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Application of New Literacy and Newton Rapshon Methods in Numerical Solving of Roots of Nonlinear Equations

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Abstract: Solving non-linear equations is crucial in various scientific and engineering fields, especially when analytical solutions are difficult or impossible to obtain. This research compares the Newton-Raphson Method with the New Iterative Method for solving non-linear equations through numerical simulations using MATLAB. The objective is to evaluate both methods based on solution accuracy, convergence speed, and computational efficiency. The study examines four types of non-linear equations: trigonometric, polynomial, exponential, and logarithmic. Both methods are implemented in MATLAB and assessed based on the number of iterations, error values, and the accuracy of the obtained roots. The results indicate that the New Iterative Method is more efficient for solving trigonometric equations, requiring fewer iterations while maintaining comparable accuracy. In contrast, the Newton-Raphson Method performs better on polynomial equations, yielding more accurate results. For exponential and logarithmic equations, neither method proves optimal, with unrealistic or divergent root results and high error values. This highlights that the effectiveness of each method strongly depends on the type of function and the initial guess used. This study emphasizes the importance of selecting appropriate numerical methods and contributes to the practical and academic application of numerical analysis techniques.

Keywords: Newton Rapshon Method, New Iteration Method, Numerical Simulation, Non-Linear Equations.

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A. INTRODUCTION

As we all know that the Non-Linear Equation System is a System of Equations used to calculate the Root of Non-Linear Equations using one variable X, f(x), or generally written with the formula: f(x)=0 (Sunandar & Indrianto, 2020). Nonlinear equations are widely used in engineering and science (Sapari & Bahri, 2019). In some mathematical problems and engineering problems or certain other problems it is not enough to just use a method to get the desired results, we also need to know whether the method does provide an approximate solution, and how good the approximation is, this gave birth to a new study, namely numerical analysis (Ritonga & Suryana, 2019).

Numerical methods are an important approach in solving mathematical problems computationally, and Matlab is one of the software that strongly supports the implementation of this method. Matlab stands for Matrix Laboratory which consists of 5 main components namely Toolbar, Current Folder, Command Windows, and Command (Syaharuddin & Mandailina, 2017). Numerical methods in computing will be very helpful in solving problems that are complicated to solve arithmetically. Numerical methods are used to solve mathematical problems that are difficult to answer using analytical methods (Mara Doli Nasution, Elfrianto Nasution, 2017). Execution in numerical method programming must be based on a clear algorithm so that the syntax can run or does not generate errors. The algorithm

must also be based on the correct concept so that the results can be obtained accurate and valid approximations (Mulyatna & Kusumaningtyas, 2017). In other words, calculations in numerical methods are calculations that are carried out repeatedly to continuously obtain results that play close to the exact settlement value (Hutagalung, 2017).

New literacy is all efforts to gain knowledge and answer the challenges of the times with the competency aspects of data literacy, technology, and human resources/humanism (Kusmiarti & Hamzah, 2019). New literacy includes data literacy, technological literacy, and human literacy. Data literacy is related to the ability to read, analyze, and make thinking conclusions based on the data and information (big data) obtained (Ibda, 2020). Digital literacy is essential for improving critical thinking and problem-solving skills. The ability to understand, evaluate, and use information effectively is an important skill in an era where information is highly accessible (Cynthia & Sihotang, 2023).

While the Newton Raphson Method is a method to find an approximation or approach to the roots of a real function (Syata & Nisa, 2022). The Newton Raphson method is a method to find an approximation of the roots of an equation. This method is implemented in one variable x: f(x) = 0. The process of finding the derivative value takes time. In addition, not all equations are easy to find the derivative. To overcome this difficulty, finding an equation equivalent to the function derivative formula, using the gradient of the line through the points (x0, f(x0)) and (x1, f(x1)) (Batarius et al., 2018).

The Newton-Raphson method in its solution uses the derivatives of the equation and the calculation process involves the rules of matrix algebra to find the deviation values which are then used to obtain the values of the solution to the system of non-linear equations (Nasiha, 2018). This method begins by finding the tangent line of the curve at point . The intersection of the tangent line with the axis will be the new value. This method is repeated until the root of the equation is obtained (Dwi Estuningsih et al., 2019).

