

# Numerical Solution of Partial Differential Equations

In these notes we develop a method for generating, numerically, approximate solutions to the vibrating string problem



$$u_{tt}(x, t) = c^2 u_{xx}(x, t) \quad 0 \leq x \leq l \quad t \geq 0 \quad (\text{wave equation}) \quad (1)$$

$$u(x, 0) = f(x) \quad 0 \leq x \leq l \quad (\text{initial position}) \quad (2a)$$

$$u_t(x, 0) = g(x) \quad 0 \leq x \leq l \quad (\text{initial speed}) \quad (2b)$$

$$u(0, t) = L(t) \quad t \geq 0 \quad (\text{left boundary}) \quad (3a)$$

$$u(l, t) = R(t) \quad t \geq 0 \quad (\text{right boundary}) \quad (3b)$$

The function  $u(x, t)$  gives the amplitude of the string at position  $x$  and time  $t$ . Equation (1) is the wave equation. It is the equation of motion for the vibrating string and is a consequence of Newton's law,  $F = ma$ . Equations (2a,b) specify the initial position and speed of the string and equations (3a,b) specify the position of the two ends of the string for all time.

The method will be an extension of those (like Euler's method, for example) used for generating, numerically, approximate solutions to the initial value problem

$$y'(t) = f(t, y(t)) \quad t \geq 0 \quad (\text{ode}) \quad (4)$$

$$y(0) = y_0$$

Recall that under Euler's method, rather than generating approximate values for  $y(t)$  for all values of  $t \geq 0$ , we pick a step size  $\Delta t$  and consider only  $t = 0, \Delta t, 2\Delta t, \dots, t_n = n\Delta t, \dots$ . We approximate the ordinary differential equation (4) by an equation, that does not contain any derivatives and that involves only the times  $t_n$ , by approximating

$$y'(t_n) = \lim_{h \rightarrow 0} \frac{y(t_n + h) - y(t_n)}{h} \approx \frac{y(t_n + \Delta t) - y(t_n)}{\Delta t} = \frac{y(t_{n+1}) - y(t_n)}{\Delta t}$$

Denoting  $y(t_n) = y_n$ , this gives

$$\frac{y_{n+1} - y_n}{\Delta t} \approx y'(t_n) = f(t_n, y(t_n)) = f(t_n, y_n)$$

# Numerical Solution Partial Differential Equations

**Lauren Gardner**



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