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ROLE OF NUMERICAL ANALYSIS AND IT'S APPLICATIONS

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Abstract: Math that has discovered effective ways to arrive at numerical solutions to challenging mathematical problems is known as numerical analysis. The majority of mathematical issues that occur in research and engineering are extremely challenging and occasionally unsolvable. The field of mathematics known as numerical analysis is concerned with developing effective strategies for coming up with numerical answers to challenging mathematical problems. Mathematical numerical issues are continually being created and used using the method of numerical analysis, which is mostly used in the domains of mathematics and computer science.

Index Terms **- Numerical Analysis, Methods and it's applications.**

I. INTRODUCTION

The field of mathematics and computer science known as numerical analysis develops, examines, and applies methods to produce numerical solutions to issues involving continuous variables. These issues come up in all fields, including the scientific and social sciences, engineering, health care, and business. Since the middle of the 20th century, there has been an increase in the usage of realistic mathematical models in science and engineering, and to solve these more intricate models of the world, numerical analysis of increasing sophistication is required. The formal academic field of numerical analysis encompasses everything from computer science difficulties to highly theoretical mathematical topics.

The new field of computational science, or scientific computing, evolved in the 1980s and 1990s as a result of the expansion in computer accessibility. For the purpose of simplifying the construction, solution, and interpretation of challenging mathematical models of the actual world, the discipline blends numerical analysis, symbolic mathematical computations, computer graphics, and other disciplines of computer science.

The study of numerical methods, from their theoretical development and comprehension to their practical application as trustworthy and effective computer programs, is a key component of numerical analysis. The majority of numerical analysts focus on narrow subfields, however they have some similar issues, viewpoints, and analytical techniques.

II. EVOLUTION OF NUMERICAL ANALYSIS

Numerical analysis, as opposed to discrete mathematics, is the study of techniques that use numerical approximation for mathematical analysis issues. The study of numerical methods aims to identify approximate rather than precise answers to issues. In addition to the physical and technical sciences, the biological and social sciences, business, and even the arts are all sectors where numerical analysis is used today.

As computing power has increased, more advanced numerical analysis has been used to create precise and accurate mathematical models for use in research and engineering. Examples of numerical analysis include numerical linear algebra for data analysis and stochastic differential equations, which are used in celestial mechanics to forecast the motions of planets, stars, and galaxies.

Numerical approximation has grown in popularity and is now a common technique for scientists and engineers because of the tremendous advancement in computational technology. As a result, a lot of scientific software (like Matlab, Mathematica, Maple, etc.) is created to handle more challenging situations effectively and simply.

This software has functions that employ conventional numerical techniques, allowing a user to enter the necessary parameters and obtain the results with a single command without being aware of the specifics of the numerical technique. Therefore, one would wonder why we need to comprehend numerical procedures when we have access to such tools.

In fact, most of the time, an end user can utilise some common software without having a deep understanding of numerical methods and their analysis.
But learning the fundamentals of the theoretical underpinnings of numerical methods is important for at least three reasons.

1. Learning various numerical techniques and their analysis will increase one's familiarity with the process of creating new numerical techniques. This is crucial when the existing solutions to a particular problem are insufficient or ineffective.
2. There are frequently multiple solutions to a given issue. Therefore, using the right approach is crucial for delivering an accurate result in a shorter amount of time.
3. With a solid foundation, one can employ methods correctly (especially since each approach has its own limitations and/or drawbacks in some particular situations) and, most crucially, one can identify the problem when outcomes are not what was anticipated.

III. Methods and it's Types

Numerical methods are methods for approximating mathematical operations. Because the technique cannot be solved analytically or because the analytical method is intractable (solving a set of 1,000 simultaneous linear equations for 1,000 unknowns is an example), we require approximations.

The mathematical analysts and mathematicians employ a range of technologies to create numerical solutions to mathematical issues. The idea of replacing a given problem with a "near problem" that may be solved quickly is the most crucial one that applies to all types of mathematical problems. Other viewpoints on the type of mathematical problem solved diverge.

