MATLAB and Octave

An Introduction

INTRODUCTION

- Octave and MATLAB are high-level languages, primarily intended for numerical computations.
- They provide a convenient command line interface for solving linear and nonlinear problems numerically.
- They can also be used for prototyping and performing other numerical experiments.

Octave

- MATLAB is a proprietary product that requires a license.
- Octave is freely redistributable software. You may redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation.
- This document corresponds to Octave version 2.0.13.

Starting Octave

- To start Octave type the shell command octave. You see a message then a prompt:

  `octave:1>`

- If you get into trouble, you can usually interrupt octave by typing **`Ctrl-C`** to return to the prompt.
- To exit Octave, type **`quit`** or **`exit`** at the prompt.

Creating a matrix

- To create a new matrix and store it in a variable, type the command:

  octave:1>
  A=[1,1,2;3,5,8;13,21,34]

- Octave will respond by printing the matrix in neatly aligned columns.

```
1    1     2
3    5     8
13   21    34
```

Controlling matrix output

- Ending a command with a semicolon tells Octave to not print the result of a command.

```
octave:2> B=rand(3,2);
```

- will create a 3 row, 2 column matrix with each element set to a random value between zero and one.
- To display the value of any variable, simply type the name of the variable.

```
octave:3> B
```

Matrix arithmetic

- Octave has a convenient operator notation for performing matrix arithmetic. To multiply the matrix a by a scalar, type:

  octave:4> 2*A

- To multiply the two matrices **A** and **B**, type:

  octave:5> A*B

- To form the matrix product type:

  octave:6> A'*A

Solving linear equations

- To solve the set of linear equations **`Ax=b,`** use the left division operator \ :

  `octave:7> A\b`

- This is conceptually equivalent to inverting the **`A`** matrix but avoids computing the inverse of a matrix directly.
- If the coefficient matrix is singular, Octave will print a warning message.

Graphical output

- To display an x-y plot, use the command:
  `octave:8> plot(x,sin(x))`
- If you are using the X Window System, Octave will automatically create a separate window to display the plot.
- Octave uses gnuplot to display graphics, and can display graphics on any terminal that is supported by gnuplot.

Getting hardcopy

- To capture the output of the plot command in a file rather than sending the output directly to your terminal, you can use a set of commands like this:

  ```
  gset term postscript
  gset output "foo.ps"
  replot
  ```

- This will work for other types of output devices as well.

DATA TYPES

- The standard built-in data types are
  - real and complex **scalars**,
  - real and complex **matrices**,
  - **ranges**,
  - **character strings**,
  - a **data structure** type.

Numeric data objects

- All built-in numeric data is currently stored as double precision numbers.
- On systems that use the IEEE floating point format, values in the range of approximately **1.80e+308** to **2.23e-308** can be stored, and the relative precision is approximately **2.22e-16.**
- The exact values are given by the variables **realmin, realmax** and **eps** respectively.

Matrix objects

- Matrix objects can be of any size, and can be dynamically reshaped and resized.
- It is easy to extract:
  - **rows**, `A(i,:)` selects the **`i`**th row of the matrix,
  - **columns** , `A(:,j)` selects the **`j`**th column of the matrix, or
  - **sub-matrices**, `A([i1:i2],[j1:j2])` selects rows **`i1`** to **`i2`** and columns **`j1`** to **`j2`**.

Range objects

- A range expression is defined by the value of the first element in the range, an optional value for the increment between elements, and a maximum value which the elements of the range will not exceed.
- The base, increment, and limit are separated by colons and may contain any arithmetic expressions and function calls.

String objects

- A character string in Octave consists of a sequence of characters enclosed in either double-quote or single-quote marks.
- Internally, Octave currently stores strings as matrices of characters.
- All the indexing operations that work for matrix objects also work for strings.

Data structure objects

- Octave's data structure type can help you to organize related objects of different types.
- The current implementation uses an associative array with indices limited to strings

```
x.a=1
x.b=[1,2;3,4]
x.c="string"
```

creates a structure with three elements.

Object sizes

- A group of functions allow you to display the size of a variable or expression.
- These functions are defined for all objects. They return -1 when the operation doesn't make sense.
- For example, the data structure type doesn't have rows or columns, so the rows and columns functions return -1 for structure arguments.

