MATLAB Project

Theme: Cubic Equation, Signal Generator

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1. Introduction

What is MATLAB?

MATLAB (an abbreviation of "MATrix LABoratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.

Although MATLAB is intended primarily for numeric computing, an optional toolbox uses the MuPAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

As of 2020, MATLAB has more than 4 million users worldwide. They come from various backgrounds of engineering, science, and economics. As of 2017, more than 5000 global colleges and universities use MATLAB to support instruction and research.

Short History of MATLAB

MATLAB was invented by mathematician and computer programmer Cleve Moler. The idea for MATLAB was based on his 1960s PhD thesis. Moler became a math professor at the University of New Mexico and started developing MATLAB for his students as a hobby. He developed MATLAB's initial linear algebra programming in 1967 with his one-time thesis advisor, George Forsythe. This was followed by Fortran code for linear equations in 1971.

Before version 1.0, MATLAB "was not a programming language; it was a simple interactive matrix calculator. There were no programs, no toolboxes, no graphics. And no ODEs or FFTs."

The first early version of MATLAB was completed in the late 1970s. The software was disclosed to the public for the first time in February 1979 at the Naval Postgraduate School in California. Early versions of MATLAB were simple matrix calculators with 71 pre-built functions. At the time, MATLAB was distributed for free to universities. Moler would leave copies at universities he visited and the software developed a strong following in the math departments of university campuses.

In the 1980s, Cleve Moler met John N. Little. They decided to reprogram MATLAB in C and market it for the IBM desktops that were replacing mainframe computers at the time. John Little and programmer Steve Bangert re-programmed MATLAB in C, created the MATLAB programming language, and developed features for toolboxes.

About my Project

My project consists of a simple signal generator given by the default formula. The parameters are Amplitude, Frequency and Phase, all of them being entered inside the program by the user using the keyboard. The signal is then shown visually on the XOY axis in the graph on the right.

The second part of my project consists of Cubic Equation representation in both 2D axis and 3D model. Another feature of my project is finding the roots of the equation.

Besides that, as a visual theme I have used butterflies, the application also having a fun part for the user to enjoy after successfully finishing up their work.

2. Theoretical presentation

The Signal Generator

The application uses 3 numeric edit fields, a text edit field, a button and a graph, to obtain the 3 parameters given by the user. After the user presses the button, the signal is displayed inside the graph. The signal shown is given by the formula: `x * sin(y * t + z)`, where `t = linspace(0, 2 * pi, 1000), y = linspace(x1,x2)` returns a row vector of 100 evenly spaced points between x1 and x2. X is the amplitude of the signal, y is the frequency, and `z` is the phase of the signal.

The Cubic Equation

There are 3 features revolving around the Cubic Equation inside the application.

The first one is to display the 2D graph with coefficients entered by the user from the keyboard. Same as with the signal generator, edit fields, a button and a graph were used. The formula used to display the graph is: `wave = a*x.^3 + b*x.^2 + c*x + d;`

Where `x = linspace(-10, 10, 100),` and a, b, c, d are the coefficients manually entered by the user in the GUI

The second feature is to display the graph of the Cubic Equation with the given coefficients in a 3D environment. The GUI elements of this feature are the same as with the first feature, but this time, the way the graph is displayed is different.

```
x = linspace(-10, 10, 100);

y = linspace(-10, 10, 100);

[X, Y] = meshgrid(x, y);
```

```
    Z = a*X.^3 + b*X.^2 + c*X + d*Y;
```

[X,Y] = meshgrid(x,y) returns 2-D grid coordinates based on the coordinates contained in vectors x and y. X is a matrix where each row is a copy of x, and Y is a matrix where each column is a copy of y. The grid represented by the coordinates X and Y has length(y) rows and length(x) columns.

```
surf(app.UIAxes, X, Y, Z, 'EdgeColor', 'none');
```

surf(X,Y,Z) creates a three-dimensional surface plot, which is a three-dimensional surface that has solid edge colors and solid face colors. The function plots the values in matrix Z as heights above a grid in the x-y plane defined by X and Y. The color of the surface varies according to the heights specified by Z.

The third feature is the root calculation of the Cubic Equation with the coefficients given by the user. Firstly, i'm inserting the coefficients in a vector, and then calculate the roots using the roots() function. After that, using a few IF conditions, the roots of the equation are displayed. The application is not able to detect wheter the equation actually has solutions, it displays them only if they exist.

r = roots(p) returns the roots of the polynomial represented by p as a column vector. Input p is a vector containing n+1 polynomial coefficients, starting with the coefficient of xn.
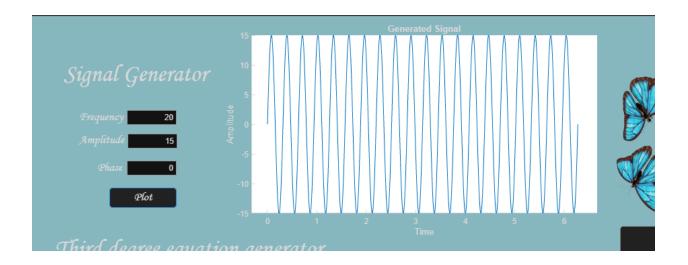
In addition to that, every graph is cleared with the cla() function.

3. Experiments

Signal Generator Experiment

Entered values: A=15, f=20, ϕ=0

As shown below, the graph correctly displayed the designed signal.

