYMBOL	VARIABLE TYPE
`s`	scalar
`p`	polynomial
`l`	list (untyped)
`c`	character string
`m`	function
`xxx`	list (typed)

A typed list is one in which the first entry of the list is a character string where the first three characters of the string are represented by the `xxx` in the above table. For example a list representing a linear system has the form `list('lss',a,b,c,d,x0,'c')` and, thus, the `xxx` above is `lss`.

An example of the function name which multiplies two linear systems together (to represent their series inter-connection) is `%lssmlss`. Here the first field is %, the second field is `lss` (linear state-space), the third field is `m` "multiply" and the fourth one is `lss`. A possible user function which performs this multiplication is as follows

```
function [s]=%lssmlss(s1,s2)
[A1,B1,C1,D1,x1,dom1]=s1(2:7),
[A2,B2,C2,D2,x2]=s2(2:6),
```

```
B1C2=B1*C2,
s=list('lss',[A1,B1C2;0*B1C2' ,A2],...
       [B1*D2;B2],[C1,D1*C2],D1*D2,[x1;x2],dom1),
```

An example of the use of this function after having loaded it into Scilab (using for example `getf` or inserting it in a library) is illustrated in the following Scilab session

```
-->A1=[1 2;3 4];B1=[1;1];C1=[0 1;1 0];

-->A2=[1 -1;0 1];B2=[1 0;2 1];C2=[1 1];D2=[1,1];

-->s1=syslin('c',A1,B1,C1);

-->s2=syslin('c',A2,B2,C2,D2);

-->ssprint(s1)

.   | 1  2 |    | 1 |
x = | 3  4 |x + | 1 |u

    | 0  1 |
y = | 1  0 |x

-->ssprint(s2)

.   | 1 -1 |    | 1  0 |
x = | 0  1 |x + | 2  1 |u

y = | 1  1 |x + | 1  1 |u

-->s12=s1*s2;   //This is equivalent to s12=%lssmlss(s1,s2)

-->ssprint(s12)

    | 1  2  1  1 |    | 1  1 |
.   | 3  4  1  1 |    | 1  1 |
x = | 0  0  1 -1 |x + | 1  0 |u
    | 0  0  0  1 |    | 2  1 |

    | 0  1  0  0 |
y = | 1  0  0  0 |x
```

Notice that the use of `%lssmss` is totally transparent in that the multiplication of the two lists `s1` and `s2` is performed using the usual multiplication operator `*`.

The directory `SCIDIR/macros/percent` contains all the functions (a very large number...) which perform operations on linear systems and transfer matrices. Conversions are automatically performed. For example the code for the function `%lssmlss` is there (note that it is much more complicated that the code given here!).

3.4 Debbuging

The simplest way to debug a Scilab function is to introduce a `pause` command in the function. When executed the function stops at this point and prompts `-1->` which indicates a different "level"; another `pause` gives `-2->` ... At the level 1 the Scilab commands are analog to a different session but the user can display all the current variables present in Scilab, which are inside or outside the function i.e. local in the function or belonging to the calling environment. The execution of the function is resumed by the command `return` or `resume` (the variables used at the upper level are cleaned). The execution of the function can be interrupted by `abort`.

It is also possible to insert breakpoints in functions. See the commands `setbpt`, `delbpt`, `disbpt`. Finally, note that it is also possible to trap errors during the execution of a function: see the commands `errclear` and `errcatch`. Finally the experts in Scilab can use the function `debug(i)` where i=0,..,4 denotes a debugging level.

Chapter 4

Basic Primitives

This chapter briefly describes some basic primitives of Scilab. More detailed information is given in the manual (see the directory `SCIDIR/man/LaTex-doc`).

4.1 The Environment and Input/Output

In this chapter we describe the most important aspects of the environment of Scilab: how to automatically perform certain operations when entering Scilab, and how to read and write data from and to the Scilab environment.

4.1.1 The Environment

Scilab is loaded with a number of variables and primitives. The command `who` lists the variables which are available.

The `who` command also indicates how many elements and variables are available for use. The user can obtain on-line help on any of the functions listed by typing `help <function-name>`.

Variables can be saved in an external binary file using `save`. Similarly, variables previously saved can be reloaded into Scilab using `load`.

Note that after the command `clear x y` the variables `x` and `y` no longer exist in the environment. The command `save` without any variable arguments saves the entire Scilab environment. Similarly, the command `clear` used without any arguments clears all of the variables, functions, and libraries in the environment.

Functions which exist in files can be seen by using `disp` and loaded by using `getf`.

Libraries of functions are loaded using `lib`.

The list of functions available in the library can be obtained by using `disp`.

4.1.2 Startup Commands by the User

When Scilab is called the user can automatically load into the environment functions, libraries, variables, and perform commands using the the file `.scilab` in his home directory. This is particularly useful when the user wants to run Scilab programs in the background (such as in batch mode). Another useful aspect of the `.scilab` file is when some functions or libraries are often used. In this case the command `getf` can be used in the `.scilab` file to automatically load the desired functions and libraries whenever Scilab is invoked.

4.1.3 Input and Output

Although the commands `save` and `load` are convenient, one has much more control over the transfer of data between files and Scilab by using the commands `read` and `write`. These two commands work similarly to the read and write commands found in Fortran. The syntax of these two commands is as follows.

```
--> x=[1 2 %pi;%e 3 4]
 x         =

!   1.           2.    3.1415927 !
!   2.7182818    3.    4.        !

--> write('x.dat',x)

--> clear x

--> xnew=read('x.dat',2,3)
 xnew      =

!   1.           2.    3.1415927 !
!   2.7182818    3.    4.        !
```

Notice that `read` specifies the number of rows and columns of the matrix `x`. Complicated formats can be specified.

4.2 Help

On-line help is available either by clicking on the `help` button or by entering `help item` (where `item` is usually the name of a function or primitive). The help facility is based on the Unix `xman` command. `apropos item` looks for `item` in the `whatis` file. This facility is equivalent to the Unix `whatis` command. To add a new item in the manual is easy: just look at the `SCIDIR/man` subdirectories. The Scilab LaTeX manual is automatically obtained from the manual items by a `Makefile`. See the directory `SCIDIR/man/Latex-doc`. Note that the command `manedit` opens an help file with an editor (default editor is `emacs`).

4.3 Nonlinear Calculation

Scilab has several powerful non-linear primitives for simulation or optimization.

4.3.1 Externals

An "external" is a function or Fortran routine which is used as an argument of some high-level primitives (such as `ode`, `optim`...). The calling sequence of the external (function or routine) is imposed by the high-level primitive which sets the arguments of the external. For example the external function `costfunc` is an argument of the `optim` primitive. Its calling sequence must be: `[f,g,ind]=costfunc(x,ind)` as imposed by the `optim` primitive. The following non-linear primitives in Scilab need externals: `ode`, `optim`, `impl`, dassl, intg, fsolve. For problems where computation time is important, it is recommended to code the externals as Fortran subroutines. Examples of such subroutines are given in the directory SCIDIR/routines/default. When such a subroutine is written it must be linked to Scilab. This link operation can be "dynamic" (see link). It is also possible to introduce the code in a more permanent manner by inserting it in a specific interface (see e.g. fydot.f in SCIDIR/routines/default and rebuild a new Scilab by a make.

4.3.2 Nonlinear Primitives

The main simulation primitives in Scilab allow integrating a broad range of non-linear system functions of both explicit and implicit nature. It is also possible to integrate a system of differential equations with a stopping time: integration is performed until the trajectory reaches a given surface. In the following we illustrate the basic ode syntax for example.

The example illustrates the basic usage of ode. Here we simulate the motion of a double pendulum. Let θ_1 and θ_2 be the angles that the first and second pendulum elements make with the vertical and r_1, r_2, m_1 and m_2 be the lengths and masses of the respective pendulum elements. The non-linear differential equation which describes the motion of the pendulum is:

$$\left[\begin{array}{cc} mr_1 & m_2 r_2 \cos\theta \\ r_1\cos\theta_1 & r_2 \end{array}\right]\left[\begin{array}{c} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{array}\right] = \left[\begin{array}{c} -m_2 r_2 \dot{\theta}_2^2 \sin\theta \\ r_1\dot{\theta}_1^2 \sin\theta \end{array}\right] - \left[\begin{array}{c} m\sin\theta_1 \\ \sin\theta_2 \end{array}\right] g \tag{4.1}$$

where g is the acceleration due to gravity, $m = m_1 + m_2$, and $\theta = \theta_1 + \theta_2$. The following Scilab session simulates the movement of the pendulum for 1.5 seconds where $g = 9.8m/s$, $r_1 = r_2 = 1m$, and $m1 = m2 = 1kg$. The initial conditions are $\theta_1 = \pi/2$, $\theta_2 = \pi/2$, $\dot{\theta}_1 = 0$, and $\dot{\theta}_2 = 0$.

```
--> m1=1;m2=1;r1=1;r2=1;

--> g=9.8;

--> t0=0;

--> t=0:.1:1.5;

--> z0=[%pi/2;%pi/2;0;0];

--> getf('../macros/dpend.sci','c');

--> z=ode(z0,t0,t,dpend);

--> pp(z)
```

The result of the above session is plotted in Figure 4.1. Note that ode takes four arguments: an initial condition vector z0, the initial time t0, a vector of times t for which the integrated values z are desired, and the function dpend which exists in the environment of Scilab and which calculates the value of the derivative zd given the time t and the value of z at this time.

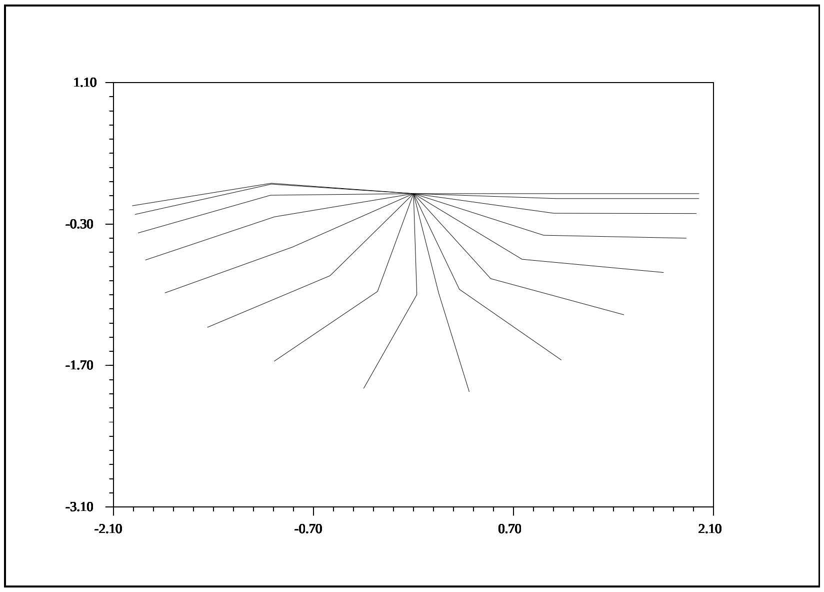

Figure 4.1: Simulation of a Double Pendulum

Note that the dpend function calculates the derivative of the state of the double pendulum following (4.1).

```
function [zdot]=dpend(time,z)
   th1=z(1);th2=z(2);th1d=z(3);th2d=z(4);
   s12=sin(th1-th2);c12=cos(th1-th2);
   m12=m1+m2;s1=sin(th1);s2=sin(th2);
   mat=[m12*r1 m2*r2*c12;...
        r1*c12 r2];
   vec=-[m12*g*s1+m2*r2*th2d*th2d*s12;...
         g*s2-r1*th1d*th1d*s12];
   res=mat\vec;
   th1dd=res(1);th2dd=res(2);
   zdot=[th1d;th2d;th1dd;th2dd];

function []=pp(z)
   th1=z(1,:);th2=z(2,:);
   rc1=r1*cos(th1);rc2=r2*cos(th2);
   rs1=r1*sin(th1);rs2=r2*sin(th2);
   rs12=rs1+rs2;rc12=rc1+rc2;
   rect=[-2.1,-3.1,2.1,1.1];
   for k=1:maxi(size(th1));
      plot2d([0 rs1(k) rs12(k)]',-[0 rc1(k) rc12(k)]',...
[-1],"011",' ',rect,[10,3,10,3]);
   end,
```

The Scilab "external" function which calculates the derivative (dpend in this example) must have a certain format. This format is as follows

```
function [xdot]=f(time,x)
    .
    .
    .
```

The format specifies that the argument list contain two variables. The first variable `time` is a scalar which represents time, the second variable `x` is a vector (or matrix) of the state values. The returned value `xdot` is the calculated derivative and has the same dimensions as `x`. For differential equations of order greater than one state augmentation is used.