The Newton-Raphson method has a major advantage in its quadratic convergence rate, which means that the number of correct digits in the approximation approximately doubles with each iteration, provided that the initial guess is sufficiently close to the true root. However, this method requires the calculation of the derivative of the function, which is not always available or easy to calculate, and convergence is not guaranteed if the initial guess is not close enough to the root or if the function is not well behaved around the root (Gawade et al., 2024). The Newton-Raphson method cannot be used if the first derivative of the function at the initial point value is equal to zero or close to zero. The Newton-Raphson method is known as a quadratically convergent method (Agustini & Gunawan, 2024).

This study aims to examine and compare the application of the New Literacy Method with the Newton-Raphson Method in numerical simulation to solve non-linear equations. Through this research, it is expected to find a clear comparison between the two methods in terms of efficiency, accuracy, and ability to solve non-linear equation problems. The results of this study can provide valuable information for researchers and practitioners in choosing the most appropriate and effective method, both in the context of numerical analysis and in the application of new literacy in technology and education.

B. METHOD

This study applies two numerical computing methods, namely the New Literacy Method and the Newton-Raphson Method, to solve non-linear equations through numerical simulation with Matlab software. The purpose of this research is to evaluate the performance of both methods based on solution accuracy, convergence speed, and computational efficiency. The accuracy of the solution is the main factor, while convergence speed and computational efficiency are also important to determine the effectiveness of the method. This study aims to

compare the two methods and see if the New Literacy Method is more efficient and accurate than the Newton-Raphson Method. An explanation of the algorithm of each method as well as simulation results will be presented in detail in the next section to provide insight into the advantages and disadvantages of each method.

1. New Literacy 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:

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

Where:

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

2. Newton Rapshon Method

The Newton-Raphson method is an iterative method used to find the roots of non-linear equations. The basic principle of this method is to improve the root estimate by using the first derivative information of the function in question. For a function $f(x)$, the root of the equation $f(x) = 0.$ is found using iteration expressed in the following form:

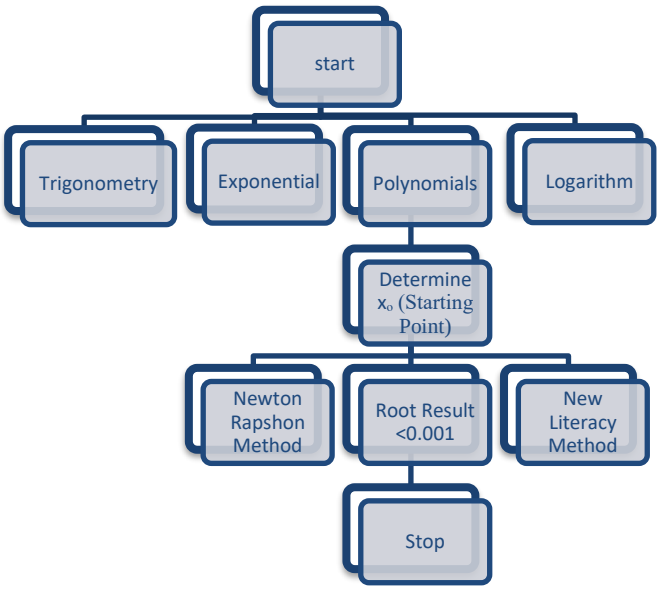
$$\boldsymbol{x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}}$$

Where:

a. x_n is the root estimate value at the n-th iteration,
b. $f(x_n)$ is the function value at x_n,
c. $f'(x_n)$ is the first derivative of the function at x_n,
d. $x_n + 1$ is the estimated value of the root at the next iteration