Code snippet used as callback for the button:

```
x = app.AmplitudeEditField.Value;
y = app.FrequencyEditField.Value;
z = app.PhaseEditField.Value;

t = linspace(0, 2 * pi, 1000);
signal = x * sin(y * t + z);


cla(app.UIAxes);


plot(app.UIAxes, t, signal);

title(app.UIAxes, 'Generated Signal');
xlabel(app.UIAxes, 'Time');
ylabel(app.UIAxes, 'Amplitude');
```
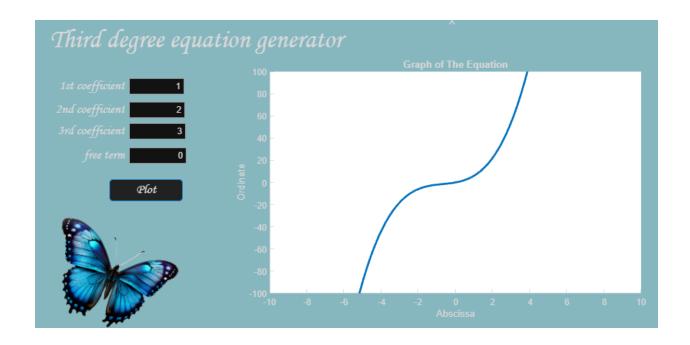
2D Cubic Equation Representation

Entered values: a=1, b=2, c=3, d=0

As shown below, the result was correcly displayed in the graph.
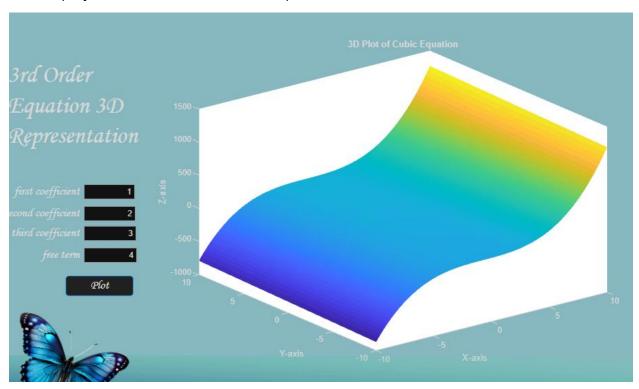
Code snippet used as callback for the button:

```
a = app.stcoefficientEditField.Value;
b = app.ndcoefficientEditField.Value;
c = app.rdcoefficientEditField.Value;
d = app.freetermEditField.Value;


x = linspace(-10, 10, 100);


wave = a*x.^3 + b*x.^2 + c*x + d;


cla(app.UIAxes2);


plot(app.UIAxes2, x, wave, 'LineWidth', 2);


title(app.UIAxes2, 'Graph of The Equation');
xlabel(app.UIAxes2, 'Abscissa');
ylabel(app.UIAxes2, 'Ordinate');


xlim(app.UIAxes2, [-10, 10]);
ylim(app.UIAxes2, [-100, 100]);
```

(The last 2 lines of code were implemented for a better visualization of the graph)

3D Cubic Equation Representation

The entered values are : a=1, b=2, c=3, d=4

The displayed result was correct, as expected.

Code snippet used as callback for the button:

```
a = app.firstcoefficientEditField.Value;
b = app.secondcoefficientEditField.Value;
c = app.thirdcoefficientEditField.Value;
d = app.freetermEditField.Value;

x = linspace(-10, 10, 100);
y = linspace(-10, 10, 100);

[X, Y] = meshgrid(x, y);

Z = a*X.^3 + b*X.^2 + c*X + d*Y;


cla(app.UIAxes);

surf(app.UIAxes, X, Y, Z, 'EdgeColor', 'none');
title(app.UIAxes, '3D Plot of Cubic Equation');
```

```
xlabel(app.UIAxes, 'X-axis');
ylabel(app.UIAxes, 'Y-axis');
zlabel(app.UIAxes, 'Z-axis');
```

Root Finder Experiment

Entered values: a=1, b=6, c=5, d=0

The results were correct, but the application only works if the roots are real.

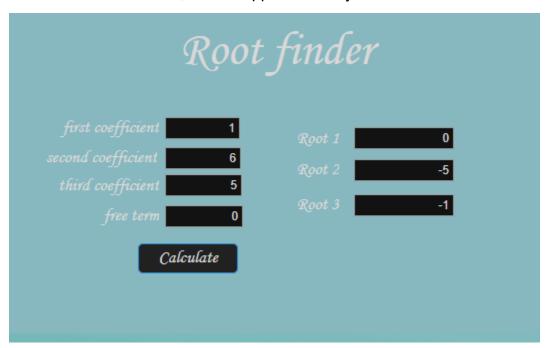Code snippet used as callback for the button:

```
a = app.firstcoefficientEditField.Value;
b = app.secondcoefficientEditField.Value;
c = app.thirdcoefficientEditField.Value;
d = app.freetermEditField.Value;


equationCoefficients = [a, b, c, -d];
rootsArray = roots(equationCoefficients);


if numel(rootsArray) >= 1
    app.Root1EditField.Value = rootsArray(1);
else
    app.Root1EditField.Value = 0;
end

if numel(rootsArray) >= 2
    app.Root2EditField.Value = rootsArray(2);
```

```
else
    app.Root2EditField.Value = 0;
end

if numel(rootsArray) >= 3
    app.Root3EditField.Value = rootsArray(3);
else
    app.Root3EditField.Value = 0;
end
```

Conclusions

Having a simple signal generator and a few features surrounding the cubic equation, the results were as expected. The one thing that I would like to improve about this project is the fact that the root finder cannot work if there arent 3 real roots.

