



# MATLAB Basics 7

## symbolic algebra

Anthony Rossiter

University of Sheffield

**For a neat organisation of all videos and resources**

**<http://controleducation.group.shef.ac.uk/indexwebbook.html>**

# Introduction

1. The previous resources demonstrate how to use basic MATLAB functionality.
2. It is useful to next to consider how MATLAB supports basic algebra, that is, variables which do not contain numerical values.
3. This includes support for operations such as differentiation, integration, solving equations, function description and so forth.

**Some times your need to automate mathematical operations, and the symbolic toolbox is an easy way of doing this (e.g. to find an exact tangent.)**

# Common symbolic algebra options

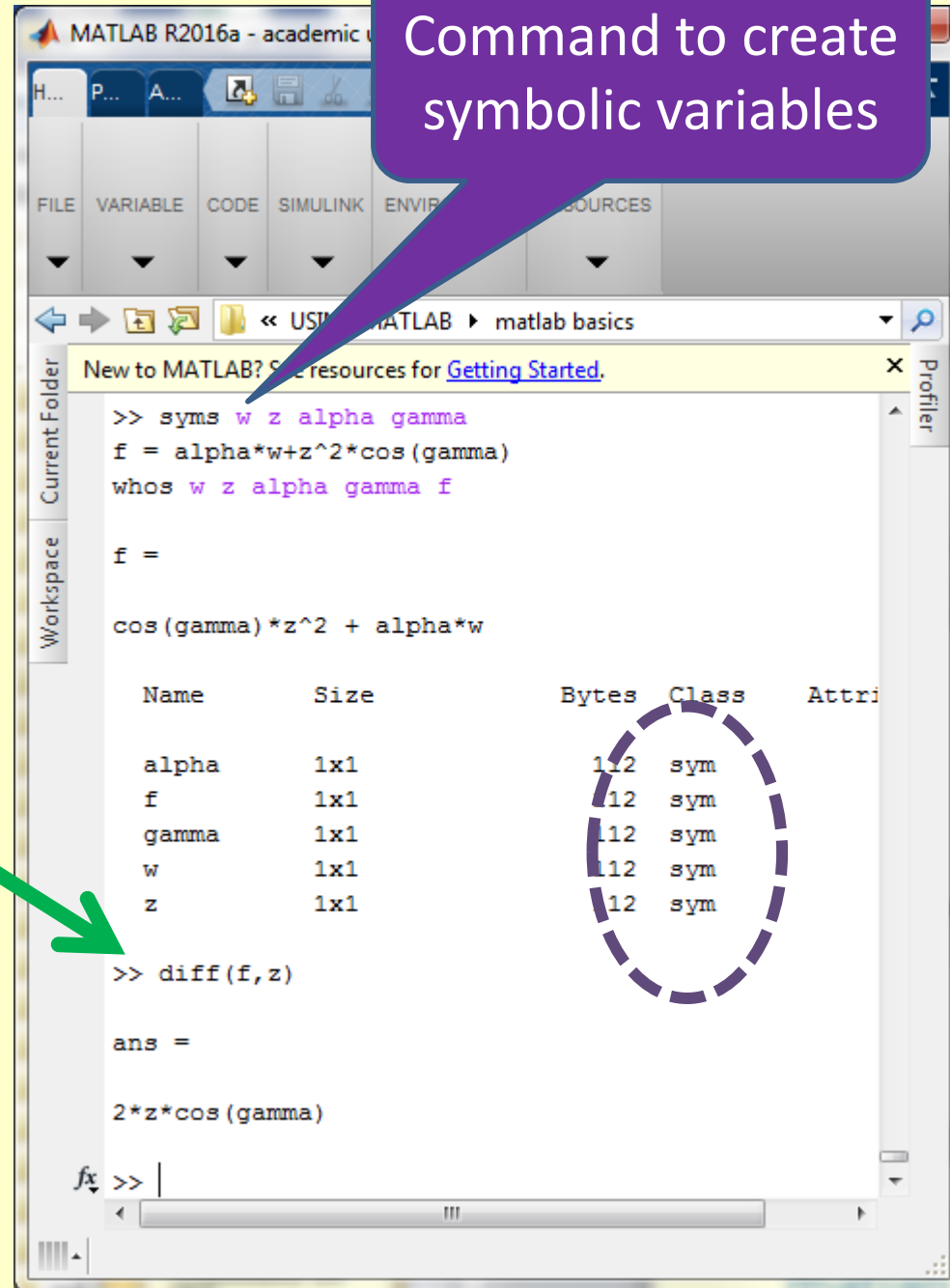
- Defining symbolic variables.
- Defining functions such as  $f(x)$ .
- Differentiation and integration.
- Tangents and normals.
- Solution of ODEs.
- Taylor series.
- Solving equations.
- For a more complete list use: ***>> help symbolic***