This iteration process will continue until the difference between two consecutive root estimate values $|x_n + 1 - x_n|$ is smaller than a predetermined tolerance value. The convergence speed of the Newton-Raphson method is highly dependent on the selection of the initial guess x_0 if the initial guess is close enough to the root, the method tends to converge quickly. 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. $f(x) = 2x^2 \sin(3x + 1)$ (trigonometry)
b. $f(x) = 2x^3 + 5x - 1$ (polynomials)
c. $f(x) = 2xe^{-4x} + 1$ (exponential)
d. $f(x) = 2x \log(2^{x+1} + 1)$ (logarithm)

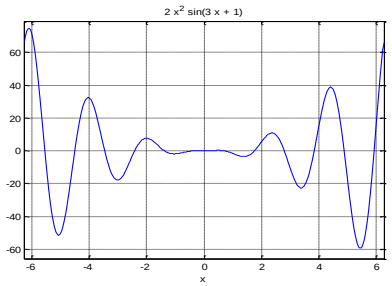


Gambar 1. Research Flow Chart

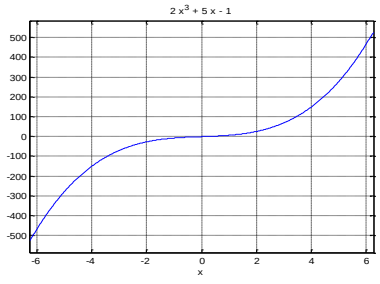
C. RESULTS AND DISCUSSION

Researchers used four non-linear equation problems consisting of polynomial, trigonometric, exponential, and logarithmic equations. According to the steps that have been done is a graph due to each equation. Synchronize Figure 1, Figure 2, Figure 3 and Figure 4 below:

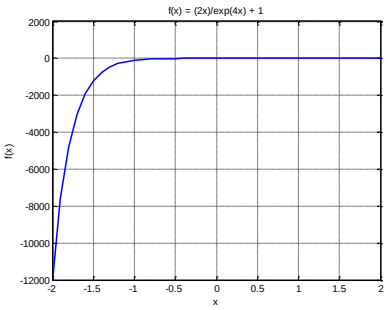
Table 1. Non-Linear Equations Graphs



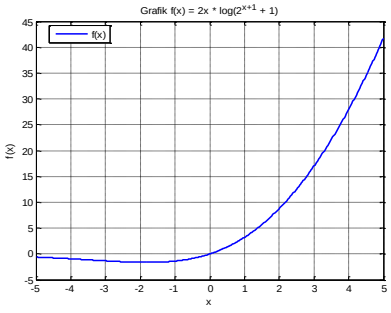
a. Trigonometric Function Graphs



b. Polynomial Function Graph



c. Exponential Function Graph



d. Logarithmic Function Graph

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

roots of the equation. In Figure 2 above, it can be seen that the root of the equation $f(x) = 2x^3 + 5x - 1$ is in the interval [-6,5]. In this case, the starting point $x0 = (1)$ is used as the starting point to find the roots of the polynomial equation. In Figure 3 above, it can be seen that the roots of the equation $f(x) = 2xe^{-4x} + 1$ are in the interval $(-2,2)$. In this case, the interval (-1) is chosen as the starting point to find the roots of the equation. In Figure 4 above, it can be seen that the root of the equation $2x \log(2^{x+1} + 1)$ is in the interval $(-5,5)$. In this case, the interval (1) is chosen as the starting point to find the root of the equation. In the simulation process in matlab with the algorithms of the two methods, namely the Chebyshev method and the Euler method, the following results were obtained. In the simulation process in matlab with the algorithms of the two methods, namely the New Iteration method and Newton Rapshon, the following results were obtained:

Table 2. New Literacy and Newton Rapshon Method Script

Method	Script

New Literacy	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));
	galat=abs((x2-x1)/x2);
	x1=x2;
	y=feval(f,x1);

Newton Rapshon	for k=1:imax
	iter=iter+1;
	x2=x1-(feval(f,x1)/feval(f_diff,x1));
	galat=abs((x2-x1)/x2);
	x1=x2;
	y=feval(f,x1);
	fprintf('%10.0f %6.10f %6.10f %6.10f\n', [iter;x1;y; error])
	if (error < error 1 || (iter>imax)), break, end
	end
	fprintf('The root is = %6.10f\n',x1)

