Numerical Methods in Civil Engineering - Video course

COURSE OUTLINE

This course attempts to give a broad background to numerical methods common to various branches of civil engineering.

It starts with core concepts of error estimate and accuracy of numerical solutions.

It then introduces the student to methods of solution of linear and non-linear equations.

Both direct and iterative solution methods are discussed.

Next we introduce the numerical solution of partial differential equations, after a brief review of canonical partial differential equations and well known analytical techniques for their solution, stressing when and why numerical solutions are necessary.

Finite difference operators are introduced and used to solve typical initial and boundary value problems.

Following this we introduce the finite element method as a generic method for the numerical solution of partial differential equations.

The concepts of weak form, finite element discretization, polynomial interpolation using Lagrange polynomials and numerical quadrature are introduced.

Numerical integration in the time domain is discussed, emphasizing the key requirements of stability and accuracy of time integration algorithms.

Finally we discuss integral equations and introduce numerical techniques for their solution.

NP-TEL

NPTEL

http://nptel.iitm.ac.in

Civil Engineering

Additional Reading:

1. "The Finite Element Method", by T. J. R. Hughes, Prentice Hall, Englewood Cliffs, NJ, 1987.
2. "Green's functions and Boundary Value Problems" by I. Stakgold, Wiley, 1998.

Coordinators:

Dr. A. Deb
Department of Civil EngineeringIIT Kharagpur

COURSE DETAIL

Sl. No	Topic	No. of Hours
1	**Introduction to Numerical Methods:** • Why study numerical methods. • Sources of error in numerical solutions: truncation error, round off error. • Order of accuracy - Taylor series expansion.	2
2	**Direct Solution of Linear systems:** • Gauss elimination, Gauss Jordan elimination. • Pivoting, inaccuracies due to pivoting. • Factorization, Cholesky decomposition.	4

	• Diagonal dominance, condition number, ill conditioned matrices, singularity and singular value decomposition. • Banded matrices, storage schemes for banded matrices, skyline solver.	
3	**Iterative solution of Linear systems:** • Jacobi iteration. • Gauss Seidel iteration. • Convergence criteria.	3
4	**Direct Solution of Non Linear systems:** • Newton Raphson iterations to find roots of a 1D nonlinear equation. • Generalization to multiple dimensions. • Newton Iterations, Quasi Newton iterations. • Local and global minimum, rates of convergence, convergence criteria.	4
5	**Iterative Solution of Non Linear systems:** • Conjugate gradient. • Preconditioning.	3
6	**Partial Differential Equations:** • Introduction to partial differential equations. • Definitions & classifications of first and second order equations. • Examples of analytical solutions. • Method of characteristics.	4
7	**Numerical Differentiation:** • Difference operators (forward, backward and central difference). • Stability and accuracy of solutions. • Application of finite difference operators to solve initial and boundary value problems.	4
8	**Introduction to the Finite Element Method as a method to solve partial differential equations:** • Strong form of the differential equation. • Weak form. • Galerkin method: the finite element approximation. • Interpolation functions: smoothness, continuity,	6

	completeness, Lagrange polynomials. • Numerical quadrature: Trapezoidal rule, simpsons rule,Gauss quadrature**.**	
9	**Numerical integration of time dependent partial differential equations:** • Parabolic equations: algorithms - stability, consistency and convergence, Lax equivalence theorem. • Hyperbolic equations: algorithms - Newmark's method,stability and accuracy, convergence, multi-step methods.	4
10	**Numerical solutions of integral equations:** • Types of integral equations. • Fredholm integral equations of the first and second kind. • Fredholm's Alternative theorem. • Collocation and Galerkin methods for solving integral equations.	6

References:

1. "Numerical Methods" by D. Dahlquist, and A. Bork, Dan Prentice-Hall, Englewood Cliffs, NJ,. 1974.