Contents

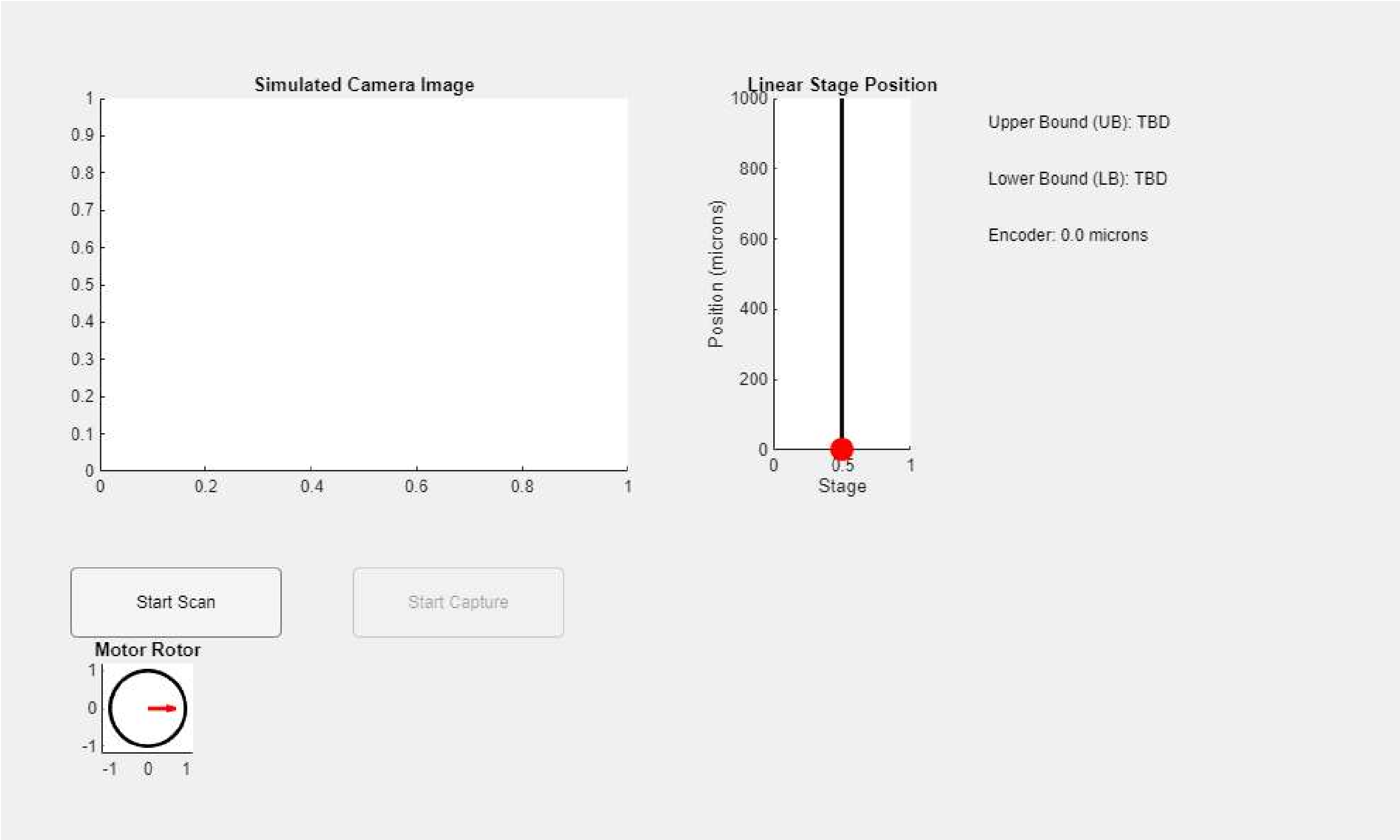

```
function motorCameraSimulation
```

Global Variables (for timers and rotor animation)

```
    global scanTimer captureTimer rotorAngle
    scanTimer = [];
    captureTimer = [];
    rotorAngle = 0; % in radians
```

