MAE 215 MATLAB Final Project Report

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MAE 215: Intro to Programming in MATLAB

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Table of contents

Introduction

In the course of MAE 215: Introduction to Programming in MATLAB, we have learned several essential coding concepts including conditional statements, looping structures, functions, and symbolic math. The objective of this course is helping us as engineering students to be prepared for entering both academic and career path. All engineering students have to be familiar with at least one programming language. Taking MATLAB for example, it is a powerful tool for engineering computation and data visualizing. Engineers are responsible for making decisions, and computer can do all the repetitive tasks efficiently for us as long as we have enough knowledge on programming.

Generate Taylor Series with User-defined Function: TaylorSeriesFUN

Problem statement

In mathematics, Taylor Series is a useful tool for approximating a value at a point on a math function. Finding a Taylor Series of any math function manually can be a daunting task. Therefore, I created a MATLAB function that generates Taylor Series.

Taylor Series formula:

$$f(x) = f(a) + f'(a)(x-a) + (f''(a)/2!)(x-a)^2 + \dots +(f^n(a)/n!)(x-a)^n$$

To run the function – TaylorSeriesFUN, here is the list of required input data.

1. **f**: any original math function needs to find its Taylor Series representation. (Symbolic expression)
2. **aValue**: the point the math function is based on (Data type: double)
3. **n**: number of terms you want to find (Data type: double)
4. **xValue**: a point for test out y value (Data type: double)

For the output:

1. **C**: List of the coefficients of the Taylor Series in a row matrix (Data type: double)
2. **TaylorEXP**: the new math function in Taylor Series representation (function handle)
3. **Err**: the aboslute error between actual value and approximated value. (Data type: double)

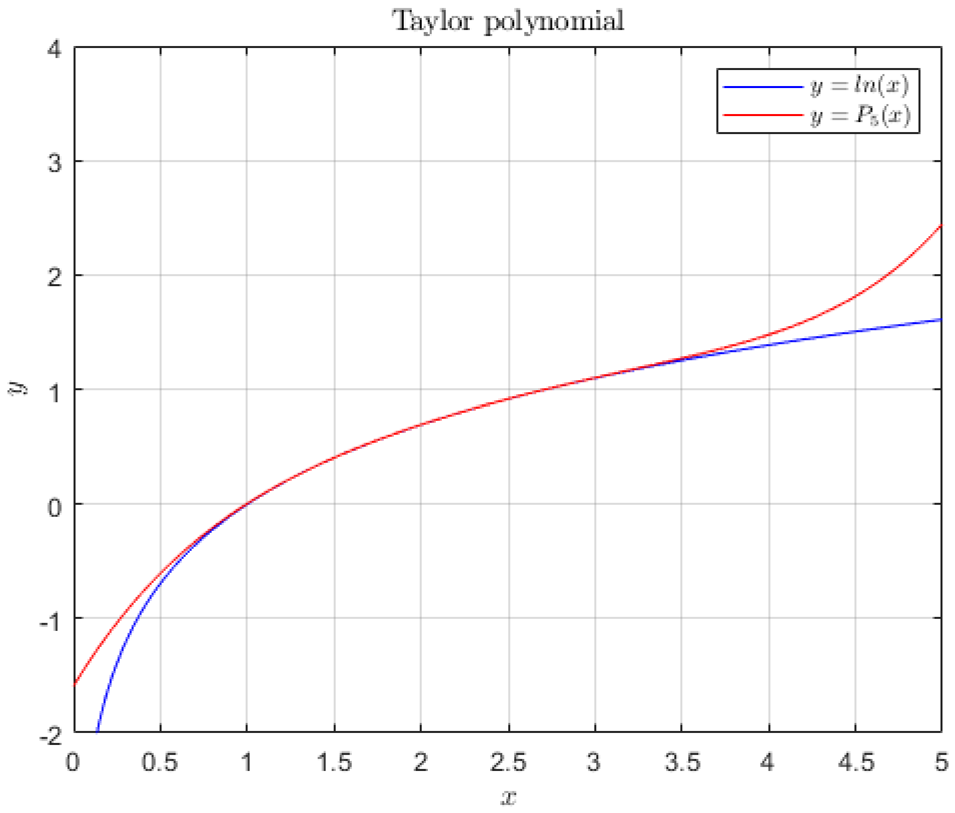
Aside from the function, the script in the end also provides the code for plotting the two functions.