Bibliography

1. https://www.mathworks.com/help/matlab/ref/roots.html
2. https://www.mathworks.com/help/matlab/ref/surf.html
3. https://www.mathworks.com/help/matlab/ref/meshgrid.html
4. https://en.wikipedia.org/wiki/MATLAB

Appendix

```
classdef app2 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                   matlab.ui.Figure
        Menu                       matlab.ui.container.Menu
        RootfinderMenu             matlab.ui.container.Menu
        DPLOTMenu                  matlab.ui.container.Menu
        MOREBUTTERFLIESMenu        matlab.ui.container.Menu
        lessbutterfliesMenu        matlab.ui.container.Menu
        Image5                     matlab.ui.control.Image
        Image4                     matlab.ui.control.Image
        Image3                     matlab.ui.control.Image
        Image2                     matlab.ui.control.Image
        SeedocumentationButton     matlab.ui.control.Button
        Image                      matlab.ui.control.Image
        PlotButton_2               matlab.ui.control.Button
        freetermEditField          matlab.ui.control.NumericEditField
        freetermEditFieldLabel     matlab.ui.control.Label
        rdcoefficientEditField     matlab.ui.control.NumericEditField
```

```matlab
        rdcoefficientEditFieldLabel   matlab.ui.control.Label
        ndcoefficientEditField        matlab.ui.control.NumericEditField
        ndcoefficientEditFieldLabel   matlab.ui.control.Label
        stcoefficientEditField        matlab.ui.control.NumericEditField
        stcoefficientEditFieldLabel   matlab.ui.control.Label
        ThirddegreeequationgeneratorLabel  matlab.ui.control.Label
        SignalGeneratorLabel          matlab.ui.control.Label
        PlotButton                    matlab.ui.control.Button
        PhaseEditField                matlab.ui.control.NumericEditField
        PhaseEditFieldLabel           matlab.ui.control.Label
        FrequencyEditField            matlab.ui.control.NumericEditField
        FrequencyEditFieldLabel       matlab.ui.control.Label
        AmplitudeEditField            matlab.ui.control.NumericEditField
        AmplitudeEditFieldLabel       matlab.ui.control.Label
        UIAxes2                       matlab.ui.control.UIAxes
        UIAxes                        matlab.ui.control.UIAxes
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: PlotButton
        function PlotButtonPushed(app, event)
x = app.AmplitudeEditField.Value;
y = app.FrequencyEditField.Value;
z = app.PhaseEditField.Value;


t = linspace(0, 2 * pi, 1000);
signal = x * sin(y * t + z);



cla(app.UIAxes);



plot(app.UIAxes, t, signal);

title(app.UIAxes, 'Generated Signal');
xlabel(app.UIAxes, 'Time');
ylabel(app.UIAxes, 'Amplitude');

        end

        % Button pushed function: PlotButton_2
        function PlotButton_2Pushed(app, event)



a = app.stcoefficientEditField.Value;
b = app.ndcoefficientEditField.Value;
c = app.rdcoefficientEditField.Value;
d = app.freetermEditField.Value;


x = linspace(-10, 10, 100);
```

```matlab
wave = a*x.^3 + b*x.^2 + c*x + d;


cla(app.UIAxes2);


plot(app.UIAxes2, x, wave, 'LineWidth', 2);


title(app.UIAxes2, 'Graph of The Equation');
xlabel(app.UIAxes2, 'Abscissa');
ylabel(app.UIAxes2, 'Ordinate');


xlim(app.UIAxes2, [-10, 10]);
ylim(app.UIAxes2, [-100, 100]);


        end

        % Menu selected function: DPLOTMenu
        function DPLOTMenuSelected(app, event)
           closereq;
           app3

        end

        % Menu selected function: MOREBUTTERFLIESMenu
        function MOREBUTTERFLIESMenuSelected(app, event)
            closereq;
            app4
        end

        % Menu selected function: lessbutterfliesMenu
        function lessbutterfliesMenuSelected(app, event)
            closereq;
            app5
        end

        % Menu selected function: RootfinderMenu
        function RootfinderMenuSelected(app, event)
            closereq;
            app1
        end
end

% Component initialization
methods (Access = private)

    % Create UIFigure and components
    function createComponents(app)

        % Get the file path for locating images
        pathToMLAPP = fileparts(mfilename('fullpath'));
```

```matlab
% Create UIFigure and hide until all components are created
app.UIFigure = uifigure('Visible', 'off');
app.UIFigure.AutoResizeChildren = 'off';
app.UIFigure.Color = [0.5255 0.7176 0.749];
app.UIFigure.Position = [100 100 1265 752];
app.UIFigure.Name = 'MATLAB App';
app.UIFigure.Resize = 'off';

% Create Menu
app.Menu = uimenu(app.UIFigure);
app.Menu.ForegroundColor = [1 1 1];
app.Menu.Text = 'Menu';

% Create RootfinderMenu
app.RootfinderMenu = uimenu(app.Menu);
app.RootfinderMenu.MenuSelectedFcn = createCallbackFcn(app,
@RootfinderMenuSelected, true);
app.RootfinderMenu.ForegroundColor = [1 1 1];
app.RootfinderMenu.Text = 'Root finder';

% Create DPLOTMenu
app.DPLOTMenu = uimenu(app.Menu);
app.DPLOTMenu.MenuSelectedFcn = createCallbackFcn(app,
@DPLOTMenuSelected, true);
app.DPLOTMenu.ForegroundColor = [1 1 1];
app.DPLOTMenu.Text = '3D PLOT ';

% Create MOREBUTTERFLIESMenu
app.MOREBUTTERFLIESMenu = uimenu(app.Menu);
app.MOREBUTTERFLIESMenu.MenuSelectedFcn = createCallbackFcn(app,
@MOREBUTTERFLIESMenuSelected, true);
app.MOREBUTTERFLIESMenu.ForegroundColor = [1 1 1];
app.MOREBUTTERFLIESMenu.Text = 'MORE BUTTERFLIES';

% Create lessbutterfliesMenu
app.lessbutterfliesMenu = uimenu(app.Menu);
app.lessbutterfliesMenu.MenuSelectedFcn = createCallbackFcn(app,
@lessbutterfliesMenuSelected, true);
app.lessbutterfliesMenu.ForegroundColor = [1 1 1];
app.lessbutterfliesMenu.Text = 'less butterflies :(';

% Create UIAxes
app.UIAxes = uiaxes(app.UIFigure);
title(app.UIAxes, 'Title')
xlabel(app.UIAxes, 'X')
ylabel(app.UIAxes, 'Y')
zlabel(app.UIAxes, 'Z')
app.UIAxes.Color = [1 1 1];
app.UIAxes.ColorOrder = [0 0.447 0.741;0.85 0.325 0.098;0.929 0.694
0.125;0.494 0.184 0.556;0.466 0.674 0.188;0.301 0.745 0.933;0.635 0.078 0.184];
app.UIAxes.Position = [292 426 559 318];

% Create UIAxes2
app.UIAxes2 = uiaxes(app.UIFigure);
```