Common Division Problems Given Below:

- *Euler method –*
  The most basic way to solve ODE
- *Clear and vague methods –*
  Vague methods need to solve the problem in every step
- *The Euler Back Road –*
  The obvious variation of the Euler method
- *Trapezoidal law –*
  The direct method of the second system
- *Runge-Kutta Methods –*
  One of the two main categories of problems of the first value.

1. *Newton Method:*

Algebra and other mathematical techniques cannot always be used to answer all calculations. Numerical approaches are required for this. One such technique, Newton's method, enables us to determine the answer to the equation $f(x) = 0$.

2. *Trapezoidal Method:*

A mathematical technique that determines the numerical value of a direct combination is the trapezoidal rule. The other significant ones cannot be evaluated in terms of integration principles or fundamental operations.

The most significant indicator of direct equity in numerical analysis is the trapezoidal law in mathematics, commonly referred to as the trapezoid law or trapezium law.

By cutting the curve into a little trapezium, the trapezoidal law is a coupling law that is used to determine the area under a curve. Space beneath the curve will be provided by the sum of all little trapezium regions.

3. *Simpson Method:*

Other significant ones cannot be evaluated in terms of integration principles or fundamental operations. A mathematical formula called Simpson's law can be used to determine the numerical value of a direct combination.

4. *Numerical Computation:*

The phrase "numerical computations" refers to using computers to solve real-number-based problems. We can identify numerous more or less distinct phases in this problem-solving process. Formulation represents the first stage. Scientists should keep in mind that they anticipate using a computer to solve a problem when creating a mathematical model of a physical situation. As a result, they will specify the type and quantity of output in addition to the specified objectives, appropriate input data, and acceptable checks.

Once a problem has been stated, numerical methods and an initial error analysis must be developed in order to solve it. An algorithm is a numerical approach that can be utilized to solve a problem. A comprehensive and clear sequence of steps is known as an algorithm, and it is used to solve mathematical problems. Numerical analysis is used to aid in the selection or creation of suitable algorithms. When choosing an algorithm or combination of algorithms to solve the issue, numerical analysts must take into account all potential sources of inaccuracy that could have an impact on the outcome. They ought to think about the level of accuracy needed. to establish a suitable step size or the necessary number of iterations by estimating the size of the round-off and discretization mistakes.

The suggested method should be turned into a clear set of instructions for the computer that are followed step-by-step by the programmer. The initial step in this process is the flow chart. Simply described, a flow chart is a list of steps that the computer will follow. These steps are typically written in logical block form. The difficulty of the task and the level of detail supplied will determine how complex the flow is.

However, someone other than the coder should be able to understand how the information flows from the chart. The flow chart is a useful tool for programmers, but they must convert its key functions into a program. Additionally, it is a successful method of communication.

Characteristics:

1. Numerical Instability:
   Numerical instability is another issue a numerical method might cause. Any source's errors that are factored into the calculation increase in various ways. These mistakes can sometimes happen quickly and have disastrous effects.
2. Accuracy:
   Each numerical technique includes errors. It might be because the right mathematical procedures were used, or because the computer had accurately represented and changed the values.
3. Efficiency:
   Each numerical technique includes errors. It might be because the right mathematical procedures were used, or because the computer had accurately represented and changed the values.

Numerical Computing Process:

- Construction of a Mathematical model.
- Construction of an appropriate numerical system.
- Implementation of a solution.
- Verification of the solution.

