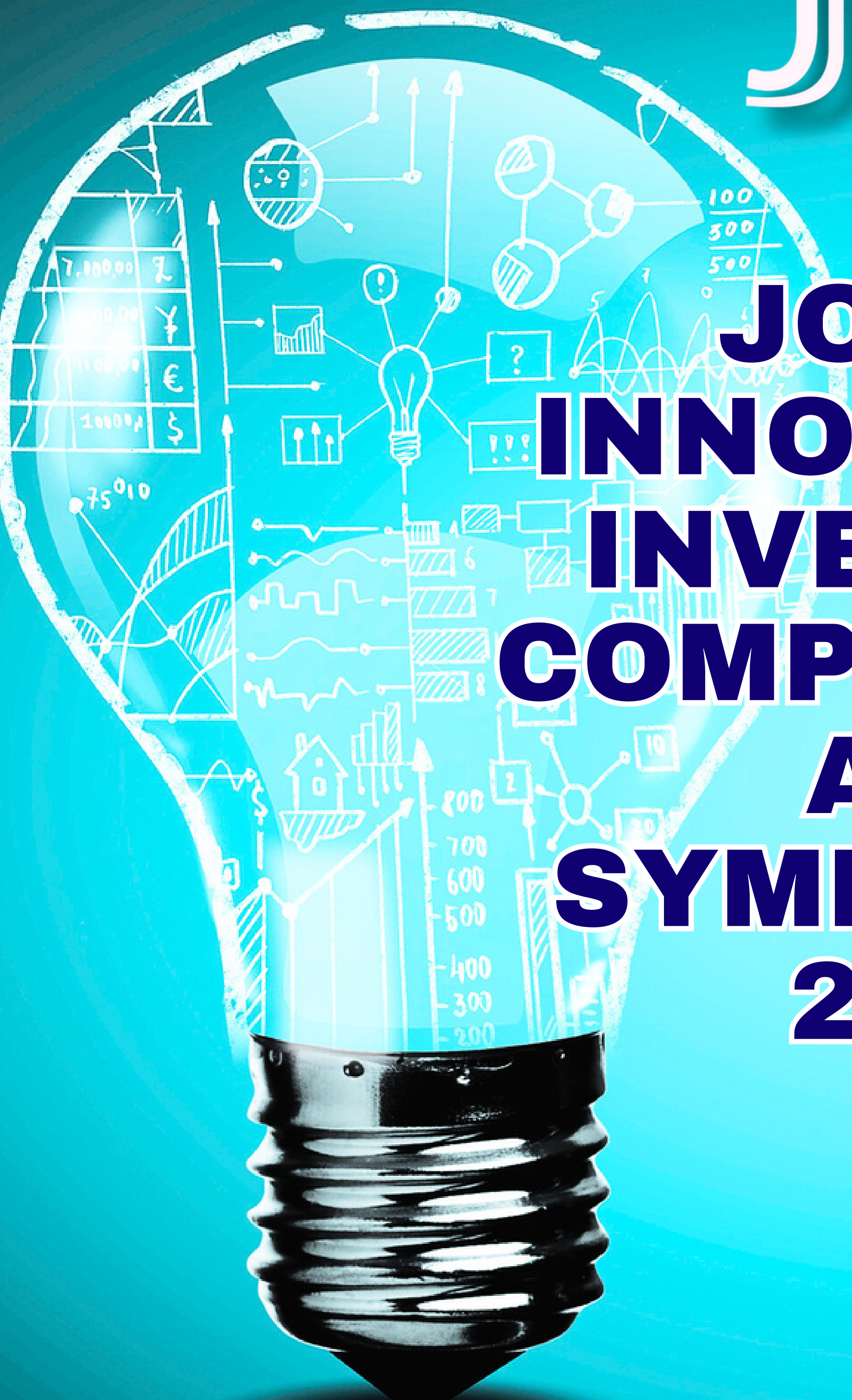
UNIVERSITI TEKNOLOGI MARA

2023 JIICaS

JOHOR INNOVATION INVENTION COMPETITION AND SYMPOSIUM 2023



" Innovation Inspires a Society to be Critical and Creative"

