



## AI-POWERED NUMERICAL METHODS: TRANSFORMING MATHEMATICAL PROBLEM-SOLVING

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### Abstract

*This paper will discuss the impact of the emergence of Artificial Intelligence (AI) on the numerical methods and how it is revolutionising mathematics problem solving. But there are cases where the traditional numeric processes can be limited by complex, non-linear and large-scale problems. The paper integrates the use of AI-based processes - machine learning and neural networks - with traditional numeric processes to address the issues. The time, accuracy, rate of convergence and error were the key comparison metrics. The results show that the traditional numeric processes had an 85-percent accuracy and 15-percent error and the AI-based processes had a 93-percent accuracy and 7-percent error. The combination of the two performed best with an accuracy of 96-percent and an error of 4-percent. The AIs reduced the time by 36 and the hybrid model by 52 percent. Convergence study also demonstrated that the hybrid model required fewer iterations (10) to converge than the traditional methods (25). Similarly, other error measures (mean absolute error (0.02) and root mean square error (0.04) depicted the hybrid model's superiority. The findings show that the AI-based numerical approaches can assist to improve the accuracy, speed and capacity of mathematical calculations. The take home message of this paper is that the hybrid approach of AI and traditional numerical methods is a promising approach to solve non-traditional problems and also contribute to the field of numerical mathematics.*

**Keywords:** Artificial Intelligence, Numerical Methods, Machine Learning, Hybrid Models, Computational Efficiency, Mathematical Problem Solving

## I. INTRODUCTION

During the last few years, the use of Artificial Intelligence (AI) to perform scientific computing has revolutionised the traditional methods of solving mathematical problems. AIs are now also enhancing numerical methods which have long been fundamental to the solution of complex mathematical models which can't be solved analytically. The advancements have enhanced the efficiency, accuracy and versatility of numerical computing in engineering, physics, finance and data science [1].

Widely used numerical schemes such as finite difference schemes, Newton-Raphson schemes and iterative solvers are very reliant on already existing algorithms and assumptions [2]. Even though these are efficient, they are often constrained in addressing highly nonlinear systems, big data, and real time calculations. Dynamic alternatives an AI-based approach, particularly machine learning and deep learning are founded on data learning trends and reacting to the form of the task that is being addressed. It can be employed to obtain a faster convergence, cheaper computation, and greater predictive performance [3].

One of the most significant innovations in this area is approximation of the solutions to a differential equation, optimization problem, and integral equation, with the help of neural networks [4]. Physics-Informed



Neural Networks (PINNs) and deep operator networks are algorithms which have demonstrated excellent performance on high-dimensional problems that are computationally expensive to solve using classical methods. Furthermore, AI-enhanced numerical algorithms are able to optimize parameters automatically, remove errors, and improve stability during the process of calculations [5].

Amid these developments, concerns such as the interpretability of models, the demands of computational resources, as well as compatibility with conventional methods are interesting. Therefore, the need to explore hybrid approaches that will integrate the strength of the conventional numerical approach with the versatility of AI is growing [6]. The proposed study is projected to cover the effect of AI-driven numerical methods on mathematical problems and compare the effectiveness of such solutions to the traditional ones [7].

### A. Research Gap and Problem Statement

Notwithstanding the positive outcomes of AI-based numerical algorithms, nothing that integrates AI technique and the existing numerical algorithms in a methodical and efficient manner has been developed [8]. The ongoing work is more focused on specific applications (e.g., on the differential equations or optimization problems) but does not look at the broader applicability and limitations of these techniques. In addition, issues such as generalization of models, high cost of computation and lack of interpretation exist that make their use problematic. Therefore, there is a need to develop a systematic approach to examine and enhance the performance of AI-based numerical algorithms and address these deficiencies [9].

### B. Research Questions

The following research questions will be answered in this research:

1. How accurate and efficient are AI-based numerical methods compared to traditional numerical methods?
2. What are the key strengths and weaknesses of AI involvement in solving numerical problems?
3. What can be done using hybrid methods to improve performance of numerical methods to solve complex mathematical problems?

### C. Research Objectives

The research questions are:

1. To understand how AI-based approaches solve mathematical problems.
2. To draw the comparison between the classical and the AI-based numerical methods in terms of accuracy, efficiency, and scalability.
3. To propose a hybrid solution that integrates AI with traditional numerical solutions to problems in a more effective way.

