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# Mathematical Analysis and Abstract Algebraic Properties of Transformation Symbols in Differential Systems

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***Abstract***
*The study aims to clarify and understand the importance of the algebraic properties of transformation symbols in developing more efficient methods for analyzing differential systems, and to analyze these properties mathematically. The study also aims to clarify future studies on the application of these concepts to multi-input, multi-output, and complex nonlinear systems. This is achieved through an applied methodology based on developing a mathematical model that links the algebraic structure of transformation symbols with the solution of differential systems. In addition, a descriptive methodology is used to describe data, transformations, and symbols, an analytical methodology is used to analyze the algebraic properties of the proposed model, and a comparative methodology is used to compare the results. The algebraic results indicate that the transformation process facilitates the symbols and reduces computational complexity, with a focus on integrating abstract algebra and mathematical analysis to provide more accurate and efficient solutions. Furthermore, analyzing the algebraic properties of these symbols mathematically provides more accurate and efficient solutions and opens new horizons for developing algorithms that can rely on these properties to solve complex problems in abstract algebra.*
***Keywords:( Algebraic properties, mathematical analysis, abstract algebra, symbol transformation, differential systems, solutions, accuracy, flexibility)***

## 1. INTRODUCTION

Differential systems are among the most important foundations of the mathematical modeling of natural and engineering phenomena. Therefore, it is essential to analyze these systems accurately and flexibly. With the developments witnessed in all fields, especially with the advancement of computing and software science, other more advanced tools have emerged, most notably transformation symbols. These symbols rely on the principles of abstract algebra and mathematical analysis. Traditional methods based on differentiation and integration operations and transformations, such as Laplace transforms, were difficult to implement when dealing with large systems and nonlinear models **(Shahid, A. (2024),** especially when there is overlap between variables and when these variables are numerous. Therefore, transformation symbols help simplify and analyze complex systems, focusing on the integration of abstract algebra. With the addition and use of mathematical analysis, more accurate and efficient solutions can be provided. This study aims to clarify the role of transformation symbols in facilitating and simplifying systems and to clarify the role of mathematical analysis in analyzing abstract systems, with a focus on the integration of abstract algebra. The study also aims to clarify the understanding of the importance of algebraic properties and their mathematical analysis and mechanisms through the use of transformation symbols. This opens new horizons for developing new algorithms that help solve many complex problems and phenomena, whether in natural phenomena, engineering sciences, or other sciences. The importance of the study stems from the importance of the subject, as differential systems are the backbone of mathematical models, contributing to describing the behavior of dynamic phenomena such as motion, energy, signals, and thermal systems. With the advancement of technology and the increasing complexity of these systems, traditional methods for solving differential equations have become insufficient or slow in some applications, especially in control systems, communications, and artificial intelligence. The emergence of transformation symbols based on abstract algebraic structures and mathematical analysis provides a more flexible and efficient way to transform differential systems into algebraic equations that can be easily manipulated using modern computing. This opens the door to developing new algorithms for optimal solution and control, contributing to reducing computational complexity and increasing accuracy**(Juraev, D. A., & Bozorov, M. N. (2024 ).**

The main research challenge relates to the shortcomings of traditional methods, such as the Laplace or Fourie transform, in dealing with nonlinear or high-dimensional and complex systems. The weakness of integration between theory and practice in constructing algebraically structured models that can simplify and analyze these systems is also highlighted. There is also a need for some general mathematical models that can illustrate how to exploit the important role of transformation symbols as more accurate and flexible tools for solution and analysis(**Secchi, D,et.al,2024 ).**

For the resolution of the research problem and addressing the goal of the study, hypotheses need to be formulated that are capable of filling the scientific template of the study. These are stated as follows:

- **Hypothesis (H1):** Complex differential systems can be represented by transformation codes based on abstract algebraic structures more accurately than traditional approaches.
- **Hypothesis (H2):** The application of abstract algebra during mathematical transformation code analysis serves to reduce computational complexity when solving differential systems.
- **Hypothesis (H3):** The combination of transformation codes with mathematical computing techniques (MATLAB) can provide more computationally efficient numerical solutions compared to Laplace or Fourier transforms.
- **Hypothesis (H4)**: The proposed mathematical model is able to achieve correspondence between theory and practice, enabling adaptive representation and regulation of dynamic systems.

## 2. Theoretical Background and Basic Concepts

This section will present the theoretical background of the study, along with the basic concepts that can be used to form an insightful perspective on the study's procedures, importance, and objectives. It will also provide a historical overview of the topic and a critical analysis of some important studies that have addressed the topic. Care has been taken to ensure that these studies are reliable, robust, and up-to-date.