# Symbolic variables

Symbolic variables do not contain values and allow the user to write algebraic expressions.

This supports operations such as differentiation.

Matrix denotes these with the classification of ***“sym”***.



Command to create symbolic variables

```

>> syms w z alpha gamma
f = alpha*w+z^2*cos(gamma)
whos w z alpha gamma f

f =
cos(gamma)*z^2 + alpha*w

Name      Size      Bytes  Class  Attri
alpha     1x1       112    sym
f         1x1       112    sym
gamma     1x1       112    sym
w         1x1       112    sym
z         1x1       112    sym

>> diff(f,z)

ans =
2*z*cos(gamma)

```

# Differentiation

Define variables as symbolic.

Use diff.m to differentiate.

```
Editor - C:\Documents and Settings\jps\M...
File Edit Text Go Cell Tools Debug Desktop Window Help
- 1.0 + ÷ 1.1 x % % %
7   %%% Creating symbolic variables x y
8   clear x y
9   syms x y
10
11  %%% differentiaton
12  f = 4*x^4-2*x+1
13  f_deriv = diff(f)
14  g = (x+1)/(exp(x)*sin(x) + x^2)
15  g_deriv = diff(g)
```

```
MATLAB 7.7.0 (R2008b)
File Edit Debug Parallel Desktop Window Help
:uments\teaching_08_09\matlab_acs108\lab3
Shortcuts How to Add What's New
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
f =
4*x^4 - 2*x + 1
f_deriv =
16*x^3 - 2
g =
(x + 1)/(exp(x)*sin(x) + x^2)
g_deriv =
1/(exp(x)*sin(x) + x^2) - ((x + 1)*(2*x + exp(x)*cos(x) + e
```

Assume symbolic expressions have just one variable so it is obvious what to differentiate wrt.

# Integration

Assuming the function is symbolic, `int.m` will attempt to integrate.

May fail if integral has a non-simple form.

Also works for functions of many variables – **see ‘help int’ for instructions.**

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Current Folder: << book powerpoint >> USING MATLAB >> matlab basics

Workspace

```

New to MATLAB? See resources for Getting Started.
2*atanh(tan(y/2)^2) + (2*tan(y/2) + 2)/(tan(y/2)^2 + 1)
>> f = 4*x^4-2*x+1
f =
4*x^4 - 2*x + 1
>> fun2 = cos(y)+tan(y)-sin(y)
fun2 =
cos(y) - sin(y) + tan(y)
>> intf=int(f)
intf2=int(fun2)
intf =
(4*x^5)/5 - x^2 + x
intf2 =
2*atanh(tan(y/2)^2) + (2*tan(y/2) + 2)/(tan(y/2)^2 + 1)
fx >>

```

# Tangents

The expression for a tangent curve is known and all the terms can be obtained with the symbolic toolbox.

$$T(x) = f(a) + (x - a) \frac{df}{dx}(a)$$

Hence tangent line is determined automatically.