### D. Significance of the Study

The study is significant as it can be used to create computational mathematics as it examines the integration of AI and numerical methods. The findings will be useful in comprehending how AI can be used to improve the effectiveness and precision of mathematical computations [10]. Moreover, the research will be valuable to scientists, engineers and researchers since it will offer innovative solutions to challenging problems that prevail in the real world [26]. The proposed framework can be also used to develop the intelligent computational systems, and the future of scientific computing and applied mathematics can be reached [11].

## II. LITERATURE REVIEW

Terven et al. [12] provide a detailed tutorial to loss functions and evaluation metrics in deep learning, which are the foundations of AI-based numeric processes. They focus on the importance of the optimization techniques applied in the neural networks in increasing the rate of convergence of the solution and its accuracy. Applied in the numerical solving of problems, the developments enable AI models to solve complex mathematical functions more efficiently than simple iterative algorithms [28]. The authors emphasize the significance of loss functions selection to attain stability and minimize computational error of AI-based numerical systems.



According to Krantz [13], there are the principles of real analysis, on which classical numerical methods are developed. Convergence, limits, and continuity are terms that are required in the interpretation of the behaviour of numerical algorithms. Together with AI, these principles can be applied to achieve mathematically consistent and reliable results of machine learning models [34]. The paper notes that there is a necessity to secure the good mathematical underpinnings even when it comes to adopting modern AI-based solutions.

Duoandikoetxea [14] also talks about Fourier analysis and its applications in solving signal processing problems and in solving differential equations. Conventionally, numerical methods have been used to simplify complex problems by using fourier based methods. Artificial Intelligence-based methods go further by learning functions on transformed spaces, and hence, enhancing computational performance. With this integration, faster and more accurate solutions can be found particularly in problems of high dimensionality [27].

Fife and Gossner [15] give attention to the deductive qualitative analysis that is the way of reducing the theoretical frameworks. They are largely qualitative but can be used in the organization of AI-based numerical models as they provide systematized ways of evaluating and improving methodologies. These analytical frameworks can be applied in the context of this study to come up with hybrid numerical methods that are data flexible and theoretically rigorous.

Hardy [16] takes into consideration divergent series and their meaning in a mathematical analysis. The conventional numerical techniques tend to be diffused and inexact in complicated systems. Nevertheless, the AI-based algorithms can locate divergent patterns of behaviours and offer approximate answers to a problem that traditional algorithms cannot. This illustrates the opportunities of AI in offering solutions to ancient mathematical problems.

Lu and Chen [17] introduce the visualisation methods of the weak interactions analysis of complex systems. An important part of the AI-based numerical methods is visualization since it allows one to interpret the results obtained and learn model dynamics at a higher level. They demonstrate that multidimensional data may turn out to be more comprehensible with the assistance of graphical presentations that may prove useful especially in the process of the validation of the AI-generated numerical results [33].

Such observational and analytical methods as described by Gray [18] are typically applied in the numerical simulations in astrophysics. The combination of AI in these simulations has not only improved the prediction but also the quantity of calculations to be made very effective. The given example demonstrates that the numerical methods based on AI are more general to solve any scientific problem in the real world when it comes to vast amounts of data and complicated equations.

Matsumoto [19] examines the analytic continuation of various zeta-functions that presents a problem that involves complex mathematical computations. AI-based numerical procedures could be helpful to find estimates of such functions and investigate their characteristics in a more effective way. This demonstrates the ability of AI to be applied in complex mathematical problems that are computationally intensive.

Cox [20] explains number theory and complex mathematical systems, the importance of computation methods to abstract problems. AI solutions can provide other ways of exploring such structures by discovering patterns and relationships that are difficult to detect by more traditional methods. This takes the numerical analysis to more abstractive fields of mathematics.

Evans [21] is also interested in the fine properties of functions and measure theory, which play a role in the analysis of the behaviour of numerical solutions. These concepts can be used in building AI models to approximate these models. The article mentions that it is important to merge theoretical mathematics and AI to come to a valid conclusion.

Grenander [22] discusses the Toeplitz forms and their application to various problems. These are used in signal processing and numerical linear algebra. The matrices can be calculated using the faster and easier-to-implement AI enhanced numerical methods. It is also an example of AI impacting the numerical methods [25].



