JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 711 - 722
https://publishoa.com
ISSN: 1309-3452

Comparison Of Jacobi Iteration Method And Gauss-Seidel Iteration Method In Solving Fuzzy Linear Equation Systems Using A Computer

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ABSTRACT

A linear equation with n variables x1, x2, x3,..... xn as an equation with the form a1 x1 + a2 x2 +..... an xn = b, where a1, a2,.....an and b are real constants. A system of linear equations is a finite collection of linear equations in the variables x1, x2,.... xn. A solution to a system of equations is a sequence of integers s1, s2,....= sn that solves each of the system's equations. The goal of this research is to compare the Jacobi Iteration Method with the Gauss-Seidel Iteration Method in order to find the solution to the Fuzzy Linear Equation System. The Jacobi iteration technique is an indirect method that begins with a rough estimate. A approach for solving a system of linear equations is the Jacobi method. A convergent approach is the Jacobi method. As a result, each equation must be adjusted such that the absolute value coefficients are the highest. The most recently computed values are utilized in all computations in the Gauss-Seidel iteration technique. The next step is to compare the two approaches by looking at the number of iterations and which error value is superior in solving the Fuzzy Linear Equation System after receiving the results of the iteration of the two ways.

Keywords— Fuzzy Linear Equation System, Jacobi Iteration Method, Gauss-Seidel Iteration Method, computer.

I. Introduction

A system of linear equations is a set of connected linear equations that may be used to determine the value of a variable that satisfies all of the equations. Real-world situations that require a solution method can occasionally give birth to systems of linear equations. Finding the values of the variables that satisfy all of the specified linear equations is what solving a linear equation entails. There are normally m equations and n variables in a system of linear equations. A matrix equation Ax = b can be constructed to represent a system of linear equations, with all elements in A and b being real integers.

In general, there are two ways for solving a system of linear equations: the direct approach and the indirect method. Approaches of elimination, substitution, LU decomposition, Cholesky decomposition, and Crout decomposition are all examples of direct methods. The Jacobi iteration technique, the SOR method, and the Gauss-Seidel method are examples of indirect procedures that are commonly referred to as iterations. The Jacobi iteration technique is an indirect approach that starts with an initial solution approximation and seeks to enhance it infinitely but at a convergent step, unlike the Gauss Seidel method employs an iteration procedure until the real

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Volume 13, No. 2, 2022, p. 711 - 722
https://publishoa.com
ISSN: 1309-3452

value is attained. This approach starts with the initial value and then switches to a previously known value in the following step.

Constants in a system of linear equations are typically real numbers, however as mathematics has progressed, constants in a system of linear equations have become fuzzy values that may be solved using the same approach. Fuzzy is a word that means "fuzzy" or "vague," and it's often used in issues when there's a lot of confusion. A system of fuzzy linear equations is a system of linear equations with constants in the form of fuzzy integers. A system of fuzzy linear equations has the same structure as a regular system of linear equations, with the exception of element b. A kind of parameters that are at specified intervals is element b in the system of fuzzy linear equations.

Several earlier studies have explored the solution of the fuzzy linear equation system. The study of the fuzzy linear equation system and the solution of the fuzzy linear equation system is discussed by Norita (2014). Allahviranloo (2004) also covers utilizing the upper and lower triangle approaches to solve a system of fuzzy linear equations. Kholifah (2014) also covers utilizing the Gauss Seidel technique to solve a completely fuzzy system of linear equations. As a consequence, in this article, we compare two approaches for solving a system of fuzzy linear equations, namely the Jacobi Iteration method and the Gauss Seidel Iteration method, by focusing on the number of iterations and the error value obtained as a result of the iteration. Reducing a Fully Fuzzy Linear Equation System with Trapezoidal Fuzzy Numbers is a study by Tuti Susanti, Sukamto. Completing a Complex Linear Fuzzy Equation System Using the QR Decomposition Method was a topic that Syafrina explored in 2013. The goal of this research is: To explore the comparison of Jacobi Iteration Method and Gauss-Seidel Iteration Method in solving Fuzzy Linear Equation Systems using a computer?