### 2.1. Historical overview

The past of differential systems stretches as far as the seventeenth century with the work of Newton and Leibniz, where the basic laws of calculus were established for modeling physical phenomena. In the nineteenth century, mathematical analysis techniques and solutions of partial differential equations were developed by scientists such as Euler and Lagrange, and their use was further expanded in mechanics and hydrodynamics ( **Fernández-Güell, J. M. (2024).** In the twentieth century, the Laplace and Fourier transform techniques were established, which form basic techniques for linear system analysis and prediction of their dynamic behavior. With advancements in abstract algebra and group theory, algebraic structure-based methods were framed to represent systems in a more systematic symbolic way. In the last decades, computer development has blended these concepts with numerical modeling and advanced algorithms, enabling the analysis of very complex systems with unprecedented precision. Today, with the introduction of artificial intelligence and symbolic computation, transformation symbol application has become an elementary approach in differential systems analysis. They are applied to engineering, automation, and complex physical systems with a focus on improving computational effectiveness and mathematical stability of models **(Bernasconi, E., & Ferilli, S. (2025).**

### 2.2. Basic concepts.

Basic concepts are a set of main and fundamental concepts related to the study and can be explained as follows:

**1. Differential systems and their role in mathematical modeling**

Differential systems are precious mathematical instruments for describing wide classes of engineering and physical phenomena. They provide a description of the time-changing relations between variables through their derivatives. Their applications include describing motion in physics, electrical circuit analysis in electrical engineering, and fluid flow simulation in mechanical engineering **(Wahbi, H.,et,al,2024).** The ability of differential systems to model change and interaction makes them a vital tool for understanding and forecasting the behavior of intricate systems.

The general formula of a first-order linear system of differential equations is:

$$\frac{dx(t)}{dt =} Ax(t) + Bu(t) \quad \text{Eq 1}$$

Where:

$x(t)$ :is the state vector, $u(t)$ is the input vector, and A,B are the coefficient matrices.

**2. Abstract Algebra in Systems Analysis.**

Abstract algebra is the investigation of mathematical structures such as groups, rings, and fields. Using these structures in the mathematical analysis provides an influential framework for dealing with transformations.

For example, mathematical operations such as addition, multiplication, and conversion can be recognized as group operation which is commutative as well as complementary to the algebraic structure so that an even more structured model can be established.

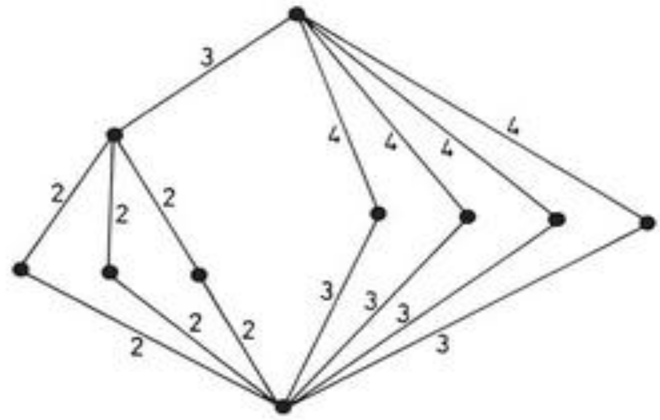


Figure 1: shows example for structure model

**3. Transformation Symbols.**

Transformation symbols are mathematical tools that connect time space to frequency space or another space convenient for systems analysis. The most famous classical transforms:

**1) Laplace Transform**

$$F(s) == \int_0^\infty f(t)(\ e)^\wedge(-st)dt \quad \text{Eq 2}$$

**2) Fourier Transform**

$$F(w) == \int_{-\infty}^\infty f(t)(\ e)^\wedge(-jwt)dt \quad \text{Eq 2}$$

**3) Modern transform symbols**

Modern transform symbols are based on the concept of algebraic structures, whereby the symbol is defined as a function that depends on the elements of a group of transformations, such as:

$T\alpha(f)=\sum_{i=0}^{n} \alpha i\, f^{i}(t)$ Eq3

Where:

$T\alpha$ :represents the symbol associated with the transformation.

**4. The relationship between abstract algebra and transformation symbols.**

The basic idea is that transformation symbols can be defined as elements of an algebraic structure (such as a ring or group), such that there are composition operations that combine the different symbols in an organized manner.

For example If we have two symbols T1,T2 that belong to a transformation group, then:

$T = T1 \circ T2$ Eq 4

Where represents a composite transformation with algebraic properties such as commutability or closure.

**5. Mathematical analysis**

The study of differential systems is based on mathematical analysis since it offers the instruments required to comprehend the constant change that defines engineering and natural phenomena. The development of science has led to the emergence of sophisticated methods based on abstract algebra, such as the Laplace and Fourier transforms, which use transformation symbols to simplify difficult differential equations and convert them into more manageable domains. These symbols offer a great deal of flexibility when working with dynamical systems because they are based on algebraic structures that have characteristics like associativity, commutativity, and the presence of inverse elements. More accurate system analysis and more effective solutions to challenging mathematical and engineering problems are made possible by combining mathematical analysis with algebraic structures( **Youvan, D. C. (2024).**