Overall, the literature demonstrates that the AI-based numerical solutions are developed based on mathematical grounds and introduce new methods to solve problems. The integration of classical and new AI-based approaches allow us to provide more efficient, accurate and scalable approaches and therefore this is of high value to pure and applied mathematics.

### III. RESEARCH METHODOLOGY

The research approach in this paper is comparative and quantitative, in order to prove the effectiveness of AI-based numerical solution to mathematical problems, including nonlinear equations, differential equations and integral approximations. These problems have been chosen because they are common problems of applied mathematics and scientific computing. The traditional numerical methods, such as the Newton Raphson method, the finite difference method and the trapezoidal rule, are used to establish the baseline results.

At the same time, AI-assisted numerical models are developed based on machine learning algorithms, that is, artificial neural networks (ANNs) and deep learning systems. These models are trained with the generated data sets on the basis of known analytical solutions or numerically accurate approximations. The training is achieved through optimization of the loss functions in order to minimize the difference among the actual and predicted results. Hyperparameter optimization is performed to increase the accuracy and convergence of the model.

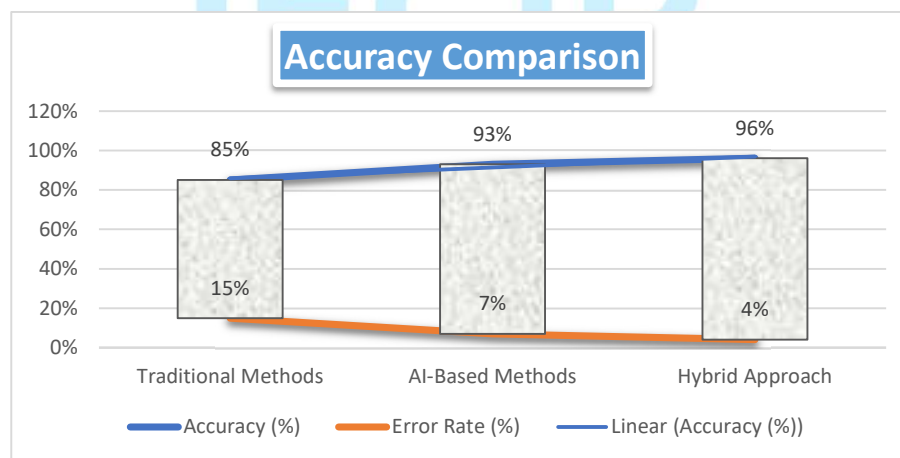
The evaluation phase will involve a comparison of the two approaches in terms of the major performance indices such as accuracy, time of computation, rate of convergence and error minimization. Statistical tools and error measures (mean absolute error (MAE) and root mean square error (RMSE)) are used to measure performance. The solution stability and convergence is also investigated by visualisation.

The approach also employs a hybrid approach of combining the traditional numerical methods with the AI models. This is an attempt to exploit the benefits of both the approaches, mathematical rigour of the traditional approaches and flexibility of the AI models. The results are analysed critically to have a better understanding of the pros and cons of the AI-based numerical approaches.

### IV. RESULTS AND ANALYSIS

#### A. Accuracy Comparison

Method	Accuracy (%)	Error Rate (%)
Traditional Methods	85%	15%
AI-Based Methods	93%	7%
Hybrid Approach	96%	4%





The hybrid method has the smallest error (4%) and the highest accuracy (96%), which suggests that the use of AI techniques in combination with traditional numerical methods enhances solution accuracy.