II. Literature Review

Fuzzy Linear Equation System

Fuzzy linear equation system is a system of linear equations with fuzzy parameters that are at certain intervals. The general form of a system of fuzzy linear equations

$$A\tilde{X} = \tilde{Y} \qquad (1)$$

Fuzzy linear equation system can be explained

$$\begin{array}{llll} a11\tilde{x}1 + & a12\tilde{x}2 + & \cdots + & a1n\tilde{x}n = \tilde{y}1 \\ a21\tilde{x}1 + & a22\tilde{x}2 + & \cdots + & a2n\tilde{x}n = \tilde{y}2 \\ \vdots & \vdots & \vdots & \vdots \\ am1\tilde{x}1 + & am2\tilde{x}2 + & am3\tilde{x}1 + & amn\tilde{x}n = \tilde{y}n \end{array} \qquad (2)$$

According to Norita (2014) The first step taken to find a solution for the system of fuzzy linear equations is to change the coefficient matrix A of size nxn into a matrix of size 2n x 2n which is assumed to be an M matrix.

The following conditions:

1. If $ai,j \geq 0$ then $bi,j = ai,j$ and $bi+n,j+n = ai,j$
2. If $ai,j < 0$ then $bi,j+n = -ai,j$ and $bi+n,j = -ai,j$ (4)
3. Other entries = 0

Definition 1 Allahviranloo.T.(2004)

The vector of fuzzy numbers 1 , 2 , … , given that $=\tilde{x}i = xi(r), xi(r)$, or i = 1,2 , ... , n and r = 0.1 is called the solution of the system linear equation if:

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https://publishoa.com
ISSN: 1309-3452

$$\underline{\sum_{j=1}^{n} a_{ij} x_j} = \sum_{j=1}^{n} \underline{a_{ij} x_j} = \underline{y_i}$$
$$\overline{\sum_{j=1}^{n} a_{ij} x_j} = \sum_{j=1}^{n} \overline{a_{ij} x_j} = \overline{y_i}$$

According to Matifar, Nasseri, and Sharabi (2008) a new fuzzy linear equation system can be explained:

S11$\tilde{x}$1 + ⋯ + S1n$\tilde{x}$n + S1n+1$\tilde{x}$2 + ⋯ + S1,2n$\tilde{x}$n = $\tilde{y}$1
⋮ ⋮ ⋮ ⋮⋮⋮
S11$\tilde{x}$1 + ⋯ + Snn$\tilde{x}$n + Snn+1$\tilde{x}$2 + ⋯ + Sn,2n$\tilde{x}$n = $\tilde{y}$n
Sn+11$\tilde{x}$1 + ⋯ + Sn+1,n$\tilde{x}$n + Sn+1n,n+1$\tilde{x}$2 + ⋯ + Sn+1,2n$\tilde{x}$n = $\tilde{y}$1
⋮ ⋮ ⋮ ⋮
S2n,1$\tilde{x}$1 + ⋯ + S2n,1n$\tilde{x}$n + S2n,n+1$\tilde{x}$2 + ⋯ + S2n,2n$\tilde{x}$n = $\tilde{y}$1

Definition 2 Matinfar.M, et al,(2008)
There is$X$ = $xi(r)$, $xi(r)$, $1 \leq i \leq n$is a solution of$SX = Y$with fuzzy numbers
$U = ui(r)$, $ui(r)$, $1 \leq i \leq n$;
$u(r)$ = min $xi(r)$, $xi(r)$, $xi(1)$, $xi(1)$
$u(r)$ = max $xi(r)$, $xi(r)$, $xi(1)$, $xi(1)$
Solution$fuzzy\tilde{U}$ is called a strong fuzzy solution if $ui = xi$, $ui = \tilde{x}i$, then if there is one that is not the same then is a weak fuzzy solution.