MATLAB Script

```
%% Generate Taylor Series With User-defined Function: TaylorSeriesFUN

clear, clc, close all
format rational % For dispalying fraction
format compact

syms x
f = log(x); % Define a function symbolically
aValue = 2;
n = 5;
xValue = 1;

disp('Note: TaylorEXP(aValue,xValue) The function inputs must be aValue first then xValue')
disp(['List of the coefficients from C_0 to C_',num2str(n)])

[C,TaylorEXP,Err] = TaylorSeriesFUN(f,aValue,n,xValue) % Call out the function

fprintf('The abosulte error is %f\n',double(Err))

% Plot the function and the taylor polynomial
figure(1)
fplot(f,'b')
hold on
s=linspace(0,5,1e5); % range might vary from different function
t=TaylorEXP(aValue,s);
ylim([-2,4])
grid on
plot(s,t,'r')
title('Taylor polynomial','Interpreter','latex')
xlabel('$x$','Interpreter','latex')
ylabel('$y$','Interpreter','latex')
legend('$y=ln(x)$','$y=P_5(x)$','interpreter','latex')


```

The Output

```
Note: TaylorEXP(aValue,xValue) The function inputs must be aValue first
      then xValue

List of the coefficients from C_0 to C_5

C =
   Columns 1 through 6
      1588/2291      1/2       -1/8         1/24        -1/64        1/160

TaylorEXP =

  function_handle with value:

   @(a,x)a.*(-1.0./2.0)+x./2.0-(a-x).^2./8.0-(a-x).^3./2.4e+1-(a-x).^4./6.4e
+1-(a-x).^5./1.6e+2+6.931471805599453e-1

Err =
  61/13245

The absolute error is 0.004606
```



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The Function: TaylorSeriesFUN

```matlab
function [C,TaylorEXP,Err] = TaylorSeriesFUN(f,aValue,n,xValue)
% This function grnerates taylor series of any given function

%% Inputs & Outputs:

% f: function (symbolic math)
% aValue: point at which the function based on
% n: number of terms needed
% xValue: a point for test out y value

% C: list of coefficient from C_0 to C_n
% TaylorEXP: TaylorEXP(aValue,xValue) function handle
% Err: the aboslute error between f(xValue) and TaylorEXP(aValue,xValue)

%% Function

syms x a

C = zeros(1,n);      % preallocate coefficient
N = sym('x',[1 n]); % preallocate symbolic matrices

for i = 0:1:n
    dnfsym = diff(f,x,i); % find the (i)th derivative: f'n(x)
    dnfasym = subs(dnfsym,x,aValue); % substitute x with aValue to evaluate f'n(a)
    C(1,i+1) = double(dnfasym)/factorial(i); % assign coefficients: [C_0,C_1,C_2,...,C_n]
    N(1,i+1) = (x-a)^i; % Create terms:[(x-a)^0,(x-a)^1,(x-a)^2,...(x-a)^n]

end

TaylorEXP = matlabFunction(sum(C.*N)); % Combine terms and coefficient and put it into function
F = matlabFunction(f); % Turn the original function from 'sym' into function handle
Err = abs(F(xValue)-TaylorEXP(aValue,xValue)); % determine the absolute error

end
```

Calculates Center of Mass for Particles with User-defined Function: MassCenterSUM

Problem Statement

In physics, finding the center of mass of an object is crucial to calculate many other physical properties. This function is designed to solve simplified tasks – finding the center of mass for particles system. The function MassCenterSUM has flexible number of input varables ranging from 2 to 4, but it has to be in the order of **xi**, **yi**, **zi**, and **mi,** representing x, y, z coordinates and individual mass. Each of them is a single column matrix imported from external data files. For the output, the function simply returns the corresponding coordinates of its center of mass. To be clear, plug in **xi**, **yi** then **mi** as 3 inputs for getting (m_x, m_y). Also the function provides visualize data shows masses distribution and marks the center of mass in red.

