
```
%Roll number : AM25M807
%Name : NIRAJ KUMAR SINGH
%Assignment: Numerical Derivative Assignment 5 (Q1)
% -----
%Clear workspace and command window

clc;
clear all;
close all;

% Define symbolic variable and test function
syms t
test_func = exp(t) * cos(t);

% Create function handles for numerical evaluation
func_handle = matlabFunction(test_func);
derivative_exact = matlabFunction(diff(test_func, t));

% Define numerical differentiation schemes
diff_forward = @(func, point, step) (func(point + step) - func(point)) /
step;
diff_backward = @(func, point, step) (func(point) - func(point - step)) /
step;
diff_centered = @(func, point, step) (func(point + step) - func(point -
step)) / (2 * step);

% Store methods in cell array with corresponding names
numerical_methods = {diff_forward, diff_backward, diff_centered};
scheme_labels = ["Forward Difference", "Backward Difference", "Central
Difference"];

% Analysis function for each differentiation method
function [] = AnalyzeMethod(label, diff_scheme, target_func, exact_deriv,
eval_point, initial_step)
    step_sizes = [];
    error_values = [];

    fprintf("\n\n===== %s Analysis =====\n\n", label)

    error_threshold = 1e-6;
    iteration = 0;
    current_error = inf;
    current_step = initial_step;

    while (current_error > error_threshold) || iteration == 0
        % Calculate numerical derivative
        numerical_result = diff_scheme(target_func, eval_point,
current_step);
        exact_result = exact_deriv(eval_point);

        % Compute relative error
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        current_error = abs((numerical_result - exact_result) /
exact_result);

        % Store data for plotting
        step_sizes = [step_sizes, current_step];
        error_values = [error_values, current_error];

        % Update step size and iteration counter
        current_step = current_step / 1.5;
        iteration = iteration + 1;

        fprintf("%d | %.8f | %.8f | error = %.2e\n", iteration,
numerical_result, exact_result, current_error);
    end

    % Create error plot
    plot(error_values, step_sizes)
    xlabel('Step Size (h)');
    ylabel('Relative Error');
    title(sprintf('Convergence Analysis: %s', label));
    legend show;
    grid on;
    hold on;
end

% Set evaluation parameters
evaluation_point = 1.5;
starting_step = 1;

% Execute analysis for each method
for method_idx = 1:length(numerical_methods)
    AnalyzeMethod(scheme_labels{method_idx}, numerical_methods{method_idx},
...
                func_handle, derivative_exact, evaluation_point,
starting_step)
end

===== Forward Difference Analysis =====

1 | -10.07694940 | -4.15344024 | error = 1.43e+00
2 | -7.82410570 | -4.15344024 | error = 8.84e-01
3 | -6.45385426 | -4.15344024 | error = 5.54e-01
4 | -5.61831058 | -4.15344024 | error = 3.53e-01
5 | -5.09894233 | -4.15344024 | error = 2.28e-01
6 | -4.76989422 | -4.15344024 | error = 1.48e-01