Jacobi Iteration Method

This Jacobi iteration method is used to solve linear equations with a large proportion of zero coefficients. This method was invented by the German mathematician, Carl Gustav Jakob Jacobi. This discovery is thought to be in the 1800s. Iteration can be interpreted as a process or method that is used repeatedly (repetition) in solving a mathematical problem. The Jacobi iteration method is:

$$x_i^{(k)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j\neq i}^{n} a_{ij} x_j^{(k-1)}\right), i = 1,2, \dots, n; k = 1,2,3, \dots, n$$

Gauss-Seidel Iteration Method

The Gauss-Seidel method is used to solve a system of linear equations (SPL) that is large and has a large proportion of zero coefficients, such as systems found in many systems of differential equations. Iteration technique is rarely used to solve small SPLs because direct methods such as Gaussian elimination are more efficient than iterative methods. However, for large SPLs with a percentage of zero elements in a large coefficient matrix, the iteration technique is more efficient than the direct method in terms of computer memory usage and computational time. The Gauss-Seidel iteration method can be expressed as follows:

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https://publishoa.com
ISSN: 1309-3452

$$x_i^{(k)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j=1}^{i-1} a_{ij}\, x_j^{(k)} - \sum_{j=i+1}^{r} a_{ij}\, x_j^{(k-1)}\right)$$

Introduction to Fuzzy Logic Theory

The classical theory of sets or "sets" is based on the fundamental concept of sets that an entity may or may not be a member of the set. A sharp, clear and unambiguous distinction exists between members and non-members of a set that has been defined in this theory. And there are very clear boundaries to indicate that an entity is part of this set. (Chen and Pham, 2001). When there is a question about an entity is a member of the set or not, the answer is "Yes" or "No".

In this case the answer can be for example, "The probability that this entity is a member of a set is 90%", but the conclusion can still be said that this entity is a member or not a member of a set. The probability for someone to make a correct prediction that “this entity belongs to a set” is 90%, which does not mean that this entity has 90% membership in the set and 10% non-membership of this entity. In classical set theory, this is not allowed where an element or entity exists in the set and does not exist in the set at the same time. Thus, many cases in real-world applications cannot be explained and handled by classical set theory.

In contrast, fuzzy set theory allows the use of partial membership in sets, which in classical set theory has limitations in this regard. (Chen and Pham, 2001).

A classical set is described with clear boundaries, that is, there is no uncertainty in the location and boundaries of the set. Figure 2.1a shows the boundaries of the classical set A in clear lines. Whereas the fuzzy set, defined by the property of being nebulous and ambiguous, hence, its boundaries are vaguely and ambiguously specified. Figure 2.1b shows the boundaries in the fuzzy set A. From the first figure it is clear that entity A is a member of the classical set A and entity B is clearly not a member of the set A. While the second image shows the vague, ambiguous boundaries of the fuzzy set. A. The shaded gray area is the boundary of the fuzzy set A.

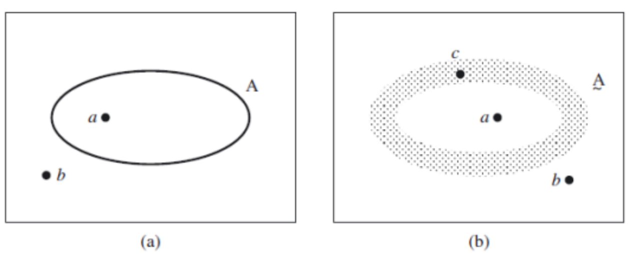

Figure 2.1 Classical Set and Fuzzy Set
Source: Ross, 2010

In the central area (unshaded) of the fuzzy set, entity a is clearly a member of this set, in the outer area of the boundary area of the fuzzy set entity b is clearly not a member of this set. However, the membership of entity c that falls within the boundary area of the fuzzy set is ambiguous. If the full set member in the set (entity a) is represented by the number 1 and the entity b which is not a member of the set is represented by the number 0, then the entity c in this set must have a median value of membership in the interval [0,1].