The optimization primitive `optim` in Scilab is capable finding locally optimum solutions to a wide range of non-linear problems. In the following we illustrate the basic `optim` syntax by example.

The example used to illustrate the use of `optim` is the classic ray-tracing problem of a plane wave travelling from one material to another. Here we pose the problem slightly differently. Imagine a lifeguard on a beach and a person calling for help in the water. The lifeguard's speed on land is different from his speed in water and, consequently, he would like to choose the point along the border between beach and water which minimizes the travel time to the calling person. This problem can be analytically solved when the border between beach and water is a straight line. The problem may not be analytically resolvable when the function of the border is more complicated than a straight line.

The problem is posed as follows. Given that the lifeguard is at the origin of a Cartesian coordinate system, that the person to be saved is at the coordinates (x, y), and that the border between the beach and the water can be described by the function $d(x)$, the lifeguard's time of travel is

$$T(p) = \frac{\sqrt{p^2 + d^2(p)}}{v_b} + \frac{\sqrt{(x-p)^2 + (y-d(p))^2}}{v_w} \tag{4.2}$$

where p is the x-axis coordinate of the point along the border through which the lifeguard passes and where v_s and v_w are the respective speeds of the lifeguard on the beach and in the water. Here we assume that the x coordinate given by p uniquely defines a point on the border between the beach and the water.

We know that a locally optimum solution must make $dT(p)/dt = 0$ and we can calculate the derivative of T as a function of the derivative of d

$$\frac{d}{dt}T(p) = \frac{p + dd_p}{v_s\sqrt{p^2 + d^2}} + \frac{(p-x) + (d-y)d_p}{v_w\sqrt{(x-p)^2 + (y-d)^2}} \tag{4.3}$$

where d_p is the partial of d with respect to p. The following Scilab functions make the calculations in (4.2) and (4.3).

```
function [t,t_p,ind]=swim(p,ind)
   [d,d_p]=dpfun(p);
   as=sqrt(d^2+p^2);
   aw=sqrt((x-p)^2+(y-d)^2);
   t=as/vs+aw/vw;
   t_p=(p+d*d_p)/(vs*as)+((p-x)+(d-y)*d_p)/(vw*aw);


function [d,d_p]=dpfun(p);
   d=1.75-exp(log(1.55)*p);
   d_p=-log(1.55)*exp(log(1.55)*p);
```

where the functions d and d_p are calculated by the function `dpfun`. These two functions are used in the following Scilab session by the primitive `optim` to find the optimum point p.

```
--> x=1;y=1;vs=5;vw=1;

--> getf('../macros/swim.sci');

--> getf('../macros/plotopt.sci');

--> [ts,ps,tps]=optim(swim,0)
 end of optimization

 tps       =

   4.580D-16
 ps        =

   0.6144065
 ts        =

   0.8303513

--> popt(ps);
```

Here it can be seen that the primitive `optim` takes two arguments and returns three values. The first argument is the name of the Scilab function which calculates the value of time (the cost) and the derivative of the time with respect to the value of p. The second argument is a first guess for the value of p. The returned values are, respectively, the optimal cost `ts` associated to the value of p which is the value in `ps`, and, finally, the value of the gradient at this point which is in `tps`.

The optimal path for the lifeguard is illustrated in Figure 4.2. The curved line represents the shape of the shoreline and the dotted line represents the lifeguard's optimal path.

4.4 Fortran or C Interface

Scilab can be easily interfaced with Fortran or C subroutines. The simplest way is using the dynamic link primitive `link` and the subroutine call primitive `fort`. Details are given in the Scilab manual.

Fortran subprograms can also be linked to Scilab by using an external Fortran program call `interf`. See the program `interf.f` in the directory `SCIDIR/default` where examples are given.

These facilities are particularly useful for simulation and optimization of non-linear problems or for introducing programs automatically generated by the computer algebra system Maple. There are two steps for interfacing dynamically a subroutine written in Fortran with Scilab. These two steps are demonstrated in what follows.

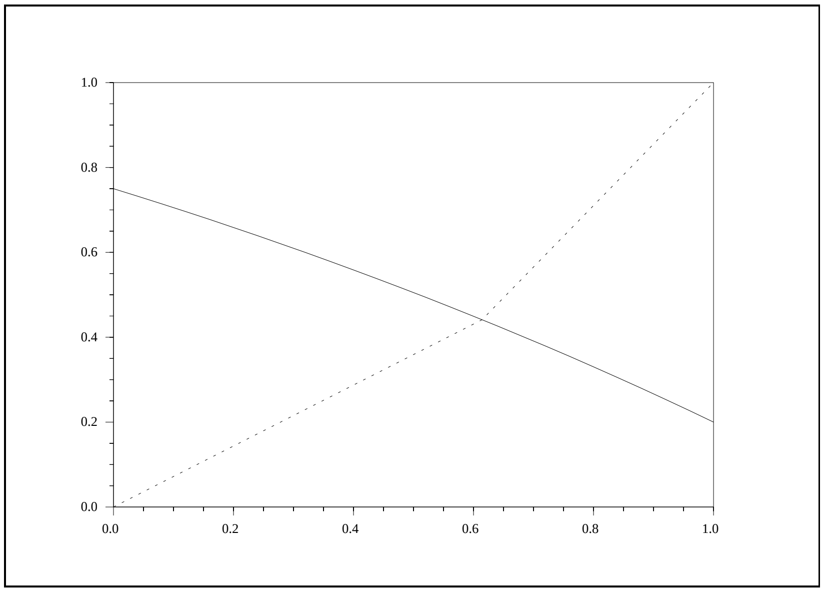

Figure 4.2: Optimal Lifeguard Path

To link a fortran subroutine with Scilab it is first necessary to have a file which contains the executable object file of the subroutine. We introduce the Fortran subroutine `fibb` which calculates the n^{th} Fibbonacci number f_n (i.e. the sequence $0, 1, 1, 2, 3, 5, 8, \ldots$ where $f_n = f_{n-1} + f_{n-2}$).

```
      subroutine fibb(fn,n)
      n0=0
      n1=1
      if(n.ge.3)then
      do 10 k=1,n-2
         fn=n0+n1
         n0=n1
         n1=fn
 10   continue
      else
         fn=n-1
      endif
      end
```

Assuming that the object file for `fibb` is available in the file `fibb.o` the following Scilab session shows how to use the subroutine from Scilab.

```
-->unix("make fibb.o");

-->link('fibb.o','fibb')

-->link()
 ans       =
```

```
 fibb

-->n=6
 n         =

    6.

-->fn=fort('fibb',n,2,'i','out',[1,1],1,'r')
 fn        =

    5.
```

The primitive `link` usually takes two arguments where the first argument is the name of the object file and the second argument is the name of the subroutine call. Note that the primitive `c_link` may be used to know all the previously linked subroutines. The use of `fort` to call the subroutine `fibb` is a bit complicated. The arguments are divided into four groups. The first argument `'fibb'` is the name of the called subroutine. The argument `'out'` divides the remaining arguments into two groups. The group of arguments between `'fibb'` and `'out'` is the list of input arguments, their positions in the call to `fibb`, and their data type. The group of arguments to the right of `'out'` are the dimensions of the output variables, their positions in the call to `fibb`, and their data type. The possible data types are real, integer, and double precision which are indicated, respectively, by the strings `'r'`, `'i'`, and `'d'`. The positions of the two arguments for `fibb` are `n` at position 2 and `fn` at positon 1 which explains the above call values. The vector `[1,1]` indicates that the output `fn` is a 1×1 matrix. The routines which are linked to Scilab can also access internal Scilab variables (see the routine `matz.f` in the directory `SCIDIR/routines/system2`).

4.5 XWindow Dialog

It may be convenient to open a specific XWindow window for entering interactively parameters inside a function or for a demo. This facility is possible thanks to e.g. the functions `x_dialog`, `x_choose`, `x_mdialog`, `x_matrix` and `x_message`. The demos which can be executed by clicking on the `demo` button provide simple examples of the use of these functions.

4.6 Maple Interface

The Maple procedure `maple2scilab` allows to numerically evaluate any Maple expression in Scilab. On input this procedure takes a Maple matrix made of symbolic expressions. When `maple2scilab` is invoked in Maple, a Fortran program is automatically generated by Maple (via `Macrofort` package in Maple) together with a Scilab function which allows to (dynamically) call this subroutine. The parameters of the function are the Maple symbols and thus the Maple matrix can be evaluated numerically in Scilab. The use of Fortran is for speed purposes since the formal Maple expression can be extremely complicated.

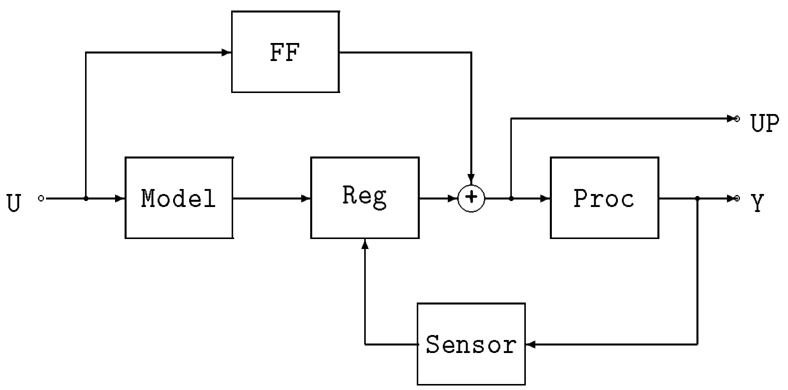

Figure 4.3: Inter-Connected Systems

4.7 System Interconnection

The purpose of this section is to illustrate some of the more sophisticated aspects of Scilab by the way of an example. The example shows how Scilab can be used to symbolically represent the inter-connection of multiple systems which in turn can then be used to numerically evaluate the performance of the inter-connected systems. The symbolic representation of the inter-connected systems is done with a function called `bloc2exp` and the evaluation of the resulting system is done with `evstr`.

The example illustrates the symbolic inter-connection of the systems shown in Figure 4.3. Figure 4.3 illustrates the classic regulator problem where the block labeled `Proc` is to be controlled using feedback from the `Sensor` block and `Reg` block. The `Reg` block compares the output from the `Model` block to the output from the `Sensor` block to decide how to regulate the `Proc` block. There is also a feed-forward block which filters the input signal `U` to the `Proc` block. The outputs of the system are `Y` and `UP`.

The system illustrated in Figure 4.3 can be represented in Scilab by using the function `bloc2exp`. The use of `bloc2exp` is illustrated in the following Scilab session. There a two kinds of objects: "transfer" and "links". The example considered here admits 5 transfers and 7 links. First the transfer are defined in a symbolic manner. Then links are defined and an "interconnected system" is defined as a specific list. The function `bloc2exp` evaluates symbolically the global transfer and `evstr` evaluates numerically the global transfer function once the systems are given "values", i.e. are defined as Scilab linear systems.

```
-->model=2;reg=3;proc=4;sensor=5;ff=6;somm=7;

-->tm=list('transfer','model');

-->tr=list('transfer',['reg(:,1)','reg(:,2)']);
```

```
-->tp=list('transfer','proc');

-->ts=list('transfer','sensor');

-->tf=list('transfer','ff');

-->tsum=list('transfer',['1','1']);

-->lum=list('link','input',[-1],[model,1],[ff,1]);

-->lmr=list('link','model output',[model,1],[reg,1]);

-->lrs=list('link','regulator output',[reg,1],[somm,1]);

-->lfs=list('link','feed-forward output',[ff,1],[somm,1]);

-->lsp=list('link','proc input',[somm,1],[proc,1],[-2]);

-->lpy=list('link','proc output',[proc,1],[sensor,1],[-1]);

-->lsup=list('link','sensor output',[sensor,1],[reg,2]);

-->syst=...
 list('blocd',tm,tr,tp,ts,tf,tsum,lum,lmr,lrs,lfs,lsp,lpy,lsup);

-->[sysf,names]=bloc2exp(syst)
 names     =


       names>1

 input

       names>2

!proc output  !
!             !
!proc input   !
 sysf      =

!proc*((eye-reg(:,2)*sensor*proc)\(-(-ff-reg(:,1)*model)))  !
!                                                           !
!(eye-reg(:,2)*sensor*proc)\(-(-ff-reg(:,1)*model))         !
```

Note that the argument to `bloc2exp` is a list of lists. The first element of the list `syst` is (actually) the character string `'blocd'` which indicates that the list represents a block-diagram inter-connection of systems. Each list entry in the list `syst` represents a block or an inter-connection in Figure 4.3. The form of a list which represents a block begins with a character string `'transfer'` followed by a matrix of character strings which gives the symbolic name of the block. If the block is multi-input multi-output the matrix of character strings must be represented as is illustrated by the block `Reg`.

