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clc
clf
clear all

%*****
%
% INPUTS
%
% Click the run button and refer to the command window
% These are the inputs that can be modified by the user
%
% f(x), the function to integrate

    f= @(x) x.^2 ;

% a, the lower limit of integration

    a=-5 ;

% b, the upper limit of integration

    b=5 ;

% n, the maximum number of segments

    n=128 ;

%*****

disp(sprintf('\n\nConvergence of the Trapezoidal Method'))
disp(sprintf('University of South Florida'))
disp(sprintf('United States of America'))
disp(sprintf('kaw@eng.usf.edu\n'))

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

disp('The following simulation illustrates the convergence of the trapezoidal')
disp('rule applied to numerically integrate functions. This section is the')
disp('only section where the user interacts with the program. The user ')
disp('enters a function in the form f(x), the lower and upper limit of integration,')
disp('a and b, and the number of subdivisions to take. By entering this data, the')
disp('program will calculate the exact (Matlab numerical value if it is not exact)')
disp('value of the solution, followed by the results using the trapezoidal method')
disp('with 1, 2, 4, 8 ... n segments. The program will also display the true error,')
disp('the absolute relative percentage true error, the approximate error, the absolute')
disp('relative approximate percentage error, and the least number of significant ')
disp('digits correct all as a function of number of segments.')

disp(sprintf('\n\n*****Input Data*****\n'))
disp(sprintf('    f(x), integrand function'))

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disp(sprintf('    a = %g, lower limit of integration ',a))
disp(sprintf('    b = %g, upper limit of integration ',b))
disp(sprintf('    n = %g, number of subdivisions',n))
format short g

% Determine the exact solution
exact = quad(f,a,b) ;

% Determine number of different segments to consider
nstep = floor(log2(n)) ;

for i=0:nstep

    % Determine number of segments and h
    NN(i+1)=2^i ;
    h=(b-a)/NN(i+1) ;

    % Apply approximatino technique
    integral = 0.5*f(a) + 0.5*f(b) ;
    for j=1:NN(i+1)-1
        integral = integral + f(a+h*j) ;
    end
    integral = integral * h ;
    YY(i+1)=integral ;

    % Compute Errors
    Et(i+1)=exact-integral ;
    Etabs(i+1)=abs((integral-exact)/exact) ;
    if(i > 0)
        Ea(i+1)=YY(i+1)-YY(i) ;
        Eaabs(i+1)=abs((YY(i+1)-YY(i))/YY(i)) ;
        SD(i+1)=floor((2-log10(Eaabs(i+1)/0.5))) ;
        if(SD(i+1)<0)
            SD(i+1)=0
        end
    else
        Ea(1)=0 ;
        Eaabs(1)=0 ;
        SD(1)=0 ;
    end

end

disp(sprintf('\n\n*****Table of
Values*****\n'))

disp('    Approx    True    Relative    Approx    Rel Appr    Sig    ')
disp(' n    Integral    Error    True Error    Error    Error    Digits ')
disp('-----')

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for i=1:nstep+1

if(i > 1)
    if(exact || YY(i) > 0)
        disp(sprintf('%4i  %+1.3e  %+1.3e  %+1.3e  %+1.3e  %+1.3e  %2i',NN(i),YY(i),Et(i),
Etabs(i),Ea(i),Eaabs(i),SD(i) ))
    else
        disp(sprintf('%4i  %+1.3e  %+1.3e      n/a      %+1.3e      n/a      n/a',NN(i),YY(i),
Etabs(i),Ea(i)))
    end
else
    disp(sprintf('%4i  %+1.3e  %+1.3e  %+1.3e      n/a      n/a      n/a',NN(i),YY(i),Et
(i),Etabs(i)))
end

end

disp('-----')

% The following generates 3 plots. This function detects information about your
% screensize and tries to then place/size the graphs accordingly.
scnsSize = get(0,'ScreenSize');

% Graph 1: The following code is needed to produce the trapezoidal method
% visualization.
x(1)=a ;
y(1)=f(a) ;
hold on
for i=1:n
    x(i+1)=a+i*h ;
    y(i+1)=f(x(i+1)) ;
    fill([x(i) x(i) x(i+1) x(i+1)], [0 y(i) y(i+1) 0], 'y')
end
xrange=a:(b-a)/1000:b;
plot(xrange,f(xrange),'k','Linewidth',2)
title('Integrand function and Graphical Depiction of Trapezoidal Method')

% Graph 2: Approximation and True Errors
fig2=figure ;
set(fig2,'Position',[0.2*scnsSize(3),0.2*scnsSize(3),0.6*scnsSize(3),0.2*scnsSize(4)]) ;
subplot(1,3,1); plot(NN,YY,'-o','Linewidth',2,'Color',[1 0 0]);
title('Appr. Integral vs No. of Segments')

subplot(1,3,2); plot(NN,Et,'-o','Linewidth',2,'Color',[0 0 1]);
title('Et vs No. of Segments')

subplot(1,3,3); plot(NN,Etabs,'-o','Linewidth',2,'Color',[0 0 1]);
title('Abs et vs No. of Segments')

% Graph 3: Relative Errors and Significant Digits
fig = figure ;
set(fig,'Position',[0.2*scnsSize(3),0,0.6*scnsSize(3),0.2*scnsSize(4)]) ;
subplot(1,3,1); plot(NN(2:nstep),Ea(2:nstep),'-o','Linewidth',2,'Color',[0 1 0]);

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title('Ea vs No. of Segments')
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```
subplot(1,3,2); plot(NN(2:nstep),Eaabs(2:nstep),'-o','LineWidth',2,'Color',[0 1 0]);  
title('Abs ea vs No. of Segments')
```

```
subplot(1,3,3); plot(NN(2:nstep),SD(2:nstep),'-o','LineWidth',2,'Color',[1 0.5 0.5]);  
title('Significant Digits Correct vs No. of Segments')
```