Fuzzy Set (Fuzzy Set)

In the classical set, the existence of an element in a set A has only two possible memberships, namely being a member of A or not being a member of A A value that indicates how big the level of membership of an element in

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 711 - 722
https://publishoa.com
ISSN: 1309-3452

a set is. commonly referred to as the membership value, which is usually written as$\mu A(x)$.
Ravita (2012) on the classical set, the membership value only pairs a value of 0 or 1 for the elements in the universe of speech, which state members or non-members.
The membership value for the set A is the functionμA: $X \to \{0,1\}$.

Fuzzy Numbers

Definition of 3 Kwang (2005)
The fuzzy number u in R is defined as a pair of functions of the following properties
(u, u) which satisfies the

1. The function u is monotonically ascending, finite, and continuous left at [0,1],
2. The function u is monotonically descending, finite and right continuous at [0,1], and
3. u(r) u(r) for every r in [0,1]

The set of fuzzy numbers is expressed by F. Furthermore, the fuzzy number u
F is written in the form of the parameter u = (u, u).

Definition 4 Allahviranloo (2005)
Fuzzy algebra operations use the definition that for every, v ∈ F and real numbers are defined:

a) $u = v$if and only if $u = v$ and$u = v$.
b) $u + v = (u + v, u + v)$
c) $\alpha u = (\alpha u, \alpha u)$ for$\alpha \geq 0$
d) $\alpha u = (\alpha u, \alpha u)$ for$\alpha \geq 0$

Basic Concepts of Programming in Visual Basic 6.0715

Visual Basic is event-driven programming, meaning that programming waits until there is a response from the user in the form of certain events or events. When an event is detected, the code associated with the event will be executed. The development of Visual Basic is very rapid because it is easy to use and there are lots of facilities provided. The following will explain the history of the development of visual basic, namely:

1. Visual basic was first introduced in 1991, namely Visual Basic for DOS and Windows.
2. Two years later, in 1993, Visual 3.0 was released.
3. At the end of 1995, Visual Basic 4.0 was released with additional support for 32-bit applications.
4. 1997 Visual Basic 5.0 was released.
5. Finally, there is the development of an updated version up to 200x.

The Visual Basic project consists of several files that are related to one another. Each file contains various information such as forms, modules and so on. The following files are created when designing a program:

1. Project file (.vbp) to store the information used.
2. Module file (bas) for storing program routines.
3. Form file (.frm) to store information about the created form.
4. Resource file (.res) to store the icon information used.
5. ActiveX Control file (.ocx) to add an icon to the tollbox which was originally still standard

The basic concept of programming Visual Basic 6.0 is making a form by following the programming rules. Visual Basic 6.0 is a software that can process various data processing. One of them is data processing using the Jacobi iteration method. In the processing, the code is written that will process the Jacobi iteration calculations. The rules for creating the form are following the programming rules for properties, methods, and events.

1. Property Visual Basic Programming properties can be set according to needs.
2. Method is a place to express the programming logic of creating an application program.
3. Events The event settings in each component will execute all the created methods.

When the data processing program in Visual Basic has been made according to the rules and the program can be run, then the program can be easily used by other people. Making programs for data processing can make it easier for everyone to calculate or process data problems. To use the program only requires converting the problem into a mathematical model. Problems are sought in real life to be analyzed and solutions to the problem are sought, then the problems will be modeled in the form of equations. By means of the equation coefficients are inputted into the program, so that when it is run it will produce a solution to the equation. The solution of the equation can be concluded to apply water conservation in various environments.

III. Research Methodology

Research Data

In this study, the application was checked using tidal height data from January 1 to December 31, 2012.