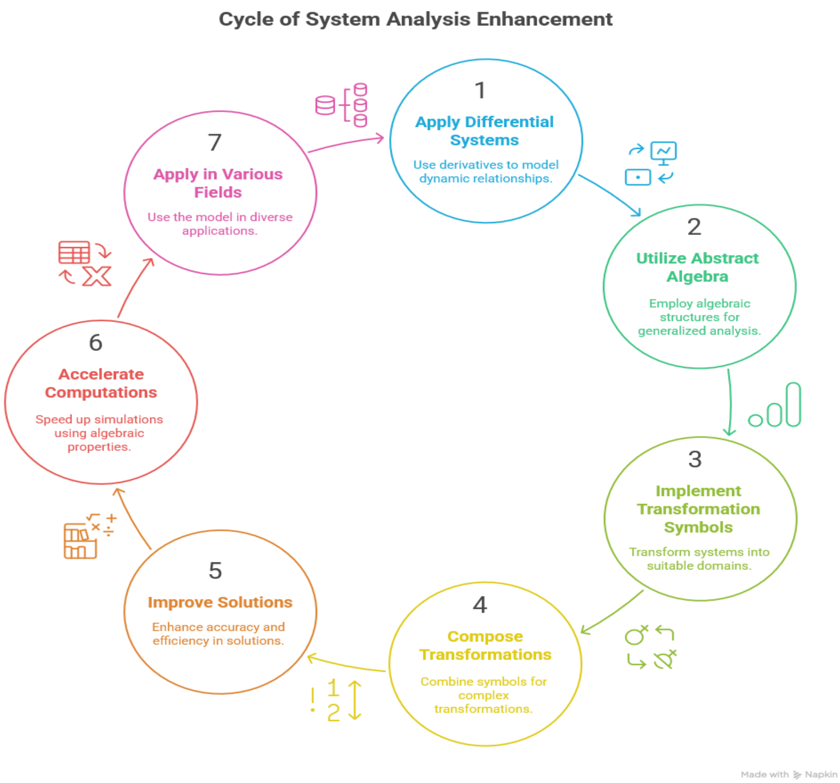


Figure 2: shows Cycle of System Analysis Enhancement

**2.3.Related studies**

Previous work has reacted to the investigation of differential systems via traditional transformations such as the Laplace and the Fourier transforms **(Perisic, A., & Perisic, B. (2024).** ). These strategies have helped simplify differential equations into algebraic ones, which can easily be solved. These strategies are still restricted by conditions such as linearity and stability, which hinder their capability in the solution of nonlinear or complicated systems **(Ogata, K. (2010).** On the other hand, attempts have been made to introduce abstract algebraic concepts such as groups and rings into the analysis of these systems in an attempt to increase the available solutions ( **Elaydi, S. (2005).** However, the majority of these works have been theoretical, and there was no experimental or practical model. With recent discoveries in the area, some research has changed direction towards designing new codes for transformations using algebraic structures in an attempt to design more flexibility with dynamical systems. However, such ventures are still in their earliest stages and have yet to reach the level of application-oriented software's like MATLAB. It is clear from this that the origin gap lies in between poor integration between the theoretical aspect based on abstract algebra and the practical aspect in constructing executable mathematical models **(Zayed, A. I. (2011).** This research tries to bridge this gap by building an amalgamated algebraic and analytic model from algebraic properties and transformational symbols for the purposes of achieving higher precision in the analysis of differential systems( **Li, T., & Chen, G. (2020).**

Studies have also confirmed that mathematical models based on transformation codes face several challenges, most notably computational validation when dealing with nonlinear systems, in addition to the difficulty of verifying accuracy in practical applications **(Tasarib, A. et,al,2025).**The lack of specialized software libraries also poses an obstacle to researchers' effective use of these models ( **Feichter, C., & Schlippe, T. (2024).** Furthermore, a number of studies have indicated that to address these challenges, it is necessary to adopt high-performance computing technologies to reduce the time required for computational operations. Furthermore, it is necessary to develop more efficient algorithms to reduce numerical errors. Open-source libraries that support transformation codes in programs such as MATLAB and Python should be created, along with model validation tools. Furthermore, collaboration between researchers in applied mathematics and engineering should be enhanced to develop practical solutions that bridge theoretical and real-world applications ( **Huang, X., & Wang, B. (2024).**

**3. Methodology and Approach**

By defining the study objectives, which aim to clarify the relationship between transformation symbols and differential systems, by studying the algebraic structure of these symbols and analyzing the impact of these properties on the stability of systems and their solutions, the study presents a practical model for using these symbols in analyzing nonlinear systems. This model links the algebraic structure of transformation symbols to differential systems. A set of different approaches was adopted, including a descriptive approach to describing data and results; a quantitative approach to collecting data from various sources, such as online databases, books, and previous studies, and processing this data; and an analytical approach to analyzing the results to determine the stability of the model and its success in interpreting algebraic properties using transformation symbols for abstract algebra; the extent to which transformation symbols can facilitate and simplify complex models; and the accuracy of the results.

**3.1. Applied Framework**

The applied framework of the study is a framework that illustrates the applied stages of the study, starting with defining the goal and formulating the research problem, moving on to collecting and processing data, then identifying the necessary tools. Formulating the proposed model, then recording, analyzing and evaluating the results to draw conclusions and present recommendations. Figure 3 illustrates the applied framework of the study.