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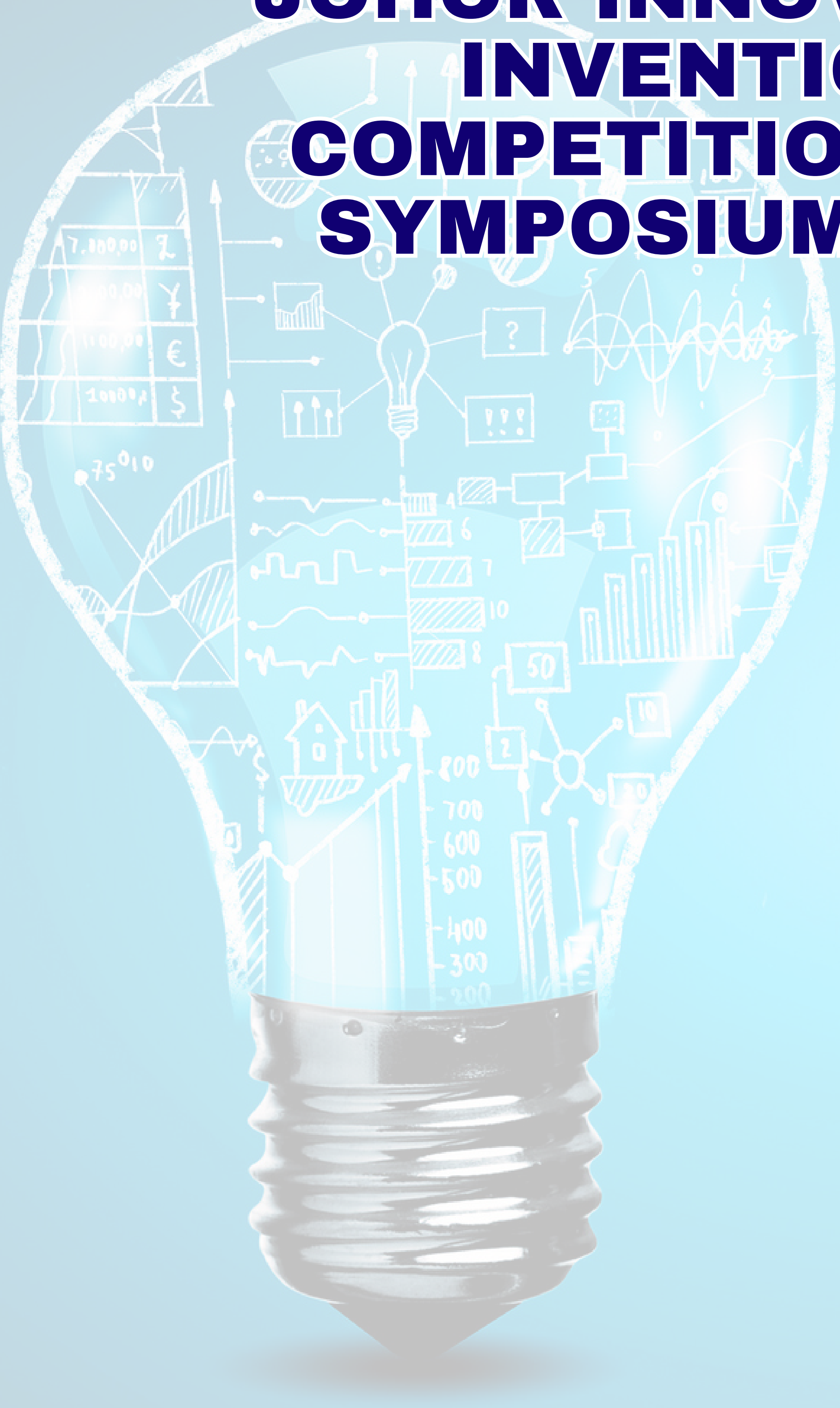

JOHOR INNOVATION INVENTION COMPETITION AND SYMPOSIUM 2023

" Innovation Inspires a Society to be Critical and Creative"

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Preface

In the name of Allah, the Almighty who gives us the enlightenment, the truth, the knowledge and with regards to Prophet Muhammad (peace be upon him) for guiding us to the straight path. We thank to Allah for giving us guidance and strength to write this e-book.