The formula for calculating center of mass:

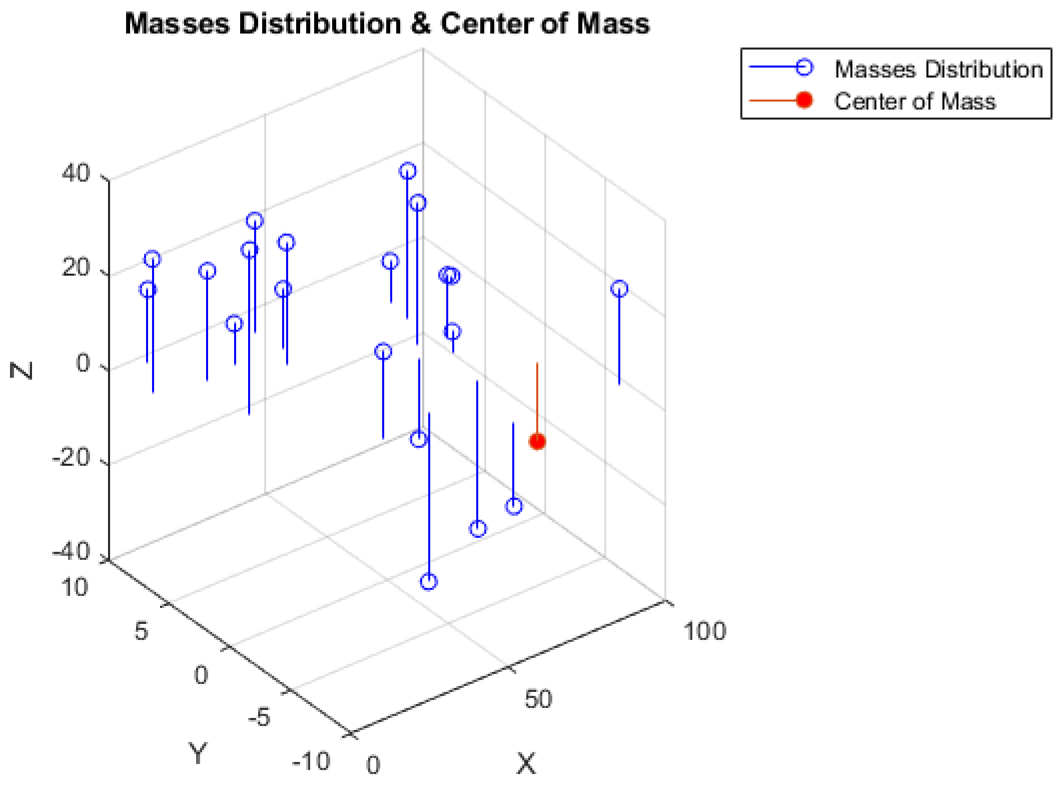
COM(x) = SUM(xi*mi)/M; COM(y) = SUM(yi*mi)/M; COM(z) = SUM(zi*mi)/M