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```matlab
            title(app.UIAxes2, 'Title')
            xlabel(app.UIAxes2, 'X')
            ylabel(app.UIAxes2, 'Y')
            zlabel(app.UIAxes2, 'Z')
            app.UIAxes2.Color = [1 1 1];
            app.UIAxes2.ColorOrder = [0 0.447 0.741;0.85 0.325 0.098;0.929 0.694
0.125;0.494 0.184 0.556;0.466 0.674 0.188;0.301 0.745 0.933;0.635 0.078 0.184];
            app.UIAxes2.Position = [292 29 559 355];

            % Create AmplitudeEditFieldLabel
            app.AmplitudeEditFieldLabel = uilabel(app.UIFigure);
            app.AmplitudeEditFieldLabel.HorizontalAlignment = 'center';
            app.AmplitudeEditFieldLabel.FontName = 'Monotype Corsiva';
            app.AmplitudeEditFieldLabel.FontSize = 18;
            app.AmplitudeEditFieldLabel.Position = [53 556 113 25];
            app.AmplitudeEditFieldLabel.Text = 'Amplitude';

            % Create AmplitudeEditField
            app.AmplitudeEditField = uieditfield(app.UIFigure, 'numeric');
            app.AmplitudeEditField.Position = [148 557 74 22];

            % Create FrequencyEditFieldLabel
            app.FrequencyEditFieldLabel = uilabel(app.UIFigure);
            app.FrequencyEditFieldLabel.HorizontalAlignment = 'center';
            app.FrequencyEditFieldLabel.VerticalAlignment = 'top';
            app.FrequencyEditFieldLabel.FontName = 'Monotype Corsiva';
            app.FrequencyEditFieldLabel.FontSize = 18;
            app.FrequencyEditFieldLabel.Position = [69 592 79 22];
            app.FrequencyEditFieldLabel.Text = 'Frequency';

            % Create FrequencyEditField
            app.FrequencyEditField = uieditfield(app.UIFigure, 'numeric');
            app.FrequencyEditField.Position = [147 592 74 22];

            % Create PhaseEditFieldLabel
            app.PhaseEditFieldLabel = uilabel(app.UIFigure);
            app.PhaseEditFieldLabel.HorizontalAlignment = 'right';
            app.PhaseEditFieldLabel.FontName = 'Monotype Corsiva';
            app.PhaseEditFieldLabel.FontSize = 18;
            app.PhaseEditFieldLabel.Position = [98 517 42 22];
            app.PhaseEditFieldLabel.Text = 'Phase';

            % Create PhaseEditField
            app.PhaseEditField = uieditfield(app.UIFigure, 'numeric');
            app.PhaseEditField.Position = [147 517 74 22];

            % Create PlotButton
            app.PlotButton = uibutton(app.UIFigure, 'push');
            app.PlotButton.ButtonPushedFcn = createCallbackFcn(app,
@PlotButtonPushed, true);
            app.PlotButton.FontName = 'Monotype Corsiva';
            app.PlotButton.FontSize = 18;
            app.PlotButton.Position = [121 469 100 30];
            app.PlotButton.Text = 'Plot';
```

```matlab
            % Create SignalGeneratorLabel
            app.SignalGeneratorLabel = uilabel(app.UIFigure);
            app.SignalGeneratorLabel.FontName = 'Monotype Corsiva';
            app.SignalGeneratorLabel.FontSize = 36;
            app.SignalGeneratorLabel.Position = [53 627 349 75];
            app.SignalGeneratorLabel.Text = 'Signal Generator';

            % Create ThirddegreeequationgeneratorLabel
            app.ThirddegreeequationgeneratorLabel = uilabel(app.UIFigure);
            app.ThirddegreeequationgeneratorLabel.FontName = 'Monotype Corsiva';
            app.ThirddegreeequationgeneratorLabel.FontSize = 36;
            app.ThirddegreeequationgeneratorLabel.Position = [40 384 410 44];
            app.ThirddegreeequationgeneratorLabel.Text = 'Third degree equation
generator';

            % Create stcoefficientEditFieldLabel
            app.stcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.stcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.stcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.stcoefficientEditFieldLabel.FontSize = 18;
            app.stcoefficientEditFieldLabel.Position = [48 334 94 22];
            app.stcoefficientEditFieldLabel.Text = '1st coefficient';

            % Create stcoefficientEditField
            app.stcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.stcoefficientEditField.Position = [148 334 75 22];

            % Create ndcoefficientEditFieldLabel
            app.ndcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.ndcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.ndcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.ndcoefficientEditFieldLabel.FontSize = 18;
            app.ndcoefficientEditFieldLabel.Position = [43 302 99 22];
            app.ndcoefficientEditFieldLabel.Text = '2nd coefficient';

            % Create ndcoefficientEditField
            app.ndcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.ndcoefficientEditField.Position = [148 302 76 22];

            % Create rdcoefficientEditFieldLabel
            app.rdcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.rdcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.rdcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.rdcoefficientEditFieldLabel.FontSize = 18;
            app.rdcoefficientEditFieldLabel.Position = [46 273 96 22];
            app.rdcoefficientEditFieldLabel.Text = '3rd coefficient';

            % Create rdcoefficientEditField
            app.rdcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.rdcoefficientEditField.Position = [148 273 77 22];

            % Create freetermEditFieldLabel
            app.freetermEditFieldLabel = uilabel(app.UIFigure);
            app.freetermEditFieldLabel.HorizontalAlignment = 'right';
            app.freetermEditFieldLabel.FontName = 'Monotype Corsiva';
```