This e-book compiles the extended abstracts that submitted to Johor Innovation Invention Competition and Symposium 2023 (JIICaS2023), where JIICaS2023 is a virtual platform for all creative minds to share and present their invention and innovation. The extended abstracts are divided into two categories, which are Category A (Higher Educational Student/ Any Recognized Institutional Students in Malaysia) and Category B (Primary/ Secondary School Students / Special Education School Students in Johor). Each abstract gives a brief background on the innovation or project.

We hope that this e-book will help the readers to get to know the innovation done by the students from both categories and get some ideas to develop future innovation products.

A084

ODEcal: Ordinary Differential Equation calculator by using MATLAB-GUI

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ABSTRACT

The ODEcal is an acronym for the Ordinary Differential Equations calculator. It is a standalone application developed using MATLAB App Designer to solve initial value problems of Differential Equations (ODEs) numerically. Initial value problems (IVPs) of ODEs are ubiquitous in science and engineering, as they model the behaviour of various phenomena over time. Solving IVPs of ODEs analytically can be challenging or impossible, especially for nonlinear or high-order systems. Therefore, numerical methods are often employed to approximate the solutions using discrete steps. This study creates an ODEcal for solving IVPs of ODEs, which is an application that implement various numerical algorithms and provide graphical and interactive features to help users explore and visualize the solutions. The interface of ODEcal in this study contains several methods comprising Euler, modified Euler, Runge Kutta of order four, and some MATLAB built-in function of ode113, ode45, ode23t, ode23s, ode15s, ode23tb and ode23.

Keywords: Ordinary differential equation, Euler method, ODE calculator, MATLAB-GUI

1.0 INTRODUCTION

Numerical methods play a pivotal role in the realm of science and engineering by providing effective solutions to complex mathematical problems, particularly when it comes to solving ordinary differential equations (ODEs). Ordinary differential equations are mathematical models that describe the behavior of dynamic systems, from the motion of celestial bodies to the flow of fluids and the behavior of electrical circuits. These equations are prevalent in various scientific disciplines, and their solutions offer valuable insights into the behavior of physical phenomena.

However, ODEs often resist closed-form analytical solutions, especially for intricate, nonlinear systems. When ODE problems with complex geometries is not possible to be solved, numerical methods is the alternative method find the approximate answer (Villegas et al., 2023). As a result, numerical methods emerge as indispensable tools, offering an innovative approach to approximating solutions when traditional analytical methods fall short. This is particularly essential when dealing with real-world problems where precision, accuracy, and efficiency is paramount.

While analytical solutions exist for some ODEs, many real-world problems are too complex to be cracked open by traditional pen-and-paper methods. Previous research on solving ODE mostly are developed using a high-level programming language such as FORTRAN, C++, PASCAL or BASIC. This require good programming skill in writing a program from first principles and it is not an easy task. This is where MATLAB steps in, offering a versatile and powerful platform for numerically solving ODE problems with low cost.

2.0 OBJECTIVES

The objectives for this project are as follows:

1. To develop a standalone application in solving initial value problems of ordinary differential equations by using MATLAB-GUI.
2. To provide graphical and interactive features to help users explore and visualize the solutions.

3.0 DESCRIPTION OF INNOVATION/METHODOLOGY

The ODEcal is an acronym for the Ordinary Differential Equation calculator. It is a standalone application developed using MATLAB App Designer to numerically solve the initial value problem (IVP) of first order differential equation (ODE). MATLAB apps designer is a tool to create GUIs for the MATLAB applications and have a packaging and sharing option that enable to export the app as a standalone executable or a web app. The interface of ODEcal contains ten different methods which are Euler (Runge-Kutta order 1), Heun (Runge-Kutta order 2), Runge Kutta order 4, programmed together with MATLAB built-in functions named ode113, ode45, ode23, ode23t, ode23tb, ode23s, ode15s. Figure 1 below shows the complete interface for ODEcal.