Object size functions

- **`columns(A)`**
  - Return the number of columns of **`A.`**
- **`rows(A)`**
  - Return the number of rows of **`A.`**
- **`length(A)`**
  - Return the number of rows of **`A`** or the number of columns of **`A,`** whichever is larger.

More object size functions

- **`d=size(A)`**
  - Return the number rows and columns of **`A`**, the result is returned in the 2 element row vector **`d`**.
- **`[nr,nc]=size(A)`**
  - The number of rows is assigned to **`nr`** and the number of columns is assigned to **`nc`**.
- **`d=size(A,n)`**
  - A second argument of either **`n=1`** or **`n=2`**, size will return only the row or column dimension.

Detecting object properties

- **`is_matrix(A)`**
  - Return 1 if **A** is a matrix. Otherwise, return 0.
- **`is_vector(A)`**
  - Return 1 if **A** is a vector. Otherwise, return 0.
- **`is_scalar(A)`**
  - Return 1 if **A** is a scalar. Otherwise, return 0.

Detecting matrix properties

- **`is_square(A)`**
  - If **`A`** is a square matrix, then return the dimension of **`A`**. Otherwise, return 0.
- **`is_symmetric(A,tol)`**
  - If A is symmetric within the tolerance specified , then return the dimension of **`A.`** Otherwise, return 0. If **`tol`** is omitted, **`tol=eps`**
- **`isempty(A)`**
  - If **`A`** is empty return 1. Otherwise, return 0.

Range definition

- The range **`1:5`**
  - defines the set of values **`[1,2,3,4,5]`**.
- The range **`1:2:5`**
  - defines the set of values **`[1,3,5]`**.
- The range **`1:3:5`**
  - defines the set of values **`[1,4]`**.
- The range **`5:-3:1`**
  - defines the set of values **`[5,2]`**.

More about ranges

- Note that the upper (or lower, if the increment is negative) bound on the range is not always included in the set of values.
- Ranges defined by floating point values can produce surprising results because floating point arithmetic is used.
- If it is important to include the endpoints of a range and the number of elements is known, use the **`linspace()`** function.

Special matrix object eye()

- **`eye(x)`**
  - If invoked with a single scalar argument, eye returns a square identity matrix with the dimension specified.
- **`eye(n,m) or eye(size(A))`**
  - If you supply two scalar arguments, eye takes them to be the number of rows and columns.
- **`eye`**
  - Calling eye with no arguments is equivalent to calling it with an argument of 1.

Special matrix object ones()

- **ones(x)**
  - If invoked with a single scalar argument, ones returns a square matrix of 1's with the dimension specified.
- **ones(n,m) or ones(size(A))**
  - If you supply two scalar arguments, ones takes them to be the number of rows and columns.
- **ones**
  - Calling ones with no arguments is equivalent to calling it with an argument of 1.

Special matrix object zeros()

- **`zeros(x)`**
  - If invoked with a single scalar argument, zeros returns a square matrix of 0's with the dimension specified.
- **`zeros(n,m) or zeros(size(A))`**
  - If you supply two scalar arguments, zeros takes them to be the number of rows and columns.
- **`zeros`**
  - Calling zeros with no arguments is equivalent to calling it with an argument of 1.

Special matrix object rand()

- **`rand(x)`**
  - If invoked with a single scalar argument, rand returns a square matrix of random numbers between 0 and 1 with the dimension specified.
- **`rand(n,m) or rand(size(A))`**
  - If you supply two scalar arguments, rand takes them to be the number of rows and columns.
- **`rand`**
  - Calling rand with no arguments is equivalent to calling it with an argument of 1.

Special matrix object randn()

- **`randn(x)`**
  - With a single scalar argument, randn returns a square matrix of Gaussian random numbers between 0 and 1 with the dimension specified.
- **`randn(n,m) or randn(size(A))`**
  - For two scalar arguments, randn takes them to be the number of rows and columns.
- **`randn`**
  - Calling rand with no arguments is equivalent to calling it with an argument of 1.