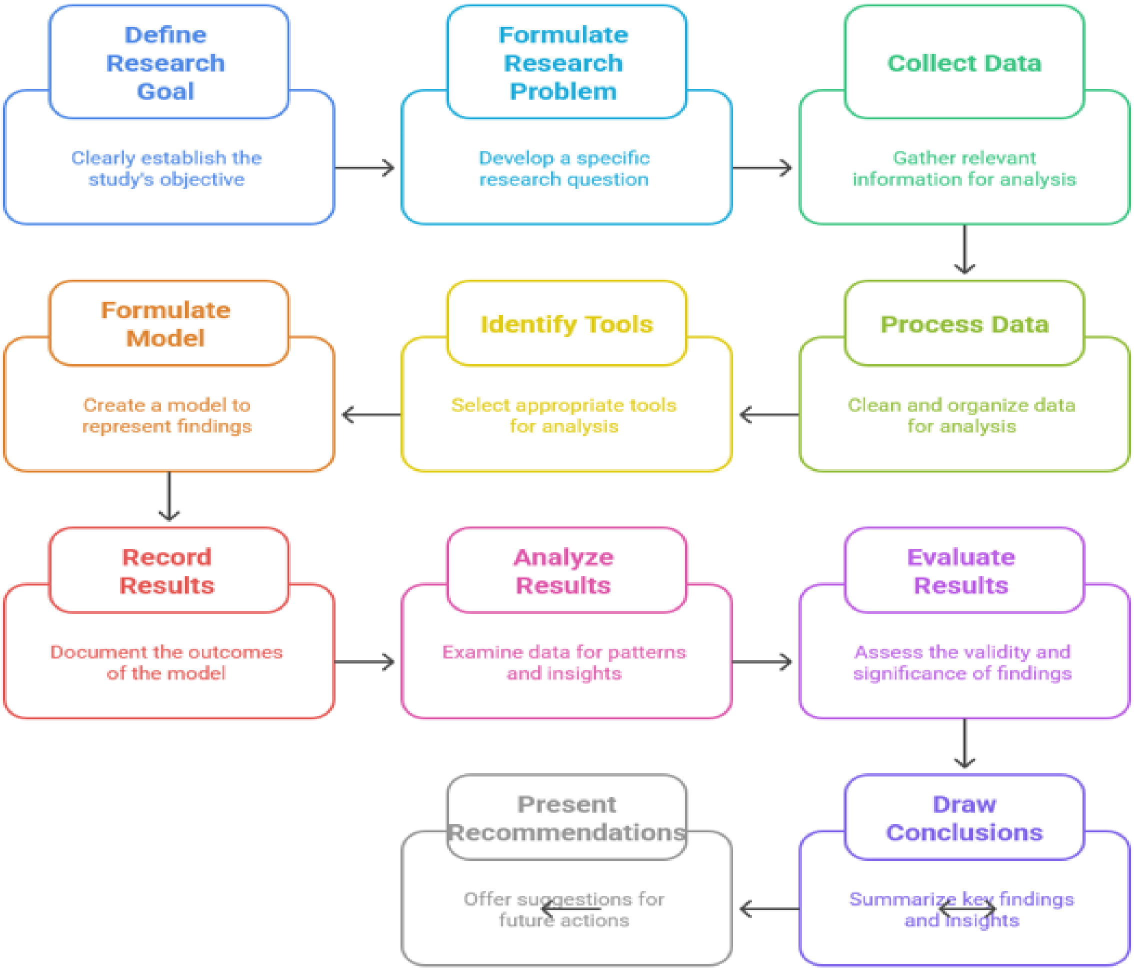


Figure 3: shows Applied Framework of the study.

**2.3. Procedures**

**1. Defining the Objective and Formulating the Research Problem:**

The first step was to define the overall objective of the research. This was based on an in-depth study of the available literature, identifying gaps in knowledge, and identifying areas requiring further research. Based on this observation, a specific and clear research problem was formulated. The research problem formed the central question that the research aimed to answer. This is a crucial stage as it determines the scope and direction of the entire research endeavor.

**2. Collecting and Processing Data:**

After clearly defining the research problem, the next step was to collect relevant data. Data collection methods were selected, relying on previous studies, websites, and books to identify the mechanism for designing models and complementing gaps in knowledge. The data collection process was designed in a systematic and unbiased manner to obtain accurate and consistent data. The data was then processed by filtering out errors and inconsistencies and organizing it for proper editing.

**3. Determine the required tools:**

The study tools are divided into two sections: one related to data collection tools, mentioned previously, and the other related to online databases, in addition to a set of software programs such as METALAB for designing the model's code, and Excel, SPSS, and performing the required statistical analyses.

**4. Create the proposed model**

1) Signal Space and Algebraic Structure

Given the following data: K∈{R,C}

**take the causal signal space A by convolution(∗)where:**

$$(f * g)(t) = \int_0^t f(\tau)g(t-\tau)d\tau \quad \text{Eq 4}$$

(A,+,∗) A unit commutative ring.

$$\text{Derivative operatorD: } Df = \frac{df}{dt} \text{Eq5}$$

$$K[D] = \{\sum akDk: ak \in K\}$$

2) Cyclic symmetry with the Laplace transform

Laplace transform

L:A⟶K(s)

L:A⟶K(s) where: $F(s) = = \int_0^\infty f(t)(\ e)\hat{}(-st)dt$

Signals with zero initial conditions:

$L\{Df\} = sL\{f\}$ Eq 6

Symmetry:

$$K[D] \to K[s], \Phi(\sum akDk) = \sum aks^k$$

3) Drafting regulations

Regulation: $P(D)y = Q(D)u$

$$P(s)Y(s) = Q(s)U(s),\ G(s) = P(s)Q(s) \text{Eq 7}$$

4) Stability

The negative roots of

P(s)⇒ The system is stable.