Here used a=1, but obviously other values are possible.

```

>> syms x
a=1;
f = 4*x^4-2*x+1
dfdx=diff(f);
f_at_a=subs(f,a);
dfdx_at_a=subs(dfdx,a);
tangent=f_at_a+(x-a)*dfdx_at_a

f =

4*x^4 - 2*x + 1

tangent =

14*x - 11
    
```

**Normal calculations follow a similar methodology.**

# Taylor series

Automatic generation of Taylor series is very useful.

MATLAB provides the file *taylor.m* for this.

Use *help taylor* to explore functionality in more depth.

Syntax is largely intuitive

```

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H... P... A...
New Script New Open Find Files Compare
VARIABLE CODE SIMULI ONMENT RESOURCES
FILE
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New to MATLAB? See resources for Getting Started.
>> g1 = (x+1)/(x^2-4)
g1_taylor_about_zero = taylor(g1,'ExpansionPoint',0,'Order',5)
g1_taylor_about_one = taylor(g1,'ExpansionPoint',1,'Order',4)

g1 =
(x + 1)/(x^2 - 4)

g1_taylor_about_zero =
- x^4/64 - x^3/16 - x^2/16 - x/4 - 1/4

g1_taylor_about_one =
1/9 - (20*(x - 1)^2)/27 - (61*(x - 1)^3)/81 - (7*x)/9
    
```

'Order' is taken as number of terms.

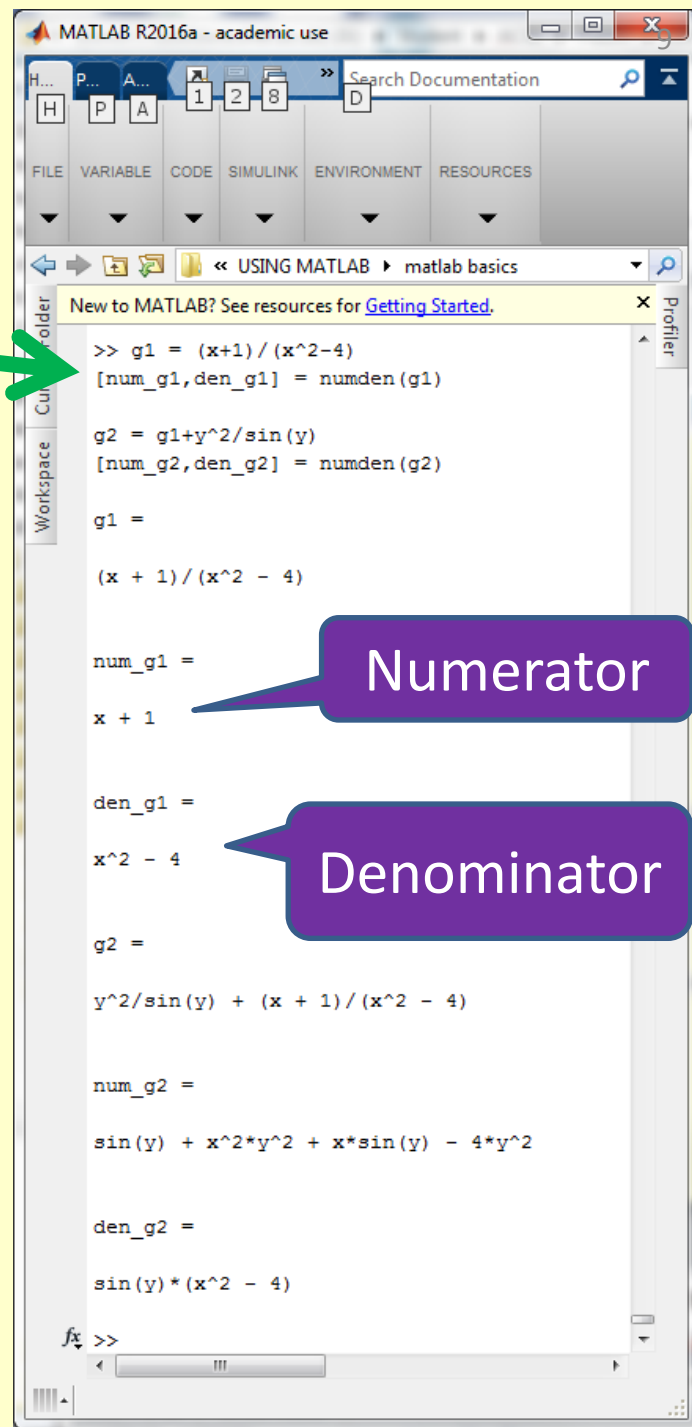
'Order=5' gives a 4<sup>th</sup> order series!