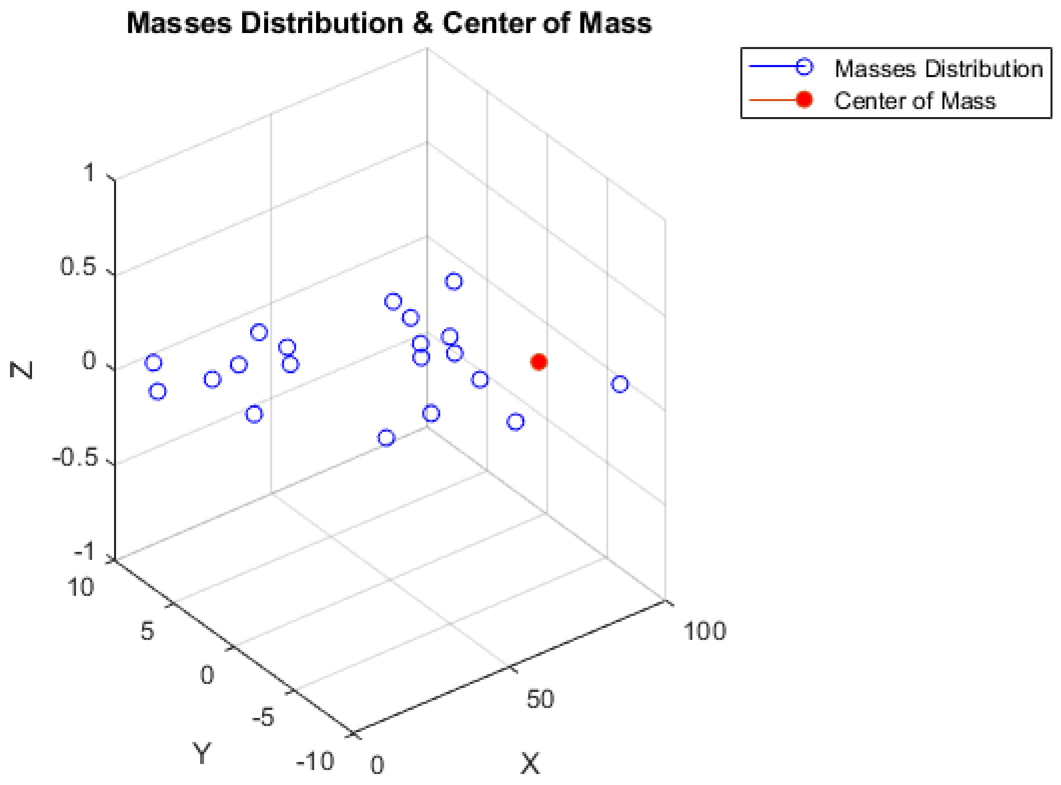
MATLAB Script

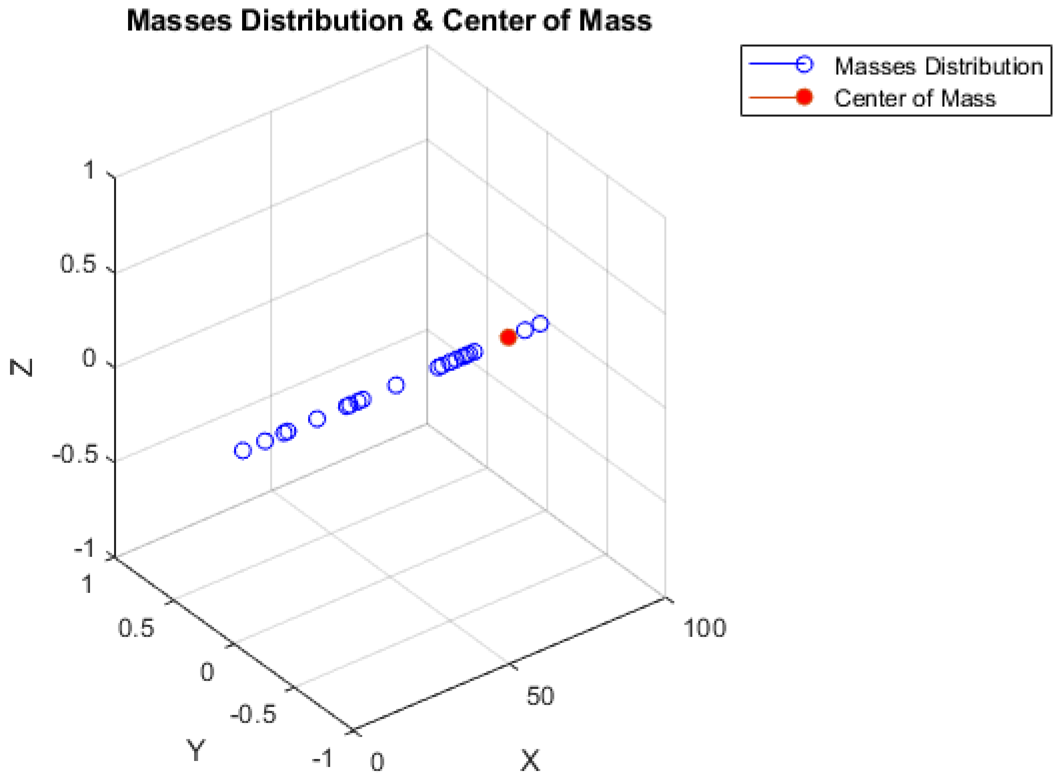
```
%% Calculates Center of Mass for Particles with User-defined Function:↙
MassCenterSUM

clear, clc, close all
M = readmatrix('MassData1.xlsx'); % Import data with Excel file and turn it into↙
a matrix
M = rmmissing(M,1); % remove non number parts of data
xi = M(:,1); % Seperate the matrix into column sets
yi = M(:,2);
zi = M(:,3);
mi = M(:,4);

[COM] = MassCenterSUM(xi,yi,zi,mi); % Run the function and test with different↙
number input variables
sprintf('The center of mass is at x = %+.3f, y = %+.3f, z = %+.3f',COM(1,1),COM↙
(1,2),COM(1,3))
[COM] = MassCenterSUM(xi,yi,mi);
sprintf('The center of mass is at x = %+.3f, y = %+.3f',COM(1,1),COM(1,2))
[COM] = MassCenterSUM(xi,mi);
sprintf('The center of mass is at x = %+.3f',COM(1,1))
[COM] = MassCenterSUM(mi);
sprintf(COM)
```

