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CUBE POLYGON: A NEW MODIFIED EULER METHOD TO IMPROVE ELECTRIC CIRCUIT EFFICIENCY

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ABSTRACT

Euler method is a numerical order process for solving problems with the Ordinary Differential Equation (ODE). It is a fast and easy way. While Euler offers a simple procedure for solving ODEs, problems such as complexity, processing time and accuracy have driven others to use more sophisticated methods. Improvements to the Euler method have attracted much attention resulting in numerous modified Euler methods. This paper proposes Cube Polygon, a modified Euler method with improved accuracy and complexity. In order to demonstrate the accuracy and easy implementation of the proposed method, several examples are presented. Cube Polygon's performance was compared to Polygon's scheme and evaluated against exact solutions using SCILAB. Results indicate that not only Cube Polygon has produced solutions that are close to identical solutions for small step sizes, but also for higher step sizes, thus generating more accurate results and decrease complexity. Also known in this paper is the general of the RL circuit due to the ODE problem.

1.0 INTRODUCTION

In order to solve complex problems in the field of engineering technology, various intensive developments in the formation of intact numerical methods are carried out. The numerical method is the method for obtaining the nearest approximation for the solution of various problems that can be described in the form of derivative equations. This research's objective is to propose a one-step method that uses the mean concept to solve the problem of Ohm circuit equations. In practice, the Euler method is used in solving the Ordinary Differential Equation (ODE) problem. Euler's method is the easiest and simple since the solution involves just one step.

Euler's method is the simplest method. This method is well-known for solving the Ordinary Differential Equation (ODE). In 1978, Euler proposed a method for solving the Initial Value Problem (IVP). This Euler method is easy to implement and has a low computing cost [1]. This is because the Euler method is an iterative type. This advantage makes the Euler method the basis of the prototype development of more complex and sophisticated methods. Although Euler's method was able to provide a simple solution, the approximate solution provided was less accurate. This is because the number of errors increases during generation at each step [1]. Thus, the performance of the Euler method is not as good as other methods such as Runge Kutta, Adams-Bashforth, and others.

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Current flow in the circuit using Ohm's law is inversely proportional to the voltage and resistor, *i.e.*, I=V/R. When two circuits are combined, the degree of complexity will increase, and the flow will also increase. Hence, the purpose of the project is to propose a new Modified Euler scheme to be applied to an electric circuit using Ohm's law. [2], in his study, it is stated that the equation of the circuit using the Ordinary Differential Equation (ODE) is very easy to analyse. The electric circuit depicted using ODE is composed of time (capacitors and inductors) that depend on the linearity (resistor, diode, and transistor). The Ohm and Kirchoff laws are part of the electrical circuit that can be solved with PTB. [3], shows that Euler's method can provide energy saving on the use of electrical equipment using Ohm's law. However, due to the large discrete points in settlement domains will be resulted, the accuracy is not appropriate. Therefore, the proposed new Modified Euler scheme will be developed to solve the problem of circuit equations by reducing complexity levels and improving accuracy.

2.0 PROPOSED METHOD

By using average concept, this paper aims to develop a new algorithm with better accuracy when compared to exact solution. The new algorithm proposed in this paper naming as Cube Polygon. The idea to improve Euler is by improving another algorithm proposed by Zulzamri [4] and Nurhafizah [5-6]. Author in [4] used average of arithmetic mean for two points at coordinate $\mathrm{y} = [\mathrm{f}(\mathrm{xn}, \mathrm{yn}) + \mathrm{f}(\mathrm{xn} + 1, \mathrm{yn} + 1)]/2$, the equation is referring to Polygon. It shows improvement in accuracy and speed compared to Euler Method. Researcher in [5] used the concept of [4] but choosing Harmonic mean and Contraharmonic to mean in the equation.