The inter-connections between blocks is also represented by lists. The first element of the list is the character string `'link'`. The second element of the inter-connection is its symbolic name. The third element of the inter-connection is the input to the connection. The remaining elements are all the outputs of the connection. Each input and output to an inter-connection is a vector which contains as its first element the block number (for instance the `model` block is assigned the number 2). The second element of the vector is the port number for the block (for the case of multi-input multi-output blocks). If an inter-connection is not attached to anything the value of the block number is negative (as for example the inter-connection labeled `'input'` or is omitted.

The result of the `bloc2exp` function is a list of names which give the unassigned inputs and outputs of the system and the symbolic transfer function of the system given by `sysf`. The symbolic names in `sysf` can be associated to polynomials and evaluated using the function `evstr`. This is illustrated in the following Scilab session.

```
-->s=poly(0,'s');

-->ff=1;sensor=1;model=1;

-->proc=s/(s^2+3*s+2);

-->reg=[1/s 1/s];

-->sys=evstr(sysf)
 sys       =

!     1 + s          !
!   ----------       !
!              2     !
!   1 + 3s + s       !
!                    !
!               2   3 !
!   2 + 5s + 4s + s  !
!   ---------------- !
!            2   3    !
!     s + 3s + s      !
```

The resulting polynomial transfer function links the input of the block system to the two outputs. Note that the output of `evstr` is the rational polynomial matrix `sys` whereas the output of `bloc2exp` is a matrix of character strings.

The symbolic evaluation which is given here is not very efficient with large interconnected systems. The function `bloc2ss` performs the previous calculation in state-space format. Each system is given now in state-space as a `syslin` list or simply as a gain (constant matrix). Note `bloc2ss` performs the necessary conversions if this is not done by the user. Each system must be given a value before bloc2ss is called. All the calculations are made in state-space representation even if the linear systems are given in transfer form.

4.8 Converting Scilab Functions to Fortran Routines

Scilab provides a compiler (under development) to transform some Scilab functions into Fortran subroutines. The routines which are thus obtained make use of the routines which are in the Fortran libraries. All the basic matrix operations are available.

Let us consider the following Scilab function:

```
function [x]=macr(a,b,n)
z=n+m+n,
c(1,1)=z,
c(2,1)=z+1,
c(1,2)=2,
c(2,2)=0,
if n=1 then,
 x=a+b+a,
else,
x=a+b-a'+b,
end,
y=a(3,z+1)-x(z,5),
x=2*x*x*2.21,
sel=1:5,
t=a*b,
for k=1:n,
 z1=z*a(k+1,k)+3,
end,
t(sel,5)=a(2:4,7),
x=[a b;-b' a']
```

which can be translated into Fortran by using the function `mac2for`. Each input parameter of the subroutine is described by a list which contains its type and its dimensions. Here, we have three input variables `a,b,c` which are, say, `integer, double precision, double precision` with dimensions `(m,m), (m,m), (1,1)`. This information is gathered in the following list:

```
l=list();
l(1)=list('1','m','m');
l(2)=list('1','m','m');
l(3)=list('0','1','1');
```

The call to `mac2for` is made as follows:

```
comp(macr);
mac2for(macr2lst(macr),l)
```

The output of this command is a string containing a stand-alone Fortran subroutine.

```
       subroutine macr(a,b,n,x,m,work,iwork)
c!
c  automatic translation
```

```
.
.
.
       double precision a(m,m),b(m,m),x(m+m,m+m),y,z1,24(m,m),work(*)
       integer n,m,z,c(2,2),sel(5),k,iwork(*)
.
.
.
       call dmcopy(b,m,x(1,m+1),m+m,m,m)
       call dmcopy(work(iw1),m,x(m+1,1),m+m,m,m)
       call dmcopy(work(iw1),m,x(m+1,m+1),m+m,m,m)
       return
c
       end
```

This routine can be linked to Scilab and interactively called.

Chapter 5

Graphics

This section introduces graphics in Scilab.

5.1 The Graphics Window

On the right side of the `Delete` button, a checker give the number `wn` of the graphics window. This number is given at the end of the title of the window, e.g. `ScilabGraphic1`. The button `Raise (Create) Window` raises the window `wn` if it exists and creates it if not. The button `Set (Create) Window` activates the window `wn` if it exists and simultaneously creates it if necessary. The `Delete` button closes the window `wn` if it exists. The execution of a plotting command automatically creates a window if necessary.

There are 4 buttons on the graphics window:

- `3D Rot.`: for applying a rotation with the mouse to a 3D plot. This button is inhibited for a 2D plot.

- `2D Zoom`: zooming on a 2D plot. This command can be recursively invoked. This button has no for a 3D plot.

- `UnZoomx`: return to the initial plot (not to the plot corresponding to the previous zoom in case of multiple zooms).

- `File`: this button opens different commands and menus.

  The first one is simple : `Clear` simply rubs out the plot of the window.

  The next command `Print...` opens a selection panel for getting a paper output of the plot.

  The `Export` command opens a panel selection for getting a copy of the plot on a file with a specified format (Postscript, Latex).

  The `save` command directly saves the plot on a file with a specified name. This file can be loaded later in Scilab for replotting.

  The `Delete` is the same command (close) than the previous one but simply applied to its window.

5.2 The Media

There are different graphics devices in Scilab which can be used to send graphics to windows or paper. The default is `ScilabGraphic0` window .

The basic Scilab graphics commands are :

- `driver`: selects a graphic driver
- `xinit`: initializes a graphic driver
- `xclear`: clears one or more graphic windows
- `xpause`: a pause in milliseconds
- `xselect`: raises the current graphic window
- `xclick`: waits for a mouse click
- `xend`: closes a graphic session

The different devices are:

- `X11` : graphics device for the X11 window system
- `Rec` : an X Window driver (X11) which also records all the graphic commands. This is the default
- `Wdp` : an X11 driver without recorded graphics; the graphics are done on a pixmap and are send to the graphic window with the command `xset("wshow")`. The pixmap is cleared with the command `xset("wwpc")` or with the usual command `xbasc()`
- `Pos` : graphics device for Postscript printers
- `Fig` : graphics device for the Xfig system

In fact, in many cases, one can ignore the existence of drivers and use the functions `xbasimp`, `xs2fig` in order to send a graphic to a printer or in a file for the `Xfig` system. For example with :

```
-->driver('Pos')

-->xinit('foo.ps')

-->plot(1:10)

-->xend()

-->driver('Rec')

-->plot(1:10)

-->xbasimp(0,'foo1.ps')
```

we get two identical Postscript files : `'foo.ps'` and `'foo1.ps.0'` (the appending 0 is the number of the active window where the plot has been done).

The default for plotting is the superposition; this can be avoided with the command `xbasc(window-number)` which clears the recorded Scilab graphics command associated with the window `window-number` and clears this window (see the warning below for the difference between `xbasc` and `xclear`).

If you enlarge a graphic window, the command `xbasr(window-number)` is executed by Scilab. This command clears the graphic window `window-number` and replays the graphic commands associated with it. One can call this function manually, in order to verify the associated recorded graphics commands.

Any number of graphics windows can be created with buttons or with the commands `xset` or `xselect`. The environment variable DISPLAY can be used to specify an X11 Display or one can use the `xinit` function in order to open a graphic window on a specific display.

5.3 2D Plotting

5.3.1 Basic 2D Plotting

The simplest 2D plot is `plot(x,y)` or `plot(y)`: this is the plot of `y` as function of `x` where `x` and `y` are 2 vectors; if `x` is missing, it is replaced by the vector `(1,...,size(y))`. If `y` is a matrix, its rows are plotted. There are optional arguments.

A first example is given by the following commands and the result is represented on figure 5.1:

```
-->//first example of plotting

-->  t=(0:0.05:1)';

-->  ct=cos(2*%pi*t);

-->  plot2d(t,ct)
```

The generic 2D multiple plot is
`plot2di(str,x,y,[style,strf,leg,rect,nax])`

with `i=missing,1,2,3,4`.

For the different values of `i` we have:

`i=missing` : piecewise linear plotting

`i=1` : as previous with possible logarithmic scales

`i=2` : piecewise constant drawing style

`i=3` : vertical bars

`i=4` : arrows style (e.g. ode in a phase space)

-Parameter `str` : it is the string `"abc"` :

`str` is empty if `i` is missing.

`a=e` : means empty; the values of `x` are not used; (The user must give a dummy value to `x`).

`a=o` : means one; the x-values are the same for all the curves

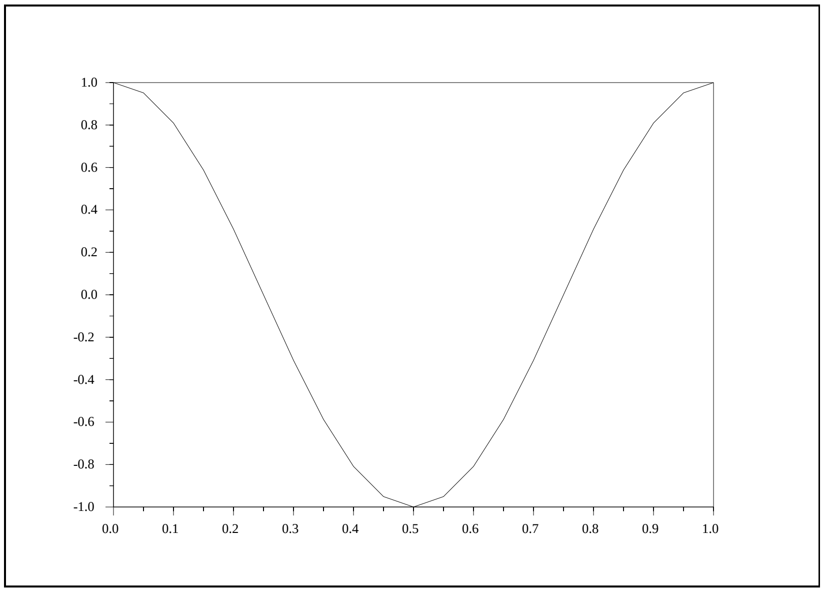

Figure 5.1: First example of plotting

`a=g` : means general.
`b=l` : a logarithmic scale is used on the X-axis
`c=l` : a logarithmic scale is used on the Y-axis

-Parameters `x,y` : two matrices of the same size `[nl,nc]` (`nc` is the number of curves and `nl` is the number of points of each curve)

-Parameter `style` : it is a real vector of size `(1,nc)`; the style to use for curve j is defined by `size(j)` (when only one curve is drawn `style` can specify the style and a position to use for the caption).

-Parameter `strf` : it is a string of length 3 `"xyz"` corresponding to :

`x=1` : captions displayed
`y=1` : the argument `rect` is used to specify the boundaries of the plot.
`rect=[xmin,ymin,xmax,ymax]`
`y=2` : the boundaries of the plot are computed
`y=0` : the current boundaries
`z=1` : an axis is drawnand the number of tics can be specified by the `nax` argument
`z=2` : the plot is only surrounded by a box

-Parameter `leg` : it is the string of the captions for the different plotted curves . This string is composed of fields separated by the `@` symbol: for example `‘‘module@phase’’` (see example below). These strings are displayed under the plot with small segments recalling the styles of the corresponding curves.

-Parameter `rect` : it is a vector of 4 values specifying the boundaries of the plot `rect=[xmin,ymin,xmax,ymax]`.

