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by Mr Adnan

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TITLE OF THE PROPOSAL:-

Symbolic regression in Calculus and Particle Physics

[*Application to Maclaurin* 14 *series (For the function f(x)*=e^*x) and Schrödinger's equation*]

SUBMITTED BY:-

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BACKGROUND:- I've successfully completed the NASA open science curriculum, which has equipped me with a solid foundation in research methodologies and open science principles. So, this training in addition to my academic background has prepared me to applications of Symbolic regression in Calculus and Particle Physics.

INTRODUCTION:

Symbolic Regression is like a treasure hunt for the perfect mathematical equation to describe a dataset. Imagine having a bunch of data points, and you want to find the best way to represent them mathematically. That's where SR comes in. It searches through a vast space of mathematical expressions, looking for the one that not only fits the data accurately but is also simple enough for us humans to understand.

Purpose :- The purpose of Symbolic regression in physics and mathematics is the automated discovery of concise, interpretable, closed-form mathematical equations from data, aiming to find the underlying relationship between variables rather than just numerical predictions. Its purpose is to extract fundamental scientific laws, understand system dynamics, and uncover relationships that may be complex or unknown to human experts, leading to insights for material design, process optimization, and scientific discovery.

Context:- Symbolic regression (SR) is a powerful method used to identify patterns within complex data sets. This proposal focuses on applying SR to two key concepts: the Maclaurin series in calculus and Schrödinger's equation in physics.

The Maclaurin series approximates functions as polynomials around zero, simplifying complex calculations in calculus. By applying SR, we aim to discover new patterns in function approximation.

Schrödinger's equation, fundamental to quantum mechanics, describes how quantum states change over time. Using SR on this equation could yield insights into quantum behavior and its mathematical underpinnings. Through SR, this research seeks to uncover innovative problem-solving approaches and enhance our understanding of these fundamental concepts.

Objective:-The objective of this research is to utilize symbolic regression to uncover new patterns and insights within the Maclaurin series and Schrödinger's equation. By applying SR, we aim to enhance the understanding of function approximation in calculus and explore novel insights into quantum mechanics. This study seeks to advance both mathematical and physical frameworks through innovative analytical techniques.

LITERATURE REVIEW:-

Current research:- Current research in symbolic regression for calculus focuses on advancing deep learning methods like reinforcement learning-based frameworks and foundation models, alongside genetic programming techniques, to improve accuracy and interpretability in discovering mathematical expressions from data.

For example, the most recent paper on it really demonstrates the fact:-

Discovering Interpretable Physical Models using Symbolic Regression and Discrete Exterior Calculus

Simone Manti, Alessandro Lucantonio

It represents that Computational modeling is a key resource to gather insight into physical systems in modern scientific research and engineering.

On the other hand, Papers from 2024 and 2025 discuss using SR to extract precision physical laws, develop tools for discovering equations from network dynamics, and improve the accuracy and simplicity of phenomenological analyses in particle physics.

For example,

Symbolic regression for precision LHC physics

Manuel Morales-Alvarado, Daniel Conde, Josh Bendavid, Veronica Sanz, Maria Ubiali

The following paper focuses on the potential of symbolic regression (SR) to derive compact and precise analytic expressions that can improve the accuracy and simplicity of phenomenological analyses at the Large Hadron Collider (LHC).

Purpose of the following proposal:-This research proposal aims to explore the intriguing possibilities of symbolic regression in calculus and particle physics by focusing on the Maclaurin series and Schrödinger's equation. The study seeks to extend current understanding and explore new methodologies with the knowledge of existing research. The objective is to satisfy a curiosity for how symbolic regression can offer fresh perspectives and potential applications in these mathematical and physical contexts.

RESEARCH OBJECTIVE:

The primary objective of this research is to explore the application of symbolic regression in simplifying complex mathematical equations, specifically focusing on the Maclaurin series in calculus and Schrödinger's equation in particle physics. This study aims to address the following key questions:

How can complex equations be transformed into simpler forms? By utilizing symbolic regression techniques, this research seeks to identify patterns and relationships within complex equations that allow for their simplification. The ultimate goal is to make these equations more accessible and easier to manipulate computationally.

How can we develop a computational model for these equations? The study will investigate methods to construct computational models that accurately represent the simplified versions of these equations. This involves programming algorithms capable of performing symbolic regression to derive equations that maintain the integrity of the original complex forms while being more computationally efficient.

By achieving these objectives, the research aims to contribute to the fields of calculus and particle physics by providing tools and methodologies that enhance the understanding and application of these fundamental equations.

METHODOLOGY:- This study employs PySR (Python Symbolic Regression), a tool by Miles Cranmer, to simplify complex equations using symbolic regression. PySR utilizes genetic programming to discover mathematical expressions that best fit a dataset, making it ideal for this research.

Maclaurin Series of (e^x):

Generate dataset using the series: ($e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!}$).

Apply PySR to derive a simplified symbolic expression.

Validate the expression’s accuracy.

Schrödinger's Equation:

Create datasets from solutions under specific potentials.

Use PySR to simplify the equation.

Verify accuracy against known solutions.

Python Implementation:

Develop Python scripts to automate data generation and symbolic regression using PySR, which optimizes search for simpler forms of complex equations.

EXPECTED OUTCOMES:-

Benefits:-Maclaurin Series:

Simplifies complex functions for easier analysis.
Automates series derivation, boosting efficiency and reducing errors.
Enhances mathematical modeling and solution development.

Schrödinger's Equation:

Offers insights into quantum mechanics and particle behavior.
Automates solutions, accelerating research and discovery.
Facilitates advancements in technology and quantum understanding.

Results of the application :-

Δ Maclaurin Series for (e^x):

Before SR: The Maclaurin series for (e^x) is expressed as:

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots$$

After SR: Symbolic regression is expected to identify a simplified expression, potentially such as:

$$e^x \approx 1 + x + \frac{x^2}{2} - \frac{x^3}{6} + \alpha x^4$$

where (α) is a parameter learned through SR to capture higher-order behavior with fewer terms.

Δ Schrödinger's Equation:

Before SR: The time-independent Schrödinger equation is generally written as:

$$-\frac{\hbar^2}{2m} \nabla^2 \psi + V\psi = E\psi$$

After SR: By applying symbolic regression, the goal might be to derive a more compact form, such as:

$$-\frac{\hbar^2}{2m} \nabla^2 \phi + V_0 \phi = E_0 \phi$$

where (V_0) and (E_0) are constants or simplified expressions derived from the original potential (V) and energy (E).

CONCLUSION:- This research opens avenues for extending symbolic regression techniques to broader mathematical and physical models, enhancing computational efficiency and accessibility.
Key points:-Achieve simplified, computationally efficient models of the Maclaurin series and Schrödinger's equation using PySR.

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