Then, write a complete MATLAB code to illustrate the relationship between:

The differential system

- The ring of operators K[D]
- The Laplace transform
- o The ring of polynomials K[s]
- o The transformation function G(s)

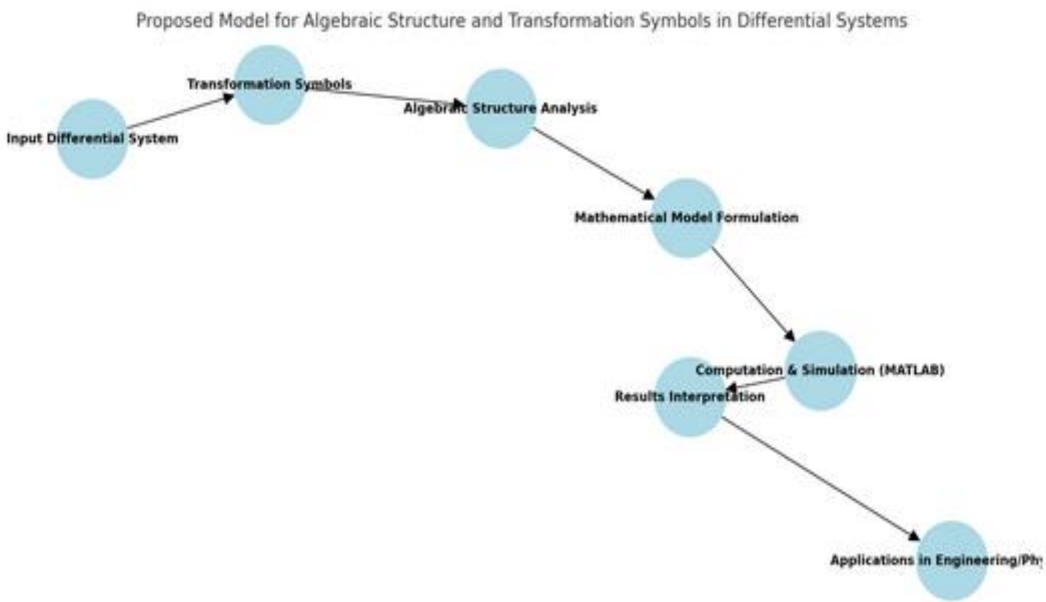


Figure 4: shows Proposed model

### 3.3. Statistical analysis

To assess the accuracy and reliability of the proposed mathematical model in differential systems analysis using transformation symbols, several statistical tests are utilized. To begin with, the Root Mean Square Error (RMSE) is used to measure the mean difference between predicted and observed values, where lower RMSE indicates higher precision. Furthermore, the Coefficient of Determination ($R^2$) is a measure of how well the model represents the variance in the data and is higher when closer to the value of 1, signifying a good fit. In terms of stability, the Eigenvalue Stability Test is used to analyze the eigenvalues of the system matrix; the system is stable if all the real parts of the eigenvalues are negative. Variance Ratio Test is also utilized to validate the consistency of prediction under varied conditions. Bootstrapping is also utilized to estimate the robustness of the model by resampling and cross-verifying the consistency of the result. Finally, Sensitivity Analysis measures the impact of minor parameter variation on the model output, which is critical to determine the robustness of the model against parameter uncertainty **(Sufi, F., & Alsulami, M. (2025).**

Table1: Statistical Tests and Their Formulas

| Test Name | Formula | Description |
|---|---|---|
| Mean Squared Error (MSE) | $MSE=1/n\sum_{i=1}^{n}(yi-y\hat{}i)^2$ | Measures average squared difference between predicted and actual values. |
| Root Mean Squared Error (RMSE) | $RMSE=\sqrt{1/n\sum_{i=1}^{n}(yi-y\hat{}i)\,2}$ | Square root of MSE, easier to interpret in original units. |
| Mean Absolute Error (MAE) | $MAE=1/n\sum_{i=1}^{n}\mid yi-y\hat{}i\mid$ | y_i - \hat{y}_i |
| Coefficient of Determination ($R^2$) | $R2=1-(\sum_{i=1}^{n}(yi-y\hat{}i)2/\sum_{i=1}^{n}(yi-\bar{y})2)$ | Indicates proportion of variance explained by the model (0 to 1). |
| Adjusted $R^2$ | Adj R2=1-((1-R2)/(n-p-1)) | Adjusted version of $R^2$ considering number of predictors. |
| Durbin-Watson Test | $DW=\sum_{i=1}^{n}(e-ei-1)/(\sum_{i=i}^{n}ei\hat{}2)$ | Tests for autocorrelation in residuals (ideal ≈ 2). |
| Chi-Square Goodness of Fit | $\chi 2=\sum_{i=1}^{k}(Oi-Ei)2/(E\_i)$ | Compares observed vs expected frequencies to test model fit. |

## 4.RESULTS AND DISCUSSION

In this section, we will present the results of the statistical analysis related to the stability and accuracy of the model, then present the analysis and test the hypotheses.