For different plots the simple commands without any argument show a demo (e.g `plot2d3()`).

5.3.2 Specialized 2D Plottings

- `champ` : vector field in R^2

- `fchamp` : for a vector field in R^2 defined by a function
- `fplot2d` : 2D plotting of a curve described by a function
- `fgrayplot` : gray level on a 2D plot
- `errbar` : creates a plot with error bars

5.3.3 Captions and Presentation

- `xgrid` : adds a grid on a 2D graphic
- `xtitle` : adds title and axis names on a 2D graphic
- `titlepage` : graphic title page
- `plotframe` : graphic frame with scaling and grid

The command `plotframe` is used to add a grid and graduations by choosing the number of graduations and getting rounded numbers.

5.3.4 Plotting Some Geometric Figures

Polylines Plotting

- `xsegs` : draws a set of unconnected segments
- `xrect` : draws a single rectangle
- `xfrect` : fills a single rectangle
- `xrects` : fills or draws a set of rectangles
- `xpoly` : draws a polyline
- `xpolys` : draws a set of polylines
- `xfpoly` : fills a polygon
- `xfpolys` : fills a set of polygons
- `xarrows` : draws a set of unconnected arrows
- `xfrect` : fills a single rectangle
- `xclea` : erases a rectangle on a graphic window

Curves Plotting

- `xarc` : draws an ellipsis
- `xfarc` : fills an ellipsis
- `xarcs` : fills or draws a set of ellipsis

5.3.5 Writing by Plotting

- `xstring` : draws a string or a matrix of strings
- `xstringl` : computes a rectangle which surrounds a string
- `xstringb` : draws a string in a specified box
- `xnumb` : draws a set of numbers

5.3.6 Manipulating the Plot and Graphics Context

Graphics Context

Some parameters of the graphics are controlled by a graphic context (for example the line thickness) and others are controlled through graphics arguments. In the first example (Figure (5.1)), we use all the default arguments.

- `xset` : to set graphic context values. Some examples of the use of `xset` :

  (i)-`xset("use color",flag)` changes to color or gray plot according to the values (1 or 0) of `flag`.

  (ii)-`xset("window",window-number)` sets the current window to the window `window-number` and creates the window if it doesn't exist.

  (iii)-`xset("wpos",x,y)` fixes the position of the upper left point of the graphic window.

  The choice of the font, the width and height of the window, the driver... can be done by `xset`.

- `xget` : to get informations about the current graphic context. All the values of the parameters fixed by `xset` can be obtained by `xget`.
- `xlfont` : to load a new family of fonts from the XWindow Manager

Some Manipulations

Coordinates transforms :

- `isoview` : isometric scale without window change

  allows an isometric scale in the window of previous plots without changing the window size (see the example below).

- `square` : isometric scale with resizing the window

  the window is resized according to the parameters of the command.

- `scaling` : scaling on data
- `rotate` : rotation

  `scaling` and `rotate` executes respectively an affine transform and a geometric rotation of a 2-lines-matrix corresponding to the `(x,y)` values of a set of points.

- `xgetech, xsetech` : change of scale inside the graphic window

  The current graphic scale can be fixed by a high level plot command. You may want to get this parameter or to fix it directly : this is the role of `xgetech, xsetech` .

5.4 Some Examples

We give here a sequence of commands corresponding to the different capabilities of the 2D plot and the generated figures. This first example corresponds to the figure 5.3.

```
x=-%pi:0.3:%pi;
y1=sin(x);y2=cos(x);y3=x;
X=[x;x;x]; Y=[y1;y2;y3];
plot2d2("g00",X',Y');
xbasc();
plot2d1("g00",X',Y',[1 2 3]',"101","caption1@caption2@caption3");
xtitle(["General";"Title"],"x-axis title","y-axis title");
xgrid([10,20]);
xclea(0.5,-0.5,1.5,1.5);
titlepage("titlepage");
xstring(0.65,0.3,["xstring after";"xclear"],0,1);
```

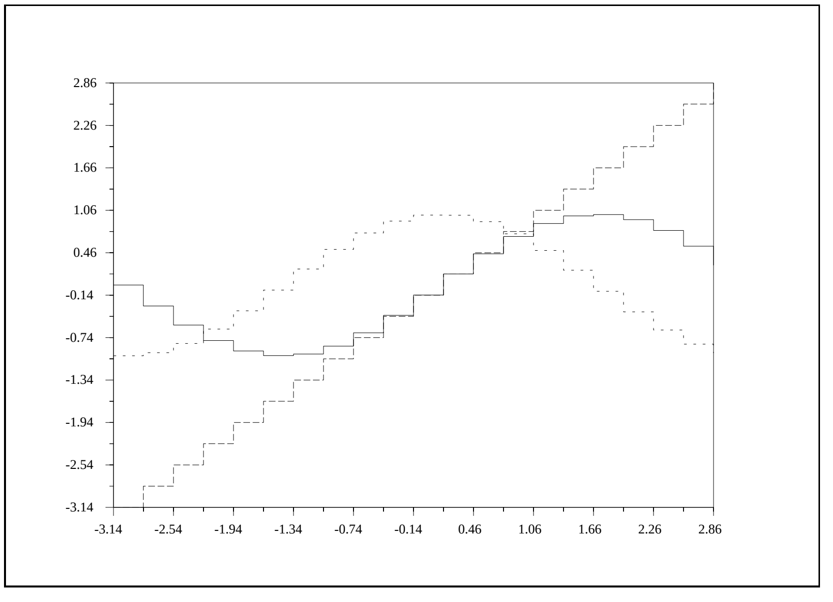

Figure 5.2: Simple 2D Plot

We give now the sequence of the commands for obtaining the figure 5.5.

```
// initialize default environment variables
plot(1:10)
xbasc()
// simple rectangle
xrect(0,1,3,1)
// filling a rectangle
xfrect(3.1,1,3,1)
// writing in the rectangle
```

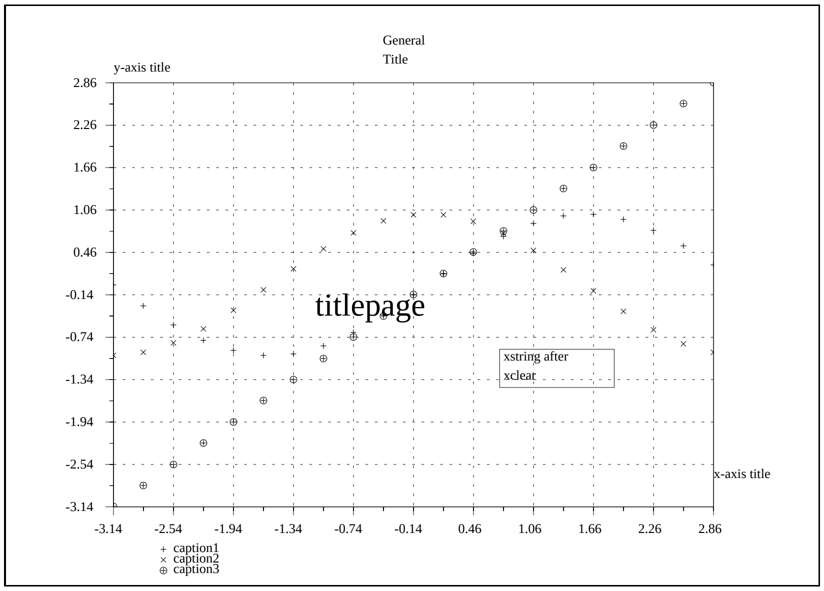

Figure 5.3: Some Capabilities of 2D Plot

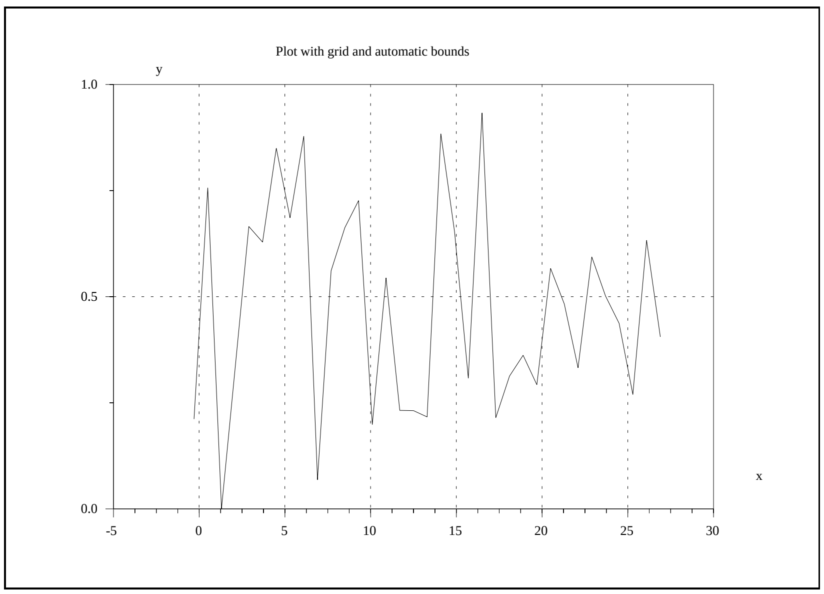

Figure 5.4: Use of plotframe

```
xstring(0.5,0.5,"xrect(0,1,3,1)")
// writing black on black !
xstring(4.,0.5,"xfrect(3.1,1,3,1)")
// reversing the video
xset("alufunction",6)
xstring(4.,0.5,"xfrect(3.1,1,3,1)")
xset("alufunction",3)
// drawing a polyline
xv=[0 1 2 3 4]
yv=[2.5 1.5 1.8 1.3 2.5]
xpoly(xv,yv,"lines",1)
xstring(0.5,2.,"xpoly(xv,yv,""lines"",1)")
// drawing arrows
xa=[5 6 6 7 7 8 8 9 9 5]
ya=[2.5 1.5 1.5 1.8 1.8 1.3 1.3 2.5 2.5 2.5]
xarrows(xa,ya)
xstring(5.5,2.,"xarrows(xa,ya)")
// drawing a part of an ellipsis
xarc(0.,5.,4.,2.,0.,64*300.)
xstring(0.5,4,"xarc(0.,5.,4.,2.,0.,64*300.)")
xfarc(5.,5.,4.,2.,0.,64*360.)
xset("alufunction",6)
xstring(5.5,4.,"xfarc(5.,5.,4.,2.,0.,64*360.)")
xset("alufunction",3)
// writing a string
xstring(0.,4.5,"WRITING-BY-XSTRING()",-22.5)
```

5.5 3D Plotting

5.5.1 Generic 3D Plotting

- `plot3d` : 3D plotting of a matrix of points : plot3d(x,y,z) with x,y,z 3 matrices, z being the values for the points with coordinates x,y. Other arguments are optional
- `plot3d1` : 3d plotting of a matrix of points with gray levels
- `fplot3d` : 3d plotting of a surface described by a function; z is given by an external z=f(x,y)
- `fplot3d1` : 3d plotting of a surface described by a function with gray levels

5.5.2 Specialized 3D Plotting

- `param3d` : plots parametric curves in 3d space
- `contour` : level curves for a 3d function given by a matrix
- `grayplot10` : gray level on a 2d plot

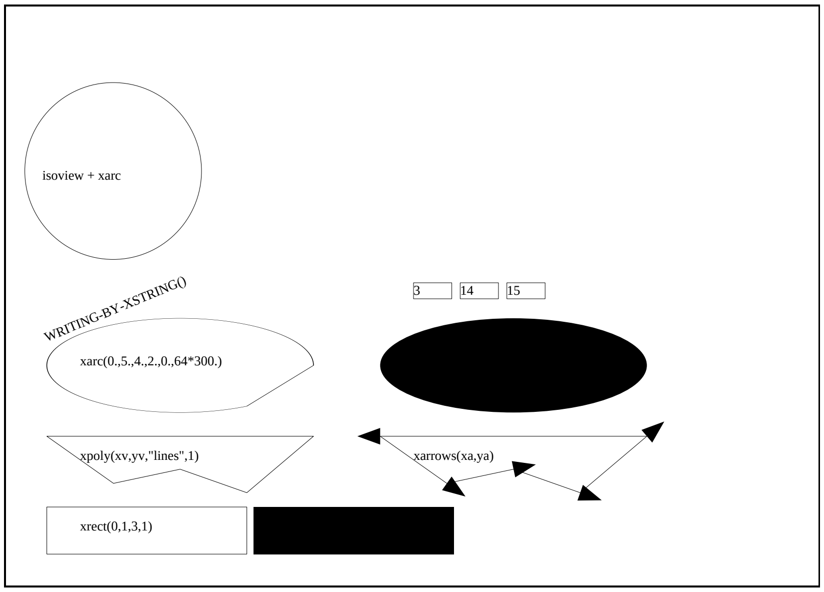

Figure 5.5: Geometric Graphics and Comments

- `fcontour10` : level curves for a 3d function given by a function
- `hist3d` : 3d histogram
- `secto3d` : conversion of a surface description from sector to plot3d compatible data
- `eval3d` : evaluates a function on a regular grid. (see also feval)

