An Overview of Numerical Analysis and its Approaches

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Perspective

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ABOUT THE STUDY

Numerical analysis is the study of methods for mathematical analysis problems that employ numerical approximation (rather than symbolic operations) (as distinguished from discrete mathematics). Numerical analysis is used in all sectors of engineering and the physical sciences, as well as in the life and social sciences, health, business, and even the arts in the twenty-first century. As computational power has increased, more complicated numerical analysis has been possible, resulting in comprehensive and realistic mathematical models in science and engineering. Ordinary differential equations, which are used in celestial mechanics to predict the motions of planets, stars, and galaxies, numerical linear algebra in data analysis, and stochastic differential equations and Markov chains for simulating living cells in medicine and biology, are all examples of numerical analysis.

Numerical approaches used to rely on manual interpolation formulae and data from massive printed tables before the advent of contemporary computers. Computers have been calculating the essential functions since the mid-twentieth century, yet most of the same formulae are still employed in software algorithms.

The numerical perspective may be traced all the way back to the first mathematical publications. The square root of 2, the length of the diagonal of a unit square, is approximated by a sexagesimal numerical approximation on a tablet from the Yale Babylonian Collection (YBC 7289). Rather of delivering accurate symbolic answers translated into numbers that are only applicable to real-world measurements; numerical analysis uses approximate solutions within specified error limitations.

The general purpose of numerical analysis is to build and analyze procedures that provide approximate but correct solutions to difficult problems, as evidenced by the following:

In order to make numerical weather prediction possible, advanced numerical algorithms are required. The precise numerical solution of a set of ordinary differential equations is required to compute a spacecraft's trajectory. Car firms may use computer simulations of car collisions to enhance the crash safety of their vehicles. The majority of these simulations include numerically solving partial differential equations. Hedge funds (private investment funds) try to determine the value of stocks and derivatives more precisely than other market players using technologies from all domains of numerical analysis.

Evaluating integrals

Numerical integration, also known as numerical quadrature in some cases, is the process of determining the value of a definite integral. One of the Newton–Cotes formulae (such as the midpoint rule or Simpson's rule) or Gaussian quadrature is popular technique. These approaches use a "divide and conquer" strategy, in which an integral on a big set is broken down into smaller sets of integrals. In larger dimensions, where these approaches become unacceptably expensive in terms of computational effort, one can utilize Monte Carlo or quasi-Monte Carlo methods (Monte Carlo integration) or the sparse grids method (in modestly large dimensions).

The following problem is solved by interpolation: given the value of an unknown function at a number of points, what value does that function have at a position between the supplied points. Extrapolation is identical to interpolation, except that the unknown function's value must now be discovered at a place outside the provided points. Regression is similar, but it takes into consideration the imprecise nature of the data. The unknown function can be discovered given some places and a measurement of the value of some function at these points (with an error). One approach to do this is to use the least squares method.

Optimization

The point at which a given function is maximized is targeted in optimization issues (or minimized). Frequently, the point must also adhere to certain limitations. Depending on the nature of the objective function and the constraint, the discipline of optimization is subdivided into numerous subfields. Linear programming, for example, is used when both the goal function and the constraints are linear. The simplex technique is a well-known linear programming approach. The Lagrange multiplier approach may be used to reduce confined optimization issues to unconstrained optimization problems.

Differential equations

The solution of differential equations, including ordinary and partial differential equations, is also computed (in an approximate method) in numerical analysis. To solve a partial differential equation, first discretize it, putting it into a finite-dimensional subspace. A finite element technique, a finite difference approach, or (especially in engineering) a finite volume method can all be used to do this. Theorems from functional analysis are frequently used in the theoretical rationale of these procedures. As a result, the problem is reduced to an algebraic equation to solve.