The Output

```
ans =
    'The center of mass is at x = +87.833, y = -2.548, z = -16.672'
ans =
    'The center of mass is at x = +87.833, y = -2.548'
ans =
    'The center of mass is at x = +87.833'
ans =

    'Error'
```


Masses Distribution & Center of Mass
Masses Distribution
Center of Mass
Z
40
20
0
-20
-40
Y
10
5
0
-5
-10
X
0
50
100


Masses Distribution & Center of Mass
Masses Distribution
Center of Mass
Z
1
0.5
0
-0.5
-1
Y
10
5
0
-5
-10
X
0
50
100



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The Function: MassCenterSUM

```
function [COM] = MassCenterSUM(varargin)
% This function calculates center of mass for particles
% Input: ex. 4 column sets containing xi,yi,zi coordinates, and masses mi
% Output: A coordinate of the center of mass in a row vector.

% This function accepts different number of input variables for solving a
% task in one, two, and three dimensions.
% Whatever number of variables are taken, the order has to be xi,yi,zi,mi

if nargin == 4    % Determine number of input variables
    xi = varargin{1}; % Assign variables
    yi = varargin{2};
    zi = varargin{3};
    mi = varargin{4};
    Cx = sum(xi.*mi)/sum(mi); % Apply the formula
    Cy = sum(yi.*mi)/sum(mi);
    Cz = sum(zi.*mi)/sum(mi);
    COM = [Cx,Cy,Cz];

    fig = figure(1);
    movegui(fig,'northeast'); % Top right corner
    stem3(xi,yi,zi,'b')     % Display particles
    hold on
    stem3(Cx,Cy,Cz,'MarkerFaceColor','r')     % Display center of mass; mark red
    xlabel('X'); % Add labels, title, and legend
    ylabel('Y');
    zlabel('Z');
    title('Masses Distribution & Center of Mass');
    legend('Masses Distribution','Center of Mass');

elseif nargin == 3
    xi = varargin{1};
    yi = varargin{2};
    mi = varargin{3};
    Cx = sum(xi.*mi)/sum(mi);
    Cy = sum(yi.*mi)/sum(mi);
    COM = [Cx,Cy];

    fig = figure(2);
    movegui(fig,'east'); % Right center
    stem3(xi,yi,zeros(1,size(mi,1)),'b') % Assign zeros into zi
    hold on
    stem3(Cx,Cy,0,'MarkerFaceColor','r')
    xlabel('X');
    ylabel('Y');
    zlabel('Z');
    title('Masses Distribution & Center of Mass');
    legend('Masses Distribution','Center of Mass');

elseif nargin == 2
    xi = varargin{1};
    mi = varargin{2};
    Cx = sum(xi.*mi)/sum(mi);
    COM = Cx;
```

```matlab

    fig = figure(3);
    movegui(fig,'southeast'); % Bottom right corner
    stem3(xi,zeros(1,size(mi,1)),zeros(1,size(mi,1)),'b') % Assign zeros into yi and zi
    hold on
    stem3(Cx,0,0,'MarkerFaceColor','r')
    xlabel('X');
    ylabel('Y');
    zlabel('Z');
    title('Masses Distribution & Center of Mass');
    legend('Masses Distribution','Center of Mass');

else
    COM = 'Error'; % Display 'Error' when number of varables out of range.
    % disp('The number of input varables is out of range.')
    % error('The number of input varables is out of range.')

end
```

MassData1.xlsx

Mi	Xi	Yi	Zi
21.97321	5.922959	22.17562	1.1863
20.0634	2.462746	31.1204	-7.45444
55.10689	-7.93491	4.075427	6.917686
23.06616	6.130381	39.15273	11.22623
38.80016	8.79719	-19.9899	8.350633
52.37725	1.977374	27.21079	-3.47194
78.63589	0.941887	15.26774	15.99723
54.14278	6.958654	14.43024	9.478923
32.42348	-2.98457	-7.04078	7.585167
48.93565	5.033116	4.790579	11.93258
56.47665	7.213921	17.0424	-1.4844
21.47604	-4.9119	-8.00789	1.29033
69.83339	4.607875	37.57876	14.36836
61.88257	0.114094	35.12619	10.85067
75.6802	-2.71532	-11.3361	15.43013
53.11947	0.274265	19.00312	23.10682
86.78038	8.591074	23.01698	-17.6904
88.03405	-6.01695	12.64197	5.931594
80.40724	8.203654	9.429478	12.28218
6.30702	1.4606	9.256099	-5.58828