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Analysis of Tuberculosis (TB) Case Patterns Using the Hurst Exponent Fractal Dimension Method in North Sumatra

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Abstract
Tuberculosis is a chronic infectious disease caused by *Mycobacterium tuberculosis*. This bacteria is commonly known as *Acid Resistant Bacilli* (BTA). The *Hurst* Exponent Fractal Dimension method was used in this work to identify the properties of time series data and fractal patterns in TB patients. The *Hurst* exponent method is calculated by the smallest prime factor that divides the data (pi). This fractal dimension's value is calculated using the *Hurst* exponent value. Time series data is classified into three groups depending on computation results: random, *anti-persistence*, and *persistence*. In the study, three data ranges (n) were obtained from the observed data, namely TB patients from July to December 2023 (174, 87, and 29). The value of the *Hurst* exponent obtained was 0,475 $(0 < H < 0{,}5)$ and the value of the fractal dimension obtained was 1,525 $(1{,}5 < H < 2)$. Based at the *Hurst* exponent value and fractal dimension fee, it indicates that the records is *anti-persistence*. *Anti-persistence* means that the time series data of cases of TB patients which if the data increases at one time, it tends to decrease at the next time and if the data decreases at one time, it tends to increase at the next time.

Keywords: TB, Fractal Dimension, *Hurst* Exponent Method.

1. Introduction

Indonesia has a dual disease burden, with an increase in noncommunicable diseases and a high prevalence of infectious diseases. TB is a major risk to country wide and global health, and one of the *Sustainable Development Goals* (SDGs). Tuberculosis (TB) is a continual infectious disorder as a result of *Mycobacterium tuberculosis*. This micro organism is normally referred to as *Acid Resistant Bacilli* (BTA) because to its stem shape, that is 1-10 microns in period and 0,2-0,6 microns in width, in addition to its acid resistance (Kemenkes RI, 2023). According to the Ministry of Health of the Republic of Indonesia, 30,8% (7 million) of Indonesian minors are stunted before the age of five. In just three years (2016-2019), adult obesity has climbed by up to five times the 2019 RPJMN target. Indonesia has the highest maternal mortality rate in Southeast Asia, with 305 fatalities for every 100.000 live births. TB was one of the five leading causes of disease burden in 2017 (Kemenkes RI, 2020). Cases of TB often occur in developing countries as well as countries with fairly high population density. In 2020, the World Health Organization (WHO) reported that pulmonary TB caused 1,2 million deaths in developing countries, 10 million new cases, and 1,3 million deaths worldwide, resulting in 890.000 deaths in men, 480.000

in women and 180.000 in children. Indonesia ranks third, after China and India, in terms of TB infection rates (Hasan *et al.*, 2023).

Indonesia is the world's second most TB-affected country, after India, in terms of new cases compared to all cases worldwide. In 2021, an estimated 10,6 million people worldwide were infected with tuberculosis. In 2017, 443.670 tuberculosis cases were reported. In 2018, the number increased to 565.869 cases, with five provinces accounting for more than 50% of TB case notifications: West Java (105.794 cases), East Java (71.791 cases), Central Java (65.014 cases), DKI Jakarta (41.441 cases), and North Sumatra (35.035 cases). These five provinces are located in Indonesia's most populous areas, and the total number of cases in 2019 was 568.987. In 2020, TB cases in Indonesia decreased to 351.936 cases (Kaban *et al.*, 2023). In 2021, the Ministry of Health (Kemenkes) reported around 397.377 cases of TB throughout Indonesia. The age range of 45-54 years accounts for 17,5% of all TB cases nationwide. The age group of 25-34 years has the highest proportion (17,1%), followed by the age group of 15-24 years (16,9%) (Dinas Kesehatan Sumatera Utara, 2022).

North Sumatra Province in 2016 had the coverage of the discovery of TB cases with a total of 17.798 cases, the number of new cases of BTA-positive pulmonary TB patients amounted to 11.771 cases. Based on gender in North Sumatra, the number of BTA-positive TB patients with male sex reached 7.764 people and female reached 4.007 people, the CNR (*Case Notification Rate*) of all cases was 126 and the CNR (*Case Notification Rate*) of BTA was positive amounting to 83 cases. In 2021, it had the sixth highest number of TB cases, from several provinces such as West Java, Central Java, East Java, DKI Jakarta, and Banten. The North Sumatra Provincial Health Office reported that the cities of Medan, Deli Serdang, and Simalungun had the highest number of positive cases of BTA TB in 2020. In Medan City, the number of TB cases found in 2021 has reached 10% of the target of 18.000 cases, or approximately 1.000 cases. According to data from the Central Statistics Agency (BPS) of North Sumatra in 2023, pulmonary TB patients in North Sumatra reached 19.147 patients, Medan 2.697 patients and Binjai 1.457 patients. The North Sumatra Provincial Government continues to strive to end the spread of TB by cutting off the transmission of transmission in order to achieve the elimination target by 2028 (Dinas Kesehatan Sumatera Utara, 2022).