Random number seeds

- Normally, **`rand`** and **`randn`** obtain their initial seeds from the system clock,so that the sequence of random numbers is not the same each time you run Octave.
- To allow generation of identical sequences, **`rand`** and **`randn`** allow the random number seed to be specified.

  `rand('seed',value) or`

  `randn('seed',value)`

STRINGS

- A string constant consists of a sequence of characters enclosed in either double-quote or single-quote marks:
- Strings in Octave can be of any length.
- Since the single-quote mark is also used for the transpose operator it is best to use double-quote marks to denote strings.

Literals

- Some characters cannot be included literally in a string constant. You represent them instead with escape sequences, which are character sequences beginning with a backslash (\ ).
- Another use of backslash is to represent unprintable characters such as newline \n or tab \t and others.

String functions

- **`blanks(n)`** Return a string of n blanks.
- **`setstr(A)`** Convert a matrix to a string. Each numeric element is converted to an ascii character.
- **`strcat(s1,...,sn)`** Return a string containing all the arguments concatenated.
- **`str2mat(s1,..., sn)`** Return a valid string matrix containing the strings s1, ..., sn as its rows.
- **`deblank(s)`** Removes the trailing blanks from the string s.

String comparison

- **`index(s1,s2)`** Return the position of the first occurrence of the string s2 in s1, or 0 if not found.

  Note: index does not work for arrays of strings.
- **`rindex(s1,s2)`** Return the position of the last occurrence of the string s2 in s1, or 0 if not found.

  Note: rindex does not work for arrays of strings.
- **`strcmp(s1,s2)`** Compares two strings, return 1 if they are the same, otherwise 0.
- **`isstr(s)`** Return 1 if s is a string, otherwise, 0.

Substring functions

- **`findstr(s1,s2)`** Return the vector of all positions in the longer string where an occurrence of the shorter substring starts.
- **`split(s1,s2)`** Divide s1 into substrings separated by s2, returning a valid string array.
- **`strrep(s1,s2,s3)`** In string s1, replace all occurrences of the substring s2 with substring s3.
- **`substr(s,n1,n2)`** Return the substring of s starting at character n1 and is n2 characters long.

String conversions

- **`bin2dec(s)`** Return a decimal number corresponding to the binary number represented as a string of 0s and 1s.
- **`dec2bin(n)`** Return a binary number as a string of 0s and 1s corresponding the non-negative decimal number n.
- **`hex2dec(s)`** Return a decimal number corresponding to the hexadecimal number stored in the string s.
- **`dec2hex(n)`** Return the hex number corresponding to the non-negative decimal number n, as a string.
- **`str2num(s)`** Convert the string s to a number.
- **`num2str(n)`** Convert the number n to a string.

More string conversions

- **`toascii(s)`** Return ascii representation of s in a matrix.
- **`tolower(s)`** Return a copy of the string s, with each upper-case character replaced by the corresponding lower-case one; non-alphabetic characters are left unchanged.
- **`toupper(s)`** Return a copy of the string s, with each lower-case character replaced by the corresponding upper-case one; non-alphabetic characters are left unchanged.

Testing characters

isalnum(s)	**isalpha(s)**	**isascii(s)**	**iscntrl(s)**
isdigit(s)	**isgraph(s)**	**islower(s)**	**isprint(s)**
ispunct(s)	**isspace(s)**	**isupper(s)**	**isxdigit(s)**

- The above functions return 1 (true) or 0 (false) if the tested character is in the set represented by the function.

VARIABLES

- Variables let you give names to values and refer to them later.
- The name of an Octave variable must be a sequence of letters, digits and underscores, but it may not begin with a digit.
- There is no limit on the number of characters in a variable name.
- Case is significant in variable names. The symbols **a** and **A** are distinct variables.

Built-in variables

- A number of variables have special built-in meanings. For example, **`PWD`** holds the current working directory, and **`pi`** names the ratio of the circumference of a circle to its diameter.
- Octave has a long list of all the predefined variables. Some of these built-in symbols are constants and may not be changed.

Status of variables

- **`clear options pattern`**

  Delete the names matching the given patterns from the symbol table.

- **`who options pattern`**
- **`whos options pattern`**

  List currently defined symbols matching the given patterns.