Using the script, the researcher then simulated 8 times with the matlab script. The simulation was carried out with the aim of calculating the iteration and the root of the equation, then obtained the simulation results in table 2 below:

Table 3. Simulation Results

No	Case	Method	Iiteration	x	$f(x)$	Error
1.	$2x^2 \sin(3x + 1)$	Newton Rapshon	6	0.713864218	0.000000000	0.000000000
		New Literacy	5	0.713864218	-0.000000000	0.000000000
2	$2x^3 + 5x - 1$	Newton Rapshon	6	0.196944438	0.000000000	0.000000000
		New Literacy	1	1.000000000	6.000000000	0.000000000
3	$2xe^{-4x} + 1$	Newton Rapshon	3	16332548654127828.000000000	1.000000000	1.000000000

		New Literacy	1	1.000000000	1.036631278	1.000000000
4	$2xlog(2^{x+1}+1)$	Newton Rapshon	100	-0.603916001	0.668396358	1.149774765
		New Literacy	1	1.000000000	3.772588722	1.149774765

For the function $f(x) = 2x^2 \sin(3x + 1)$ the Newton-Raphson method required 6 iterations to converge, producing a root of x=0.7138642179, a function value of f(x)=0, and a very small error of 0.0000000006. Meanwhile, the New Literacy Method only required 5 iterations to achieve the exact same result. This indicates that for trigonometric functions, the New Literacy Method is more efficient, providing the same accuracy with fewer iterations. The second function tested was $f(x) = 2x^3 + 5x - 1$ Newton-Raphson showed excellent performance, finding the root at x=0.1969444377 in 6 iterations, with a function value close to zero f(x)=0, and an error of 0.0000000000 In contrast, the New Literacy Method completed only 1 iteration, but produced a root of x=1.0000000000 with a function value still far from zero, f(x)=6. This shows that Newton-Raphson is more accurate in this polynomial case, although it requires more iterations.

For the exponential function $f(x) = 2xe^{-4x} + 1$, both methods struggled to provide accurate results. Newton-Raphson produced an unrealistic root, x=1.6332548654127828×10^{16}. with a function value still at f(x)=1, and an error of 1. The New Literacy Method performed only 1 iteration, producing x=1x = 1x=1 with a function value of f(x)=1.0366312778 and also an error of 1. In this case, both methods proved ineffective, and may require better initial guesses or alternative strategies. In the function $f(x) = 2x \log(2^{x+1} + 1)$ the Newton-Raphson method failed to converge even after 100 iterations, producing a root of x=−0.6031960011 with a function value of f(x)=0.6683963583 and a high error of 1.1497747647 The New Literacy Method also failed to provide an accurate result, performing only 1 iteration and producing an initial root of x=1 with a function value of f(x)=3.7725887222 and the same error of 1.1497747647. This shows that logarithmic functions are complex and not easily solved by either method without proper adjustment of the initial guess.

D. CONCLUSIONS AND SUGGESTIONS

Based on the MATLAB simulation results for four types of nonlinear functions trigonometric, polynomial, exponential, and logarithmic it can be concluded that both the Newton-Raphson Method and the New Literacy Method have their own advantages depending on the characteristics of the function. For the trigonometric function, the New Literacy Method is superior as it achieves the same level of accuracy as Newton-Raphson but with fewer iterations only 5 compared to 6. This demonstrates good convergence efficiency. Conversely, for the polynomial function, Newton-Raphson performs better, producing a highly accurate root even though it requires more iterations. In contrast, the New Literacy Method is less accurate despite completing the process in just one iteration. For the exponential and logarithmic functions, both methods perform suboptimally, yielding unrealistic or non-convergent roots with high error values. This shows that the effectiveness of each method strongly depends on the type of function and the choice of initial guess. Overall, neither method is universally superior. The New Literacy Method excels in efficiency for certain functions, while Newton-Raphson is more stable and accurate for functions with well-defined

derivatives. Therefore, the selection of a numerical method should align with the function's characteristics and the specific goals of the computation.

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