```matlab
            app.freetermEditFieldLabel.FontSize = 18;
            app.freetermEditFieldLabel.Position = [81 240 61 22];
            app.freetermEditFieldLabel.Text = 'free term';

            % Create freetermEditField
            app.freetermEditField = uieditfield(app.UIFigure, 'numeric');
            app.freetermEditField.Position = [148 240 78 22];

            % Create PlotButton_2
            app.PlotButton_2 = uibutton(app.UIFigure, 'push');
            app.PlotButton_2.ButtonPushedFcn = createCallbackFcn(app,
@PlotButton_2Pushed, true);
            app.PlotButton_2.FontName = 'Monotype Corsiva';
            app.PlotButton_2.FontSize = 18;
            app.PlotButton_2.Position = [121 189 100 30];
            app.PlotButton_2.Text = 'Plot';

            % Create Image
            app.Image = uiimage(app.UIFigure);
            app.Image.Position = [27 13 214 178];
            app.Image.ImageSource = fullfile(pathToMLAPP, '—Pngtree—picture of blue
dreamy glowing_9071029.png');

            % Create SeedocumentationButton
            app.SeedocumentationButton = uibutton(app.UIFigure, 'push');
            app.SeedocumentationButton.FontName = 'Monotype Corsiva';
            app.SeedocumentationButton.FontSize = 36;
            app.SeedocumentationButton.Position = [880 372 360 70];
            app.SeedocumentationButton.Text = 'See documentation';

            % Create Image2
            app.Image2 = uiimage(app.UIFigure);
            app.Image2.Position = [1065 547 191 206];
            app.Image2.ImageSource = fullfile(pathToMLAPP, 'klipartz.com.png');

            % Create Image3
            app.Image3 = uiimage(app.UIFigure);
            app.Image3.Position = [1049 7 208 213];
            app.Image3.ImageSource = fullfile(pathToMLAPP, 'klipartz2.png');

            % Create Image4
            app.Image4 = uiimage(app.UIFigure);
            app.Image4.Position = [870 89 379 284];
            app.Image4.ImageSource = fullfile(pathToMLAPP, 'Flying-Blue-Butterflies-
PNG-Download-Image.png');

            % Create Image5
            app.Image5 = uiimage(app.UIFigure);
            app.Image5.Position = [862 457 361 256];
            app.Image5.ImageSource = fullfile(pathToMLAPP, 'Flying-Blue-Butterflies-
PNG-Download-Image.png');

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
```

```matlab
        end

        % App creation and deletion
        methods (Access = public)

            % Construct app
            function app = app2

                % Create UIFigure and components
                createComponents(app)

                % Register the app with App Designer
                registerApp(app, app.UIFigure)

                if nargout == 0
                    clear app
                end
            end

            % Code that executes before app deletion
            function delete(app)

