Scilab

Vachan Potluri
vachanpotluri@iitb.ac.in

Spring 2023

Introduction

What is Scilab?

A free alternative to MATLAB

What can it do?

1. Advanced calculator
2. Programming
3. Plotting, visualisation

Simple calculations

Try out these and see if they give expected results

```
2+3-4
4^2
4**4
6/4
2+(2^2-(1/2))
1e-3 + 1d-2
```

See what happens when you add a semicolon

```
6/4;
```

Variables

All calculations are stored by default in `ans`

```
6/4;
ans
```

You can specify a variable to store the value instead

```
pi_approx = 22/7;
```

And see its value later

```
pi_approx
disp(pi_approx)
```

More on variables

Some useful pre-defined variables

```
%pi
%e
%i
%t
%f
%inf
%nan
%eps
```

Pre-defined functions

See if the outputs of these lines are as expected

```
abs(-2)
min(3,4,5)
max(-2,-3,-4)
sin(%pi/2)
cos(%pi)
tan(%pi/4)
asin(1)/(%pi/2)
exp(2)/%e^2
log10(100)
log(%e)
```

Auto-completion: hit TAB

Other Scilab windows

- Variable Browser
  - Only lists user-defined variables
  - To list all variables:

```
whos
```

  - You can delete all or specific user-defined variables

```
pi_approx = 22/7;
disp(pi_approx)
clear pi_approx
disp(pi_approx)
```

- Command History
  - Execute an old command by double clicking
  - Can also navigate using ↑ and ↓ keys
  - Clear screen using `clc`
- File Browser
  - Useful when working with multiple files

Basic matrix creation

Wrap inside `[]`, use `,` and `;` to separate columns and rows

```
x = [1,2,3]
y = [4;5;6;7]
A = [1,0;0,1]
```

`Scilab` will warn you if the dimensions are inconsistent

```
B = [1,2,3;4,5]
```

Adding `'` will transpose the matrix

```
B = [1,2,3;4,5,6];
B'
```

You can fill matrices with pre-existing matrices

```
row1 = [1,2,3,4];
row2 = [5,6,7,8];
M = [row1;row2]
```

Special functions for matrix creation

Creating ranges

```
i = 1:10
j = 1:2:10
x = 0:0.1:1
y = linspace(0,1,25)
```

Some useful commands for creating dummy matrices of required size

```
A = zeros(2,2)
B = ones(3,2)
M = eye(3,3)
```

Can you make sense of this result?

```
M = [[zeros(1,2);ones(1,2);eye(2,2)],ones(4,1)]
```

Matrix operations

Scalar operations affect all elements of matrices

```
A = eye(3,3);
A*2
A/4
A+5
```

Scilab automatically figures out matrix operations too

```
B = 2*ones(3,3)
A+B
A*B
B^2
```

Special element wise operations

```
A.*B
A.^B
A./B
A.^2
```

How is `A^2` different from `A.^2`?

Matrix functions

Most Scilab functions can operate element-wise on matrices

```
A = %pi/2*[0,1;2,3];
sin(A)
```

Some special functions for matrices

```
length(A)
size(A)
sum(A)
det(A)
inv(A)
trace(A)
```

Matrix indexing

Access elements using `(row,col)`

```
A = eye(3,3);
A(1,2) = 2;
A
```

A single index can also be used: increments column-wise

```
A(4)
```

Extract rows and columns using `:`

```
A(:,2)
A(1,:)
```

Special symbol `$`

```
A($,3)
```

Arrays can also be used to access and modify

```
A([1,2],2)
A(4,:) = [10,20,30]
```

See if this makes sense

```
A = eye(4,4);
j = [2,4];
A(1,j) = j
A([7,8]) = 50
A($,$) = -1
B = [9,10;j];
A(B) = 100
```

Strings

Wrap in `""` or `''`

```
fname = "Vachan";
lname = 'Potluri';
fname + lname
```

Function `string` converts variables to strings

```
A = eye(2,2)
string(A)
```

Saving and loading data

`Scilab` has a working directory

```
pwd
```

Working directory can be changed from File Browser (and also using `cd` or `chdir`)

Function `save` saves user-defined variables to a file in working directory

```
x = 1.5;
A = [1,2;3,4]
save("data.dat")
```

These variables can be loaded for use later

```
listvarinfile("data.dat")
load("data.dat")
```

Accessing help

`Scilab`'s built-in help functionality is very useful

```
help
help save
```

Exercises[1]

Exercise

The pressure drop Δp required for a flow rate Q in a pipe of diameter D is

$$\Delta p = 4.52 \frac{Q^{1.85}}{C^{1.7} D^{4.87}}$$

Find Δp for these combinations of flow rates and diameters:

- $Q = 50,\ 100,\ 200,$ 400 and 1000
- $D = 0.5,\ 1,\ 1,\ 2$ and 4

Use $C = 2.5$ for all cases

Exercise

A magic square is a matrix in which all rows, columns and diagonals sum to same number.

