

TMA4215 Numerical Mathematics

Autumn 2009

Exercise 3

Task 1

Show that the second column in the Romberg array is the same as what you get by using the composite Simpson's rule.

Task 2

Write a MATLAB program that calculates the Romberg array for a given integral. Stop when $|R(n, n) - R(n - 1, n - 1)| \leq tol$, where tol is the tolerance supplied by the user. Test the program on the integrals

$$\int_0^1 \sin(x) dx, \quad \int_0^1 \sqrt{x} \sin(x) dx.$$

Comment the results. (See the exam 2008, problem 2).

Task 3

Construct an adaptive trapezoid algorithm. Apply the algorithm to find the value of the *Fresnel integral*

$$S(x) = \int_0^x \sin(t^2) dt.$$

for $x = 0.8$. Use $tol = 2 \cdot 10^{-3}$.

Task 4

a) Find an approximation to the integral

$$\int_{-1}^1 \frac{e^x}{\sqrt{1-x^2}} dx$$

by using Gaussian quadrature with $n = 1$ (two nodes). Use the Gaussian quadrature based on the Legendre polynomials.

b) Find a Gaussian quadrature of the form

$$\int_{-1}^1 \frac{f(x)}{\sqrt{1-x^2}} dx \approx A_1 f(x_1) + A_2 f(x_2)$$

and use this to calculate the integral in a). Compare with the exact solution.

c) Find an upper limit for the error in b).

Task 5

Find the first three Laguerre polynomials, i.e. polynomials that are orthogonal with respect to the inner product

$$\langle p, q \rangle = \int_0^{\infty} e^{-x} p(x) q(x) dx.$$

Task 6

Show that the polynomials defined by

$$\Phi_k(x) = \frac{1}{2^k k!} \frac{d^k}{dx^k} [(x^2 - 1)^k]$$

are orthogonal with respect to the inner product

$$\langle p, q \rangle = \int_{-1}^1 p(x) q(x) dx.$$

Hint: Note that the j -th derivative of $(x^2 - 1)^k$ is divisible by $(x^2 - 1)$ if $j < k$. Use partial integration repeatedly.

Relevant exam problems:

- December 2008, problem 3,
- December 2007, problem 3,
- December 2006, problem 2,
- August 2006, problem 3.