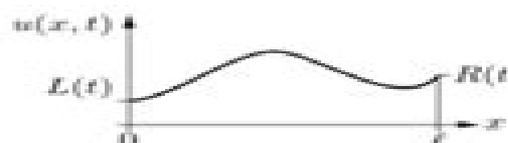# Numerical Solution of Partial Differential Equations

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

$$u_{tt}(x,t) = c^2 u_{xx}(x,t) \quad 0 \le x \le \ell \quad t \ge 0 \quad \text{(wave equation) (1)}$$

$$u(x,0) = f(x) \qquad 0 \le x \le \ell \qquad \text{(initial position) (2a)}$$

$$u_t(x,0) = g(x) \qquad 0 \le x \le \ell \qquad \text{(initial speed) (2b)}$$

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

$$u(\ell,t) = R(t) \qquad t \ge 0 \qquad \text{(right boundary) (3b)}$$

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

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

$$y(0) = y_0$$

Recall that under Euler's method, rather that generating approximate values for $y(t)$ for all values of $t \ge 0$, we pick a step size Δt and consider only $t = 0,\ \Delta t,\ 2\Delta t,\ \cdots,\ t_n = n\Delta t,\ \cdots$. 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

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

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

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

1

Numerical Solution Partial Differential Equations

Scott C. Dulebohn

Numerical Solution Partial Differential Equations:

Numerical Solution of Partial Differential Equations Gordon D. Smith,1985 Substantially revised this authoritative study covers the standard finite difference methods of parabolic hyperbolic and elliptic equations and includes the concomitant theoretical work on consistency stability and convergence The new edition includes revised and greatly expanded sections on stability based on the Lax Richtmeyer definition the application of Pade approximants to systems of ordinary differential equations for parabolic and hyperbolic equations and a considerably improved presentation of iterative methods A fast paced introduction to numerical methods this will be a useful volume for students of mathematics and engineering and for postgraduates and professionals who need a clear concise grounding in this discipline **Numerical Solution of Partial Differential Equations** K. W. Morton,D. F. Mayers,2005-04-11 This is the 2005 second edition of a highly successful and well respected textbook on the numerical techniques used to solve partial differential equations arising from mathematical models in science engineering and other fields The authors maintain an emphasis on finite difference methods for simple but representative examples of parabolic hyperbolic and elliptic equations from the first edition However this is augmented by new sections on finite volume methods modified equation analysis symplectic integration schemes convection diffusion problems multigrid and conjugate gradient methods and several sections including that on the energy method of analysis have been extensively rewritten to reflect modern developments Already an excellent choice for students and teachers in mathematics engineering and computer science departments the revised text includes more latest theoretical and industrial developments **Solving Numerical PDEs: Problems, Applications, Exercises** Luca Formaggia,Fausto Saleri,Alessandro Veneziani,2012-04-05 This book stems from the long standing teaching experience of the authors in the courses on Numerical Methods in Engineering and Numerical Methods for Partial Differential Equations given to undergraduate and graduate students of Politecnico di Milano Italy EPFL Lausanne Switzerland University of Bergamo Italy and Emory University Atlanta USA It aims at introducing students to the numerical approximation of Partial Differential Equations PDEs One of the difficulties of this subject is to identify the right trade off between theoretical concepts and their actual use in practice With this collection of examples and exercises we try to address this issue by illustrating academic examples which focus on basic concepts of Numerical Analysis as well as problems derived from practical application which the student is encouraged to formalize in terms of PDEs analyze and solve The latter examples are derived from the experience of the authors in research project developed in collaboration with scientists of different fields biology medicine etc and industry We wanted this book to be useful both to readers more interested in the theoretical aspects and those more concerned with the numerical implementation *Numerical Solution of Partial Differential Equations by the Finite Element Method* Claes Johnson,2009-01-15 This accessible introduction offers the keys to an important technique in computational mathematics It outlines clear connections with applications and considers numerous examples from a variety of specialties

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International Mathematical Congress and part of the celebration of the 650th anniversary of Charles University the Partial Differential Equations Theory and Numerical Solution conference was held in Prague in August 1998 With its rich scientific program the conference provided an opportunity for almost 200 participants to gather and discuss emerging directions and recent developments in partial differential equations PDEs This volume comprises the Proceedings of that conference In it leading specialists in partial differential equations calculus of variations and numerical analysis present up to date results applications and advances in numerical methods in their fields Conference organizers chose the contributors to bring together the scientists best able to present a complex view of problems starting from the modeling passing through the mathematical treatment and ending with numerical realization The applications discussed include fluid dynamics semiconductor technology image analysis motion analysis and optimal control The importance and quantity of research carried out around the world in this field makes it imperative for researchers applied mathematicians physicists and engineers to keep up with the latest developments With its panel of international contributors and survey of the recent ramifications of theory applications and numerical methods Partial Differential Equations Theory and Numerical Solution provides a convenient means to that end   **Methods for the Numerical Solution of Partial Differential Equations** Dale U. Von Rosenberg,1969 This postgraduate text describes methods which can be used to solve physical and chemical problems on a digital computer The methods are described on simple physical problems with which the student is familiar and then extended to more complex ones Emphasis is placed on the use of discrete grid points the representation of derivatives by finite difference ratios and the consequent replacement of the differential equations by a set of finite difference equations Efficient methods for the solution of the resulting set of equations are given and five solution algorithms are presented in the book   **Partial Differential Equations with Numerical Methods** Stig Larsson,Vidar Thomee,2008-11-19 The main theme is the integration of the theory of linear PDE and the theory of finite difference and finite element methods For each type of PDE elliptic parabolic and hyperbolic the text contains one chapter on the mathematical theory of the differential equation followed by one chapter on finite difference methods and one on finite element methods The chapters on elliptic equations are preceded by a chapter on the two point boundary value problem for ordinary differential equations Similarly the chapters on time dependent problems are preceded by a chapter on the initial value problem for ordinary differential equations There is also one chapter on the elliptic eigenvalue problem and eigenfunction expansion The presentation does not presume a deep knowledge of mathematical and functional analysis The required background on linear functional analysis and Sobolev spaces is reviewed in an appendix The book is suitable for advanced undergraduate and beginning graduate students of applied mathematics and engineering   The Numerical Solution of Ordinary and Partial Differential Equations Granville Sewell,2005-07-25 Learn to write programs to solve ordinary and partial differential equations The Second Edition of this popular text provides an insightful introduction to the

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