7 | -4.55823568 | -4.15344024 | error = 9.75e-02
8 | -4.42056138 | -4.15344024 | error = 6.43e-02
9 | -4.33030308 | -4.15344024 | error = 4.26e-02
10 | -4.27080789 | -4.15344024 | error = 2.83e-02
11 | -4.23144507 | -4.15344024 | error = 1.88e-02
12 | -4.20533671 | -4.15344024 | error = 1.25e-02
13 | -4.18799046 | -4.15344024 | error = 8.32e-03

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| | | | | | | |
|----|---|-------------|---|-------------|---|------------------|
| 14 | / | -4.17645264 | / | -4.15344024 | / | error = 5.54e-03 |
| 15 | / | -4.16877248 | / | -4.15344024 | / | error = 3.69e-03 |
| 16 | / | -4.16365757 | / | -4.15344024 | / | error = 2.46e-03 |
| 17 | / | -4.16024994 | / | -4.15344024 | / | error = 1.64e-03 |
| 18 | / | -4.15797922 | / | -4.15344024 | / | error = 1.09e-03 |
| 19 | / | -4.15646586 | / | -4.15344024 | / | error = 7.28e-04 |
| 20 | / | -4.15545715 | / | -4.15344024 | / | error = 4.86e-04 |
| 21 | / | -4.15478478 | / | -4.15344024 | / | error = 3.24e-04 |
| 22 | / | -4.15433656 | / | -4.15344024 | / | error = 2.16e-04 |
| 23 | / | -4.15403777 | / | -4.15344024 | / | error = 1.44e-04 |
| 24 | / | -4.15383859 | / | -4.15344024 | / | error = 9.59e-05 |
| 25 | / | -4.15370580 | / | -4.15344024 | / | error = 6.39e-05 |
| 26 | / | -4.15361728 | / | -4.15344024 | / | error = 4.26e-05 |
| 27 | / | -4.15355826 | / | -4.15344024 | / | error = 2.84e-05 |
| 28 | / | -4.15351892 | / | -4.15344024 | / | error = 1.89e-05 |
| 29 | / | -4.15349269 | / | -4.15344024 | / | error = 1.26e-05 |
| 30 | / | -4.15347521 | / | -4.15344024 | / | error = 8.42e-06 |
| 31 | / | -4.15346355 | / | -4.15344024 | / | error = 5.61e-06 |
| 32 | / | -4.15345578 | / | -4.15344024 | / | error = 3.74e-06 |
| 33 | / | -4.15345060 | / | -4.15344024 | / | error = 2.49e-06 |
| 34 | / | -4.15344714 | / | -4.15344024 | / | error = 1.66e-06 |
| 35 | / | -4.15344484 | / | -4.15344024 | / | error = 1.11e-06 |
| 36 | / | -4.15344331 | / | -4.15344024 | / | error = 7.39e-07 |

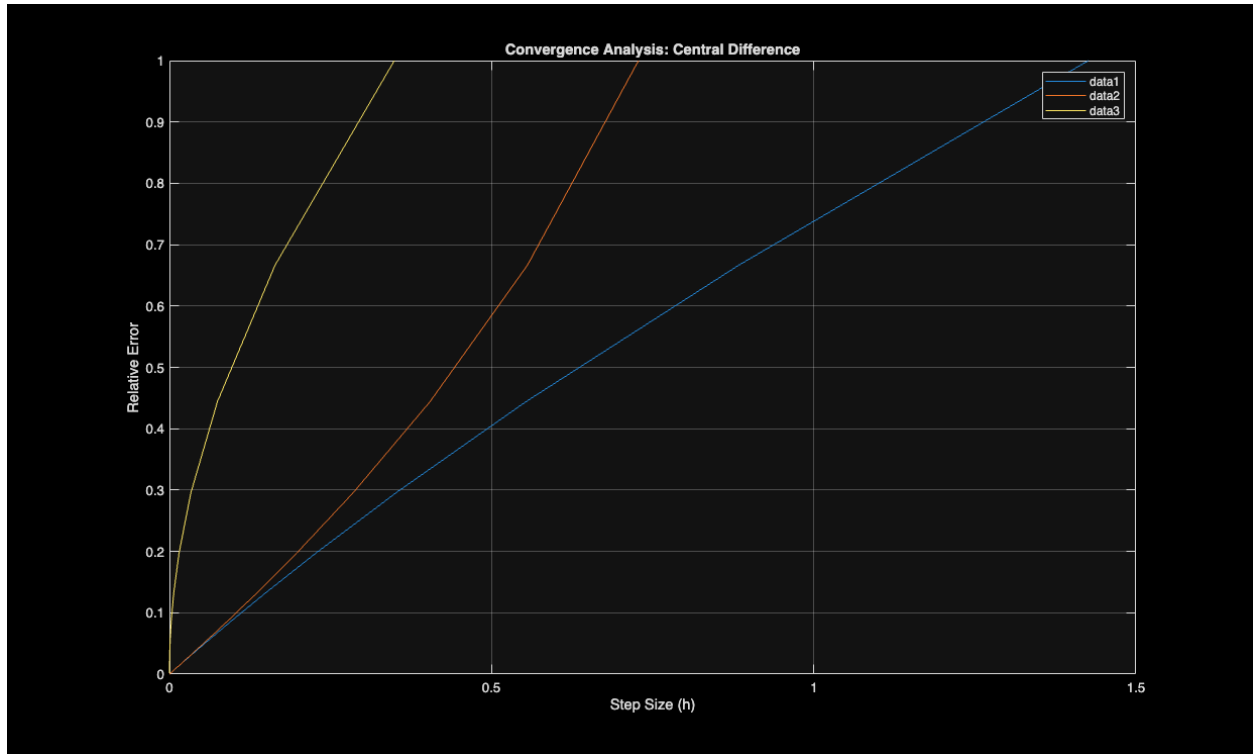
===== Backward Difference Analysis =====

| | | | | | | |
|----|---|-------------|---|-------------|---|------------------|
| 1 | / | -1.12986689 | / | -4.15344024 | / | error = 7.28e-01 |
| 2 | / | -1.84527333 | / | -4.15344024 | / | error = 5.56e-01 |
| 3 | / | -2.47255622 | / | -4.15344024 | / | error = 4.05e-01 |
| 4 | / | -2.96662578 | / | -4.15344024 | / | error = 2.86e-01 |
| 5 | / | -3.33204914 | / | -4.15344024 | / | error = 1.98e-01 |
| 6 | / | -3.59225110 | / | -4.15344024 | / | error = 1.35e-01 |
| 7 | / | -3.77322754 | / | -4.15344024 | / | error = 9.15e-02 |
| 8 | / | -3.89724882 | / | -4.15344024 | / | error = 6.17e-02 |
| 9 | / | -3.98143585 | / | -4.15344024 | / | error = 4.14e-02 |
| 10 | / | -4.03823206 | / | -4.15344024 | / | error = 2.77e-02 |
| 11 | / | -4.07639520 | / | -4.15344024 | / | error = 1.85e-02 |
| 12 | / | -4.10197034 | / | -4.15344024 | / | error = 1.24e-02 |