Options

The following are valid options for the **`clear`** and **`who`** functions. They may be shortened to one character but may not be combined.

- -a(ll) List all currently defined symbols.
- -b(uiltins) List built-in variables and functions.
- -f(unctions) List user-defined functions.
- -l(ong) Print a long listing of symbols
- -v(ariables) List user-defined variables.

EXPRESSIONS

- Expressions are the basic building block of statements in Octave.
  - An expression evaluates to a value, which you can print, test, store in a variable, pass to a function, or assign a new value to a variable with an assignment operator.
  - An expression alone can serve as a statement. Most statements contain one or more expressions which specify data to be operated on.
  - Expressions include variables, array references, constants, and function calls, as well as combinations of these with various operators.

Index expressions

- An index expression allows you to reference or extract selected elements of a matrix or vector.
- Indices may be scalars, vectors, ranges, or the special operator (:) ,which may be used to select entire rows or columns.
  - **`A(i,:)`**
  - **`A(:,j)`**
  - **`A(i1:i2,j1:j2)`**

Addition operators

- **`x+y`**
  - Addition. If both operands are matrices, the number of rows and columns must both agree.
- **`x.+y`**
  - Element by element addition. This is equivalent to the + operator.
- **`x-y`**
  - Subtraction. If both operands are matrices, the number of rows and columns of both must agree.
- **`x.-y`**
  - Element by element subtraction. This is equivalent to the - operator.

Multiplication operators

- **`x*y`**
  - Matrix multiplication. The number of columns of x must agree with the number of rows of y.
- **`x.*y`**
  - Element by element multiplication. If both operands are matrices, the number of rows and columns must both agree.

Division operators

- `x/y`
  - Right division. Equivalent to **`(inv(y')*x')'`**
- `x./y`
  - Element by element right division. Each element of x is divided by each corresponding element of y.
- `x\y`
  - Left division. Equivalent to the **`inv(x)*y`**
- `x.\y`
  - Element by element left division. Each element of y is divided by each corresponding element of x.

Power operators

- `x^y or x**y`
  - Power operator.
    - **x and y both scalar:** returns x raised to the power y.
    - **x scalar, y is a square matrix :** returns result using eigenvalue expansion.
    - **x is a square matrix and y scalar:** returns result by repeated multiplication if y is an integer, else by eigenvalue expansion.
    - **x and y both matrices:** returns an error.
- `x.^y or x.**y`
  - Element by element power operator.
    - If both operands are matrices, the number of rows and columns must both agree.

Unary operators

- **`+x` or `+x.`**
  - A unary plus operator has no effect on the operand.
- **`-x` or `-x.`**
  - Negation or element by element negation.
- **`x'`**
  - Complex conjugate transpose. For real arguments, this is the same as the transpose operator. For complex arguments, equivalent to **`conj(x.')`**
- **`x.'`**
  - Element by element transpose.

Comparison operators

- Comparison operators compare **numeric** values for relationships.
  - All of comparison operators return a value of 1 if the comparison is true, or 0 if it is false.
  - For matrix values, the comparison is on an element-by-element basis.
    - **`[1,2;3,4]==[1,3;2,4];ans=[1,0;0,1]`**
  - For mixed scalar and matrix operands, the scalar is compared to each element in turn.
    - **`[1,2;3,4]==2;ans=[0,1;0,0]`**

Relational operators

- `x<y` True if x is less than y.
- `x<=y` True if x is less than or equal to y.
- `x==y` True if x is equal to y.
- `x>=y` True if x is greater than or equal to y.
- `x>y` True if x is greater than y.
- `x!=y` True if x is not equal to y.
- `x~=y` True if x is not equal to y.
- `x<>y` True if x is not equal to y.

Boolean expressions

- A boolean expression is a combination of comparisons using the boolean operators "or" (**|**),"and" (**&**), and "not" (**!**).
  - Boolean expressions can be used wherever comparison expressions can be used.
  - If a matrix value used as the condition it is only true if all of its elements are nonzero.
  - Each element of an element-by-element boolean expression has a numeric value (1 true, 0 false).

