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function Central
clc
clear all

% Revised:
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% Purpose

% To illustrate the concept of approximate error, absolute approximate
% error, relative approximate error and absolute relative approximate
% error, number of significant digits correct when using Difference
% Approximation of the first derivative of continuous functions method.

% Inputs
% Clearing all data, variable names, and files from any other source and
% clearing the command window after each successive run of the program.

% This is the only place in the program where the user makes changes to
% the data
% Function f(x)

function k=f(x)
    k=exp(2*x);
end

% Declaring 'x' as a variable

x = sym('x','real');

% Value of x at which f '(x) is desired, xv

xv=4;

% Starting step size, h

h=0.2;

% Number of times starting step size is halved

n=12;

%-----
disp(sprintf('                Differentiation of Continuous Functions'))
disp(sprintf('          Central Difference Approximation of the First Derivative'))
disp(sprintf('                Ana Catalina Torres, Autar Kaw'))
disp(sprintf('                University of South Florida'))
disp(sprintf('                United States of America'))
disp(sprintf('                kaw@eng.usf.edu'))
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%-----
disp(sprintf('\n\n***** Introduction
*****'))

disp(sprintf('\nThis worksheet demonstrates the use of Matlab to illustrate Central ')
disp(sprintf('Difference Approximation of the first derivative of continuous functions.))
disp(sprintf('Central Difference Approximation of the first derivative uses a point h'))
disp(sprintf('ahead and a point h behind of the given value of x at which the \nderivative
of f(x) is to be found.))

disp(sprintf('\n\n***** Section 1: Input
*****'))
format short g
disp(sprintf('\nThe following simulation approximates the first derivative of a'))
disp(sprintf('function using Central Difference Approximation. \n\nThe user inputs are'))
disp(sprintf('      a) function, \nf(x)=%g'))
disp(f(x))
disp(sprintf('      b) point at which the derivative is to be found, xv = %g',xv))
disp(sprintf('      c) starting step size, h = %g',h))
disp(sprintf('      d) number of times user wants to halve the starting step size, n = %
g',n))

disp(sprintf('\nThe outputs include'))
disp(sprintf('      a) approximate value of the derivative at the point and given ')
disp(sprintf('          initial step size'))
disp(sprintf('      b) exact value'))
disp(sprintf('      c) true error, absolute relative true error, approximate error ')
disp(sprintf('          and absolute relative approximate error, least number of ')
disp(sprintf('          correct significant digits in the solution as a function of ')
disp(sprintf('          step size.))

disp(sprintf('\nAll the information must be entered at the beginning of the M-File.))

disp(sprintf('\n\n***** Section 2: Simulation
*****'))
disp(sprintf('\nThe exact value EV of the first derivative of the equation:))
disp(sprintf('\nFirst, using the derivative command the solution is found. ))
Soln=diff(f(x))
disp(sprintf('In a second step, the exact value of the derivative is shown'))
disp(sprintf('The exact solution of the first derivative is:))
Ev=subs(Soln,x,xv)

disp(sprintf('\nAn internal loop calculates the following:))
disp(sprintf('Av: Approximate value of the first derivative using Central Difference
\nApproximation'))
disp(sprintf('Ev: Exact value of the first derivative'))
disp(sprintf('Et: True error'))
disp(sprintf('et: Absolute relative true percentage error'))
disp(sprintf('Ea: Approximate error'))
disp(sprintf('ea: Absolute relative approximate percentage error'))
disp(sprintf('Sig: Least number of correct significant digits in an approximation'))

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disp(ResultsCont)

disp(sprintf('\n\n***** Section 4: Graphs
*****'))

disp(sprintf('\nThe attached graphs show the approximate solution, absolute relative
true'))
disp(sprintf('error, absolute relative approximate error and least number of
significant'))
disp(sprintf('digits as a function of the number of iterations.\n'))

set(0,'Units','pixels')
    scnsz=get(0,'ScreenSize');
    wid=round(scnsz(3));
    hei=round(0.9*scnsz(4));
    wind=[1, 1, wid, hei];
    figure('Position',wind)

%   Approximate Solutions vs. Step size:

subplot(2,2,1); plot(H,Av,'LineWidth',2,'Color','g')
xlabel('Step Size')
ylabel('Approximate Value')
title({'Approximate Solution of the First Derivative using'; 'Central Difference
Approximation as a Function of Step Size'})

%   Absolute relative true error vs. Step size:

subplot(2,2,2); plot(H,et,'LineWidth',2,'Color','y')
xlabel('Step Size')
ylabel('Absolute Relative True Error')
title('Absolute Relative True Percentage Error as a Function of Step Size')

%   Absolute relative approximate error vs. Step size:

subplot(2,2,3); plot(H(2:n),ea(2:n),'LineWidth',2,'Color','m')
xlabel('Step Size')
ylabel('Absolute Relative Approximate Error')
title('Absolute Relative Approximate Percentage Error as a Function of Step Size')

%   Number of significant digits vs. the number of iterations.
subplot(2,2,4);
bar(j,Sig);
xlabel('Number of iterations');
ylabel('Number of Significant digits');
title('Number of Significant Digits as function of Number of Iterations');

disp(sprintf('\n\n***** References
*****'))

disp(sprintf('\nNumerical Differentiation of Continuous Functions. See'))
disp(sprintf('http://numericalmethods.eng.usf.'))

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edu/mws/gen/02dif/mws_gen_dif_txt_\ncontinuous.pdf'))

disp(sprintf('\n\n***** Questions
*****'))

disp(sprintf('\n1. The velocity of a rocket is given by\n\n          v(t)=2000*ln
(140000/(140000-2100t))-9.8*t'))

disp(sprintf('\nUse Central Divided Difference method with a step size of 0.25 to find
the'))
disp(sprintf('acceleration at t=5s. Compare with the exact answer and study the effect\nof
the step size.'))

disp(sprintf('\n\n2. Look at the true error vs. step size data for problem # 1. Do you
see'))
disp(sprintf('a relationship between the value of the true error and step size ? \nIs this
concidental? '))
disp(sprintf('\n3. Choose a step size of h=10^-10 in problem #1. Keep halving the step'))
disp(sprintf('size. Does the approximate value get closer to the exact result or does\nthe
result seem odd?'))

disp(sprintf('\n\n***** Conclusions
*****'))

disp(sprintf('\n Central Difference Approximation is a very accurate method to find the'))
disp(sprintf('first derivative of a function. Also, as the spreadsheet shows, the
smaller'))
disp(sprintf('the step size value is, the approximation is closest to the exact value.'))
disp(sprintf('However, too small a step size can result in noticeable round-off errors,
\nand hence giving highly inaccurate results.'))

disp(sprintf(
('\n\n-----'))
disp(sprintf('\nLegal Notice: The copyright for this application is owned by the '))
disp(sprintf('author(s). Neither Mathcad nor the author are responsible for any errors '))
disp(sprintf('contained within and are not liable for any damages resulting from the '))
disp(sprintf('use of this material. This application is intended for non-commercial, '))
disp(sprintf('non-profit use only. Contact the author for permission if you wish to
use\nthis application for-profit activities.'))

end

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