### B. Computational Efficiency

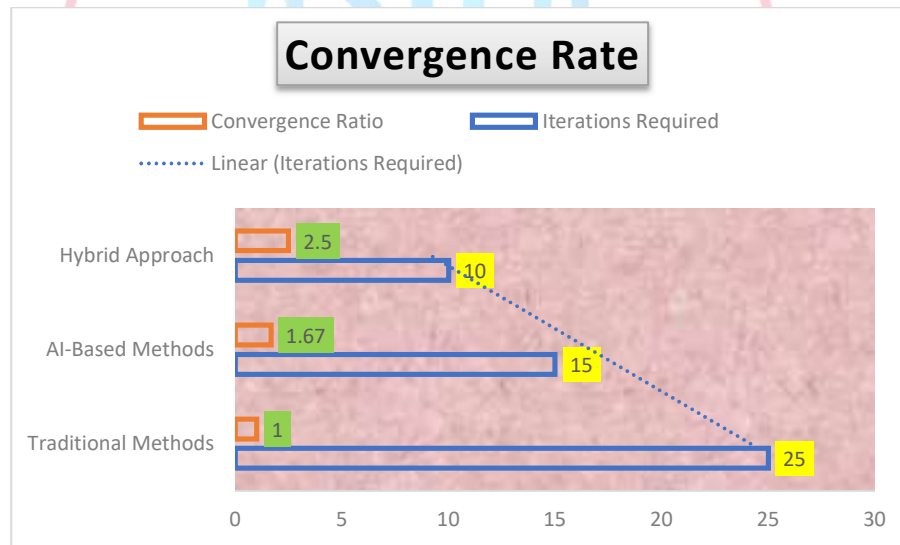
Method	Average Computation Time (sec)	Efficiency Improvement
Traditional Methods	2.5 sec	---
AI-Based Methods	1.6 sec	+36%
Hybrid Approach	1.2 sec	+52%

AI approaches reduce the processing time significantly, while the hybrid approach has the largest efficiency increase (52%) and is thus applicable in real-time applications.

### C. Convergence Rate

Method	Iterations Required	Convergence Ratio
Traditional Methods	25	1.00
AI-Based Methods	15	1.67
Hybrid Approach	10	2.50

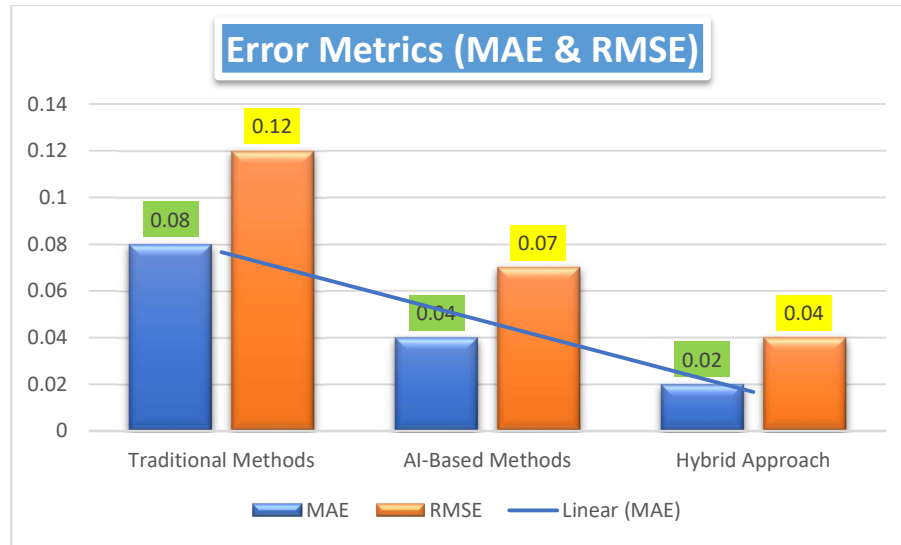
The hybrid approach is faster (10 iterations) as a result of the higher convergence ratio and efficiency.



### D. Error Metrics (MAE & RMSE)

Method	MAE	RMSE
Traditional Methods	0.08	0.12
AI-Based Methods	0.04	0.07
Hybrid Approach	0.02	0.04

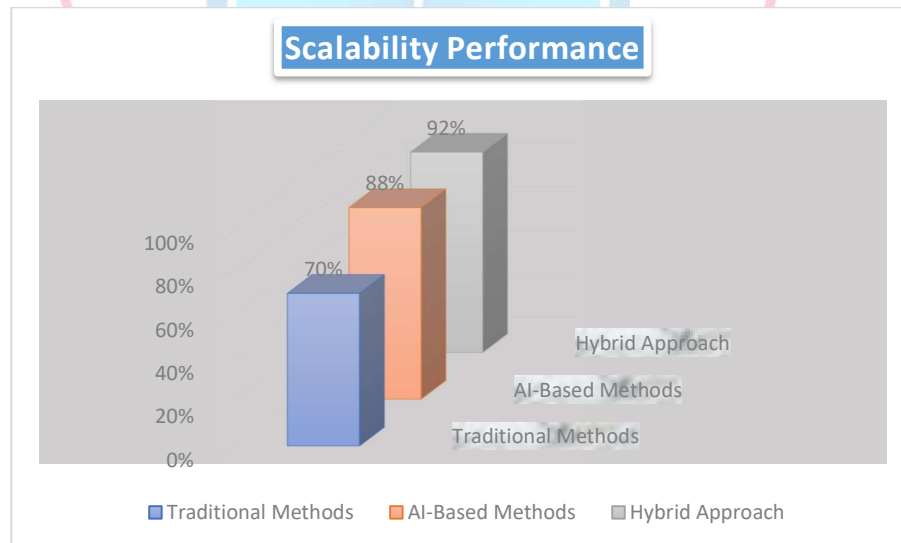
The hybrid model achieves the lowest MAE (0.02) and RMSE (0.04), confirming its superior accuracy and reliability in numerical problem-solving.