Create GUI

```
    fig = uifigure('Name','Motor-Camera System Simulation','Position',[100,100,1000,600]);

    % Axes for simulated camera image
    axImage = uiaxes(fig, 'Position',[50,250,400,300]);
    title(axImage, 'Simulated Camera Image');

    % Axes for linear stage (vertical view)
    axStage = uiaxes(fig, 'Position',[500,250,150,300]);
    title(axStage, 'Linear Stage Position');
    xlabel(axStage, 'Stage');
    ylabel(axStage, 'Position (microns)');
    axStage.XLim = [0 1];
    axStage.YLim = [0 1000];
    hold(axStage, 'on');
    % Draw vertical stage line:
    plot(axStage, [0.5 0.5], [0 1000], 'k-', 'LineWidth',2);
    stageMarker = plot(axStage, 0.5, 0, 'ro', 'MarkerSize',12, 'MarkerFaceColor','r');

    % Axes for motor rotor animation
    axRotor = uiaxes(fig, 'Position',[50,50,100,100]);
    axis(axRotor, 'equal');
    axRotor.XLim = [-1.2 1.2];
    axRotor.YLim = [-1.2 1.2];
    title(axRotor, 'Motor Rotor');
    hold(axRotor, 'on');
    theta = linspace(0,2*pi,100);
    x_circle = cos(theta);
    y_circle = sin(theta);
    plot(axRotor, x_circle, y_circle, 'k-', 'LineWidth',2);  % Rotor circle
    rotorMarker = quiver(axRotor, 0, 0, 0.8, 0, 'r','LineWidth',2, 'MaxHeadSize',2);

    % Labels for UB, LB, and Encoder reading
    lblUB = uilabel(fig, 'Position',[700,500,250,30], 'Text','Upper Bound (UB): TBD');
    lblLB = uilabel(fig, 'Position',[700,460,250,30], 'Text','Lower Bound (LB): TBD');
    lblEncoder = uilabel(fig, 'Position',[700,420,250,30], 'Text','Encoder: 0.0 microns');

    % Buttons for scanning and capturing phases
    btnScan = uibutton(fig, 'push', 'Text','Start Scan',...
        'Position',[50,150,150,50], 'ButtonPushedFcn', @(~,~) startScan());
    btnCapture = uibutton(fig, 'push', 'Text','Start Capture',...
        'Position',[250,150,150,50], 'Enable','off', 'ButtonPushedFcn', @(~,~) startCapture());
```



Simulation Parameters

```
stagePositions = 0:10:1000;  % 0 to 1000 microns in 10-micron steps
numPos = numel(stagePositions);
% Synthetic focus metric function: Gaussian centered at 400 microns, sigma=100.
focusMetricFun = @(z) exp(-((z-400)/100).^2)*100;
```

Build Focus FIS (FocusFIS)

```
fis = mamfis('Name','FocusFIS');
fis = addInput(fis, [0 100], 'Name', 'FocusMetric');
fis = addMF(fis, 'FocusMetric', 'trimf', [0 0 50], 'Name', 'NotFocused');
fis = addMF(fis, 'FocusMetric', 'trimf', [30 100 100], 'Name', 'Focused');
fis = addOutput(fis, [0 1], 'Name', 'FocusDegree');
fis = addMF(fis, 'FocusDegree', 'trimf', [0 0 0.5], 'Name', 'NotFocus');
fis = addMF(fis, 'FocusDegree', 'trimf', [0.5 1 1], 'Name', 'Focus');
% Rule: If FocusMetric is Focused then FocusDegree is Focus.
ruleList = "FocusMetric==Focused => FocusDegree=Focus";
fis = addRule(fis, ruleList);
focusThreshold = 0.5;
```

Build Motor Regulation FIS (MotorFIS)

```
motorFIS = mamfis('Name','MotorFIS');
motorFIS = addInput(motorFIS, [-2 2], 'Name', 'Error');
motorFIS = addMF(motorFIS, 'Error', 'trimf', [-2 -2 0], 'Name', 'Negative');
motorFIS = addMF(motorFIS, 'Error', 'trimf', [-1 0 1], 'Name', 'Zero');
motorFIS = addMF(motorFIS, 'Error', 'trimf', [0 2 2], 'Name', 'Positive');
motorFIS = addOutput(motorFIS, [-2 2], 'Name', 'Adjustment');
motorFIS = addMF(motorFIS, 'Adjustment', 'trimf', [-2 -2 0], 'Name', 'Increase');
motorFIS = addMF(motorFIS, 'Adjustment', 'trimf', [-0.5 0 0.5], 'Name', 'NoChange');
motorFIS = addMF(motorFIS, 'Adjustment', 'trimf', [0 2 2], 'Name', 'Decrease');
% Rules:
% If Error is Negative then Adjustment is Increase;
% If Error is Zero then Adjustment is NoChange;
% If Error is Positive then Adjustment is Decrease.
ruleListMotor = [1 1 1 1; 2 2 1 1; 3 3 1 1];
motorFIS = addRule(motorFIS, ruleListMotor);
```

Variables for storing scan results

```
focusValues = zeros(1, numPos);
fuzzyOut = zeros(1, numPos);
UB = NaN; LB = NaN;
currentScanIndex = 1;
currentCaptureIndex = 1;
rotorAngle = 0; % Initialize rotor angle in radians
```

Timer Objects for Simulation Phases

```
if isempty(scanTimer) || ~isvalid(scanTimer)
    scanTimer = timer('ExecutionMode', 'fixedRate', 'Period', 0.2, 'TimerFcn', @scanStep);
end
if isempty(captureTimer) || ~isvalid(captureTimer)
    captureTimer = timer('ExecutionMode','fixedRate', 'Period', 0.5, 'TimerFcn', @captureStep);
end
```