5.5.3 Mixing 2D and 3D graphics

When one uses 3D plotting function, default graphic boundaries are fixed, but in R^3. If one wants to use graphic primitives to add informations on 3D graphics, the `geom3d` function can be used to convert 3D coordinates to 2D-graphics coordinates. The figure 5.6 illustrates this feature.

```
xinit('d7-10.ps');
   r=(%pi):-0.01:0;x=r.*cos(10*r);y=r.*sin(10*r);
   deff("[z]=surf(x,y)","z=sin(x)*cos(y)");
   t=%pi*(-10:10)/10;
   fplot3d(t,t,surf,35,45,"X@Y@Z",[-1,2,3]);
   z=sin(x).*cos(y);
   [x1,y1]=geom3d(x,y,z);
   xpoly(x1,y1,"lines");
   [x1,y1]=geom3d([0,0],[0,0],[5,0]);
   xsegs(x1,y1);
   xstring(x1(1),y1(1),' The point (0,0,0)');
```

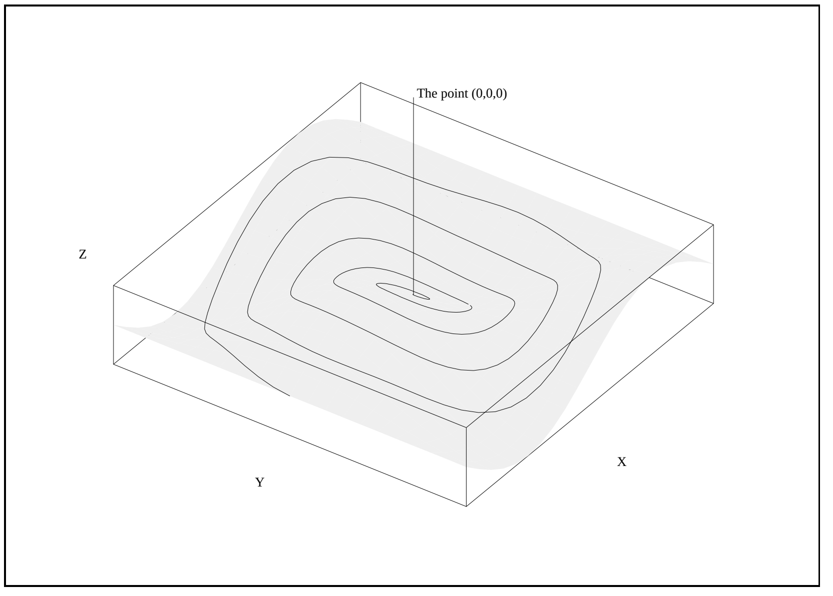

Figure 5.6: 2D and 3D plot

5.5.4 Sub-windows

It is also possible to make multiple plotting in the same graphic window (Figure 5.7).

```
xinit('d7-8.ps');
  t=(0:.05:1)';st=sin(2*%pi*t);
  xsetech([0,0,1,0.5]);
  plot2d2("onn",t,st);
  xsetech([0,0.5,1,0.5]);
  plot2d3("onn",t,st);
  xsetech([0,0,1,1]);
```

5.5.5 A Set of Figures

In this next example we give a brief summary of different plotting functions for 2D or 3D graphics. The figure 5.8 is obtained and inserted in this document with the help of the command `Blatexprs`.

```
//some examples
str_l=list();
//
str_l(1)=['plot3d1();';
      'title=[''plot3d1 : z=sin(x)*cos(y)''];';
      'xtitle(title,'' '','' '');'];
//
str_l(2)=['contour();';
      'title=[''contour ''];';
```

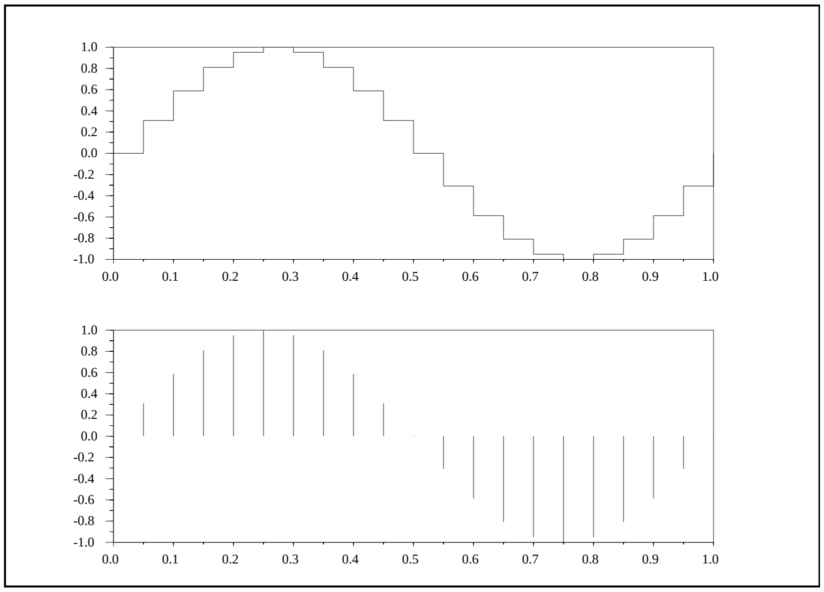

Figure 5.7: Use of xsetech

```
      'xtitle(title,'' '','' '');'];
//
str_l(3)=['champ();';
      'title=[''champ ''];';
      'xtitle(title,'' '','' '');'];
//
str_l(4)=['t=%pi*(-10:10)/10;';
          'deff(''[z]=surf(x,y)'',''z=sin(x)*cos(y)'');';
          'rect=[-%pi,%pi,-%pi,%pi,-5,1];';
          'z=feval(t,t,surf);';
          'contour(t,t,z,10,35,45,''X@Y@Z'',[1,1,0],rect,-5);';
          'plot3d(t,t,z,35,45,''X@Y@Z'',[2,1,3],rect);';
          'title=[''plot3d and contour ''];';
          'xtitle(title,'' '','' '');'];
//
for i=1:4,xinit('d7a11.ps'+string(i)');
          execstr(str_l(i)),xend();end
```

5.6 Printing and Inserting Scilab Graphics in LaTeX

We describe here the use of programs (Unix shells) for handling Scilab graphics and printing the results. These programs are located in the sub-directory `bin` of Scilab.

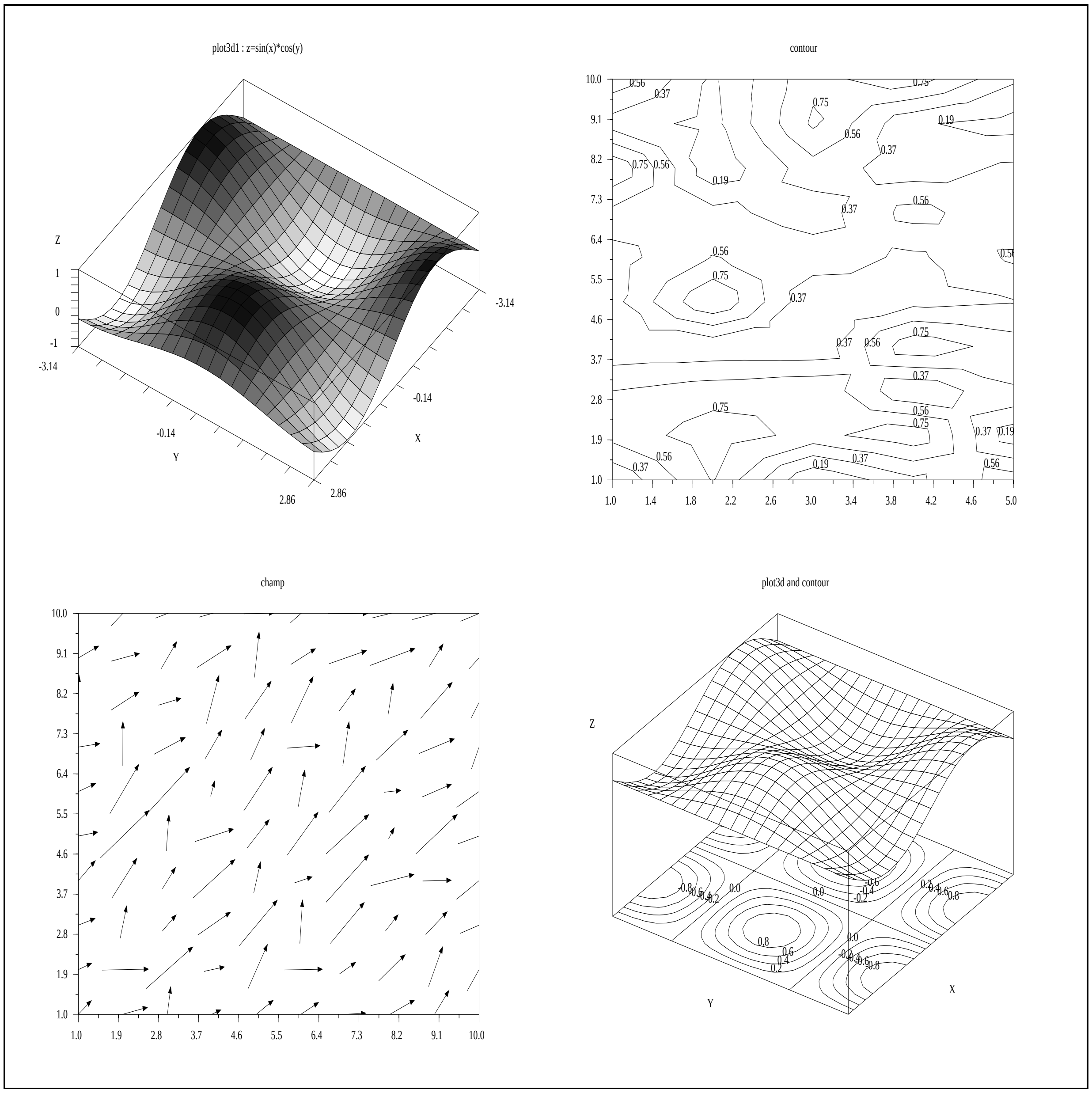

Figure 5.8: Group of figures

5.6.1 Window to Paper

The simplest command to get a paper copy of a plot is to click on the `print` button of the ScilabGraphic window.

5.6.2 Creating a Postscript File

We have seen at the beginning of this chapter that the simplest way to get a Postscript file containing a Scilab plot is :

```
-->driver('Pos')

-->xinit('foo.ps')

-->plot3d1();

-->xend()

-->driver('Rec')

-->plot3d1()

-->xbasimp(0,'foo1.ps')
```

The Postscript files (`foo.ps` or `foo1.ps`) generated by Scilab cannot be directly sent to a Postscript printer, they need a preamble. Therefore, printing is done through the use of Unix scripts or programs which are provided with Scilab. The program `Blpr` is used to print a set of Scilab Graphics on a single sheet of paper and is used as follows :

```
 Blpr string-title file1.ps file2.ps > result
```

You can then print the file `result` with the classical Unix command :

```
lpr -Pprinter-name result
```

or use the `ghostview` Postscript interpreter on your Unix workstation to see the result.

You can avoid the file `result` with a pipe, replacing `> result` by the printing command `| lpr` or the previewing command `| ghostview -`.

The best result (best sized figures) is obtained when printing two pictures on a single page.

5.6.3 Including a Postscript File in LaTeX

The `Blatexpr` Unix shell and the programs `Batexpr2` and `Blatexprs` are provided in order to help inserting Scilab graphics in LaTeX.