                % Delete UIFigure when app is deleted
                delete(app.UIFigure)
            end
        end
end
classdef app1 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                         matlab.ui.Figure
        Menu                             matlab.ui.container.Menu
        BacktoMainMenu                   matlab.ui.container.Menu
        Image6                           matlab.ui.control.Image
        Image5                           matlab.ui.control.Image
        Image4                           matlab.ui.control.Image
        Image3                           matlab.ui.control.Image
        Image2                           matlab.ui.control.Image
        Image                            matlab.ui.control.Image
        Root3EditField                   matlab.ui.control.NumericEditField
        Root3EditFieldLabel              matlab.ui.control.Label
        Root2EditField                   matlab.ui.control.NumericEditField
        Root2EditFieldLabel              matlab.ui.control.Label
        Root1EditField                   matlab.ui.control.NumericEditField
        Root1EditFieldLabel              matlab.ui.control.Label
        RootfinderLabel                  matlab.ui.control.Label
        freetermEditField                matlab.ui.control.NumericEditField
        freetermEditFieldLabel           matlab.ui.control.Label
        thirdcoefficientEditField        matlab.ui.control.NumericEditField
        thirdcoefficientEditFieldLabel   matlab.ui.control.Label
        secondcoefficientEditField       matlab.ui.control.NumericEditField
        secondcoefficientEditFieldLabel  matlab.ui.control.Label
        firstcoefficientEditField        matlab.ui.control.NumericEditField
        firstcoefficientEditFieldLabel   matlab.ui.control.Label
```

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```matlab
        CalculateButton                    matlab.ui.control.Button
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: CalculateButton
        function CalculateButtonPushed(app, event)



a = app.firstcoefficientEditField.Value;
b = app.secondcoefficientEditField.Value;
c = app.thirdcoefficientEditField.Value;
d = app.freetermEditField.Value;


equationCoefficients = [a, b, c, -d];
rootsArray = roots(equationCoefficients);


if numel(rootsArray) >= 1
    app.Root1EditField.Value = rootsArray(1);
else
    app.Root1EditField.Value = 0;
end

if numel(rootsArray) >= 2
    app.Root2EditField.Value = rootsArray(2);
else
    app.Root2EditField.Value = 0;
end

if numel(rootsArray) >= 3
    app.Root3EditField.Value = rootsArray(3);
else
    app.Root3EditField.Value = 0;
end

        end

        % Menu selected function: BacktoMainMenu
        function BacktoMainMenuSelected(app, event)
            closereq;
            app2
        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)
```

```matlab
            % Get the file path for locating images
            pathToMLAPP = fileparts(mfilename('fullpath'));

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Color = [0.5294 0.7216 0.749];
            app.UIFigure.Position = [100 100 1026 687];
            app.UIFigure.Name = 'MATLAB App';

            % Create Menu
            app.Menu = uimenu(app.UIFigure);
            app.Menu.ForegroundColor = [1 1 1];
            app.Menu.Text = 'Menu';

            % Create BacktoMainMenu
            app.BacktoMainMenu = uimenu(app.Menu);
            app.BacktoMainMenu.MenuSelectedFcn = createCallbackFcn(app,
@BacktoMainMenuSelected, true);
            app.BacktoMainMenu.ForegroundColor = [1 1 1];
            app.BacktoMainMenu.Text = 'Back to Main Menu';

            % Create CalculateButton
            app.CalculateButton = uibutton(app.UIFigure, 'push');
            app.CalculateButton.ButtonPushedFcn = createCallbackFcn(app,
@CalculateButtonPushed, true);
            app.CalculateButton.FontName = 'Monotype Corsiva';
            app.CalculateButton.FontSize = 18;
            app.CalculateButton.Position = [373 277 100 30];
            app.CalculateButton.Text = 'Calculate';

            % Create firstcoefficientEditFieldLabel
            app.firstcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.firstcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.firstcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.firstcoefficientEditFieldLabel.FontSize = 18;
            app.firstcoefficientEditFieldLabel.Position = [292 422 102 22];
            app.firstcoefficientEditFieldLabel.Text = 'first coefficient';

            % Create firstcoefficientEditField
            app.firstcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.firstcoefficientEditField.Position = [400 422 75 22];

            % Create secondcoefficientEditFieldLabel
            app.secondcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.secondcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.secondcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.secondcoefficientEditFieldLabel.FontSize = 18;
            app.secondcoefficientEditFieldLabel.Position = [276 390 116 22];
            app.secondcoefficientEditFieldLabel.Text = 'second coefficient';

            % Create secondcoefficientEditField
            app.secondcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.secondcoefficientEditField.Position = [400 390 76 22];

            % Create thirdcoefficientEditFieldLabel
```

```matlab
app.thirdcoefficientEditFieldLabel = uilabel(app.UIFigure);
app.thirdcoefficientEditFieldLabel.HorizontalAlignment = 'right';
app.thirdcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
app.thirdcoefficientEditFieldLabel.FontSize = 18;
app.thirdcoefficientEditFieldLabel.Position = [288 361 106 22];
app.thirdcoefficientEditFieldLabel.Text = 'third coefficient';

% Create thirdcoefficientEditField
app.thirdcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
app.thirdcoefficientEditField.Position = [400 361 77 22];

% Create freetermEditFieldLabel
app.freetermEditFieldLabel = uilabel(app.UIFigure);
app.freetermEditFieldLabel.HorizontalAlignment = 'right';
app.freetermEditFieldLabel.FontName = 'Monotype Corsiva';
app.freetermEditFieldLabel.FontSize = 18;
app.freetermEditFieldLabel.Position = [333 328 61 22];
app.freetermEditFieldLabel.Text = 'free term';

% Create freetermEditField
app.freetermEditField = uieditfield(app.UIFigure, 'numeric');
app.freetermEditField.Position = [400 328 78 22];

% Create RootfinderLabel
app.RootfinderLabel = uilabel(app.UIFigure);
app.RootfinderLabel.FontName = 'Monotype Corsiva';
app.RootfinderLabel.FontSize = 48;
app.RootfinderLabel.Position = [414 483 200 60];
app.RootfinderLabel.Text = 'Root finder';

% Create Root1EditFieldLabel
app.Root1EditFieldLabel = uilabel(app.UIFigure);
app.Root1EditFieldLabel.HorizontalAlignment = 'right';
app.Root1EditFieldLabel.FontName = 'Monotype Corsiva';
app.Root1EditFieldLabel.FontSize = 18;
app.Root1EditFieldLabel.Position = [526 411 48 22];
app.Root1EditFieldLabel.Text = 'Root 1';

% Create Root1EditField
app.Root1EditField = uieditfield(app.UIFigure, 'numeric');
app.Root1EditField.Position = [589 411 100 22];

% Create Root2EditFieldLabel
app.Root2EditFieldLabel = uilabel(app.UIFigure);
app.Root2EditFieldLabel.HorizontalAlignment = 'right';
app.Root2EditFieldLabel.FontName = 'Monotype Corsiva';
app.Root2EditFieldLabel.FontSize = 18;
app.Root2EditFieldLabel.Position = [526 378 48 22];
app.Root2EditFieldLabel.Text = 'Root 2';

% Create Root2EditField
app.Root2EditField = uieditfield(app.UIFigure, 'numeric');
app.Root2EditField.Position = [589 378 100 22];

% Create Root3EditFieldLabel
```

```matlab
            app.Root3EditFieldLabel = uilabel(app.UIFigure);
            app.Root3EditFieldLabel.HorizontalAlignment = 'right';
            app.Root3EditFieldLabel.FontName = 'Monotype Corsiva';
            app.Root3EditFieldLabel.FontSize = 18;
            app.Root3EditFieldLabel.Position = [526 340 48 22];
            app.Root3EditFieldLabel.Text = 'Root 3';

            % Create Root3EditField
            app.Root3EditField = uieditfield(app.UIFigure, 'numeric');
            app.Root3EditField.Position = [589 340 100 22];

            % Create Image
            app.Image = uiimage(app.UIFigure);
            app.Image.Position = [838 497 173 180];
            app.Image.ImageSource = fullfile(pathToMLAPP, 'klipartz.com.png');

            % Create Image2
            app.Image2 = uiimage(app.UIFigure);
            app.Image2.ScaleMethod = 'stretch';
            app.Image2.Position = [1 1 1026 213];
            app.Image2.ImageSource = fullfile(pathToMLAPP, 'pngwing.com.png');

            % Create Image3
            app.Image3 = uiimage(app.UIFigure);
            app.Image3.Position = [825 14 186 186];
            app.Image3.ImageSource = fullfile(pathToMLAPP, 'klipartz2.png');

            % Create Image4
            app.Image4 = uiimage(app.UIFigure);
            app.Image4.Position = [19 475 184 224];
            app.Image4.ImageSource = fullfile(pathToMLAPP, 'klipartz4.png');

            % Create Image5
            app.Image5 = uiimage(app.UIFigure);
            app.Image5.Position = [19 19 184 176];
            app.Image5.ImageSource = fullfile(pathToMLAPP, 'klipartz3.png');

            % Create Image6
            app.Image6 = uiimage(app.UIFigure);
            app.Image6.Position = [175 -47 677 309];
            app.Image6.ImageSource = fullfile(pathToMLAPP, 'Butterfly-PNG-1.png');

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = app1

            % Create UIFigure and components
            createComponents(app)
```

```matlab
            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
classdef app3 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                          matlab.ui.Figure
        Menu                              matlab.ui.container.Menu
        BacktomainMenu                    matlab.ui.container.Menu
        Image                             matlab.ui.control.Image
        Image2                            matlab.ui.control.Image
        rdOrderEquation3DRepresentationLabel  matlab.ui.control.Label
        freetermEditField                 matlab.ui.control.NumericEditField
        freetermEditFieldLabel            matlab.ui.control.Label
        thirdcoefficientEditField         matlab.ui.control.NumericEditField
        thirdcoefficientEditFieldLabel    matlab.ui.control.Label
        secondcoefficientEditField        matlab.ui.control.NumericEditField
        secondcoefficientEditFieldLabel   matlab.ui.control.Label
        firstcoefficientEditField         matlab.ui.control.NumericEditField
        firstcoefficientEditFieldLabel    matlab.ui.control.Label
        PlotButton                        matlab.ui.control.Button
        UIAxes                            matlab.ui.control.UIAxes
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Menu selected function: BacktomainMenu
        function BacktomainMenuSelected(app, event)
            closereq;
            app2
        end

        % Menu selected function: Menu
        function MenuSelected(app, event)

        end

        % Button pushed function: PlotButton
        function PlotButtonPushed(app, event)
```

```matlab
        a = app.firstcoefficientEditField.Value;
        b = app.secondcoefficientEditField.Value;
        c = app.thirdcoefficientEditField.Value;
        d = app.freetermEditField.Value;

        x = linspace(-10, 10, 100);
        y = linspace(-10, 10, 100);

        [X, Y] = meshgrid(x, y);

        Z = a*X.^3 + b*X.^2 + c*X + d*Y;


        cla(app.UIAxes);

        surf(app.UIAxes, X, Y, Z, 'EdgeColor', 'none');
        title(app.UIAxes, '3D Plot of Cubic Equation');
        xlabel(app.UIAxes, 'X-axis');
        ylabel(app.UIAxes, 'Y-axis');
        zlabel(app.UIAxes, 'Z-axis');

            end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Get the file path for locating images
            pathToMLAPP = fileparts(mfilename('fullpath'));

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Color = [0.5294 0.7216 0.749];
            app.UIFigure.Position = [100 100 992 653];
            app.UIFigure.Name = 'MATLAB App';

            % Create Menu
            app.Menu = uimenu(app.UIFigure);
            app.Menu.MenuSelectedFcn = createCallbackFcn(app, @MenuSelected, true);
            app.Menu.ForegroundColor = [1 1 1];
            app.Menu.Text = 'Menu';

            % Create BacktomainMenu
            app.BacktomainMenu = uimenu(app.Menu);
            app.BacktomainMenu.MenuSelectedFcn = createCallbackFcn(app,
@BacktomainMenuSelected, true);
            app.BacktomainMenu.ForegroundColor = [1 1 1];
            app.BacktomainMenu.Text = 'Back to main';

            % Create UIAxes
            app.UIAxes = uiaxes(app.UIFigure);
```