Therefore, this paper suggests a modified Euler method using the concept of the Cube mean. The method was developed by extracting the formula Polygon (P) in [4] and using the mean Cube in the equation. The proposed algorithm is contrasted with the exact solution between modified Euler known as Polygon. Three different step sizes, h 0.1, 0.01 and 0.001 is comparing to indicate the accuracy of the proposed method. The algorithm used Cube Mean in Polygon. Polygon (P) is a well-known Euler method improvement technique. The algorithm was based on the Euler methods used in [7] and [8]. Cube means within two coordinate points of function were used to improve the methods. Eqn. (1) is a basic formula of the Euler method.

$$y_{n+1} = y_n + \Delta t f(x_{0,} y_0) \tag{1}$$

Using the average principle, Eqn. (2) by [1] was updated.

$$y_{n+1} = y_n + hf\left(\frac{x_n + (x_n + h)}{2}\right),\left(\frac{y_n + (y_n + f(x_{n,} y_n)}{2}\right) \tag{2}$$

The proposed mean in Cube is written as Eqn. (3) for the two midpoints.

$$y_{n+1} = y_n + hf(\sqrt[3]{\frac{(x_n)^3 + (x_n + h)^3}{2}}, \sqrt[3]{\frac{(y_n)^3 + (y_n + hf(x_n, y_n))^3}{2}}). \tag{3}$$

Changes to the feature slope at predicted midpoints would improve Euler's stability and accuracy.

3.0 RESEARCH METHOD

In order to ensure the research objective is achieved, a research methodology that serves as a guide to ensure research will be done smoothly as per plan. In this research, the one-step method in solving the complexity of the RL circuit equation will be discussed.

The first phase is the development of the proposed scheme. This phase is produced after researching the idea of pre-research from a previous study of Euler's Method, Modified Euler, and the concept of the mean. In this phase, the authors developed a new scheme by combining Euler (R) and mean (T) methods. The original Euler method with a general formula is chosen as the basis for developing a proposed method. Cube mean was selected in developing this proposed method. The general formula for the Cube

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means for the two numbers resulted in a new Modified Euler scheme. Fig. 1 shows how the proposed method is developed.

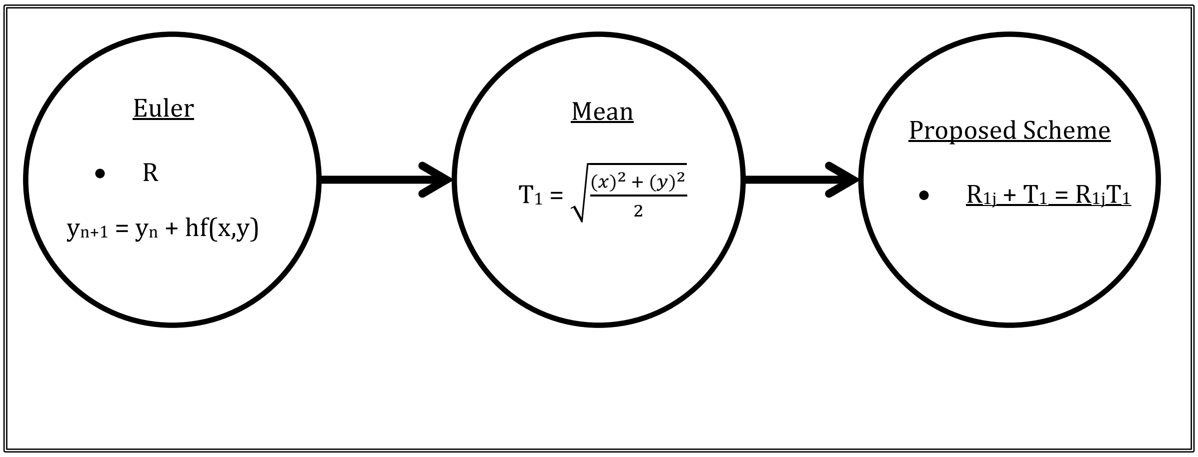

Figure 1. Proposed method

The second phase focuses on the design and development of the new Modified Euler scheme. In this phase, the new Modified Eulers scheme is compared to the complexities obtained from previous studies. Comparisons are concentrated among the new Modified Euler scheme towards existing and stable Modified Euler methods. Existing and stable Modified Euler methods selected are Polygon. This new Modified Eulers scheme will convert to the program code first. The program code to be used is the programming language of Scilab 6.0. The next phase is an algorithm testing phase. This phase will test the complexity of the new Modified Euler scheme. Three ODE numerical tests will be tested using SCILAB Programming. Then, the three ODE will be tested to the effectiveness of the new Modified Euler scheme for three electric equilibrium experiments on the RL circuit. The result of this phase is the result of the complexity of the proposed method.

