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A Study of Solution Techniques for Ordinary Differential Equations

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ABSTRACT

Ordinary Differential Equations (ODEs) are fundamental to the mathematical modeling of physical, biological, economic, and engineering systems. The solution techniques for ODEs vary depending on their order, linearity, and homogeneity. Broadly, ODEs are classified into first-order and higher-order equations, and each class requires specific analytical or numerical methods. Analytical methods include techniques such as separation of variables, integrating factor method, variation of parameters, undetermined coefficients, Laplace transform, and the power series method. These methods provide exact solutions when applicable, especially for linear and simple nonlinear equations. However, many real-world ODEs are complex and nonlinear, making analytical solutions difficult or impossible. In such cases, numerical methods—such as Euler’s method, Runge-Kutta methods, and finite difference techniques—are used to obtain approximate solutions with high accuracy. Modern approaches also include the use of transform methods, perturbation techniques, and semi-analytical methods like the Differential Transform Method (DTM) and Adomian Decomposition Method (ADM). The choice of method depends on the nature of the equation, initial or boundary conditions, and the desired accuracy. This paper reviews the major analytical and numerical solution techniques for ODEs, highlighting their applications, strengths, limitations, and relevance in modeling and solving practical problems across scientific disciplines.