Research Stages

At the research stage, the process of making tidal data processing applications will be explained. The stages of this research are:

a. Study of literature
The collection of literature studies sourced from previous research and used as the theoretical basis for this Final Project research.
b. Tidal Observation Data
Data collection used in application testing activities.
c. Modeling of Data Processing Programs
Activities of designing and creating display models (*interfaces*) in the Tidal v.1.0 application program.
d. Data Processing With Tidal v.1.0
Processing of data using the collected data to test the application program.
e. Data Processing With SLP64 and T-Tide
Data processing using the data collected to compare the results of data processing Tidal v.1.0 with SLP64 and T-Tide v.1.3.
f. Significance Test
Application testing activities to determine the correlation between Tidal v.1.0 with SLP64 and T-Tide v.1.3
g. *Usability* Test
Application testing activities using questionnaires to test the effectiveness and usability test, to determine the effectiveness of the application and the usability of the application to users (*users*)

Processing Stage

In making tidal data processing applications with *Visual Basic for Application* Ms. Excel has several stages in its processing, including making application models, testing data processing with *Tidal v.1.0* , program validation and results using *software* SLP4 and T-Tide v.1.3, as well as analysis and discussion of results..

IV. Findings and Discussion

Jacobi. Iteration Method

Based on equation (5)

$x_i^{(k)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j\neq i}^{n} a_{ij}x_j^{(k-1)}\right), i = 1,2,\dots,n; k = 1,2,3,\dots,n$

$$\underline{x}_1{}^{(k)} = -\overline{x}_2{}^{(k-1)} - 7 + 2r$$
$$\underline{x}_2{}^{(k)} = -\frac{1}{3}\underline{x}_1{}^{(k-1)} + \frac{19+4r}{3}$$
$$\overline{x}_1{}^{(k)} = -\underline{x}_2{}^{(k-1)} - 3 - 2r$$
$$\overline{x}_2{}^{(k)} = -\frac{1}{3}\overline{x}_1{}^{(k-1)} + \frac{27-4r}{3}$$

First Iteration

$$\underline{x}_1^{(1)} = -\overline{x}_2^{(0)} - 7 + 2r$$
$$\underline{x}_2^{(1)} = -\frac{1}{3}\underline{x}_1^{(0)} + \frac{19+4r}{3}$$
$$\overline{x}_1^{(1)} = -\underline{x}_2^{(0)} - 3 - 2r$$
$$x_2^{(1)} = -\frac{1}{3}\overline{x}_1^{(0)} + \frac{27-4r}{3}$$

Second Iteration

$$\underline{x}_1^{(2)} = -\overline{x}_2^{(1)} - 7 + 2r$$
$$\underline{x}_2^{(2)} = -\frac{1}{3}\underline{x}_1^{(1)} + \frac{19+4r}{3}$$
$$\overline{x}_1^{(2)} = -\underline{x}_2^{(1)} - 3 - 2r$$
$$x_2^{(2)} = -\frac{1}{3}\overline{x}_1^{(1)} + \frac{27-4r}{3}$$

So the result of the second iteration is

$$\tilde{x}^{(2)} = \left[\frac{-48+10r}{3}, \frac{26+2r}{3}, \frac{-28-10r}{3}, \frac{30-2r}{3}\right]$$

Gauss–Seidel. Iteration Method

Based on the equation

$$x_i^{(k)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j=1}^{i-1} a_{ij}\, x_j^{(k)} - \sum_{j=i+1}^{r} a_{ij}\, x_j^{(k-1)}\right)$$

So that it is obtained

$$\underline{x}_1{}^{(k)} = -\overline{x}_2{}^{(k-1)} - 7 + 2r$$
$$\underline{x}_2{}^{(k)} = -\frac{1}{3}\underline{x}_1{}^{(k)} + \frac{19+4r}{3}$$
$$\overline{x}_1{}^{(k)} = -\underline{x}_2{}^{(k)} - 3 - 2r$$
$$\overline{x}_2{}^{(k)} = -\frac{1}{3}\overline{x}_1{}^{(k)} + \frac{27-4r}{3}$$