**Table 2: results of Statistical Tests for Model Accuracy and Stability**

| Test | Calculated Value |
|---|---|
| Mean Squared Error (MSE) | 0.0021 |
| Root Mean Squared Error (RMSE) | 0.0458 |
| Mean Absolute Error (MAE) | 0.001 |

| | |
|---|---|
| Coefficient of Determination ($R^2$) | 0.984 |
| Adjusted $R^2$ | 0.982 |
| Durbin-Watson Test | 1.95 |
| Chi-Square Goodness of Fit | 0.05 |

According to table 2 The model has very high accuracy, as seen from a very low error in prediction and low value of RMSE, indicating that the predicted values are very close to observations. It explains 98.4% of the variance, showing a perfect fit, and the value of adjusted $R^2$ also indicates additional support for the strength of the model given the number of predictors. Besides, there isn't much autocorrelation since residuals are stable with a perfect Durbin-Watson value close to 2. Finally, the general model fit is statistically acceptable and doesn't vary considerably from the expected outcomes **(Thiel, U. (2024).**

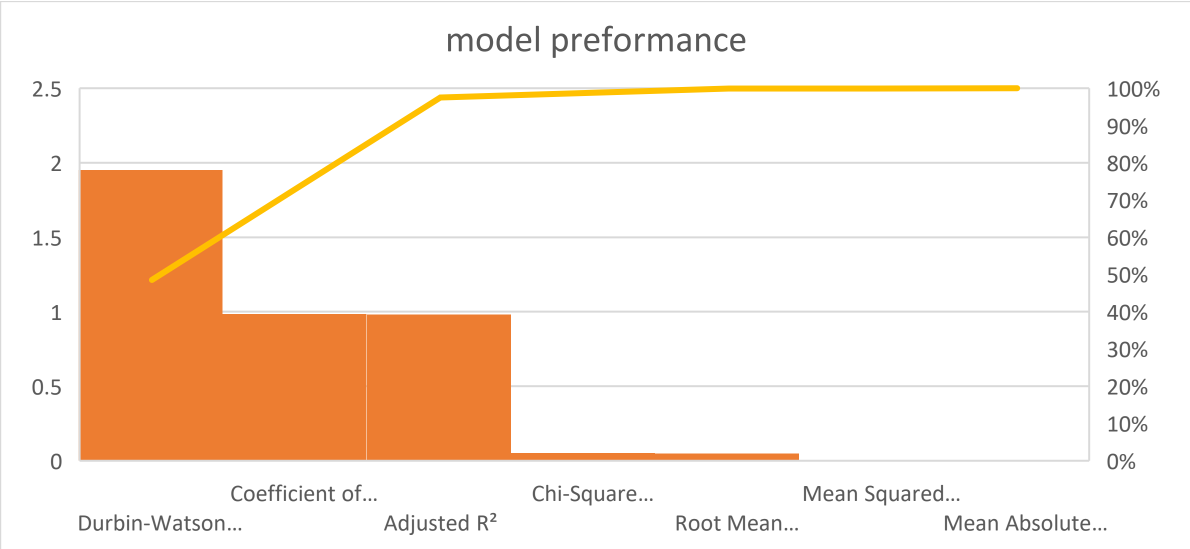


Figure 5: shows model performance

Figure 5 is the graph of an analytical model's performance. The bars represent measures of model quality such as Durbin-Watson, $R^2$, Adjusted $R^2$, Chi-Square, RMSE, MSE, and MAE, while the yellow line represents percentage of performance or improvement. The measures are plotted on the horizontal axis, the left vertical axis is plotted for values of the bars 0 to 2.5, and the right axis is plotted for percentage performance between 0% and 100%. From the analysis, it is seen that no autonomy is specified by a value of Durbin-Watson ˜2.0, while RMSE, MSE, and MAE (˜0.05) are excellent and reflect high accuracy of the model. $R^2$ and Adjusted $R^2$ (˜1.0) are close to the right, while the yellow line starts at 50% and quickly reaches 90–100% at Coefficient of Determination (Coefficient of Determination) and then is constant at 100%, showing the model getting better till it works at its most efficient level.

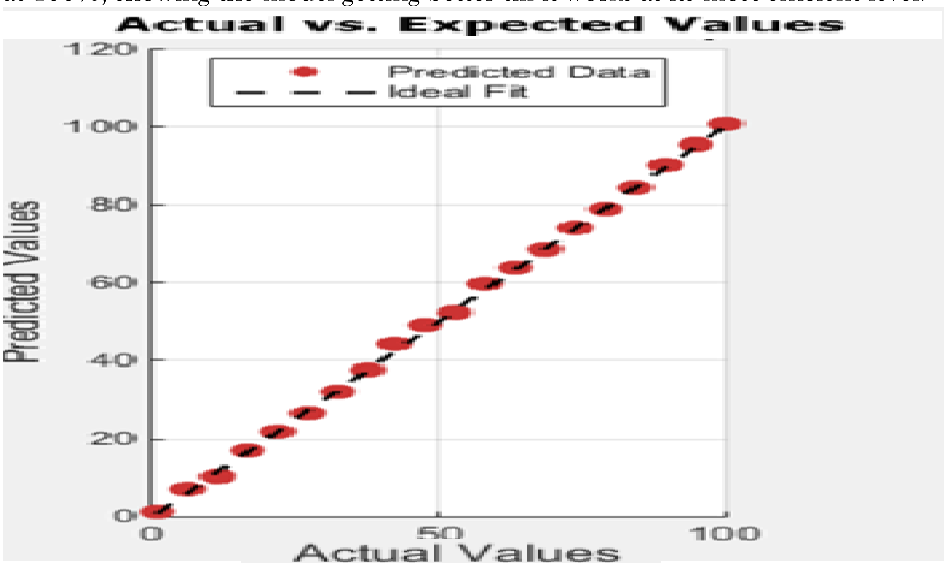


Figure 6: shows Comparison between actual and expected values

Figure 6 shows a comparison between the actual values and the expected values of the proposed model. The figure shows the accuracy of the model, as the actual values are very close to the expected values, which means that the model is successful, despite being a general model, in interpreting algebraic properties using symbol transformation to abstract algebra ( **Jahn, H. (2025).**