1. Generate a magic square of size 10
2. Verify that all rows and columns sum up to the same value

Hint: search `Scilab` help for the function `testmatrix`, and use the `sum` function

[1] Amos Gilat. *MATLAB: An Introduction with Applications*. 6th ed. Wiley, 2017.

SciNotes: built-in editor

- Console is only useful for short calculations
  - Imagine typing 10s of commands again after changing just one input
- A single file containing all commands is useful for large calculations
- Such files are called “scripts” or “executables”
- `SciNotes` is `Scilab`'s built-in GUI for handling scripts
- Customary to save such files with `.sce` or `.sci` extension
- Comments begin with `//`, or can be wrapped with `/* */`

```
// this is a single line comment
/* this is a
   multi-line comment */
```

Conditional statements

Can you make sense of this?

```
x=6;
reminder = modulo(x,3);

if reminder==0 then
    disp("3 divides x")
elseif reminder==1 then
    disp("x leaves reminder 1 when divided by 3")
else
    disp("x leaves reminder 2 when divided by 3")
end
```

Hint: look at help for function `modulo`

Logical expressions generally use
`==, ~=, <, <=, >, >=, &&, ||, %t, %f`

Loops

```
array = 1:10;
value = 5;

for a=array
    if value==a then
        disp("Value exists in
    ↪array");
        break;
    end
end
```

What does `break` statement do?

Scilab always loops over columns

```
array=[1;2;3]
i=1;
for a=array
    disp("Element " + string(i)
    ↪+ ":")
    disp(a)
    i = i+1;
end
```

Functions

```
function [Tf,Tk] = centigradeToFarenhietKelvin(Tc)
    Tf = Tc*9/5 + 32;
    Tk = Tc + 273;
endfunction

[Tf,Tk] = centigradeToFarenhietKelvin(37);
disp(Tf)
disp(Tk)
```

Here `Tf` and `Tk` are the "return" values; `Tc` is the parameter

Can also have multiple parameters

```
function s = sum(a,b)
    s = a+b;
endfunction
disp(sum(1,2));
```

Exercises

Exercise

Write a function to calculate the cross product of two 3d vectors

```
function v = cross_product(v1,v2)
    // fill this
endfunction
```

Exercise

Write a function that takes in an array and a value, and returns the indices where the value occurs in an array.
Example: for `array=[1,2,1,4,5,2]` and `value=2`, the function should return `[2,6]` (since `array(2)=array(6)=value`)

```
function indices = multiple_find(array,value)
    // fill this
endfunction
```

Working with multiple files

- Many times we use multiple user-written functions to accomplish our task
- Having them all in a single file makes it hard to read and debug
- Splitting the script into multiple files is preferable
  - One for each function
  - One main file
- How to access content from another file?

my_function_file.sce

```
function y=my_function(x)
    // do something
endfunction
```

main.sce

```
// 'include' the file
exec("my_function_file.sce",-1);
// use the function
result=my_function(2.5);
```

Exercises

Exercise

1. Recall the `cross_product()` function you have written previously. Save it in a file `cross_product.sce`
2. Write a file `vector_norm.sce` which contains a function `vector_norm()` to calculate the length (norm) of a 3d vector
3. Now in the file `triangle_area.sce`, write a function to calculate the area of an arbitrarily oriented triangle with points p_1, p_2 and p_3

```
function area = triangle_area(p1, p2, p3)
    // fill this
endfunction
```

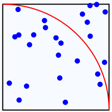
Hint: The area of a triangle is half the magnitude of cross product of any of its two sides

Exercise

We will calculate π approximately here

1. Write a function `get_random_point()` which generates a random point in a 2d square $x \in [0, 1], \; y \in [0, 1]$
   Hint: Use the `rand` function of `Scilab`
2. Now write a function `inside_circle()` which takes any point and returns a boolean value saying whether or not the point lies inside the unit circle $x^2 + y^2 = 1$
3. Now write a function `approximate_pi()` that takes N is an parameter and does the following
   - Generate N random points
   - Find out how many of these points (say N_i) lie inside the unit circle
   - Return the value N_i/N

$$\frac{N_i}{N} \to \frac{\pi}{4} \text{ as } N \to \infty$$



This is known as the Monte-Carlo simulation

A useful feature: plotting ability

- Many basic programming languages do not have inbuilt plotting ability
- Results are written to a file
  which is used by a different software for plotting
- High level programming languages like `Scilab`
  also have inbuilt plotting capability
- Our focus
  1. 1d plotting: line plots
  2. 2d plotting: surface, contour and vector plots

Single line plot

```
x = linspace(-%pi,%pi);
y = sin(x);

f = figure(1);
plot(x,y);
```

Too plain, let's add some description

```
help axes_properties
help xs2png
```

```
ax = gca();
ax.parent.background = -2;
ax.tight_limits(1)="on";
ax.font_size=3;
ax.grid=[1,1];
ax.title.text="A sample plot";
ax.title.font_size=5;
ax.y_label.text="sin(x)";
ax.y_label.font_size=4;
ax.x_label.text="x";
ax.x_label.font_size=4;
xs2png(f, "sin_plot.png");
```