First iteration

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https://publishoa.com
ISSN: 1309-3452

$$\begin{aligned}
\underline{x}_1^{(1)} &= -\overline{x}_2^{(0)} - 7 + 2r \\
\underline{x}_2^{(1)} &= -\frac{1}{3}\underline{x}_1^{(1)} + \frac{19+4r}{3} \\
\overline{x}_1^{(1)} &= -\underline{x}_2^{(1)} - 3 - 2r \\
\overline{x}_2^{(1)} &= -\frac{1}{3}\overline{x}_1^{(1)} + \frac{27-4r}{3}
\end{aligned}$$

so first iteration

$\tilde{x}^{(1)} = \left[-7+2r, \frac{26+2r}{3}, \frac{-35-8r}{3}, \frac{116-4r}{9}\right]$.

Second iteration:

$$\begin{aligned}
\underline{x}_1^{(2)} &= -\overline{x}_2^{(1)} - 7 + 2r \\
\underline{x}_2^{(2)} &= -\frac{1}{3}\underline{x}_1^{(2)} + \frac{19+4r}{3} \\
\overline{x}_1^{(2)} &= -\underline{x}_2^{(2)} - 3 - 2r \\
\overline{x}_2^{(2)} &= -\frac{1}{3}\overline{x}_1^{(2)} + \frac{27-4r}{3}
\end{aligned}$$

Where is the first iteration obtained

$$\tilde{x}^{(1)} = \left[-7+2r, \frac{26+2r}{3}, \frac{-35-8r}{3}, \frac{116-4r}{9}\right]$$

Then obtained:

$$\begin{aligned}
\underline{x}_1^{(2)} &= -\overline{x}_2^{(1)} - 7 + 2r = -\left(\frac{116-4r}{9}\right) - 7 + 2r = \frac{-116-63+4r+18r}{9} \\
&= \frac{-179+22r}{9} \\
\underline{x}_2^{(2)} &= -\frac{1}{3}\underline{x}_1^{(2)} + \frac{19+4r}{3} = -\frac{1}{3}\left(\frac{-179+22r}{9}\right) + \frac{19+4r}{3} = \frac{179+171-22r+36r}{27} \\
&= \frac{350+14r}{27} \\
\overline{x}_1^{(2)} &= -\underline{x}_2^{(2)} - 3 - 2r = -\left(\frac{350+14r}{27}\right) - 3 - 2r = \frac{-350-81-14r-54r}{27} \\
&= \frac{-431-68r}{27} \\
\overline{x}_2^{(2)} &= -\frac{1}{3}\overline{x}_1^{(2)} + \frac{27-4r}{3} = -\frac{1}{3}\left(\frac{-431-68r}{27}\right) + \frac{27-4r}{3} = \frac{431+729+68r-108r}{81} \\
&= \frac{1160-40r}{81}
\end{aligned}$$

So the result of the second iteration is

$$\tilde{x}^{(2)} = [\frac{-179+22r}{9}, \frac{350+14r}{27}, \frac{-431-68r}{27}, \frac{1160-40r}{81}]$$

The Jacobi iteration method gets a stop iteration on the 22nd iteration and the Gauss-Seidel iteration method gets a stop iteration on the 8th iteration and the error in the Gauss-Seidel method converges faster than the Jacobi method. This shows that the Gauss-Seidel iteration method is better to use than the Jacobi iteration method.

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Volume 13, No. 2, 2022, p. 711 - 722
https://publishoa.com
ISSN: 1309-3452

V. Computer Application

The results of this application will be explained about the description of the appearance of the application and the use V.of the application from the information on the use of this application. Here are the results of the Tidal v.1.0 application display.