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```matlab
            title(app.UIAxes, 'Title')
            xlabel(app.UIAxes, 'X')
            ylabel(app.UIAxes, 'Y')
            zlabel(app.UIAxes, 'Z')
            app.UIAxes.Color = [1 1 1];
            app.UIAxes.ColorOrder = [0 0.447 0.741;0.85 0.325 0.098;0.929 0.694
0.125;0.494 0.184 0.556;0.466 0.674 0.188;0.301 0.745 0.933;0.635 0.078 0.184];
            app.UIAxes.Position = [254 88 690 479];

            % Create PlotButton
            app.PlotButton = uibutton(app.UIFigure, 'push');
            app.PlotButton.ButtonPushedFcn = createCallbackFcn(app,
@PlotButtonPushed, true);
            app.PlotButton.FontName = 'Monotype Corsiva';
            app.PlotButton.FontSize = 18;
            app.PlotButton.Position = [121 189 100 30];
            app.PlotButton.Text = 'Plot';

            % Create firstcoefficientEditFieldLabel
            app.firstcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.firstcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.firstcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.firstcoefficientEditFieldLabel.FontSize = 18;
            app.firstcoefficientEditFieldLabel.Position = [40 334 102 22];
            app.firstcoefficientEditFieldLabel.Text = 'first coefficient';

            % Create firstcoefficientEditField
            app.firstcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.firstcoefficientEditField.Position = [148 334 75 22];

            % Create secondcoefficientEditFieldLabel
            app.secondcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.secondcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.secondcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.secondcoefficientEditFieldLabel.FontSize = 18;
            app.secondcoefficientEditFieldLabel.Position = [26 302 116 22];
            app.secondcoefficientEditFieldLabel.Text = 'second coefficient';

            % Create secondcoefficientEditField
            app.secondcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.secondcoefficientEditField.Position = [148 302 76 22];

            % Create thirdcoefficientEditFieldLabel
            app.thirdcoefficientEditFieldLabel = uilabel(app.UIFigure);
            app.thirdcoefficientEditFieldLabel.HorizontalAlignment = 'right';
            app.thirdcoefficientEditFieldLabel.FontName = 'Monotype Corsiva';
            app.thirdcoefficientEditFieldLabel.FontSize = 18;
            app.thirdcoefficientEditFieldLabel.Position = [36 273 106 22];
            app.thirdcoefficientEditFieldLabel.Text = 'third coefficient';

