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Use of Secant Method and New Iteration Method for Numerical Simulation in Finding Solution

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Abstract: Numerical simulation has become a very important tool in solving complex mathematical problems, especially when analytical solutions cannot be found. In this study, the use of **Secant Method** and **New Iteration Method** as two numerical methods to find the root solutions of non-linear equations are discussed. The Secant Method is used to find the roots of non-linear functions with an iterative approach that does not require explicit derivative calculations, while the New Iteration Method is applied to accelerate the solution convergence with an adaptive update technique. Both methods are applied to the search case of non-linear equations, with the aim of testing their efficiency and accuracy in numerical simulations. The results from the simulation show that both methods can provide fast and accurate solutions in finding the root of the function, although the New Iteration method shows an advantage in terms of more stable convergence on certain problems. This research also discusses the potential applications of these two methods in various scientific and engineering applications, and demonstrates their versatility in handling various types of complex non-linear equations.

Keywords: Secant Method, New Iteration Method, Numerical Simulation, Non-Linear Equations, Convergence.

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A. INTRODUCTION

In various fields of science, such as applied mathematics, physics, and engineering, numerical simulation plays an important role in solving complex problems that are difficult or even impossible to solve analytically (Darajat, 2021). These problems often involve non-linear functions or dynamic systems that require iterative approaches to obtain accurate approximate solutions (Negara et al., 2018). In this context, this report explores the use of a combination of Secant Method and New Iteration Method to find numerical solutions efficiently. Numerical methods are a branch of mathematics that has an important role in solving problems that cannot be solved analytically (Arfinanti, 2018). One of the problems often encountered in numerical methods is finding solutions to non-linear equations(Azmi et al., 2019). There are several methods that can be used to solve non-linear equations, including the Secant Method and the New Iteration Method (Hutagalung, 2017).

The Secant method is an iterative method for finding the roots of a non-linear function f(x), i.e. the values$x$ that satisfy$f(x) = 0$. This method does not require the calculation of the derivative of the function, which makes it very suitable for functions that are complex or do not have explicit derivatives (Wungguli et al., 2022) . By using a straight line approximation connecting two points on the graph of the function, the Secant method can provide a faster solution than closed methods such as bisection, provided that the initial value chosen is close enough to the true root (Datangeji et al., 2019) . Its applications are widely found in finding parameters of mathematical models, calculating boundary conditions, or initial estimates for differential equations.

Secant method is one of the iterative methods used to find the roots of non-linear equations (Yose Amelia et al., 2024). This method has several advantages, including faster convergence compared to the Bisection Method and the Newton-Raphson Method (Wulan et al., 2017). In addition, the Secant Method also does not require the calculation of the derivative of the function, making it more efficient in computational use(Arfinanti, 2018). The New Iteration Method is one of the iterative methods developed to solve non-linear equations (Fenando, 2020). This method has several advantages, including faster convergence compared to the Secant Method and Newton-Raphson Method (Pricillia & Zulfachmi, 2021). However, claims regarding better stability compared to the Secant Method need to be further reviewed, as the existing literature does not consistently support this statement (Sunandar & Indrianto, 2020).

In several studies, Secant Method and New Iteration Method have been used to solve various non-linear problems, such as traffic equilibrium problem (Wungguli et al., 2022), non-linear matrix problem Julianto et al. (2022), and fractional differential problem (Deswita et al., 2022). However, there has been no research that specifically compares the use of Secant Method and New Iteration Method for numerical simulation in finding solutions. Therefore, this study aims to examine the use of Secant Method and New Iteration Method for numerical simulation in finding the solution of non-linear equations. The results of this study are expected to provide useful information for researchers and practitioners in choosing the right method to solve non-linear problems.

B. METHOD

In this study, the researcher made use for numerical simulation in finding the solution of solving non-linear equations using Secant and New Iteration methods. Each method was tested and implemented using Matlab software. This implementation aims to evaluate the performance of both methods in terms of accuracy, convergence speed, and computational efficiency. The explanation related to the two methods used will be discussed in detail in the following section.

