Lab 7

Quadrature formulas (1)

Repeated trapezium formula:

$$\int_a^b f(x)dx = \frac{b-a}{2n}[f(a)+f(b)+2\sum_{k=1}^{n-1} f(x_k)] + R_n(f);$$

with

$$x_k = a+kh, \quad k=0,1,...,n; \quad h=\frac{b-a}{n}.$$

Repeated Simpson's formula:

$$\int_a^b f(x)dx = \frac{b-a}{6n}[f(a)+f(b)+4\sum_{k=1}^{n} f(\frac{x_{k-1}+x_k}{2})+2\sum_{k=1}^{n-1} f(x_k)] + R_n(f),$$

with

$$x_k = a+kh, \quad k=0,1,...,n; \quad h=\frac{b-a}{n}.$$

Trapezium formula for double integral

Applying succesively trapezium formula with respect to y, and with respect to x, we get

$$\begin{aligned}\int_a^b \int_c^d f(x,y)dydx \approx \frac{(b-a)(d-c)}{16}&\left[f(a,c)+f(a,d)+f(b,c)+f(b,d)\right. \\ &+2f\left(\frac{a+b}{2},c\right)+2f\left(\frac{a+b}{2},d\right)+2f\left(a,\frac{c+d}{2}\right) \\ &\left.+\,2f\left(b,\frac{c+d}{2}\right)+4f\left(\frac{a+b}{2},\frac{c+d}{2}\right)\right]\end{aligned} \tag{1}$$

Problems

1. a) Approximate the integral

$$I = \int_0^1 f(x)dx, \qquad \text{for } f(x) = \frac{2}{1+x^2},$$

using trapezium formula.

b) Plot the graph of the function f and the graph of the trapezium with vertices $(0,0), (0, f(0)), (1, f(1))$ and $(1, 0)$.

c) Approximate the integral I using Simpson's formula.

2. Approximate the following double integral

$$\int_{1.4}^{2} \int_{1}^{1.5} \ln(x + 2y) dy dx$$

using trapezium formula for double integrals, given in (1). (*Result*: 0.4295545)

3. Evaluate the integral that arises in electrical field theory:

$$H(p, r) = \frac{60r}{r^2 - p^2} \int_0^{2\pi} \left[1 - \left(\frac{p}{r}\right)^2 \sin x\right]^{1/2} dx,$$

for $r = 110$, $p = 75$, using the repeated trapezium formula for two given values of n. (*Result:* 6.3131)

4. Find the smallest value of n that gives an approximation of the integral $\int_1^2 x \ln(x) dx$ which is correct to three decimals, using the program for the repeated trapezium formula. (*Result: 0.636294368858383*)

5. Evaluate the integral

$$\int_0^{\pi} \frac{dx}{4 + \sin 20x}$$

using the repeated Simpson's formula for $n = 10$ and 30. (*Result: 0.8111579*)

6. The error function $erf(x)$ is defined by

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt.$$

Use the repeated Simpson's formula to evaluate $erf(0.5)$ with $n = 4$ and $n = 10$. Estimate the accuracy of your result and compare with the correct value $erf(0.5) = 0.520499876$.

Facultative:

7. The volume of a solid is given by $\int_{0.1}^{0.5} \int_{0.01}^{0.25} e^{\frac{y}{x}} dy dx$. Approximate this volume applying Simpson's algorithm for double integrals considering 21 equidistant points in $[0.1, 0.5]$, respectively in $[0.01, 0.25]$. See the algorithm below. (*Result*: 0.178571)

Simpson's formula for double integral

Consider the integral $I=\int_a^b\int_c^d f(x,y)dydx$. Let $m,n\in\mathbb{N}$ and the equidistant points $x_0,...,x_{2m}$ in $[a,b]$, with step $h=\frac{b-a}{2m}$, respectively $y_0,...,y_{2n}$ in $[c,d]$, with step $k=\frac{d-c}{2n}$.

We apply the repeated Simpson's formula to the integral $\int_c^d f(x,y)dy$ and then to the integral $\int_a^b\int_c^d f(x,y)dydx$.

Algorithm:

INPUT: a,b,c,d,m,n

OUTPUT: the approximant J of the integral I

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h=(b-a)/(2*n);
j1=0; j2=0; j3=0
for i=0,1,...,2*n
        Let x=a+i*h;
         h1=(d-c)/(2*m);
         k1=f(x,c)+f(x,d);
         k2=0;
         k3=0;
         for j=1,2,...,2*m-1
                 y=c+j*h1;
                 z=f(x,y);
                 if j is even do k2=k2+z;
                      else k3=k3+z;
                end{if}
         end{for}
        l=(k1+2*k2+4*k3)*h1/3;
         if (i==0)| (i==2*n) do j1=j1+l;
              else if i is even do j2=j2+l;
                     else j3=j3+l;
                     end{if}
             end{if}
end
J=(j1+2*j2+4*j3)*h/3
```