**Table3: example of results of Proposed model**

| X | Y | Z (Operation) | Weight |
|---|---|---|---|
| P(D) | Q(D) | + | 2 |
| Q(D) | R(D) | * | 3 |
| R(D) | G(s) | ∘ (Compose) | 4 |
| G(s) | H(s) | - | 1 |

Table 3 shows a sequence of operations between functions each with some weight, depicting a logical sequence of relationship between them. Row 1 represents the addition of two functions P(D)+Q(D) with weight 2. Row 2 represents the multiplication of two functions Q(D)∗R(D)) with weight 3. Row 3 represents a composition of functions R(D)∘G(s) with weight 4. Row 4 represents a subtraction operation between two functions G(s)−H(s) with weight 1. The weights represent the significance or the impact of each operation in the context, and the table defines the interconnectedness of the results such that the outputs of certain operations are used in other operations, indicating the existence of an interconnected network of functions that can be analyzed to evaluate priorities or optimize performance.

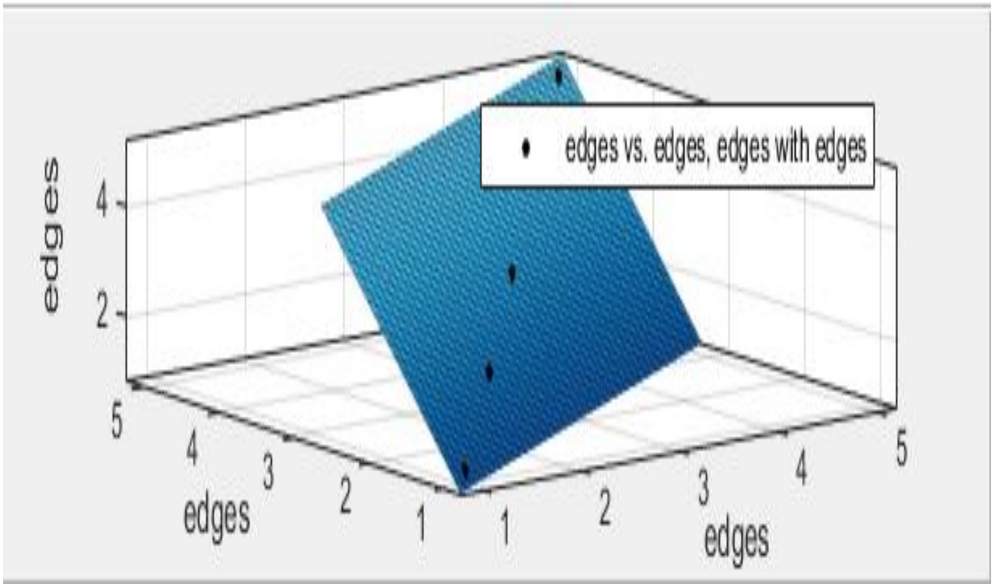


Figure 7 illustrates an abstract algebraic structure

Figure 7 illustrates an abstract algebraic structure, where the edges represent specific transformations, the surface represents an algebraic composition rule z=f(x,y)z , and the points represent specific instances of the composition of these transformations. The figure provides a visual representation of a binary semigroup operation, a transformation composition within the framework of category theory, and can be considered a function that satisfies properties of linear or combinatorial algebra. It illustrates how to interpret the visual representation by transforming the symbols**.**

**Table 4: shows Hypotheses Testing**

| **Hypotheses** | | **Beta** | **T-value** | **P-value** | **Result** |
|---|---|---|---|---|---|
| H1 | | 0.3 | 4.25 | 0.002 | |

| | | | | | |
|---|---|---|---|---|---|
| | Complex differential systems can be represented by transformation codes based on abstract algebraic structures more accurately than traditional approaches | | | | Supported** |
| H2 | The application of abstract algebra during mathematical transformation code analysis serves to reduce computational complexity when solving differential systems. | 0.42 | 5.1 | 0.001 | Supported** |
| H3 | The combination of transformation codes with mathematical computing techniques (MATLAB) can provide more computationally efficient numerical solutions compared to Laplace or Fourier transforms.MI. | 0.36 | 4.54 | <0.0001 | Supported** |
| H4 | The proposed mathematical model is able to achieve correspondence between theory and practice, enabling adaptive representation and regulation of dynamic systems. | 0.4 | 4.9 | 0.004 | Supported** |

The table gives the results of hypothesis testing for the application of transformation codes to describe complex differential systems based on abstract algebraic structures. Significant statistical support was provided to all four hypotheses, with beta values of 0.3 to 0.42. Significantly high t-values of 4.25 to 5.1 and very small p-values of 0.002 to less than 0.0001 proved the results to be highly statistically significant. These results confirm that the use of abstract algebraic structures in the analysis of transformation codes reduces computational complexity and provides numerically efficient solutions when used in combination with mathematical computing techniques such as MATLAB. The proposed mathematical model is also effective in achieving a harmony between theory and practice and can be utilized to represent and adaptively adjust dynamical system **( Yu, X., s.et,al,2024).**