Boolean operators

- `b1 & b2`
  - Elements of the result are true if both corresponding elements of b1 and b2 are true.
- `b1 | b2`
  - Elements of the result are true if either of the corresponding elements of b1 or b2 is true.
- `!b`
- `~b`
  - Each element of the result is true if the corresponding element of b is false.

Assignment expressions

- An assignment is an expression that stores a new value into a variable.
  - **`z=1`**
- Assignments can store string values also.
  - **`thing="food"`**
  - **`kind="good"`**
  - **`message=["this ",thing," is ",kind]`**
- It is important to note that variables do not have permanent types. The type of a variable is whatever it happens to hold .

Assigning indexed expressions

- Assignment of a scalar to an indexed matrix sets all of the elements that are referenced by the indices to the scalar value.
  - **`A(:,2)=5`**
- Assigning an empty matrix **[]** allows you to delete rows or columns of matrices and vectors.
  - **`A(3,:)=[]`**
  - **`A(:,1:2:5)=[]`**

Assigning multiple variables

- An assignment is an expression, so it has a value. Thus, **`z=1`** as an expression has the value 1. One consequence of this is that you can write multiple assignments together:
  - **`x=y=z=0`**
- This is also true of assignments to lists, so the following are valid expressions
  - **`[a,b,c]=[u,s,v]=svd(A)`**
  - **`[a,b,c,d]=[u,s,v]=svd(A)`**
  - **`[a,b]=[u,s,v]=svd(A)`**

Increment operators

- Increment operators increase or decrease the value of a variable by 1.
  - The operators to increment and decrement a variable are written as **++** and **- -**.
  - It may be used to increment a variable either before (**++x**) or after (**x++**) taking its value.
  - For matrix and vector arguments, the increment and decrement operators work on each element of the operand.

CONTROL STATEMENTS

- Control statements control the flow of execution in programs.
  - All the control statements start with special keywords
  - Each control statement has a corresponding end keyword
  - The list of statements contained between the start keyword the corresponding end keyword is called the body of a control statement.

Control structures

- **Octave if statement**
  - The else and elseif clauses are optional. Any number of elseif clauses may exist.

```
if (condition)
  then-body;
elseif (condition)
  elseif-body;
else
  else-body;
endif
```

More control structures

- **Octave switch statement**
  - Any number of case labels are possible

```
switch expression
  case label
    command_list;
  case label
    command_list;
  ...
  otherwise
    command_list;
endswitch
```

More control structures

- **Octave while statement**

```
while (condition)
  body;
endwhile
```

- **Octave for statement**

```
for var = expression
  body;
endfor
```

More control statements

- **The `break` statement**
  - jumps out of the innermost **`for`** or **`while`** loop that encloses it. The **`break`** statement may only be used within the body of a loop.
- **The `continue` statement**
  - like **`break`**, is used only inside **`for`** or **`while`** loops. It skips over the rest of the loop body, causing the next cycle around the loop to begin immediately.

FUNCTIONS

- A function is a name for a particular calculation. For example, the function **`sqrt`** computes the square root of a number.
- A fixed set of functions are built-in, which means they are available in every program. The **`sqrt`** function is a built-in function.
- In addition, you can define your own functions.

Calling functions

- A function call expression is a function name and list of arguments in parentheses.
  - The arguments are expressions which give the data for function to operate on.
  - When there is more than one argument, they are separated by commas.
  - If there are no arguments, you can omit the parentheses.

Arguments for functions

- Most functions expects a particular number of arguments.
  - `sqrt(x^2+y^2) # One argument`
  - `ones(n,m)      # Two arguments`
  - `rand()         # No arguments`
  - `rand(“seed”,1)# Two arguments`
- Some functions like **`rand`** take a variable number of arguments and behave differently depending on the number of arguments.

Return values for functions

- Most functions return one value

  `y=sqrt(x)`

- Functions in Octave (in common with perl) may return multiple values.

  `[u,s,v]=svd(A)`

- computes the singular value decomposition of the matrix **`A`** and assigns the three result matrices to **`u,s,`** and **`v.`**

Functions and script files

- Complicated programs can often be simplified by defining functions.
- Functions can be defined directly on the command line during interactive sessions.
- Alternatively, functions can be created as external files, and can be called just like built-in functions.