Taking the previous file `foo.ps` and typing the following statement under a Unix shell :

```
Blatexpr 1.0 1.0 foo.ps
```

creates two files `foo.epsf` and `foo.tex`. The original Postscript file is left unchanged. To include the figure in a LaTeX document you should insert the following LaTeX code in your LaTeX document :

```
\input foo.tex
\dessin{The caption of your picture}{The-label}
```

You can also see your figure by using the Postscript previewer `ghostview`.

The program `Blatexprs` does the same thing: it is used to insert a set of Postscript figures in one LaTeXpicture.

In the following example, we begin by using the Postscript driver `Pos` and then initialize successively 4 Postscript files `fig1.ps, ..., fig4.ps` for 4 different plots and at the end return to the driver `Rec` (X11 driver with record).

```
-->//multiple Postscript files for Latex

-->driver('Pos')

-->
-->t=%pi*(-10:10)/10;

-->

-->plot3d1(t,t,sin(t)'*cos(t),35,45,'X@Y@Z',[2,2,4]);

-->xend()

-->

-->contour(1:5,1:10,rand(5,10),5);

-->xend()

-->

-->champ(1:10,1:10,rand(10,10),rand(10,10));

-->xend()

-->

-->t=%pi*(-10:10)/10;

-->deff('[z]=surf(x,y)','z=sin(x)*cos(y)');

-->rect=[-%pi,%pi,-%pi,%pi,-5,1];

-->z=feval(t,t,surf);

-->contour(t,t,z,10,35,45,'X@Y@Z',[1,1,0],rect,-5);

-->plot3d(t,t,z,35,45,'X@Y@Z',[2,1,3],rect);
```

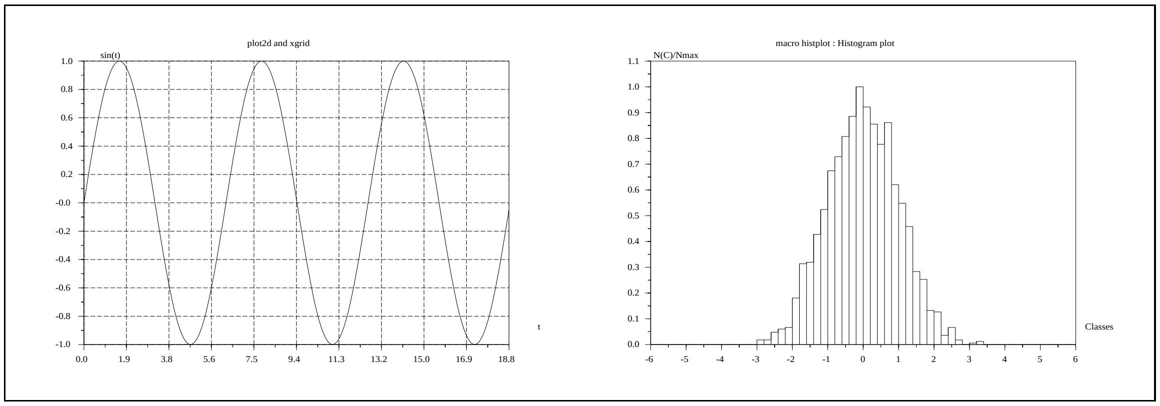

Figure 5.9: Blatexp2 Example

```
-->title=['plot3d and contour '];

-->xtitle(title,' ',' ');

-->xend()

-->
-->driver('Rec')
```

Then we execute the command :

```
Blatexprs multi fig1.ps fig2.ps fig3.ps fig4.ps
```

and we get 2 files `multi.tex` and `multi.ps` and you can include the result in a LaTeX source file by :

```
\input multi.tex
\dessin{The caption of your picture}{The-label}
```

Note that the second line `dessin...` is absolutely necessary and you have of course to give the absolute path for the input file if you are working in another directory (see below). The file `multi.tex` is only the definition of the command `dessin` with 2 parameters : the caption and the label; the command `dessin` can be used with one or two empty arguments ‘‘ ‘‘ if you want to avoid the caption or the label.

The Postscipt files are inserted in LaTeX with the help of the `\special` command and with a syntax that works with the `dvips` program.

The program `Blatexpr2` is used when you want two pictures side by side.

```
Blatexpr2 Fileres file1.ps file2.ps
```

It is sometimes convenient to have a main LaTeX document in a directory and to store all the figures in a subdirectory. The proper way to insert a picture file in the main document, when the picture is stored in the subdirectory `figures`, is the following :

```
\def\Figdir{figures/} % My figures are in the {\tt figures/ } subdirectory.
\input{\Figdir fig.tex}
\dessin{The caption of you picture}{The-label}
```

The declaration `\def\Figdir{figures/}` is used twice, first to find the file `fig.tex` (when you use `latex`), and second to produce a correct pathname for the `special` LaTeX command found in `fig.tex`. (used at dvips level).

-WARNING : the default driver is `Rec`, i.e. all the graphic commands are recorded, one record corresponding to one window. The `xbasc()` command erases the plot on the active window and all the records corresponding to this window. The `clear` button has the same effect; the `xclear` command erases the plot but the record is preserved. So you almost never need to use the `xbasc()` or `clear` commands. If you use such a command and if you re-do a plot you may have a surprising result (if you forget that the environment is wiped out); the scale only is preserved and so you may have the "window-plot" and the "paper-plot" completely different.

5.6.4 Postscript by Using Xfig

Another useful way to get a Postscript file for a plot is to use Xfig. By the simple command `xs2fig(active-window-number,file-name)` you get a file in Xfig syntax.

This command needs the use of the driver `Rec`.

The window ScilabGraphic0 being active, if you enter :

```
-->t=-%pi:0.3:%pi;

-->plot3d1(t,t,sin(t)'*cos(t),35,45,'X@Y@Z',[2,2,4]);

-->xs2fig(0,'demo.fig');
```

you get the file `demo.fig` which contains the plot of window 0.

Then you can use Xfig and after the modifications you want, get a Postscript file that you can insert in a LaTeX file. The following figure is the result of Xfig after adding some comments.

5.6.5 Encapsulated Postscript Files

As it was said before, the use of `Blatexpr` creates 2 files : a `.tex` file to be inserted in the LaTeX file and a `.epsf` file.

It is possible to get the encapsulated Postscript file corresponding to a `.ps` file by using the command `BEpsf`.

Notice that the `.epsf` file generated by `Blatexpr` is not an encapsulated Postscript file : it has no bounding box and `BEpsf` generates a `.eps` file which is an encapsulated Postscript file with a bounding box.

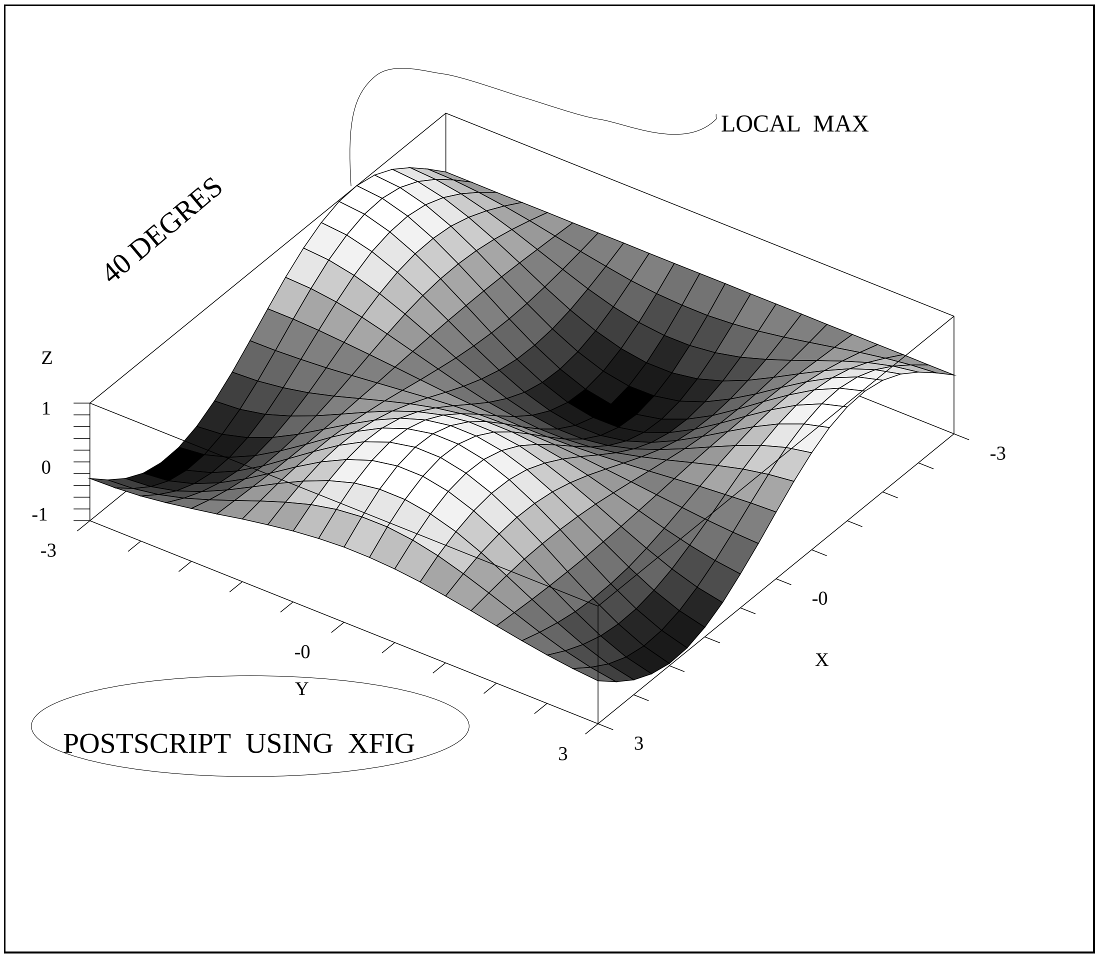

Figure 5.10: Encapsulated Postscript by Using Xfig

Chapter 6

Maple to Scilab Interface

To combine symbolic computation of the computer algebra system Maple with the numerical facilities of Scilab, Maple objects can be transformed into Scilab functions. To assure efficient numerical evaluation this is done through numerical evaluation in Fortran. The whole process is done by a Maple procedure called `maple2scilab`.

6.1 Maple2scilab

The procedure `maple2scilab` converts a Maple object, either a scalar function or a matrix into a Fortran subroutine and writes the associated Scilab function. The code of `maple2scilab` is in the directory `SCIDIR/maple`.

The calling sequence of `maple2scilab` is as follows:
`maple2scilab(function-name,object,args)`

- The first argument, `function-name` is a name indicating the function-name in Scilab.
- The second argument `object` is the Maple name of the expression to be transferred to Scilab.
- The third argument is a list of arguments containing the formal parameters of the Maple-object `object`.

When `maple2scilab` is invoked in Maple, two files are generated, one which contains the Fortran code and another which contains the associated Scilab function. Aside their existence, the user has not to know about their contents.

The Fortran routine which is generated has the following calling sequence:
`<Scilab-name>(x1,x2,...,xn,matrix)`
and this subroutine computes matrix(i,j) as a function of the arguments `x1,x2,...,xn`. Each argument can be a Maple scalar or array which should be in the argument list. The Fortran subroutine is put into a file named `<Scilab-name>.f`, the Scilab-function into a file named `<Scilab-name>.sci`. For numerical evaluation in Scilab the user has to compile the Fortran subroutine, to link it with Scilab (e.g. Menu-bar option '`link`') and to load the associated function (Menu-bar option '`getfc`'). Information about `link` operation is given in Scilab's manual: Fortran routines can be incorporated into Scilab by dynamic link or through the `interf.f` file in the `default` directory. Of course, this two-step procedure can be automatized using a shell-script (or using `unix` in Scilab). Maple2scilab uses the "Macrofort" library which is in the share library of Maple.