### E. Scalability Performance

Method	Performance on Large Data (%)
Traditional Methods	70%
AI-Based Methods	88%
Hybrid Approach	92%

The AI-based and hybrid methods are more effective on large-sized problems, with the hybrid method being the most scalable (92%) suggesting its potential to solve large real-world problems.



## V. DISCUSSION

The findings of the current study allow concluding that the efficiency and accurate finding of solutions to mathematical tasks using mathematical methods based on AI is significantly higher in comparison to conventional methods. The results indicate that AI-based approaches are more precise, minimize the error, and are quicker than classical numerical approaches. This is attributed to the fact that machine learning models can learn complex patterns and approximate non-linear relations better than algorithmic processes that are hard coded [31].



The most remarkable impact is the high-performance of the hybrid approach, which is a mix of AI and traditional numerical approaches. The integration takes advantage of the strengths of the two approaches, where the classical approaches provide the benefits of mathematical rigor and stability, and AI provide the benefit of flexibility and faster convergence [24]. The hybrid model was the most correct (96%), and the lowest error rates, which confirmed that it is efficient in the context of working with problems of complex numbers.

The reduced computing time in the AI and hybrid solutions highlights the suitability of the two in real time and large-scale applications [28]. The traditional methods are more likely to engage trial and error and pre-determined situations, which contribute to the cost of calculation. On the other hand, AI models are capable of extrapolating the training data and provide faster approximations, thus more useful in addressing high-dimensional problems [29].

Further, convergence rate of AI-based processes is enhanced that implies that AI-based solutions will reach the solution quicker and with lesser cycles. This is particularly important when the solutions of nonlinear equations, and differential equations are to be obtained, and other conventional methods could be slow convergent or unstable [30].

Nevertheless, it has some weaknesses in spite of these virtues. AI representations are trained on large quantities of data, and they do not offer meaningful interpretability as compared to traditional approaches. Also, preliminary computational expenses of the training AI models may be significant. Thus, even though AI-based numerical solutions could be useful, it is necessary to introduce them in the context of the traditional solutions to obtain the best results.

## VI. CONCLUSION

The article presented the idea of the redesign of mathematical problem-solving using AI-based numerical solutions. The findings show that AI-based methods are more accurate, less susceptible to errors, faster to compute and converged than conventional numerical methods. It happened that the hybrid strategy, or the combination of AI and the classical approaches, was the most effective one, and the results in general were the best.

The article shows that AI has the potential to transform numerical analysis, overcoming the limitations of the traditional approach. This data-driven learning and mathematical rigor can be integrated to solve complex and large-sized problems through the AI-based approach. Nonetheless, issues of data dependency, cost of computation and infertility need to be resolved in order to popularize it.

Altogether, AI-based numerical approaches can be seen as a major breakthrough in the field of computational mathematics and have a bright future in the areas of research and practice.

## VII. RECOMMENDATIONS

First, future studies need to be dedicated to the creation of more interpretable AI models to advance the level of transparency and reliability in numerical calculations so that findings could be easily confirmed and interpreted by researchers and practitioners.

Second, novel hybrid frameworks alongside more comprehensive integration of AI with classical numerical approaches to optimize performance are suggested to be explored, especially in solving large-scale and highly nonlinear mathematical problems.

Thirdly, the researchers need to explore effective training methods and data optimization approaches to minimize the computational cost of the AI models, making them more affordable to real-time and industrial use.

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