# Numerator and denominator

The function *numden.m* allows the user to automatically extract the numerator and denominator components.

This may be useful for some operations and decision making.



```
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Search Documentation
FILE VARIABLE CODE SIMULINK ENVIRONMENT RESOURCES
<< USING MATLAB matlab basics
New to MATLAB? See resources for Getting Started.
>> g1 = (x+1)/(x^2-4)
[num_g1,den_g1] = numden(g1)

g2 = g1+y^2/sin(y)
[num_g2,den_g2] = numden(g2)

g1 =
(x + 1)/(x^2 - 4)

num_g1 =
x + 1

den_g1 =
x^2 - 4

g2 =
y^2/sin(y) + (x + 1)/(x^2 - 4)

num_g2 =
sin(y) + x^2*y^2 + x*sin(y) - 4*y^2

den_g2 =
sin(y)*(x^2 - 4)

fx >>
```

Numerator

Denominator

There is an entire resource on ODEs in the **MATLAB for control** section.

Also see the direct link if desired:

[https://www.youtube.com/watch?v=VcMeG\\_4BBdQ&feature=youtu.be](https://www.youtube.com/watch?v=VcMeG_4BBdQ&feature=youtu.be)

SOLVING ODEs

The screenshot shows a web browser window with the URL `controleducation.group.shef.ac.uk/matlabcontrol.html`. The page has a navigation menu on the left with the following items: 'HOME PAGE AND CHAPTER INDEX', 'Resources on mathematical skills', 'Chapter on use of MATLAB', 'Section on MATLAB BASICS', 'Section on MATLAB for control', 'Section on MATLAB GUIs', and 'Soft copy power point and m-files'. The main content area features a heading 'USE OF MATLAB WITH control system analysis and design' and a portrait of a man in a red shirt. Below this is a paragraph: 'This is a brief section on how to use MATLAB to support learning of topics within the control, systems and modelling theme of engineering programmes. It is not intended to be comprehensive but rather covers the basic skills required for introductory modules.' A large green arrow points from the 'Section on MATLAB for control' link in the menu to the text 'USE OF MATLAB WITH control system analysis and design'. Another green arrow points from the text 'Also see the direct link if desired:' to the URL in the text block on the left. At the bottom of the page, there is a paragraph: 'Some historical short courses on generic MATLAB skills (variable types, loops conditionals, function files, etc.) are available at the following website.' followed by a list of two links: '1. Use of Matlab 1 - solving ODEs.' and '2. Use of Matlab 2 - creating transfer functions.'

# LIVE DEMONSTRATIONS WITH MATLAB

[Go through the following to see examples](#)

[matlab\\_basics7.m](#)

[matlab\\_basics7b.m \(with plotting\)](#)

# Conclusions

Demonstrated the usefulness of the symbolic toolbox.

1. Allows complex or messy algebra to be handled by the computer rather than by hand.
2. This includes differentiation, integration, solution of ODEs, matrix inverse and so on.

**REMARK: Symbolic expressions can be created from strings and also evaluated with specified numerical values where this is helpful.**

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