6.1.1 Simple Scalar Example

Maple-Session

```
> read(`maple2scilab.maple`):
> f:=b+a*sin(x);

                              f := b + a sin(x)

> maple2scilab('f_m',f,[x,a,b]);
```

Here the Maple variable `f` is a scalar expression but it could be also a Maple vector or matrix. `'f_m'` will be the name of `f` in Scilab (note that the Scilab name is restricted to contain at most 6 characters). The procedure `maple2scilab` creates two files: `f_m.f` and `f_m.sci` in the directory where Maple is started. To specify another directory just define in Maple the path : `rpath:=`/work/``; then all files are written in the sub-directory `work`. The file `f_m.f` contains the source code of a stand alone Fortran routine which is dynamically linked to Scilab by the function `f_m` in defined in the file `f_m.sci`.

Scilab Session

```
-->unix('make f_m.o');

-->link('f_m.o','f_m');

linking  _f_m_ defined in f_m.o

-->getf('f_m.sci','c')

-->f_m(%pi,1,2)
 ans       =

    2.
```

6.1.2 Matrix Example

This is an example of transferring a Maple matrix into Scilab.

Maple Session

```
> with(linalg):read(`maple2scilab.maple`):

> x:=vector(2):par:=vector(2):

> mat:=matrix(2,2,[x[1]^2+par[1],x[1]*x[2],par[2],x[2]]);

                              [     2                     ]
                              [ x[1]   + par[1]  x[1] x[2] ]
                      mat :=  [                           ]
                              [     par[2]          x[2]   ]
```

```
> maple2scilab('mat',mat,[x,par]);
```

Scilab Session

```
-->unix('make mat.o');

-->link('mat.o','mat')

linking  _mat_ defined in mat.o

-->getf('mat.sci','c')

-->par=[50;60];x=[1;2];

-->mat(x,par)
 ans       =

!   51.    2. !
!   60.    2. !
```

Generated code Below is the code (Fortran subroutines and Scilab functions) which is automatically generated by `maple2scilab` in the two preceding examples.

Fortran routines

```
c
c     SUBROUTINE f_m
c
      subroutine f_m(x,a,b,fmat)
      doubleprecision x,a,b
      implicit doubleprecision (t)
      doubleprecision fmat(1,1)
         fmat(1,1) = b+a*sin(x)
      end

c
c     SUBROUTINE mat
c
      subroutine mat(x,par,fmat)
      doubleprecision x,par(2)
      implicit doubleprecision (t)
      doubleprecision fmat(2,2)
         t2 = x(1)**2
         fmat(2,2) = x(2)
         fmat(2,1) = par(2)
         fmat(1,2) = x(1)*x(2)
         fmat(1,1) = t2+par(1)
      end
```

Scilab functions

```
function [var]=f_m(x,a,b)
var=fort('f_m',x,1,'d',a,2,'d',b,3,'d','out',[1,1],4,'d')
//end

function [var]=fmat(x,par)
var=fort('fmat',x,1,'d',par,2,'d','out',[2,2],3,'d')
//end
```