Defining functions

- In its simplest form, the definition of a function named name looks like this:

```
function name
  body;
endfunction
```

- A valid function name any valid variable name.
- The function body consists of expressions and control statements.

Passing information to functions

- Normally, you will want to pass some information to the functions you define.

```
function name(arg-list)
  body;
endfunction
```

- where **`arg-list`** is a comma-separated list of arguments. When the function is called, the argument names hold the values given in the call.

Returning information

- In most cases, you will also want to get some information back from the functions you define.

```
function ret-var=name(arg-list)
  body;
endfunction
```

- The symbol **`ret-var`** is the name of the variable, defined within the function, that will hold the value to be returned.

Returning more information

- Functions may return more than one value.

```
function [ret-list]=name(arg-list)
  body;
endfunction
```

- where **`ret-list`** is a comma-separated list of variable names that will hold the values returned from the function. Note that **`ret-list`** is a vector enclosed in square brackets.

Script files

- A script file is a file containing (almost) any sequence of commands.
  - It is read and evaluated just as if you had typed each command at the prompt.
  - It provides a way to store a sequence of commands that do not logically belong inside a function.
  - Unlike a function file, a script file must not begin with the keyword function..
  - Variables named in a script file are not local variables, but are in the same scope as the other variables entered at the prompt.

Function subdirectories (1)

`audio`	for playing and recording sounds.
`control`	for design and simulation of automatic control systems.
`elfun`	elementary functions.
`general`	miscellaneous matrix manipulations.
`image`	image processing tools.
`io`	input-ouput functions.

Function subdirectories (2)

`linear-algebra`	for linear algebra applications
`miscellaneous`	functions that don't fit in any other category
`plot`	for MATLAB-like plotting.
`polynomial`	for polynomial manipulations.
`set`	for creating and manipulating sets of unique values.
`signal`	for signal processing applications.

Function subdirectories (3)

`specfun`	special mainly inverse functions.
`special-matrix`	to create special matrix forms.
`statistics`	for statistical applications.
`strings`	for string manipulations.
`time`	for time keeping.

INPUT AND OUTPUT

- There are two distinct classes of input and output functions.
  - The first set are modelled after the functions available in MATLAB.
  - The second set are modelled after the standard I/O library used by the C programming language and offer more flexibility and control.
- When running interactively, Octave sends output that is more than one screen long to a paging program, such as **`less`** or **`more`**.

Terminal output

- Since Octave normally prints the value of an expression as soon as it has been evaluated, the simplest of all I/O functions is a simple expression.

```
octave:1> pi
     pi = 3.1416
```

- This works well as long as it is acceptable to have the name of the variable (or the default **`ans`**) printed along with the value.

More terminal output

- To print the value of a variable without printing its name, use the function **`disp`**.

```
octave:1> disp (pi)
     3.1416
```

  - Note output from **`disp`** always ends with a newline.
- The **`format`** command offers some control over the way Octave prints values with **`disp`** and through the normal echoing mechanism.

Terminal output format

- **`format options`**
  - Control the format of the output produced by **`disp`** and normal echoing. Valid options:

short	5 sig figs	3.1416
long	15 sig figs	3.14159265358979
short e	5 sig figs	3.14e+00
long e	15 sig figs	3.141592653590e+00
short E	5 sig figs	3.14E+00
long E	15 sig figs	3.141592653590E+00
free	Don’t align decimal points	
none		

More format options

- **`format options`**
  - bank — two decimal places
  - + — + for nonzero, space for zero elements
  - hex — 8 byte IEEE real
  - bit — 8 byte IEEE real

Terminal input

- Octave has three functions that make it easy to prompt users for input.
  - **`input`**
  - **`menu`**
  - **`keyboard`**
- The input and menu functions are used for managing an interactive dialog with a user.
- The keyboard function is used for simple debugging.

Terminal input function

- **`input(prompt)`**
  - Print a prompt and wait for user input.
    - The string entered by the user is evaluated as an expression, so it may be a literal constant, a variable name, or any other valid expression.
- **`input(prompt,"s")`**
  - Print a prompt and wait for user input.
    - Return the string entered by the user directly, without evaluating it first.