1. Secant Method

The secant method is a numerical method for finding the roots of a function$f(x)$, which is the value of$x$ so that$f(x) = 0$. This method is an improvement of the Newton-Raphson iteration method, but does not require the calculation of the derivative$f'(x)$. Instead, it uses the derivative approximation by replacing it with a straight line connecting two points on the graph of the function. The secant method belongs to the category of open methods because it does not require an initial interval like the bisection method. The secant method uses two starting pointsx_0 andx_1 then iteration is performed using the following formula:

$$\boldsymbol{x_{i+1} = x_i - \frac{f(x_i)(x_{i-1} - x_i)}{f(x_{i-1}) - f(x_i)}}$$

Secant Method Procedure:

Specify two starting points,$\boldsymbol{x_{i-1}}$ and$\boldsymbol{x_1}$. Determine the starting point arbitrarily. After that, calculate$\boldsymbol{x_{i+1}}$ using the equation above. In the next iteration, the points taken are$\boldsymbol{x_1}$ and$\boldsymbol{x_2}$ as the starting point to calculate$\boldsymbol{x_3}$. Then$\boldsymbol{x_2}$ and$\boldsymbol{x_3}$ are determined as the starting point to calculate$\boldsymbol{x_4}$. It is done continuously until it reaches a small enough error.

2. New Iteration Method

The new iteration method is a numerical approach used to find solutions of non-linear equations $f(x) = 0$. The method is iteration-based, where the solution is obtained incrementally through a series of calculations approximating the root of the equation sought using iterations expressed in the following form:

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \cdot (1 + \frac{f(x_n + f(x_n)}{f(x_n)})^{-1}$$

Where:

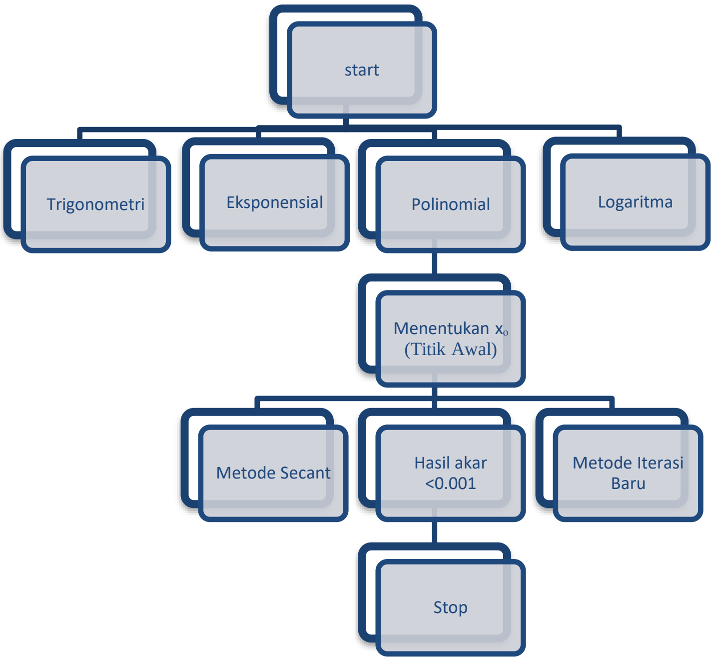
- $f(x_n)$ is the function value at the iteration$n$
- $f'(x_n)$ is the first derivative of the function at the pointx_n
- $f(x_n + f(x_n))$is the evaluation of the function at the point shifted $f(x_n)$
- The expression $(1 + \frac{f(x_n+f(x_n)}{f(x_n)})^{-1}$ serves as a correction factor for the newtonian approximation

Both methods are then used to solve the problem of non-linear equations. The non-linear equations used involve trigonometric, logarithmic, polynomial and exponential non-linear equations. Furthermore, the problems used for the simulation consist of:

a. $f(x) = 2x^2 \sin(3x + 12)$ (trigonometry).
b. $f(x) = 2x^3 + 5x - 12$ (polynomial).
c. $f(x) = 2xe^{-4x} + 12$ (exponential).
d. $f(x) = 2x \log (2^{x+1} + 12)$ (logarithm).

The form of the workflow is shown in the following diagram, which contains the steps of solving non-linear equations using the Secant method and the New Iteration method. The process starts from selecting the type of function, determining the starting pointx_0 , until iteration is carried out until the root is obtained with an error of less than 0.001.