            % Create thirdcoefficientEditField
            app.thirdcoefficientEditField = uieditfield(app.UIFigure, 'numeric');
            app.thirdcoefficientEditField.Position = [148 273 77 22];

            % Create freetermEditFieldLabel
```

```matlab
            app.freetermEditFieldLabel = uilabel(app.UIFigure);
            app.freetermEditFieldLabel.HorizontalAlignment = 'right';
            app.freetermEditFieldLabel.FontName = 'Monotype Corsiva';
            app.freetermEditFieldLabel.FontSize = 18;
            app.freetermEditFieldLabel.Position = [81 240 61 22];
            app.freetermEditFieldLabel.Text = 'free term';

            % Create freetermEditField
            app.freetermEditField = uieditfield(app.UIFigure, 'numeric');
            app.freetermEditField.Position = [148 240 78 22];

            % Create rdOrderEquation3DRepresentationLabel
            app.rdOrderEquation3DRepresentationLabel = uilabel(app.UIFigure);
            app.rdOrderEquation3DRepresentationLabel.VerticalAlignment = 'top';
            app.rdOrderEquation3DRepresentationLabel.WordWrap = 'on';
            app.rdOrderEquation3DRepresentationLabel.FontName = 'Monotype Corsiva';
            app.rdOrderEquation3DRepresentationLabel.FontSize = 36;
            app.rdOrderEquation3DRepresentationLabel.Position = [36 389 218 150];
            app.rdOrderEquation3DRepresentationLabel.Text = '3rd Order Equation 3D
Representation';

            % Create Image2
            app.Image2 = uiimage(app.UIFigure);
            app.Image2.ScaleMethod = 'stretch';
            app.Image2.Position = [1 1 992 100];
            app.Image2.ImageSource = fullfile(pathToMLAPP, 'pngwing.com.png');

            % Create Image
            app.Image = uiimage(app.UIFigure);
            app.Image.Position = [10 9 244 181];
            app.Image.ImageSource = fullfile(pathToMLAPP, '—Pngtree—picture of blue
dreamy glowing_9071029.png');

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = app3

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end
```

```matlab
        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
classdef app4 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                    matlab.ui.Figure
        BacktoMainMenuButton        matlab.ui.control.Button
        BUTTERFLIESEVERYWHERELabel  matlab.ui.control.Label
        Image                       matlab.ui.control.Image
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: BacktoMainMenuButton
        function BacktoMainMenuButtonPushed(app, event)
            closereq;
            app2
        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Position = [100 100 1342 855];
            app.UIFigure.Name = 'MATLAB App';

            % Create Image
            app.Image = uiimage(app.UIFigure);
            app.Image.Position = [-250 1 1844 897];
            app.Image.ImageSource = 'michochuan-butterflies-alex-guillaume-
unsplash.jpg.1200x800_q85_crop.jpg';

            % Create BUTTERFLIESEVERYWHERELabel
            app.BUTTERFLIESEVERYWHERELabel = uilabel(app.UIFigure);
            app.BUTTERFLIESEVERYWHERELabel.BackgroundColor = [0.851 0.3255 0.098];
            app.BUTTERFLIESEVERYWHERELabel.HorizontalAlignment = 'center';
            app.BUTTERFLIESEVERYWHERELabel.FontName = 'Monotype Corsiva';
            app.BUTTERFLIESEVERYWHERELabel.FontSize = 48;
            app.BUTTERFLIESEVERYWHERELabel.Position = [339 488 699 169];
            app.BUTTERFLIESEVERYWHERELabel.Text = 'BUTTERFLIES EVERYWHERE';

            % Create BacktoMainMenuButton
```

```matlab
            app.BacktoMainMenuButton = uibutton(app.UIFigure, 'push');
            app.BacktoMainMenuButton.ButtonPushedFcn = createCallbackFcn(app,
@BacktoMainMenuButtonPushed, true);
            app.BacktoMainMenuButton.FontName = 'Monotype Corsiva';
            app.BacktoMainMenuButton.FontSize = 48;
            app.BacktoMainMenuButton.Position = [489 321 368 67];
            app.BacktoMainMenuButton.Text = 'Back to Main Menu';

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = app4

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
classdef app5 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                matlab.ui.Figure
        BacktoMainMenuButton    matlab.ui.control.Button
        NobutterflieshereLabel  matlab.ui.control.Label
        Image                   matlab.ui.control.Image
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: BacktoMainMenuButton
        function BacktoMainMenuButtonPushed(app, event)
            closereq;
            app2
```

```matlab
        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Position = [100 100 983 682];
            app.UIFigure.Name = 'MATLAB App';

            % Create Image
            app.Image = uiimage(app.UIFigure);
            app.Image.Position = [-162 1 1310 725];
            app.Image.ImageSource = 'empty_field.jpg';

            % Create NobutterflieshereLabel
            app.NobutterflieshereLabel = uilabel(app.UIFigure);
            app.NobutterflieshereLabel.FontName = 'Monotype Corsiva';
            app.NobutterflieshereLabel.FontSize = 48;
            app.NobutterflieshereLabel.Position = [326 383 333 76];
            app.NobutterflieshereLabel.Text = 'No butterflies here';

            % Create BacktoMainMenuButton
            app.BacktoMainMenuButton = uibutton(app.UIFigure, 'push');
            app.BacktoMainMenuButton.ButtonPushedFcn = createCallbackFcn(app,
@BacktoMainMenuButtonPushed, true);
            app.BacktoMainMenuButton.FontName = 'Monotype Corsiva';
            app.BacktoMainMenuButton.FontSize = 36;
            app.BacktoMainMenuButton.Position = [353 302 279 52];
            app.BacktoMainMenuButton.Text = 'Back to Main Menu';

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = app5

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
```

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```matlab
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
```