Terminal menu function

- **`menu(title,opt1,...)`**
  - Print a title string followed by a series of options. Each option will be printed along with a number. The return value is the number of the option selected by the user.

```
Are you there
1. Yes
2. No
>
```

Terminal keyboard function

- **`keyboard(prompt)`**
  - This function is used for simple debugging. When the keyboard function is executed, Octave prints a prompt and waits for user input. The default prompt is **`debug>`**
    - The input strings are then evaluated and the results are printed. This makes it possible to examine the values of variables within a function, and to assign new values to variables. The keyboard function continues to prompt for input until the user types **`quit`** or **`exit`**.

Terminal kbhit function

- kbhit ()
  - Read a single keystroke from the keyboard.

```
x=kbhit();
```

  - will set x to the next character typed at the keyboard as soon as it is typed.

Simple file I/O

- The **save** and **load** commands allow data to be written to and read from disk files in various formats.
- The format of files written by the **save** command can be controlled using the built-in variables **default_save_format** (default value = “ascii”) and **save_precision** **(**default value = **17)**.

File I/O save function

- **`save options file v1 v2 ...`**
  - Save the named variables **`v1,v2,...`** in the file **`file`**. All variables are saved by default.
    - **`-ascii`** Save the data in text data format.
    - **`-binary`** Save the data in binary data format.
    - **`-float-binary`** Save the data in single precision binary data format.
    - **`-mat-binary`** Save the data in MATLAB binary data format.
    - **`-save-builtins`** Save the of built-in variables.

File I/O load function

- **`load options file v1 v2 ...`**
  - Load the named variables from the file **`file`**. Existing variables are overwritten using the option **`-force`**. File type is auto-detected.
    - **`-force`** Force variables currently in memory to be overwritten by file variables with the same name.
    - **`-ascii`** Assume file is text format.
    - **`-binary`** Assume file is binary format.
    - **`-mat-binary`** Assume file is MATLAB binary format.

Graphical output

- Octave plotting functions use **`gnuplot`** to handle the actual graphics.
  - There are two low-level functions, **`gplot`** and **`gsplot`**, that behave almost exactly like the corresponding gnuplot functions plot and splot.
  - A number of other higher level plotting functions, patterned after the graphics functions found in MATLAB version 3.5

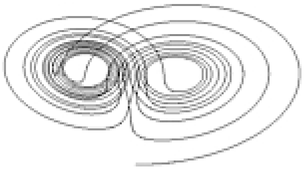
Two dimensional plotting

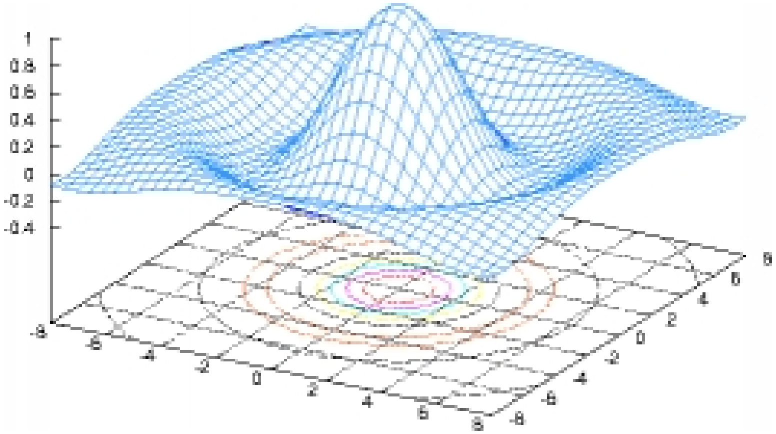
- The MATLAB-style two-dimensional plotting commands are:
  - **`plot(x,y,fmt ...)`**
  - **`axis(limits)`**
  - **`hold on|off`**
  - **`ishold`**
  - **`replot`**
  - **`clearplot`**
  - **`closeplot`**

Three dimensional plotting

- The MATLAB-style three-dimensional plotting commands are:
  - **`mesh(x,y,z)`**
  - **`meshdom(x,y)`**
  - **`figure(n)`**
- There are a large number of additional MATLAB plot formatting functions supported by Octave.

Octave updates





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Visit the Octave web site: http://www.che.wisc.edu/octave/octave.html