Figure 1. Research flow chart



C. RESULTS AND DISCUSSION

The simulation process is done using Matlab software by running the Secant and New Iteration method algorithms. Furthermore, the results of both methods are compared in determining the roots of Non-Linear equations as follows:

1. Draw graphs of each problem and the starting point taken

a. Trigonometric Function Problem: $f(x) = 2x^2 \sin(3x + 12)$

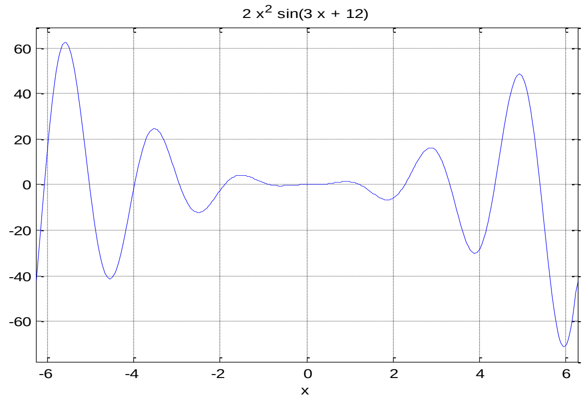


Figure 1. Trigonometric Function Graph

In Figure 1, it can be seen that the roots of the equation $f(x) = 2x^2 \sin(3x + 12)$ are in the interval [-6,6]. In this case, the interval [-5,4] is chosen as the starting point to find the roots of trigonometric equations.

b. Polynomial Function Problem: $f(x) = 2x^3 + 5x - 12$

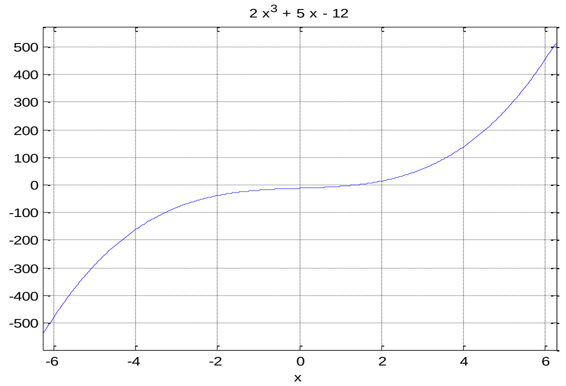


Figure 2. Polynomial Function Graph

In Figure 2, it can be seen that the roots of the equation $f(x) = 2x^3 + 5x - 12$ are in the interval [-6,6]. In this case, the interval [1,2] is chosen as the starting point to find the roots of the polynomial equation.

c. Problem Exponential function: $f(x) = 2xe^{-4x} + 12$

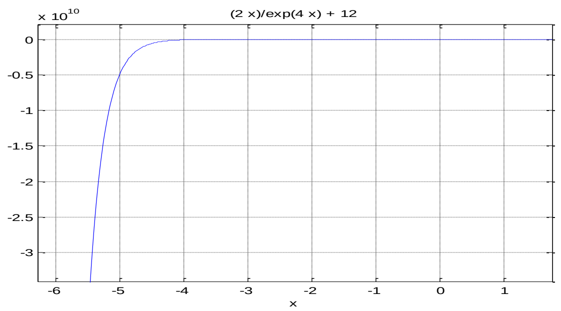


Figure 3. Exponential Function Graph

In Figure 3, it can be seen that the roots of the equation $f(x) = 2xe^{-4x} + 12$ are in the interval [-6,1]. In this case, the interval [-4,-5] is chosen as the starting point to find the root of the exponential equation.

d. Logarithmic Function Problem: $f(x) = 2x \log{(2^{x+1} + 12)}$

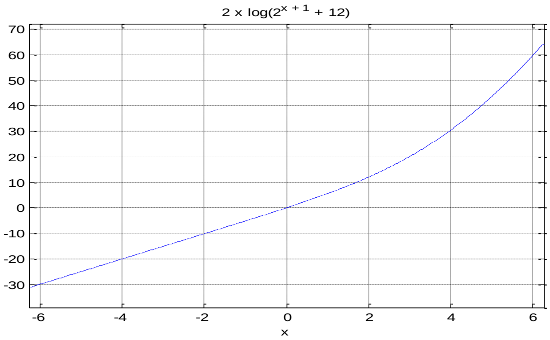


Figure 4. Logarithmic Function Graph

In Figure 4, it can be seen that the root of the equation $f(x) = 2x \log{(2^{x+1} + 12)}$ is in the interval [-6,6]. In this case, the interval [1,2] is chosen as the starting point to find the root of the logarithmic equation.