Multiple line plots

```
x = linspace(-%pi,%pi);
y1 = sin(x);
y2 = cos(x);
y3 = 0.5+sin(x);

f = figure(1);
plot(x,y1,"r-^");
plot(x,y2,"b--o");
plot(x,y3,"g:*");
ax = gca();
legend_names = ["curve1", "cos(x)", "curve3"];
legend(ax, legened_names, 1);
```

Consult help of `LineSpec` and `legend`

Exercise

1. Plot $\rho(x)$ for $x \in [-5, 5]$

$$\rho(x) = \begin{cases} 1 + 0.2\sin(5x) & x \geq -4 \\ 5 & \text{otherwise} \end{cases}$$

2. Using a line plot, find the maximum of $f(x, y) = x^2 + 2y^2$ subjected to $y = \frac{1}{x} + 2$
   Hint: Plot $f\left(x, \frac{1}{x} + 2\right)$ vs x

3. The following is a convergence history of a simulation

Iteration (n)	Error (E)
100	1×10^{-2}
200	1×10^{-3}

   Assuming $\log(E)$ varies linearly with n, find at what iteration will the error reach 1×10^{-8}

Surface plot

```
x = %pi*linspace(-1,1,100);
y = %pi*linspace(-1,1,25);

z = zeros(length(x), length(y));
for i = 1:length(x)
    for j = 1:length(y)
        z(i,j) = sin(x(i))*sin(y(j)); // important z_{i,j} = z(x_i, y_j)
    end
end

f = figure(1);
f.color_map = jetcolormap(64);
grayplot(x,y,z);
colorbar(min(z), max(z));
ax = gca();
ax.parent.background = -2;
ax.tight_limits(1:2) = "on";
```

Also see help for `colormap` and `Sgrayplot`

3d surface plot

```
x = %pi*linspace(-1,1,100);
y = %pi*linspace(-1,1,25);

z = zeros(length(x), length(y));
for i = 1:length(x)
    for j = 1:length(y)
        z(i,j) = sin(x(i))*sin(y(j));
    end
end

f = figure(1);
f.color_map = jetcolormap(64);
plot3d(x,y,z);
// gce().color_flag = 1; // color according to z values
colorbar(min(z), max(z));
ax = gca();
ax.parent.background = -2;
ax.tight_limits(1:2) = "on";
```

You can interact with the 3d plot

Contour plot

```
x = %pi*linspace(-1,1,100);
y = %pi*linspace(-1,1,25);

z = zeros(length(x), length(y));
for i = 1:length(x)
    for j = 1:length(y)
        z(i,j) = sin(x(i))*sin(y(j));
    end
end

f = figure(1);
f.color_map = jetcolormap(16);
contour(x,y,z,16);
// xset("fpf", " "); // floating point format of contour values
colorbar(min(z), max(z));
ax = gca();
ax.parent.background = -2;
ax.tight_limits(1:2) = "on";
```

Also consult help of `contourf` and `fpf`

Vector plot

```
x = linspace(-1,1,20);
y = linspace(-1,1,20);

u = zeros(length(x), length(y));
v = zeros(length(x), length(y));

for i = 1:length(x)
    for j = 1:length(y)
        u(i,j) = -y(j);
        v(i,j) = x(i);
    end
end
vel_mag = (u.*u + v.*v).^0.5;

f = figure(1);
f.color_map = jetcolormap(64);
champ(x,y,u,v,arfact=0.5);
gce().colored = "on";
gca().parent.background=-2;
colorbar(min(vel_mag), max(vel_mag));
```

What does `arfact` do? Tinker and see

Exercise

- The stream function for inviscid potential flow around a cylinder of radius R immersed in a free stream of velocity U is given by

$$\psi = \left[r - \frac{R^2}{r} \right] U \sin\theta$$

Plot the contours of the stream function for a cylinder of radius $0.5\,\mathrm{m}$ in a free stream with velocity $U = 1\,\mathrm{m\,s^{-1}}$ in the domain $x \in [-1, 1]$ and $y \in [-1, 1]$.
Hint: You may require $r = \sqrt{x^2 + y^2}$ and $\theta = \tan^{-1}(y/x)$

- Similarly obtain a surface plot of the pressure coefficient

$$c_p = 2\frac{p - p_\infty}{\rho U^2} p = 2\frac{R^2}{r^2}\cos 2\theta - \frac{R^4}{r^4}$$

Exercise

A mathematical rose is described by the curve

$$r(\theta) = \cos\left(\frac{n}{d}\theta\right)$$

$$x = r\cos\theta$$

$$y = r\sin\theta$$

Here n and d are integers.

Generate mathematical roses for $1 \leq n \leq 7$ and $1 \leq d \leq 9$.

Hint: To put them all in a single picture, consult help for `subplot`