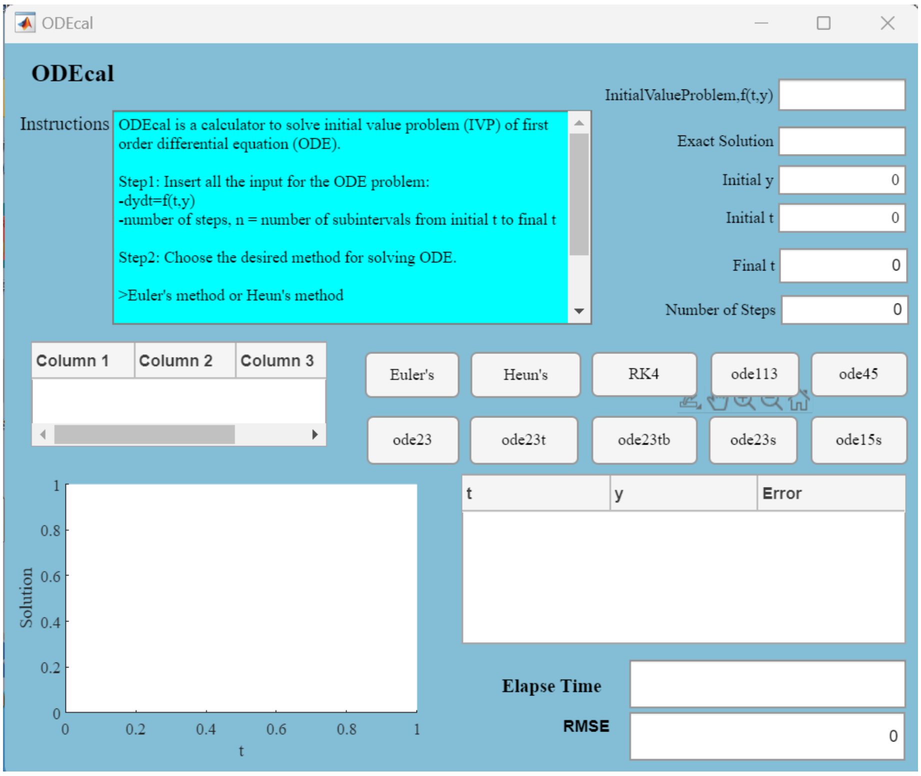

Figure 1: ODEcal interface

In order to use ODEcal apps, it is necessary to adhere to the following procedural instructions (as briefly provided in the ODEcal interface):

iv. Input the IVP of ODE function , the exact solution and other necessary parameters including the initial independent and dependent variables, the final value of independent variable, and the number of steps.

v. Select one of the available methods, such as Euler (Runge-Kutta order 1), Heun (Runge-Kutta order 2), Runge Kutta order 4, programmed together with MATLAB built-in functions named ode113, ode45, ode23, ode23t, ode23tb, ode23s, ode15s.

vi. The results can be observed in a graph comparing the exact and approximated solution together with a tabular format, displaying the independent value, t, dependent value, y and their corresponding error. Additionally, the calculation time and the root mean square error (RMSE) value can be observed.

As a simulation, we will solve $\frac{dy}{dt} = f(t,y) = e^{2t} - 2y$ with exact solution $y = e^{2t} + \frac{11}{4}e^{-2t}$, in the interval [0,1] with initial value y(0)=3. The method selected are Euler (15 number of steps) and ode113 where example of results as shown in Figure 2 and 3, respectively.

exp(2*x)/4+(11/4)*exp(-2*x)

