Chapter 5

FINITE-DIFFERENCE METHODS

1. Boundary Value Problems for Ordinary Differential Equations

Some types of problems from fluid dynamics lead to boundary value problems for differential equations of the form

$$\frac{d^2y}{dx^2} + A(x)\frac{dy}{dx} + B(x)y = C(x), x \in [x_{\min}, x_{\max}],$$
$$y(x_{\min}) = y_m, \quad y(x_{\max}) = y_M. \tag{5.1}$$

The first step to approximately solve these problems by finite differences is to construct the grid

$$x_{\min} = x_0, \ldots, x_j = jh, \ldots, x_{N+1} = x_{\max}, j = 0, \ldots, N+1$$

with the step size $\Delta x = h = \frac{1}{N+1}$. The values of y evaluated at these points x_j will be denoted by y_j. We will evaluate also the derivatives of y at the same points x_j using the values of y at the neighboring grid points. From the Taylor expansion we have, for a small h,

$$y_{j+m} \equiv y(x_j + mh) = y_j + mhy'_j + \frac{(mh)^2}{2!}y''_j + \frac{(mh)^3}{3!}y'''_j + \cdots .$$

Therefore,

$$y_{j-1} = y_j - hy'_j + \frac{h^2}{2}y''_j - \frac{h^3}{6}y'''_j + \cdots ,$$

$$y_{j+1} = y_j + hy'_j + \frac{h^2}{2}y''_j + \frac{h^3}{6}y'''_j + \cdots$$

and, consequently,

$$y'_j = \frac{y_{j+1} - y_j}{h} - \frac{h}{2}y''_j + \cdots .$$

Chapter 5 Finite Difference Methods York University

Ensheng Dong

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