IV. Applications of Numerical Analysis

1) **Mathematical Optimization:**
   The point at which a particular function is maximized (or minimized) is requested in optimization problems. The point frequently also needs to adhere to various restrictions.
   Depending on how the objective function is constructed and the type of constraint, the field of optimization is further divided into a number of subfields. For instance, linear programming deals with the situation where the restrictions and the objective function are both linear. The simple method is a well-known linear programming technique.
   Optimization issues with constraints can be converted to unconstrained optimization problems using the Lagrange multiplier approach.
2) **Differential Equations:**
   Ordinary differential equations in mathematics and partial differential equations in mathematics. Computing the approximate solution of differential equations, including both ordinary and partial differential equations, is another focus of numerical analysis.
   The process of discretizing an equation and placing it in a finite-dimensional subspace is the first step in solving a partial differential equation. A finite element method, a finite difference approach, or (especially in engineering) a finite volume method can be used to do this. These techniques are frequently supported theoretically by theorems from functional analysis. By doing so, the issue is reduced to the resolution of an algebraic equation.
3) **Computing values of functions**:
   The evaluation of a function at a specific moment is one of the easiest problems to solve. The simplest method, which involves simply entering the number into the formula, is occasionally ineffective. The Horner scheme is a better method for polynomials since it minimizes the amount of multiplications and additions required. In general, round-off errors caused by using floating point arithmetic need to be estimated and controlled.
4) **Single valued or eigen problems:**
   Either singular value decompositions or eigenvalue decompositions can be used to formulate a number of significant issues. For instance, the singular value decomposition is the foundation of the spectral image compression technique. Principal component analysis is the name of the statistical tool that corresponds to this.
5) **System of equations:**
   The computation of an equation's solution is another important issue. Whether or whether the equation is linear determines which of two scenarios is often identified. For instance, while the equation is not linear. The development of techniques for solving systems of linear equations has received a lot of attention.
   For large systems, iterative techniques like the Jacobi method, Gauss-Seidel method, sequential over-relaxation method, and conjugate gradient method are typically preferred. A matrix splitting can be used to construct general iterative techniques.
   Since a function's root is an argument for which the function returns zero, root-finding techniques are employed to solve nonlinear equations. Newton's technique is a popular option if the function is differentiable and the derivative is known. Another method for resolving nonlinear equations is linearization.
6) **Evaluating Integrals:**
   The value of a definite integral is requested by numerical integration, which is sometimes also referred to as numerical quadrature. Popular techniques make use of Gaussian quadrature or one of the Newton-Cotes formulas (such as the midpoint rule or Simpson's rule). These techniques use a "divide and conquer" strategy in which integrals on smaller sets are divided up into integrals on a relatively big set. One may employ Monte Carlo or quasi-Monte Carlo methods (see Monte Carlo integration) in higher dimensions, when these techniques become computationally unfeasible, or the sparse grid method in moderately large dimensions.
7) **Finite Element method from MATLAB:**
   It is very simple to do finite element analysis using MATLAB, which is a really useful piece of software. It assists us in applying feminism in a number of ways:
   The built-in Partial Differential Equation Toolbox can be used to solve partial differential equations (PDEs).
   Design of experiments and other statistics and machine learning approaches can be applied in MATLAB with the aid of the Statistics and Machine Learning Toolbox.
   Additionally, using Optimization Toolbox, the optimization techniques can be used to optimize FEM simulation results.

The analysis is expedited by Parallel Computing Toolbox by allocating several Finite Element Analysis simulations to perform concurrently.

V. RESULTS

Numerical analysis is a branch of mathematics that has created effective techniques for finding numerical answers to challenging mathematical puzzles. The majority of mathematical issues that emerge in research and engineering are extremely challenging and perhaps impossible to resolve adequately.

As a result, an approximation is crucial to making a challenging mathematical issue easier to solve. Numerical approximation has grown in popularity and evolved into a contemporary tool for scientists and engineers as a result of the rapid advancements in computational technology.

As a result, a variety of scientific software programmes (such as Matlab, Mathematic, Maple, etc.) have been created to handle more challenging situations effectively and simply. Without knowing the specifics of the numerical procedure, the result can be obtained with just one command.

Without understanding the specifics of the numerical procedure, the answer can be obtained with just one command. So, one would wonder why we need to grasp numerical approaches when we have such tools at our disposal. In truth, most conventional software can be used by end users without the need for in-depth knowledge of numerical methods and their analysis.

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