Figure 1. Graphic Display

Figure 2. Display of Harmonic Constant

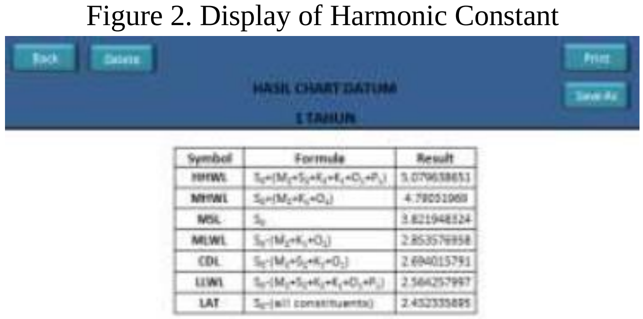

Figure 3. Display of the Datum Chart

Figure 4. Prediction Display

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 711 - 722
https://publishoa.com
ISSN: 1309-3452

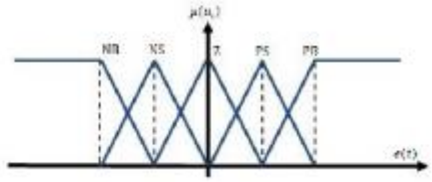

Figure 5. Fuzzy Input Set for (a) Error

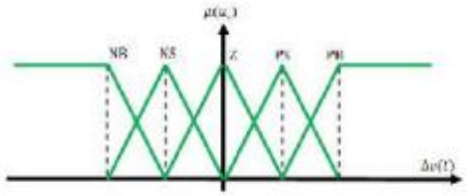

Figure 6. Fuzzy Input Set for Delta Error

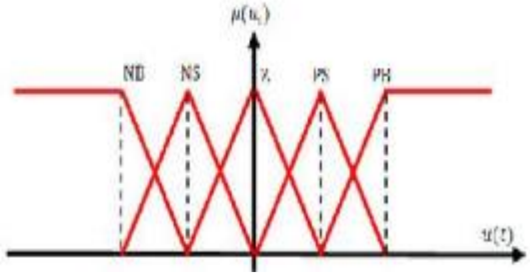

Figure 7. Fuzzy Output Set

Application Testing Results and Analysis

At this stage, the application is tested using an *effectiveness test* to see the level of application *effectiveness* and a user satisfaction test to determine the level of user satisfaction in the Tidal v.1.0 application.

Effectiveness Test

The following are the results of the recapitulation of the *effectiveness test questionnaire* in Appendix Tables 1 and 2. From the results of the recapitulation and calculation of the questionnaire on the *effectiveness test* , the final result is 81, 67%. This shows that the tidal data processing application is effective in helping users process tidal data.

Satisfaction Test

The following are the results of the user satisfaction test questionnaire recapitulation. From the results of the user satisfaction test, the final result was 83.67%. This shows that the tidal data processing application gives satisfaction to the user in helping the tidal data processing.

System Requirements Program

In using the Tidal v.1.0 program application, it has *system requirements* in the process of using it. This application has a large enough capacity so that the computer/laptop equipment used must have high specifications with RAM,

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https://publishoa.com
ISSN: 1309-3452

a large CPU *processor* . So that a lot of data processing will run faster and can complete the processing process than using a computer/laptop with low specifications.

Conclusion

The Gauss-Seidel iteration approach performs better than the Jacobi iteration method. According to Niyyaka (2016), for solving systems of linear equations using computer simulations, the Gauss-Seidel Iteration Method is superior to the Jacobi Iteration Method. Even though the context of solving equations is different, the research found that the Gauss-Seidel iteration is superior than the Jacobi iteration in the case of a system of fuzzy linear equations. This suggests that the research is in accordance with Niyyaka (2016)'s findings.

This research examines and contrasts two numerical methods: Jacobi iteration and Gauss-Seidel iteration. Other numerical approaches such as the secant method, decomposition method, and splitting method, according to the researcher, should be investigated further. Different fuzzy equations, such as Non-Linear Fuzzy Equations and Linear Fuzzy Complex Equations, can also be employed.

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