High cases of TB patients occur due to various factors. One of them is the environment. *Mycobacterium tuberculosis* bacteria thrive in low-quality environments and TB thrives. An unqualified physical environment can be a medium for disease transmission, especially for TB (Fransiska & Hartati, 2019). To prevent TB, it is necessary to make efforts to break the chain of transmission, establish early diagnosis, control infection, and provide effective treatment. Understanding TB can help society prevent its transmission. However, individuals often lack the necessary knowledge when performing their obligations. Having a positive attitude in daily life is essential to change behavior through knowledge (Nasution *et al.*, 2023).

The number of cases of TB patients and the need for appropriate action so it is necessary to conduct research to find a method that provides the highest accuracy value. The data on the number of cases of TB is one of the time series data. The analysis related to time series data aims to predict future conditions. Fractals are useful tools for analyzing data from time sequences. Determining fractal dimensions is essential for understanding complex geometric shapes. In this case, fractal objects have dimensions that exceed topology. Fractal dimensions can reveal the structure and density of objects, as well as the properties of time series data (Juniati & Suwanda, 2022). There are various methods for determining the size of fractal dimensions, including the *Hurst* exponent method and the *Box Counting* method. The *Hurst* exponent method is used to calculate fractal dimensions with data in the form of *time series* data, while the *Box Counting* method is better known as the box calculation method. The *Hurst* exponent value is calculated by means of evaluating the variety of the dataset (R) with the standard deviation (S) for every range price (n).The *Hurst* exponent method is one way for the *Hurst* exponent (H) to be used to calculate graph dynamics patterns from time series data using fractal dimension analysis. Calculating the *Hurst* exponent value (H) distinguishes three types of traits as *anti-persistence*, *persistence* and random (Kosala *et al.*, 2023). Anggraini (2019) also make this approach to her research, her research provides a novel approach to understanding and classifying cat vocalizations, which can help pet owners and veterinarians better interpret the conditions of cats. By using advanced mathematical and machine learning techniques, the study offers a reliable method for analyzing and categorizing animal sounds. Another research was conducted by Nur'Aini and Juniati (2021). Based on the results of the Hurst Exponential Fractal Dimension Algorithm, the Hurst exponent value for Indonesia is 0.8423 where the value is persistance because it is in the range of $0.5 < H \leq 1$. Meanwhile, for the other five countries, a value for Laos was obtained of 0.4918 so that the daily data of Laos was random or uncorrelated. Argentina has a Hurst exponent value of 0.8453. Meanwhile, Switzerland has a Hurst exponent value of 0.9802. These two countries both have Hurst exponential values in the range of $0.5 < H \leq 1$ so the data is persistent. As for the countries of Lesotho and the Solomon Islands, they have Hurst exponential values of 0.2671 and 0.0, respectively, so the data is antipersistent, because the Hurst exponent values are in the range of $0 \leq H < 0.5$. Because it is persistent, the data on the addition of new Covid-19 cases in Indonesia can be predicted based on existing data, as well as Argentina and Switzerland (Nur 'aini & Juniati, 2021).

2. Methods

2.1. Fractal Dimension

According to Juniati and Budyasa (2016), fractal dimensions are indices that describe fractal patterns and quantify complexity as the ratio of details that vary with scale. Alifa & Juniati (2019) said This is a mathematical approach used to determine the fractal dimension of an object. It involves covering the object with a grid of boxes and counting the number of boxes that contain part of the object. By varying the size of the boxes and analyzing how the count changes, the fractal dimension can be calculated. This dimension provides insight into the complexity and self-similarity of the object. According to Turcotte (1997), the first person to propose the concept of fractals and define a fractal "set" was Mandelbrot as follows (Anwar & Manuharawati, 2021):

$$N = \left(\frac{1}{r}\right)^{D} \tag{1}$$

where:
N = number of objects (segments)
r = ratio to scale N
D = fractal dimension

The formula used for the calculation of fractal dimensions will be generated by taking the algorithm of the two segments. To get the value D, equation (1) can be written as:

$$D = \frac{\log(N)}{\log\left(\frac{1}{r}\right)} \tag{2}$$

The higher the value of the fractal dimension can indicate that the process is dynamic. The data values fluctuate more than the low fractal dimension values. The fractal dimension can be calculated using the *Hurst* exponent method.