Appendix A

A demo session

We give here the Scilab session corresponding to the first demo.

```
-->//SCILAB OBJECTS 1. SCALARS

-->a=1               //constant
 a  =

    1.

-->1==1              //boolean
 ans  =

  T

-->'string'          //character string
 ans  =

 string

-->z=poly(0,'z')     // polynomial with variable 'z' and with one root at zero
 z  =

    z

-->p=1+3*z+4.5*z^2   //polynomial
 p  =

                 2
    1 + 3z + 4.5z

-->r=z/p             //rational
 r  =

          z
    -------------
                 2
```

```
    1 + 3z + 4.5z

-->//SCILAB OBJECTS 2. MATRICES

-->a=[a+1 2 3
     0 0 atan(1)
     5 9 -1]       //constant matrix
 a  =

!   2.    2.    3.        !
!   0.    0.    0.7853982 !
!   5.    9.  - 1.        !

-->b=[%t,%f]          //boolean matrix
 b  =

! T F !

-->mc=['this','is';
    'a' ,'matrix'] //matrix of strings
 mc  =

!this  is      !
!              !
!a     matrix  !

-->mp=[p,1-z;
    1,z*p]         //polynomial matrix
 mp  =

!                2                  !
!   1 + 3z + 4.5z     1 - z         !
!                                   !
!                           2      3 !
!   1                 z + 3z + 4.5z  !

-->mp=[p 1-z]
 mp  =

!                2          !
!   1 + 3z + 4.5z     1 - z  !

-->mp=[mp;1 1+z*p]    //matrix polynomial
 mp  =

!                2                      !
!   1 + 3z + 4.5z     1 - z             !
!                                       !
```

```
!                                2      3 !
!   1                  1 + z + 3z + 4.5z  !

-->f=mp/poly([1+%i 1-%i 1],'z')   //rational matrix
 f  =

!                 2                         !
!    1 + 3z + 4.5z        - 1               !
!   ---------------     ---------           !
!              2   3              2         !
! - 2 + 4z - 3z + z     2 - 2z + z          !
!                                           !
!                                  2      3 !
!          1            1 + z + 3z + 4.5z  !
!   ---------------     -----------------  !
!              2   3                2   3  !
! - 2 + 4z - 3z + z    - 2 + 4z - 3z + z   !

-->//SCILAB OBJECTS 3. LISTS

-->l=list(a,-(1:5), mp,['this','is';'a','list'])   //list
 l  =


       l>1

!   2.    2.    3.        !
!   0.    0.    0.7853982 !
!   5.    9.  - 1.        !

       l>2

! - 1.  - 2.  - 3.  - 4.  - 5. !

       l>3

!                 2                       !
!   1 + 3z + 4.5z     1 - z               !
!                                         !
!                                2      3 !
!   1                  1 + z + 3z + 4.5z  !

       l>4

!this  is    !
!            !
!a     list  !
```

```
-->b=[1 0;0 1;0 0];c=[1 -1 0];d=0*c*b;x0=[0;0;0];

-->sl=syslin('c',a,b,c,d,x0)    //Linear system in state-space representation.
 sl  =


      sl(1)   (state-space system:)

 lss

      sl(2) = A matrix =

!   2.    2.    3.        !
!   0.    0.    0.7853982 !
!   5.    9.  - 1.        !

      sl(3) = B matrix =

!   1.    0. !
!   0.    1. !
!   0.    0. !

      sl(4) = C matrix =

!   1.  - 1.    0. !

      sl(5) = D matrix =

!   0.    0. !

      sl(6) = X0 (initial state) =

!   0. !
!   0. !
!   0. !

      sl(7) = Time domain =

 c

-->slt=ss2tf(sl)                //  Transfer matrix
 slt  =

!                           2                               2          !
!       - 10.995574 + s + s                      46 + 3s - s           !
!   -----------------------------      -----------------------------   !
!                              2   3                               2     !
!   6.2831853 - 24.068583s - s + s     6.2831853 - 24.068583s - s      !
```

```
!        3                                                           !
!     + s                                                            !

-->//                  OPERATIONS

-->v=1:5;v*v'                   //constant matrix
 ans  =

    55.

-->mp'*mp+eye                   //polynomial matrix
 ans  =

!              2     3       4                  2                    !
!   3 + 6z + 18z + 27z + 20.25z     2 + 3z + 4.5z                    !
!                                                                    !
!               2                        2     3     4     5       6 !
!   2 + 3z + 4.5z                   3 + 8z + 15z + 18z + 27z + 20.25z  !

-->mp1=mp(1,1)+4.5*%i           //complex
 mp1  =

real part


               2
    1 + 3z + 4.5z
imaginary part


    4.5

-->fi=c*(z*eye-a)^(-1)*b;       //transfer function evaluation

-->f(:,1)*fi                    //rationals
 ans  =


         column 1

!                                              2      3      4       !
!         - 10.995574 - 31.986723z - 45.480084z + 7.5z + 4.5z        !
!   -----------------------------------------------------------------  !
!                                      2            3            4    !
! - 12.566371 + 73.269908z - 113.12389z + 72.488936z - 17.068583z     !
!          5   6                                                     !
!      - 4z + z                                                      !
!                                                                    !
```

```
!                                     2                    !
!                     - 10.995574 + z + z                  !
!   ------------------------------------------------------ !
!                                2            3            4    !
! - 12.566371 + 73.269908z - 113.12389z + 72.488936z - 17.068583z     !
!          5   6                                            !
!      - 4z + z                                             !

         column 2

!                               2       3      4             !
!                  46 + 141z + 215z + 10.5z - 4.5z           !
!   ------------------------------------------------------ !
!                                2            3            4    !
! - 12.566371 + 73.269908z - 113.12389z + 72.488936z - 17.068583z     !
!          5   6                                            !
!      - 4z + z                                             !
!                                                           !
!                                  2                        !
!                            46 + 3z - z                    !
!   ------------------------------------------------------ !
!                                2            3            4    !
! - 12.566371 + 73.269908z - 113.12389z + 72.488936z - 17.068583z     !
!          5   6                                            !
!      - 4z + z                                             !

-->m=[mp -mp; mp' mp+eye]       //usual Matlab syntax for polynomials
 m  =


         column 1 to 3

!               2                                    2 !
!   1 + 3z + 4.5z     1 - z              - 1 - 3z - 4.5z  !
!                                                      !
!                             2      3                 !
!   1                 1 + z + 3z + 4.5z   - 1          !
!                                                      !
!               2                                    2 !
!   1 + 3z + 4.5z     1                    2 + 3z + 4.5z  !
!                                                      !
!                             2      3                 !
!   1 - z             1 + z + 3z + 4.5z     1          !

         column 4

! - 1 + z               !
!                       !
```

```
!             2      3 !
! - 1 - z - 3z - 4.5z  !
!                      !
!   1 - z              !
!                      !
!             2      3 !
!   2 + z + 3z + 4.5z  !

-->[fi, fi(:,1)]                // ... or rationals
 ans  =


         column 1 to 2

!                         2                                2           !
!       - 10.995574 + z + z                      46 + 3z - z           !
!   -----------------------------      -----------------------------   !
!                            2   3                                2    !
!   6.2831853 - 24.068583z - z + z     6.2831853 - 24.068583z - z      !
!         3                                                            !
!      + z                                                             !

         column 3

!                         2        !
!       - 10.995574 + z + z        !
!   -----------------------------  !
!                            2   3 !
!   6.2831853 - 24.068583z - z + z  !

-->f=syslin('c',f);

-->num=f(2);den=f(3);           //operation on transfer matrix

-->//                  SOME NUMERICAL PRIMITIVES

-->inv(a)                       //Inverse
 ans  =

!   1.125  - 4.6154933  - 0.25 !
! - 0.625    2.705634     0.25 !
!   0.       1.2732395    0.   !

-->inv(mp)                      //Inverse
 ans  =

!                  2      3                                          !
!        - 1 - z - 3z - 4.5z                        1 - z            !
```

```
!   ------------------------------     ------------------------------  !
!             2     3     4        5              2     3     4       !
! - 5z - 10.5z - 18z - 27z - 20.25z   - 5z - 10.5z - 18z - 27z        !
!              5                                                       !
!      - 20.25z                                                        !
!                                                                      !
!                                                         2            !
!                  1                           - 1 - 3z - 4.5z         !
!   ------------------------------     ------------------------------  !
!             2     3     4        5              2     3     4       !
! - 5z - 10.5z - 18z - 27z - 20.25z   - 5z - 10.5z - 18z - 27z        !
!              5                                                       !
!      - 20.25z                                                        !

-->inv(sl*sl')                  //Product of two linear systems and inverse
 ans  =


      ans(1)   (state-space system:)

 lss

      ans(2) = A matrix =

!   5.9830447  - 2.7428339    7.3183626  - 4.2885178 !
!   2.6071355    6.0712325  - 7.7859471  - 5.4755708 !
!   0.         - 1.998D-15  - 4.9854125  - 0.7866233 !
!   0.           3.220D-15    0.5793044  - 5.0688648 !

      ans(3) = B matrix =

! - 12.503402 !
! - 6.1225032 !
!   2.1610821 !
! - 2.2230824 !

      ans(4) = C matrix =

! - 0.9983022    4.0965198  - 7.074889    0.1816573 !

      ans(5) = D matrix =

                                   2
    2.4292037 - 9.021D-17s + 0.5s

      ans(6) = X0 (initial state) =

!   0. !
```

```
!   0. !
!   0. !
!   0. !

       ans(7) = Time domain =

 c

-->w=ss2tf(ans)                 //Transfer function representation
 w  =

                                       2            3            4
   19.739209 - 151.22737s + 283.36517s + 30.351769s - 23.568583s
        5      6
      - s + 0.5s
   ------------------------------------------------------------------
                                                  2    3   4
              1118.4513 + 127.00443s - 51.995574s - 2s + s

-->inv(ss2tf(sl)*ss2tf(sl'))    //Product of two transfer functions and inverse
 ans  =

                                       2            3            4
   39.478418 - 302.45474s + 566.73034s + 60.703538s - 47.137167s
         5   6
      - 2s + s
   ------------------------------------------------------------------
                                                 2    3    4
             2236.9027 + 254.00885s - 103.99115s - 4s + 2s

-->clean(w-ans)
 ans  =

   0
   -
   1

-->n=contr(a,b)                 //Controllability
 n  =

   3.

-->k=ppol(a,b,[-1-%i -1+%i -1])        //Pole placement
 k  =

!   0.1832061  - 0.3358779    1.740458  !
!   2.7463953    3.8167939    1.7650419 !
```

```
-->poly(a-b*k,'z')-poly([-1-%i -1+%i -1],'z')    //Check...
 ans  =

                            2
  - 2.154D-14 + 2.665D-15z

-->s=sin(0:0.1:5*%pi);

-->ss=fft(s(1:128),-1);        //FFT

-->xbasc();

-->plot2d3("enn",1,abs(ss)');      //simple plot

-->x=lyap(a,diag([1 2 3]),'cont')   //Lyapunov equation
 x  =

! - 1.4958251  - 4.3299851    0.6983300 !
! - 4.3299851  - 0.3504060    1.07333   !
!   0.6983300    1.07333      1.4379815 !

-->//              ON LINE DEFINITION OF MACRO

-->deff('[x]=fact(n)','if n=0 then x=1,else x=n*fact(n-1),end')

-->10+fact(5)
 ans  =

    130.

-->//                    OPTIMIZATION

-->deff('[f,g,ind]=rosenbro(x,ind)', 'a=x(2)-x(1)^2 , b=1-x(2) ,...
f=100.*a^2 + b^2 , g(1)=-400.*x(1)*a , g(2)=200.*a -2.*b ');

-->comp(rosenbro);[f,x,g]=optim(rosenbro,[2;2],'qn')
 norm of projected gradient lower than   0.0000000D+00

 g  =

!   0. !
!   0. !
 x  =

!   1. !
!   1. !
 f  =
```

```
    0.

-->//                   SIMULATION

-->a=rand(3,3)
 a  =

!   0.3616361    0.4826472    0.5015342 !
!   0.2922267    0.3321719    0.4368588 !
!   0.5664249    0.5935095    0.2693125 !

-->e=exp(a)
 e  =

!   1.8016766    0.9861359    0.9295708 !
!   0.6462788    1.7366226    0.7731203 !
!   1.0024892    1.1047133    1.7455217 !

-->deff('[ydot]=f(t,y)','ydot=a*y');comp(f)

-->e(:,1)-ode([1;0;0],0,1,f)
 ans  =

! - 6.303D-08 !
! - 5.028D-08 !
! - 6.558D-08 !

-->//                  SYSTEM DEFINITION

-->s=poly(0,'s')
 s  =

    s

-->h=[1/s,1/(s+1);1/s/(s+1),1/(s+2)/(s+2)]
 h  =

!   1           1         !
!   -         -----       !
!   s         1 + s       !
!                         !
!     1           1       !
!   -----     ---------   !
!        2              2 !
!   s + s     4 + 4s + s  !

-->w=tf2ss(h);
```

```
-->ss2tf(w)
 ans  =

!        1             1             !
!   -------------     -----          !
! - 3.768D-15 + s     1 + s          !
!                                    !
!     1               1 + 1.548D-15s !
!   -----             -------------- !
!        2                        2  !
!   s + s               4 + 4s + s   !

-->h1=clean(ans)
 h1  =

!   1           1         !
!   -         -----       !
!   s         1 + s       !
!                         !
!     1           1       !
!   -----     ---------   !
!        2              2 !
!   s + s     4 + 4s + s  !

-->//             EXAMPLE: SECOND ORDER SYSTEM ANALYSIS

-->sl=syslin('c',1/(s*s+0.2*s+1))
 sl  =

        1
    -----------
               2
    1 + 0.2s + s

-->instants=0:0.05:20;

-->//             step response:

-->y=csim('step',instants,sl);

-->xbasc();plot2d(instants',y')

-->//             Delayed step response

-->deff('[in]=u(t)','if t<3 then in=0;else in=1;end');

-->comp(u);
```

```
-->y1=csim(u,instants,sl);plot2d(instants',y1');

-->//            Impulse response;

-->yi=csim('imp',instants,sl);xbasc();plot2d(instants',yi');

-->yi1=csim('step',instants,s*sl);plot2d(instants',yi1');

-->//             Discretization

-->dt=0.05;

-->sld=dscr(tf2ss(sl),0.05);

-->//              Step response

-->u=ones(instants);
Warning :redefining function: u


-->yyy=flts(u,sld);

-->xbasc();plot(instants,yyy)

-->//             Impulse response

-->u=0*ones(instants);u(1)=1/dt;

-->yy=flts(u,sld);

-->xbasc();plot(instants,yy)

-->//           system interconnexion

-->w1=[w,w];

-->clean(ss2tf(w1))
 ans  =

!   1          1           1           1         !
!   -        -----         -         -----       !
!   s        1 + s         s         1 + s       !
!                                                !
!     1          1           1           1       !
!   -----    ---------     -----     ---------   !
!       2              2         2             2 !
!   s + s    4 + 4s + s    s + s     4 + 4s + s  !
```

```
-->w2=[w;w];

-->clean(ss2tf(w2))
 ans  =

!   1           1         !
!   -         -----       !
!   s         1 + s       !
!                         !
!     1           1       !
!   -----     ---------   !
!        2             2  !
!   s + s     4 + 4s + s  !
!                         !
!   1           1         !
!   -         -----       !
!   s         1 + s       !
!                         !
!     1           1       !
!   -----     ---------   !
!        2             2  !
!   s + s     4 + 4s + s  !

-->//               change of variable

-->z=poly(0,'z');

-->horner(h,(1-z)/(1+z))  //bilinear transform
 ans  =

!             2             2 !
! - 7 - 8z - z     1 + 2z + z  !
!   ----------     ----------  !
!             2             2 !
! - 5 + 4z + z   - 5 + 4z + z  !
!                              !
!             2             2 !
! - 7 - 8z - z     1 + 2z + z  !
!   ----------     ----------  !
!             2             2 !
! - 5 + 4z + z   - 5 + 4z + z  !

-->//                 PRIMITIVES

-->H=[1.    1.    1.    0.;
   2.  - 1.    0.    1;
   1.    0.    1.    1.;
   0.    1.    2.  - 1];
```

```
-->ww=spec(H)
 ww  =

!   2.7320508 !
! - 2.7320508 !
!   0.7320508 !
! - 0.7320508 !

-->//             STABLE SUBSPACES

-->[X,d]=schur(H,'cont');

-->X'*H*X
 ans  =

! - 2.7320508  - 1.110D-15    0.           1.         !
!   0.         - 0.7320508  - 1.         - 7.772D-16 !
!   7.216D-16    0.           2.7320508    0.         !
!   0.         - 6.106D-16    0.           0.7320508 !

-->[X,d]=schur(H,'disc');

-->X'*H*X
 ans  =

!   0.7320508    0.           7.772D-16    1.         !
!   0.         - 0.7320508  - 1.           8.604D-16 !
!   0.           0.           2.7320508  - 1.166D-15 !
!   7.772D-16    1.110D-15  - 1.277D-15  - 2.7320508 !

-->//Selection of user-defined eigenvalues (# 3 and 4 here);

-->deff('[flg]=sel(x)','flg=0,ev=x(2)/x(3),if abs(ev-ww(3))<0.0001|abs(ev-ww(4))<0.00001 then flg=1,end')

-->[X,d]=schur(H,sel)
 d  =

    2.
 X  =

! - 0.5705632  - 0.2430494  - 0.6640233  - 0.4176813 !
! - 0.4176813    0.6640233  - 0.2430494    0.5705632 !
!   0.5705632  - 0.2430494  - 0.6640233    0.4176813 !
!   0.4176813    0.6640233  - 0.2430494  - 0.5705632 !

-->X'*H*X
 ans  =
```

```
!   0.7320508    0.           7.772D-16    1.         !
!   0.         - 0.7320508  - 1.           8.604D-16 !
!   0.           0.           2.7320508  - 1.166D-15 !
!   7.772D-16    1.110D-15  - 1.277D-15  - 2.7320508 !

-->//               With matrix pencil

-->[X,d]=gschur(H,eye(H),sel)
 d  =

    2.
 X  =

!   0.5705632    0.2430494    0.6640233    0.4176813 !
!   0.4176813  - 0.6640233    0.2430494  - 0.5705632 !
! - 0.5705632    0.2430494    0.6640233  - 0.4176813 !
! - 0.4176813  - 0.6640233    0.2430494    0.5705632 !

-->X'*H*X
 ans  =

!   0.7320508    0.           9.576D-16    1.         !
!   0.         - 0.7320508  - 1.           0.         !
!   8.882D-16    0.           2.7320508    0.         !
!   0.           0.           0.         - 2.7320508 !

-->//            block diagonalization

-->[ab,x,bs]=bdiag(H);

-->inv(x)*H*x
 ans  =

!   2.7320508    1.610D-15    0.           0.         !
! - 3.664D-15  - 2.7320508    0.           6.661D-16 !
!   0.           0.           0.7320508  - 7.910D-16 !
!   0.           0.           0.         - 0.7320508 !

-->//                     Matrix pencils

-->E=rand(3,2)*rand(2,3);

-->A=rand(3,2)*rand(2,3);

-->s=poly(0,'s');

-->w=det(s*D-A)   //determinant
```

```
 w  =

                             2
  - 0.0801176s + 0.0423727s

-->[al,be]=gspec(A,E);

-->al./(be+%eps*ones(be))
 ans  =

!   1.687D+15 !
!   1.8907826 !
! - 7.445D-17 !

-->roots(w)
 ans  =

!   0         !
!   1.8907826 !

-->[Ns,d]=coffg(s*D-A);    //inverse of polynomial matrix;

-->clean(Ns/d*(s*D-A))
 ans  =

!   1     0     0  !
!   -     -     -  !
!   1     1     1  !
!                  !
!   0     1     0  !
!   -     -     -  !
!   1     1     1  !
!                  !
!   0     0     1  !
!   -     -     -  !
!   1     1     1  !

-->[Q,M,i1]=pencan(E,A);   // Canonical form;
    rank A^k    rcond
        2.      0.354D+00
    rank A^k    rcond
        2.      0.547D+00

-->M*E*Q
 ans  =

!   1.           4.718D-16    2.776D-16 !
!   1.318D-15    1.           0.        !
```

```
!   2.725D-16    0.           0.       !

-->M*A*Q
 ans  =

!   1.8609512    0.4018602  - 4.441D-16 !
!   0.1381447    0.0298314    0.        !
!   0.           0.           1.        !

-->//           PAUSD-RESUME

-->write(%io(2),'pause command...');
pause command...

-->write(%io(2),'TO CONTINUE...');
TO CONTINUE...

-->write(%io(2),'ENTER ''resume (or return) or click on resume!!''');
ENTER 'resume (or return) or click on resume!!'

-->pause;

-1->resume;

-->//           CALLING EXTERNAL ROUTINE

-->foo=['      subroutine foo(a,b,c)';
     '      c=a+b';
     '      end'  ];

-->unix_s('\rm foo.f')

-->write('foo.f',foo);

-->unix_s('make foo.o')     //Compiling...(needs fortran compiler)

-->//..................WARNING.......................

-->//NEXT COMMAND LINE WILL DO THE LINK OF THE ROUTINE foo WITH SCILAB

-->//THIS COMMAND MAY FAIL FOR SystemV COMPILED VERSIONS OF SCILAB

-->//BECAUSE LINK NEEDS THE LIBRARIES (SEE THE HELP OF "LINK" COMMAND)

-->link('foo.o','foo')    //Linking to Scilab

-->//5+7 by fortran
```

```
-->fort('foo',5,1,'r',7,2,'r','out',[1,1],3,'r')
 ans  =

    12.

-->
```

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