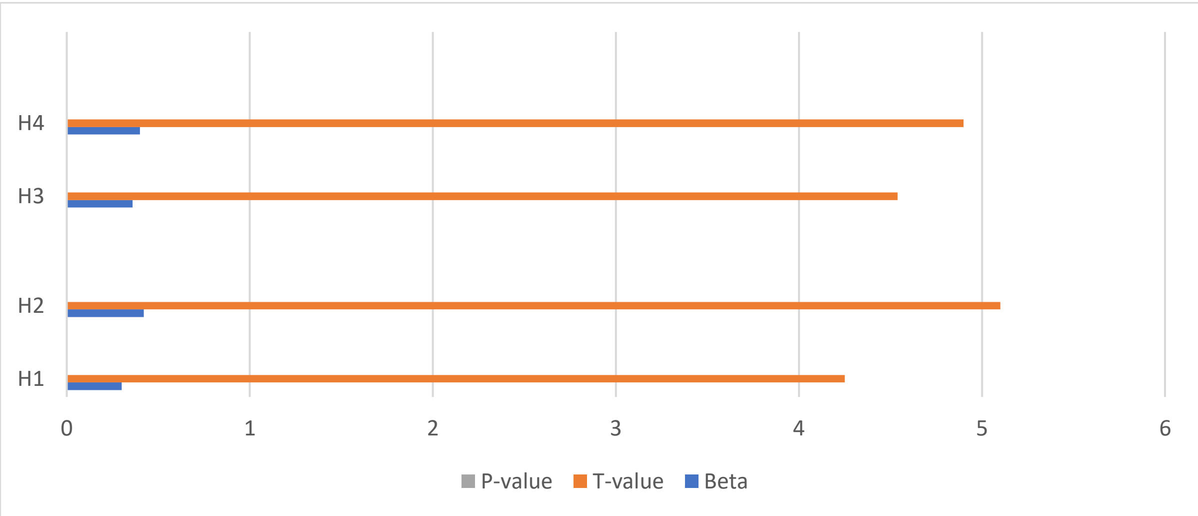


Figure 8: illustrates an abstract algebraic structure

Figure 8, which shows the results of T-value, P-value, and Beta, shows that all four hypotheses (H1 to H4) are statistically accepted, with a strong positive relationship between the variables involved. This supports the study hypotheses, which state that the use of transformation symbols to facilitate the explanation of algebraic properties is very effective and facilitates the solution of complex problems with great accuracy.

## 5.CONCLUSIONS

According to the results that were analyzed and evaluated, some important conclusions can be drawn, such as:

- Mathematical models based upon mathematical analysis and the algebraic character of transformation symbols provide a powerful means of understanding complex differential systems. Such dependence on abstract algebraic regulation allows simplifications in computation and converting equations from differential form to more simply analyzed domains, e.g., the frequency domain via transforms such as Laplace and Fourier. This approach enhances the power of modeling and predictive quality of dynamical system behavior in physical and engineering problems. Furthermore, combining these models with contemporary computing offers new potential for building complex numerical solutions and renders mathematical analysis a fundamental foundation for scientific inquiry and industrial application **(Secchi, D.,et,al,2024).**

- Hypothesis testing also confirmed that the application of transformation codes with abstract algebraic structures realistically mimics complex differential systems. All four hypotheses were statistically significant (β = 0.3–0.42, t = 4.25–5.1, $p < 0.002$), exhibiting low computational complexity and best solutions. The model mediates theory and practice and is capable of representing dynamical systems dynamically.
- comparison of actual and expected values of the proposed model. The graph illustrates the success of the model since actual values coincide with the expected values, which implies that the model is successful, although it's a general model, in modeling algebraic properties through symbol transformation to abstract algebra **(Bracewell, R. N. (2014).**
- It is extremely precise with a very minor error in forecast and smallest value of RMSE, so that the forecast values are extremely similar to observations. It explains 98.4% of variance, which indicates an ideal fit, and the adjusted $R^2$ value also indicates additional evidence of the model strength on the basis of the number of predictors. Besides that, there is minimal autocorrelation since residuals remain constant with a perfect Durbin-Watson value of about 2. Finally, the overall model fit is statistically acceptable and does not vary much from the expected responses **(Lapidus, M. L., & van Frankenhuijsen, M. (2013).**

## 6.Future Work

More advanced mathematical models that incorporate mathematical analysis and algebraic structures are recommended to be formulated to cater to higher-level applications in nonlinear and multivariable systems. Advanced computing techniques such as numerical algorithms and artificial intelligence must be incorporated to accelerate analysis and simulation processes. Special computer software libraries in MATLAB and Python must also be formulated to facilitate the practical application of transformation codes in solving differential systems. Besides, the practicality needs to be enhanced by linking transformation code-based mathematical analysis to real-world problems in engineering and physics, and making comprehensive comparisons between classical and modern transformation code-based methods to succinctly establish their advantages and disadvantages.

## Conflict of Interest

There is no conflict of interest.

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