Scanning Phase Function

```
function scanStep(~,~)
    if currentScanIndex <= numPos
        z = stagePositions(currentScanIndex);
        focusVal = focusMetricFun(z);
        focusValues(currentScanIndex) = focusVal;
        fuzzyVal = evalfis(fis, focusVal);
        fuzzyOut(currentScanIndex) = fuzzyVal;

        % Update simulated camera image
        img = uint8(ones(300,400)*focusVal);
        imshow(img, 'Parent', axImage);
        title(axImage, sprintf('Scan: Z = %d microns, Focus = %.1f', z, focusVal));

        % Update encoder and stage marker
        lblEncoder.Text = sprintf('Encoder: %d microns', z);
        stageMarker.YData = z;

        currentScanIndex = currentScanIndex + 1;
    else
        % Determine UB and LB from fuzzy outputs
        idxInFocus = find(fuzzyOut > focusThreshold);
        if ~isempty(idxInFocus)
            UB = stagePositions(idxInFocus(1));
            LB = stagePositions(idxInFocus(end));
        end
        lblUB.Text = sprintf('Upper Bound (UB): %.1f microns', UB);
        lblLB.Text = sprintf('Lower Bound (LB): %.1f microns', LB);
        stop(scanTimer);
        % Enable capture button if valid bounds found
        if ~isnan(UB) && ~isnan(LB)
            btnCapture.Enable = 'on';
        else
            uialert(fig, 'No in-focus region detected during scan!', 'Scan Error');
        end
    end
end
```

Capture Phase Function: With Motor Regulation and Rotor Animation

```
function captureStep(~,~)
    if currentCaptureIndex == 1
        [~, idx] = min(abs(stagePositions - UB));
        currentCaptureIndex = idx;
    end

    if currentCaptureIndex < numPos && stagePositions(currentCaptureIndex) < LB
        % Nominal commanded step
        commandedStep = 10;
        commandedPos = stagePositions(currentCaptureIndex);

        % Simulate actual motor error: random error in [-2,2] microns
        randomError = -2 + 4*rand();
        actualPos = commandedPos + commandedStep + randomError;
        errorVal = (actualPos - commandedPos) - commandedStep;
        adjustment = evalfis(motorFIS, errorVal);
        adjustedStep = commandedStep + adjustment;
```

```
            commandedPosNext = commandedPos + adjustedStep;

            % Update encoder and stage marker (simulate actual position)
            lblEncoder.Text = sprintf('Encoder: %.1f microns (Error: %.2f, Adj: %.2f)', actualPos, errorVal, adjustment);
            stageMarker.YData = actualPos;

            % Update simulated camera image based on focus metric at actual position
            focusVal = focusMetricFun(actualPos);
            img = uint8(ones(300,400)*focusVal);
            imshow(img, 'Parent', axImage);
            title(axImage, sprintf('Capture: Z = %.1f microns, Focus = %.1f', actualPos, focusVal));

            % Update motor rotor animation: increment rotor angle by 5 degrees per capture step
            rotorAngle = rotorAngle + (5*pi/180);
            % Update rotor marker (arrow length = 0.8)
            set(rotorMarker, 'UData', 0.8*cos(rotorAngle), 'VData', 0.8*sin(rotorAngle));

            % Find next index in stagePositions closest to commandedPosNext
            [~, nextIdx] = min(abs(stagePositions - commandedPosNext));
            currentCaptureIndex = nextIdx;
        else
            stop(captureTimer);
            uialert(fig, 'Capture phase complete!', 'Done');
            % After simulation, display and save FIS graphs and rules
            displayAndSaveFIS(fis, motorFIS);
        end
    end
```

Button Callback: Start Scan

```
    function startScan()
        currentScanIndex = 1;
        focusValues = zeros(1, numPos);
        fuzzyOut = zeros(1, numPos);
        start(scanTimer);
        btnScan.Enable = 'off';
    end
```

Button Callback: Start Capture

```
    function startCapture()
        currentCaptureIndex = 1;
        start(captureTimer);
        btnCapture.Enable = 'off';
    end
```

```
end
```

Helper Function to Display and Save FIS Membership Functions and Rules

```
function displayAndSaveFIS(fis, motorFIS)
    % Display FocusFIS membership functions
    figFocus = figure('Name','FocusFIS Membership Functions');
    subplot(2,1,1);
    plotmf(fis, 'input', 1);
    title('FocusFIS - Input: FocusMetric');
    subplot(2,1,2);
    plotmf(fis, 'output', 1);
    title('FocusFIS - Output: FocusDegree');
    % Save FocusFIS figure
    saveas(figFocus, fullfile(pwd, 'visualizations/FocusFIS_MF.png'));
    disp('FocusFIS Rules:');
    disp(fis.Rules);

    % Display MotorFIS membership functions
    figMotor = figure('Name','MotorFIS Membership Functions');
    subplot(2,1,1);
    plotmf(motorFIS, 'input', 1);
    title('MotorFIS - Input: Error');
    subplot(2,1,2);
    plotmf(motorFIS, 'output', 1);
    title('MotorFIS - Output: Adjustment');
    % Save MotorFIS figure
    saveas(figMotor, fullfile(pwd, 'visualizations/MotorFIS_MF.png'));
    disp('MotorFIS Rules:');
```

```
    disp(motorFIS.Rules);
end
```

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