Innovation in Teaching Learning Process

Implementation of Numerical Methods for Solving 2D Heat Conduction Equation using Laplace Formula

Name of the Innovation : Implementation of Numerical Methods for Solving 2D Heat Conduction Equation using Laplace Formula

Course Code and Name : 1AEES207 - Numerical Analysis with Programming Language

Class and Semester : Second Year B.Tech. Aeronautical Engineering, IV Semester

Academic Year and Term : AY 2022-23, Term - II

Faculty Name and Designation : Mr. Y. B. Kumbhar, Assistant Professor.

Introduction:

Numerical methods play a crucial role in solving complex engineering problems where analytical solutions are difficult or impossible to obtain. One such problem is the **2D steady-state heat conduction equation**, which can be solved using **Laplace's equation** and **finite difference methods**. To enhance students' understanding of numerical techniques, an activity was conducted where students implemented the **second-order central difference formula** to solve Laplace's equation using Python in **Google Colab**.

This hands-on approach provided students with practical exposure to **numerical problem-solving**, reinforcing key concepts in computational mathematics and engineering applications.

Motivation/Purpose of Innovative Technique:

The primary motivation behind this activity was to bridge the gap between **theoretical numerical analysis and practical computational applications**. Traditional classroom methods focus on mathematical derivations, which can sometimes seem abstract. By **implementing numerical algorithms using Python**, students were able to:

- **Develop problem-solving skills** by coding and debugging numerical schemes.
- **Understand the role of discretization techniques** in solving real-world engineering problems.
- **Gain hands-on experience in computational tools** such as Google Colab, which are widely used in industry and research.
- **Visualize numerical solutions** using graphical outputs like contour plots, making abstract concepts more tangible.
- **Strengthen programming skills** by working with libraries such as **NumPy and Matplotlib** for numerical computation and visualization.

This assessment was designed to align with **Course Outcome 1AEES207_8**:
"Analyze and classify partial differential equations and solve them using finite difference methods."

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Procedure Followed:

This was an **individual assessment**, conducted as part of the **In-Semester Evaluation (ISE)** with a **submission deadline of August 3, 2023, at 10:00 PM**. The weightage of this **Activity-Based Assessment (ABA)** was **25%** of the overall in-semester evaluation of course evaluation.

Assessment Details:

- **Class:** Second Year B.Tech., Semester IV
- **Course Code:** 1AEES207
- **Task:** Solve the **2D heat conduction equation** using **Laplace's formula** via numerical methods.
- **Tool Used: Google Colab with Python**
- **Numerical Method Applied: Second-order central difference formula**

Requirements:

1. **Grid Initialization:** Define a structured 2D computational domain with boundary conditions.
2. **Finite Difference Method Implementation:** Apply the second-order central difference scheme for numerical approximation.
3. **Iterative Solution Method:** Use an appropriate **iterative solver** (Jacobi, Gauss-Seidel, or Successive Over-Relaxation) to compute the temperature distribution.
4. **Convergence Criteria:** Implement an error-based stopping condition for numerical stability.
5. **Visualization:** Generate contour plots or heatmaps to display the steady-state temperature distribution.
6. **Code Documentation:** Ensure proper commenting and structuring of the code for clarity.

Deliverables:

- A Python program solving the **2D Laplace equation** using finite difference methods.
- Graphical output (heatmaps or contour plots) illustrating the temperature distribution.

Outcome:

This activity allowed students to **bridge the gap between theoretical numerical methods and practical problem-solving** using computational tools. Key takeaways include:

- **Improved understanding of finite difference methods** and their application to solving PDEs.
- **Hands-on coding experience** in implementing numerical algorithms.
- **Enhanced problem-solving skills** by debugging and optimizing numerical solutions.
- **Recognition of the importance of boundary conditions** in numerical approximations.

Students initially faced challenges in **understanding numerical discretization and convergence handling**, but with guided tutorials and discussions, they successfully implemented functional solutions.

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References:

1. https://www.slideshare.net/ManishKhose1/derivation-of-laplace-equation-2d-heat-equation
2. https://www.dam.brown.edu/people/alcyew/handouts/numdiff.pdf
3. https://colab.research.google.com/github/jakevdp/PythonDataScienceHandbook/blob/master/notebooks/04.04-Density-and-Contour-Plots.ipynb

Mr. Y.B.Kumbhar, Assistant Professor
E-Mail: ybk_aero@adcet.in