The last phase will focus on analysis, and discussion will be conducted in this study. In this phase, all the results of the test involving presentation methods in particular complexity will be recorded comparable. The comparison is based on the proposed method with the Polygon method. The analysis was also made on the capabilities of the new Modified Euler scheme in solving problems in the RL circuit equation. The results of the fifth phase testing will be analysed and discussed, especially in the complexity stage, after comparisons are made. The ability of the new Modified Euler scheme to solve the electrical equation of the RL circuit to prove the numerical method can solve the problem of electrical engineering.

4.0 RESULT AND ANALYSIS

Results are recorded from three first order ODEs. Testing Cube Polygon with three linear ODE sets with three various step sizes, *h* 0.1, 0.01 and 0.001 obtained the following results as in Table 2. Using the minimum and maximum error for the entire cycle, these sets were tested for accuracy. Table 1 shows the exact ODE solutions.

Table 1. First Order ODEs Problem [9]

Problem	Exact Solution	Initial Values	Interval of Integration
$y'=-0.5y$	$e^{(-0.5x)}$	$y(0)=0$	$0 \le x \le 20$
$y'=-30y$	$e^{(-x)}$	$y(0)=1$	$0 \le x \le 20$
$y'=-10y$	$e^{(-10x)}$	$y(0)=1$	$0 \le x \le 20$

Table 2 illustrates the comparison results between Polygon (P) and Cube Polygon (CP) methods. Relative error based on [10] was calculated as:

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Error = $[Ex - Ev]$, *Ex* = Exact value and *Ev*=Euler's modified value

Table 2. Maximum Errors in Different Step Size *h*

Method	Polygon			Cube Polygon		
Step Size (h)	0.001	0.01	0.1	0.001	0.01	0.1
Problem 1	0.080710	0.080274	0.07580	0	0.000500	0.005500
Problem 2	0.238575	0.237891	0.230857	0	0	0.000300
Problem 3	1.17E+34	1.68E+29	09.54E+13	0	0.000300	0.029000

Using maximum error, the first-order ODE approach is compared with the exact solution. Table 2 shows that the proposed Cube Polygon (CP) method has produced a better accuracy result at higher and smaller step sizes compared to Polygon (P). Problem 1 showed that the results of the CP method with a maximum error of 0.075800 and 0.005500 respectively were better than P at h=0.1. For step size, *h*=0.01 showed that CP scored 0.000500 compared to P at 0.080274. For all problems CP scored 0 compared to P 0.080710.

Problem 2 demonstrated that the maximum error for CP is 0.000300 and a P method is 0.230857 *h*=0.1. For *h*=0.01 and *h*=0.001 CP scored 0 and P scored 0.237891 and 0.238575 respectively. Problem 3 demonstrated that the equation is not suitable to solve P method which it scores at 09.54E+13, 1.68E+29 and 1.17E+34 for *h*= 0.1, 0.01 and 0.001. CP demonstrate a better solution which it scores are 0.029000, 0.000300 and 0 for *h* = 0.001, 0.01 and 0.1. It can be summarized that in solving ODEs at a higher step size, the proposed CP method provides a more accurate result than P. Thus, it can reduce the complexity and give more efficiency in applying in electric circuit.

4.1 Application of Proposed Method

A resistor–inductor circuit (RL circuit) is an electric circuit consisting of resistors and inductors powered by a voltage or current source. Composed of one resistor and one inductor, a first-order RL circuit is the simplest type of RL circuit. Comparing the RL circuit with Euler Method and Cube Polygon will show the efficiency of Cube Polygon in applying in the RL circuit.