exp(2*t)-2*y

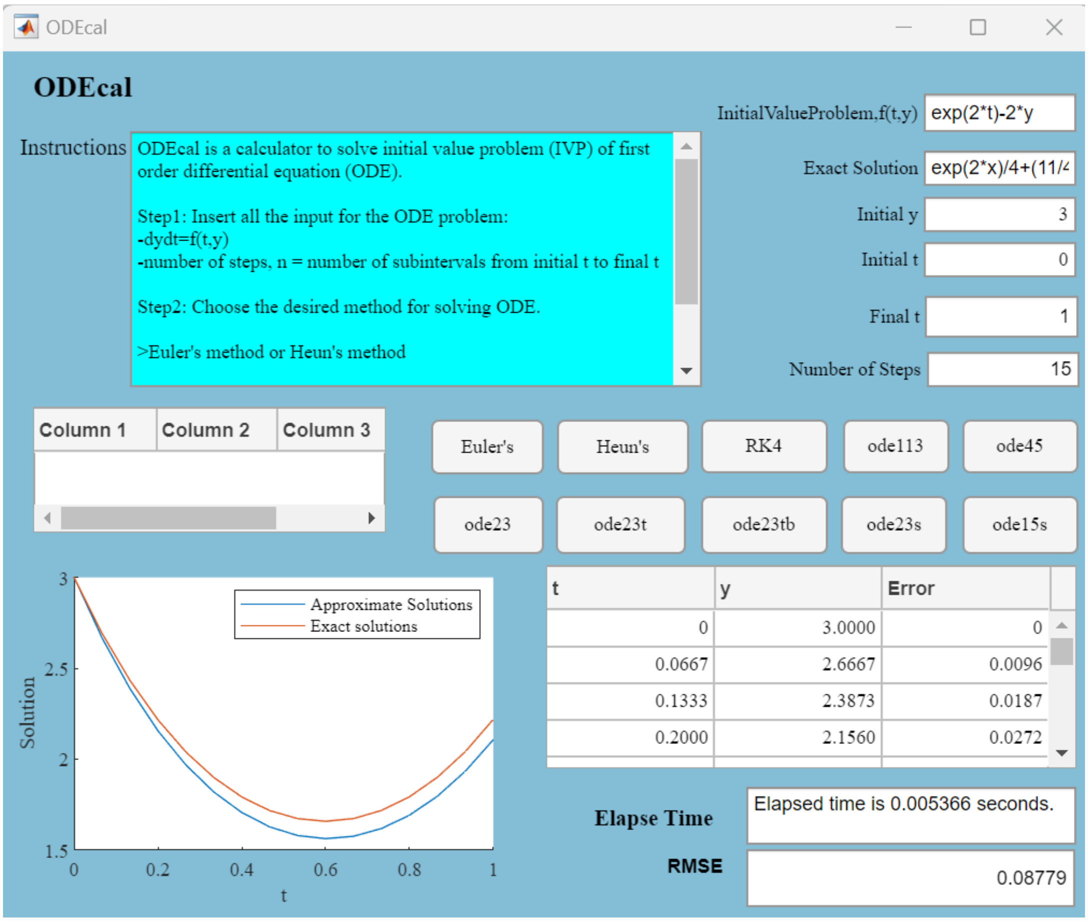

Figure 2: Example of results display using Euler method

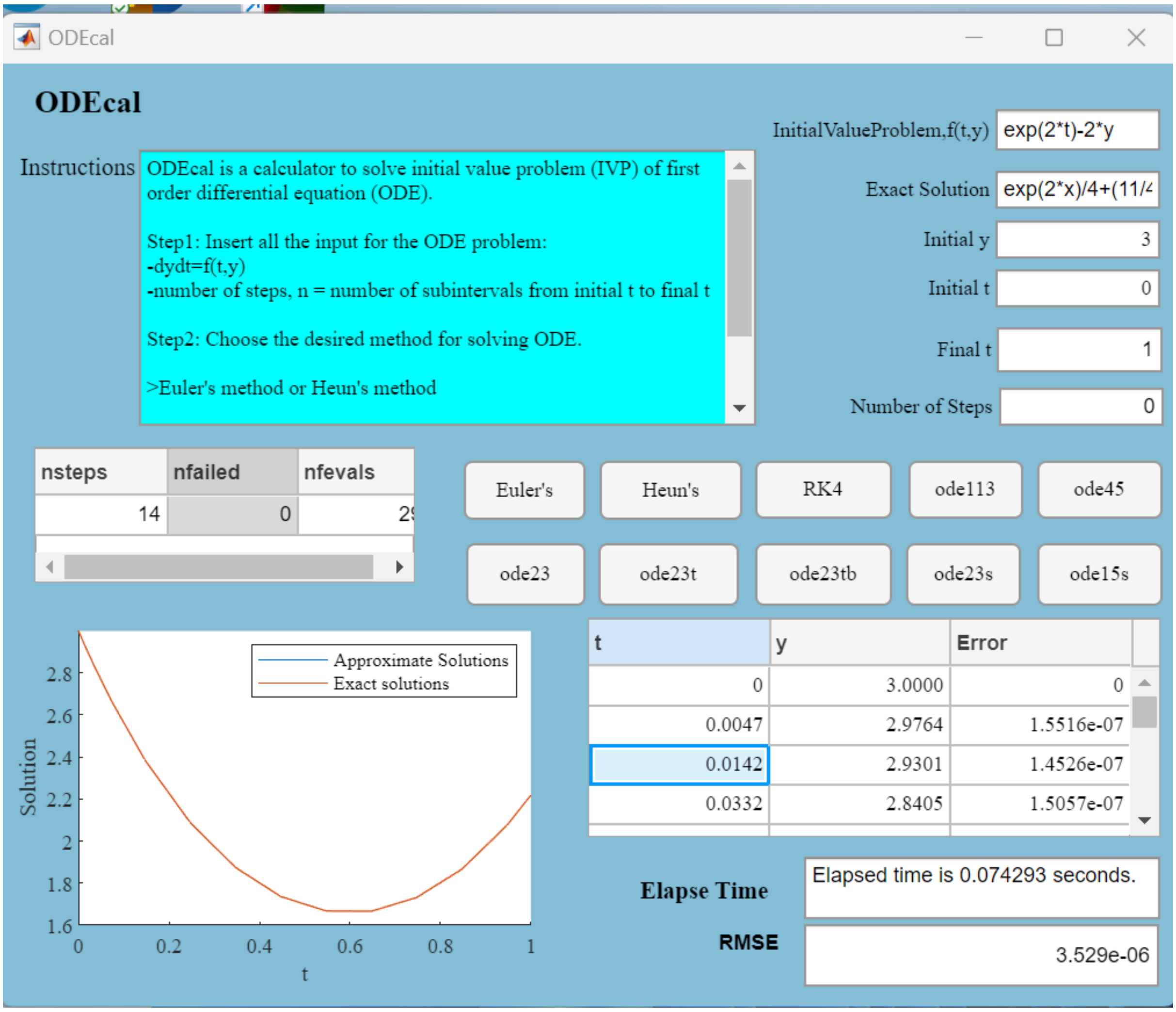

Figure 3: Example of results display using ode113 method

Table 1: Sample of results by using ODEcal

Method	Time (s)	RMSE
Euler	0.005366	0.08779
Heun	0.004406	1.16100
RK4	0.005555	4.695e-06
Ode113	0.074293	3.529e-06
Ode45	0.082410	1.418e-07
Ode23	0.021221	0.00044
Ode23t	0.091759	0.00074
Ode23tb	0.032185	0.00071
Ode23s	0.048521	0.003077
Ode15s	0.050959	0.001548

ODEcal offers various methods to solve ordinary differential equations. Depending on the problem, some methods may perform better than others in terms of accuracy and speed. Table 1 shows the results of applying different methods to a sample problem, using the root mean square error (RMSE) and the computation time as the evaluation criteria.

4.0 ADVANTAGE/IMPACT/RESULTS/NOVELTY

The best method for this problem is ode45, which has the lowest RMSE. Heun method is the fastest, but it also has the highest RMSE. Hence, the user will be able to select the preferred solution by considering either the RMSE value that approaches zero, or the way that requires the fewest subintervals or calculation time.

MATLAB provides a wide range of numerical methods and solvers to tackle various types of ODEs based on IVPs. Users can select the most suitable solver based on the problem's characteristics, such as stiffness, nonlinearity, or discontinuities. MATLAB's intuitive and interactive environment makes it accessible to users with varying levels of programming expertise. Its scripting language allows for easy coding and experimentation, while the graphical user interface (GUI) simplifies tasks for those less familiar with coding. Users can customize and extend MATLAB's functionality through user-defined functions and scripts. This flexibility allows for the implementation of specialized numerical techniques or the integration of external software and data sources.

MATLAB excels in data visualization, enabling users to create informative plots, animations, and graphs to visualize the behavior of ODE solutions. This feature aids in the interpretation and presentation of results.

5.0 CONCLUSION

ODEcal is an efficient with user-friendly interface solver that help users solve ODE problem numerically whilst reducing human error. ODEcal is a standalone apps developed by using MATLAB that gives user a variety method to solve ODE based on users' preferences such as small value of RMSE, fewest subintervals or calculation time. Hence, ODEcal is an indispensable tool for professionals and students alike for solving ordinary differential equations in diverse scientific and engineering applications.

Acknowledge

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6.0 REFERENCES

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