In the simulation process in matlab with the algorithms of the two methods, namely the Secant method and the New Iteration method, the following results were obtained:

Table 1. Script of Each Method

Method	script

Secant	k=1:imax
	iter=iter+1;
	%Secant formula
	x3=x2-((x2-x1)*feval(f,x2)/(feval(f,x2)-feval(f,x1)));
	error=abs((x3-x1)/x3);
	x1=x3;
	y=feval(f,x1);

New Iteration	k=1:imax
	iter=iter+1;
	%New Iteration Formula
	x2=x1-((feval(f_diff1,x1)+sqrt((feval(f_diff1,x1))^2-2*feval(f,x1)*feval(f_diff2,x1)))/feval(f_diff2,x1));
	error=abs((x2-x1)/x2);
	x1=x2;
	y=feval(f,x1);

Using the script, the researchers then simulated 8 times with the matlab script. Simulations are carried out with the aim of calculating iterations and roots of equations, then the simulation results are obtained in table 2 below.

Table 2. Simulation Results

No.	Case	Methods	Iterations	X	F(x)	Error
1.	$2x^2 \sin(3x + 12)$	Secant	4	1.2360104770	-0.0002082683	0.0001281092
		New Iteration	2	-5.0471975512	-0.0000000006	0.0000282520
2.	$2x^3 + 5x - 2$	Secant	6	1.3702941482	-0.0025100278	0.0003068339
		New Iteration	5	-0.6852242226	0.0000000000	0.0000013219
3.	$2xe^{-4x} + 2$	Secant	100	-2.5486784157	-136400.1094845314	0.0011062165
		New Iteration	100	-1.5794708918	-21.6629960464	0.0016852493
4.	$2xlog(2^{x+1} + 2)$	Secant	100	0.0000000000	0.0000000000	inf
		New Iteration	100	-	-	inf

According to the results of the computation above using the Secant method, for case 1 it is known that the value of x so that f(x) < 0.001 is x = 1.2360104770 with f(x) = -0.0002082683, the value was obtained after computing up to 4 iterations. Case 2 is known that the value of x such that f(x) < 0.001 is x = 1.3702941482 with f(x) =-0.0025100278, the value was obtained after computing up to 6 iterations. Case 3 is known that the value of x such that f(x) < 0.001 is x = -2.5486784157 using f(x) =-136400.1094845314, the value is obtained after computing up to 100 iterations. Case 4 is known that the value of x as a result of f(x) <0.001 means x = 0.0000000000 using f(x) = -0.0000000000, the value was obtained after computing up to 100 iterations.

By using the New Iteration method, for case 1 it is known that the value of x such that f(x) < 0.001 is x = -5.0471975512 with f(x) = -0.0000000006, the value is obtained after computing up to 2 iterations. Case 2 is known that the value of x such that f(x) < 0.001 is x = -0.6852242226 using f(x) = 0.0000000000, the value is obtained after computing up to 5 repetitions. Case 3 is known that the value of x such that f(x) < 0.001 is x = -1.5794708918 with f(x) = -21.6629960464, the value is obtained after computing up to 100 repetitions. Case 4 is known that the value of x such that f(x) < 0.001 is x = - using f(x) = - the value was obtained after computing up to 100 iterations in the New Iteration method.

D. CONCLUSIONS AND SUGGESTIONS

This it shows that for solving the root equation of f(x) =$2x^2 \sin(3x + 12)$ using the Secant method the rate of convergence is slower than the New Iteration method. For solving the root equation of f(x) = $2x^3 + 5x - 12$ using the Secant method the rate of convergence is slower than the New Iteration method. For solving the root equation of f(x) =$2xe^{-4x} + 12$ using Secant method the rate of convergence is the same as the New Iteration method. Then for solving the root equation of f(x) =$2x \log(2^{x+1} + 12)$ using Secant method and New Iteration the rate of convergence is error or does not find the result.

From the four results of solving the equations (trigonometric, polynomial, exponential, and logarithmic), it can be concluded that the fastest rate of convergence in solving equations (trigonometric, polynomial, exponential, and logarithmic) is the New Iteration method. The New Iteration method has faster convergence with fewer iterations, so the best method in solving the roots of non-linear equations is the New Iteration method.

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