| 13 | / | -4.11907961 | / | -4.15344024 | / | error = 8.27e-03 |
| 14 | / | -4.13051209 | / | -4.15344024 | / | error = 5.52e-03 |
| 15 | / | -4.13814545 | / | -4.15344024 | / | error = 3.68e-03 |
| 16 | / | -4.14323955 | / | -4.15344024 | / | error = 2.46e-03 |
| 17 | / | -4.14663793 | / | -4.15344024 | / | error = 1.64e-03 |
| 18 | / | -4.14890454 | / | -4.15344024 | / | error = 1.09e-03 |
| 19 | / | -4.15041607 | / | -4.15344024 | / | error = 7.28e-04 |
| 20 | / | -4.15142397 | / | -4.15344024 | / | error = 4.85e-04 |
| 21 | / | -4.15209598 | / | -4.15344024 | / | error = 3.24e-04 |
| 22 | / | -4.15254404 | / | -4.15344024 | / | error = 2.16e-04 |
| 23 | / | -4.15284275 | / | -4.15344024 | / | error = 1.44e-04 |
| 24 | / | -4.15304191 | / | -4.15344024 | / | error = 9.59e-05 |
| 25 | / | -4.15317468 | / | -4.15344024 | / | error = 6.39e-05 |
| 26 | / | -4.15326320 | / | -4.15344024 | / | error = 4.26e-05 |
| 27 | / | -4.15332221 | / | -4.15344024 | / | error = 2.84e-05 |

| | | | | | | |
|----|---|-------------|---|-------------|---|------------------|
| 28 | / | -4.15336155 | / | -4.15344024 | / | error = 1.89e-05 |
| 29 | / | -4.15338778 | / | -4.15344024 | / | error = 1.26e-05 |
| 30 | / | -4.15340526 | / | -4.15344024 | / | error = 8.42e-06 |
| 31 | / | -4.15341692 | / | -4.15344024 | / | error = 5.61e-06 |
| 32 | / | -4.15342469 | / | -4.15344024 | / | error = 3.74e-06 |
| 33 | / | -4.15342987 | / | -4.15344024 | / | error = 2.49e-06 |
| 34 | / | -4.15343333 | / | -4.15344024 | / | error = 1.66e-06 |
| 35 | / | -4.15343563 | / | -4.15344024 | / | error = 1.11e-06 |
| 36 | / | -4.15343717 | / | -4.15344024 | / | error = 7.39e-07 |

===== Central Difference Analysis =====

| | | | | | | |
|----|---|-------------|---|-------------|---|------------------|
| 1 | / | -5.60340815 | / | -4.15344024 | / | error = 3.49e-01 |
| 2 | / | -4.83468952 | / | -4.15344024 | / | error = 1.64e-01 |
| 3 | / | -4.46320524 | / | -4.15344024 | / | error = 7.46e-02 |
| 4 | / | -4.29246818 | / | -4.15344024 | / | error = 3.35e-02 |
| 5 | / | -4.21549574 | / | -4.15344024 | / | error = 1.49e-02 |
| 6 | / | -4.18107266 | / | -4.15344024 | / | error = 6.65e-03 |
| 7 | / | -4.16573161 | / | -4.15344024 | / | error = 2.96e-03 |
| 8 | / | -4.15890510 | / | -4.15344024 | / | error = 1.32e-03 |
| 9 | / | -4.15586947 | / | -4.15344024 | / | error = 5.85e-04 |
| 10 | / | -4.15451997 | / | -4.15344024 | / | error = 2.60e-04 |
| 11 | / | -4.15392013 | / | -4.15344024 | / | error = 1.16e-04 |
| 12 | / | -4.15365353 | / | -4.15344024 | / | error = 5.14e-05 |
| 13 | / | -4.15353503 | / | -4.15344024 | / | error = 2.28e-05 |
| 14 | / | -4.15348237 | / | -4.15344024 | / | error = 1.01e-05 |
| 15 | / | -4.15345896 | / | -4.15344024 | / | error = 4.51e-06 |
| 16 | / | -4.15344856 | / | -4.15344024 | / | error = 2.00e-06 |
| 17 | / | -4.15344393 | / | -4.15344024 | / | error = 8.91e-07 |



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