PROJECT PROPOSAL

Application of PINN's in Fluid Mechanics

MMAE-500 Data Driven Modeling, Illinois Tech

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GitHub Source Code:
https://github.com/eyobghiday/PINNs-in-Fluid-Mechanics

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1 Introduction

The flow field around a fluid object, such as an airfoil, is an essential problem in fluid mechanics that has practical applications in various fields, including aerospace, marine, and civil engineering. Solving the Navier-Stokes equations to predict the flow field around a fluid object is a challenging task due to the complex geometry and boundary conditions involved. Recently, physics-informed neural networks (PINNs) have emerged as a promising technique to solve partial differential equations (PDEs) accurately and efficiently. This proposal aims to investigate the application of PINNs in fluid mechanics to predict the flow field around a fluid object by solving the Navier-Stokes equations.

A more detailed explanation of how PINNs can be used to solve the Navier-Stokes equations for fluid flow around an airfoil. The funndamental Navier-Stokes equations describe the motion of fluids and are given by:

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \mu\nabla^2\mathbf{v} + \mathbf{f}$$
$$\nabla\cdot\mathbf{v} = 0$$

where ρ is the fluid density, $\mathbf{v}$ is the velocity field, p is the pressure field, μ is the fluid viscosity, and $\mathbf{f}$ is the external force field.

2 Main Goal

2.1 Main Goal

The main objective of this proposal is to develop a physics-informed neural network model to predict the flow field around a fluid object by solving the Navier-Stokes equations. The specific objectives follows by constructing a dataset of Navier-Stokes solutions for the flow field around a fluid object using a numerical method, such as finite volume or finite element methods. The dataset will then be used to develop the PINN model to predict the flow field around a fluid object by incorporating the Navier-Stokes equations as a constraint. Finally, the PINN model will be trained using the dataset of Navier-Stokes solutions and evaluate its performance in predicting the flow field around a fluid object.

3 Approach Methodology

The methodology involves generating a dataset of Navier-Stokes solutions for the flow field around a fluid object using a numerical method, such as finite volume or finite element methods. The dataset should include various geometries and boundary conditions to ensure the model's robustness. Regarding collecting those datasets, it will likely be obtained from the department of the aerospace engineering at Illinois Tech. Worst case scenario we can also do a random data generator method using python or MATLAB. The focus of this project is more on the application side of PINN's and not on how the data it self is obtained. We'll then develop a PINN model to predict the flow field around a fluid object by incorporating the Navier-Stokes equations as a constraint. The PINN model should consist of a neural network that takes as input the fluid object's geometry and boundary conditions and outputs the flow field variables. Training the PINN model using the dataset of Navier-Stokes solutions will be utilised after. During training, the PINN model should satisfy the Navier-Stokes equations as a constraint, and the dataset of Navier-Stokes solutions should be used to compute the loss function. As a result the performance of the PINN model will be evaluated in predicting the flow field around a fluid object using various metrics, such as mean absolute error, root mean square error, and or the correlation coefficient.

4 Expectation

Depending on the class progress and time period, the expected outcomes of this proposal to present physics-informed neural network model that accurately and efficiently predicts the flow field around a fluid object by solving the required equations. Insights into the performance and limitations of the PINN model in fluid mechanics applications. A foundation for further research into the application of PINNs will require analysing more complex fluid mechanics problems, such as multiphase flows and turbulent flows.

5 Conclusion

This proposal aims to investigate the application of PINNs in fluid mechanics to predict the flow field around a fluid object by solving the Navier-Stokes equations. The proposed methodology involves generating a dataset of Navier-Stokes solutions, developing a PINN model to predict the flow field, training the

PINN model using the dataset of Navier-Stokes solutions, and evaluating its performance. The expected outcomes include a physics-informed neural network model, insights into the performance and limitations of the PINN model, and a foundation for further research.

5.1 Alternative or Extension to PINN's

If a sound progress is not made on the implementation of PINNS by the end of this month, I will try exploring on Multinoimial Bayes Function for comparison. A MultinomialNB analysis is a probabilistic classification algorithm used in natural language processing and text mining. It is based on the Bayes theorem and assumes that the features are independent of each other. MultinomialNB is often used for document classification, sentiment analysis, and spam filtering. Therefore, the comparison between PINNs and MultinomialNB analysis depends on the specific problem being solved. Although I quite feel that PINNs may be more appropriate than MultinomialNB analysis on this class, if only problem involving text classification or sentiment analysis are discussed then during a topic the MultinomialNB may be a better choice than PINNs.