RL circuit with R=12Ω, I=4H, and R=60v resulted in 4.15965A current in the circuit for half a second [10]. Eqn. (4) shows the Euler Method with the value given.

$$I' = F(t,I) = 15-3I \qquad (4)$$
$$I_0 = I(t_0) = I(0) = 0$$

Eqn. (5) shows I1 with h = 0.1.

$$\begin{aligned} I_1 &= I_0 + hF(t_0,I_0) \qquad (5)\\ I_1 &= 0 + (0.1)[15-3(0)]\\ &= 0 + 1.5\\ &= 1.5 \end{aligned}$$

Thus, I = 1.5A for 0.1 seconds. For the result for 0.5 seconds, the result will be as the following Eqn. (6).

$$\begin{aligned} I_5 &= I_4 + hF(t_4,I_4) \qquad (6)\\ I_5 &= 3.7995 + (0.1)[15-3(3.7995)]\\ &= 3.7995 + 0.3605\\ &= 4.15965 \end{aligned}$$

Eqn. (6) demonstrates the solution for 0.5 seconds, with the current use is 4.15965A. Cube Polygon has been applying Eqn. (4) into the Cube Polygon Eqn. (7) with t=0.1 second.

$$I_1 = I_0 + hF\left(\sqrt[3]{\frac{(t_0)^3+(t_0+h)^3}{2}}\right),\left(\sqrt[3]{\frac{(I_0)^3+(I_0+hf(t_0,I_0))^3}{2}}\right) \qquad (7)$$

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$$= 0+0.1\left(\sqrt[3]{\frac{(15-3(0))^3+(12+0.1(12))^3}{2}}\right)$$

$$= 1.26285$$

Thus, I = 1.26825A for 0.1 seconds compared to Euler Method 1.5A current use. With the smaller value at 0.1 seconds, it will contribute to the lower current value at 0.5 seconds as 4.035354A. The application in the RL circuit demonstrates that using Polygon Cube in solving the RL circuit equation contributes to the efficiency of current use for an electric circuit. Here, we can assume that Polygon Cube contributes to energy efficiency.

The results of the proposed methodology will be implemented in studies related to energy security issues. The rapid development and population growth rate in Malaysia attracted researchers to study the supply of electricity in Malaysia. The main challenge is to foster the future of energy resources as well as energy storage through green technology. An example of a method towards green technology is the efficiency of electricity consumption. In this action plan, the energy sector targets energy efficiency in 2025 by a 10% reduction in electricity consumption and 15% in 2030.

5.0 CONCLUSION

This paper proposed Cube Polygon, a new method of finding this study using modified Euler. Similar to the Polygon system, the viability of the proposed algorithm was testing using SCILAB. The Cube Polygon then compared the exact solution to the Polygon scheme. Usually, using a small step size, the ordinary Euler method almost gives the solution to the exact solution. In this research, however, it has been shown that Cube Polygon offers solutions close to exact solutions at small step size and higher step size as well. Higher accuracy will be provided by the advantages of using small step size. A larger step size would therefore reduce complexity and time for processing. In conclude, Cube Polygon can be used to solve ODE problems as an alternative algorithm. For future work, the results of the proposed methodology will be implemented in studies related to energy security issues. The rapid development and population growth rate in Malaysia attracted researchers to study the supply of electricity in Malaysia.

A study conducted in Brazil by [11] found Brazil's electricity supply system showing a lack of resources. Hence, various efforts have been made by the Government to ensure that the energy sector, through the diversification of resources, can be maintained over a long period of time. Among them is the Malaysian Green Technology Master Plan 2017-2030 [12], which devises strategic plans for green technology development by creating low economic and carbon resources. The Master Plan aims to provide an overview of the Government's commitment to managing the development of green technology. To achieve the Green Technology Master Plan of Malaysia 2017-2030, a Cube Polygon is recommended, and the method is tested on the use of electricity in this research to reduce the complexity of current use. Cube Polygon reduces the complexity of the electric circuit. It can save energy on the use of electrical appliances. Hence, the production of electrical appliances that use small energy can help reduce energy consumption. The impact is also helping the community reduce the cost of targets imposed on electricity utilities as well as supporting the government's aspiration in the Malaysian Green Technology Master Plan 2017-2030.

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