2.2. *Hurst* Eksponent Method

The *Hurst* exponent method was first introduced by Harold Edwin Hurst (1880-1978). *Hurst's* exponents are denoted by the letter H. The range of values is from 0 to 1. The H value correlates with the value of the fractal dimension and measures the random fineness or hardness of the data. A low *Hurst* exponent results in a large fractal dimension value. *Hurst's* exponent method can identify movement patterns from time series data (Kosala *et al.*, 2023). The Hurst exponent values for all climate elements ranged between 0.590 and 0.884, indicating that the climate dynamics in the studied locations generally exhibit persistence (Andriyani et al., 2018).

Patterns of fluctuations in the data can be predicted using R and S analysis, which measures the relationship between the value of the range-length ratio and the calculated standard deviation. The value scale of Hurst's exponential ratio increases proportionally with the increase of each range (n) of data used in its calculations. The relationship of the statement can be reviewed using the equation (3):

$$\left(\frac{R(n)}{S(n)} = cn^H\right) \tag{3}$$

where:
R = length of data range
S = standard deviation
n = length of the data range where $n = N, N/2, N/4, \dots$, with N amount of data per segment
c = constant
H = *Hurst* exponent value

To estimate the value of the *Hurst* exponent (H),, it can be done by dividing the data by length (N) to create several segments of length n, where $\left(n = N, \frac{N}{2}, \frac{N}{4}, \dots\right)$. The mean value segment is then calculated using the data for each n. Data with length n is a variable X_t where $(t = 1,2,3, \dots, n)$. For the next step, which is to calculate the value of the *Hurst* exponent (H), there are several steps, namely:

a. Determines the average value for each n, where $\left(n = \frac{Ni}{pi}\right)$ with Ni is the amount of data on the division of prime numbers pi. In this case, pi is the smallest prime factor that divides the data. Meanwhile, TB case data is notated with X_t, where i is the smallest date sequence of the last month, namely July 2023.

$$\mu = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{4}$$

b. Determining the cumulative deviation series value at each point in time

$$Z_t = \sum_{i=1}^{t} (X_t - \mu) \tag{5}$$

where:
Z_t = cumulative deviation series value
t = 1,2,3, ..., n
μ = average value of data

c. Determine the range value at each n of the largest and smallest cumulative series total values

$$R = maks(Z_t) - min(Z_t) \tag{6}$$

where:
$max(Z_t)$ = maximum value at (Z_t)
$min(Z_t)$ = minimum value at (Z_t)

d. Calculate the standard deviation value (S) for each n by squaring the total value of the cumulative deviation series

$$S(n) = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (X_t - \mu)^2} \tag{7}$$

e. Analyze the scaled reach length ratio $\left(\frac{R(n)}{S(n)}\right)$ with the average for all time series data that has a length n.

f. Once the value (R/S) is known, the $\log(R/S)$ can be determined. For n values that have more than one value (R/S) must determine the average of the values (R/S).

g. From the results of the calculation of $\log(n)$ and $\log(R/S)$, a regression line is constructed where $\log(n)$ is the x-axis and $\log(R/S)$ is the y-axis. The value of the *Hurst* exponent (H) is derived from the result of the slope of the plot $\log\left(\frac{R}{S}\right)$ and log (n) which results in the equation as follows:

$$\log(R/S) = \log(c) + \mathrm{H} \times \log\ (n) \tag{8}$$

From equation (8) to get the result of the *Hurst* exponent value (H) is obtained by creating a flow of values $\log(R/S)$ on each log value (n). To classify a data time series based on *Hurst's* exponent value, it will be explained as follows:

a. Random, is when the value of the *Hurst* exponent is 0,5 $(H = 0{,}5)$. This indicates that the data changes are random and unrelated to subsequent data.
b. *Anti-persistence*, is when the value of *Hurst's* exponent is between 0 and 0,5 $(0 < H < 0{,}5)$. This means that if the data increases at one time, it tends to decrease at the next time and vice versa.
c. *Persistence*, is when the value of *Hurst's* exponent is between 0.5 and 1 $(0{,}5 < H < 1)$. This means that if the data increases at one time it will be followed by another high value and vice versa.

The relationship between the exponent value of *Hurst* (H) and the fractal dimension (D) is formulated by the following equation:

$$D = 2 - H \tag{9}$$

where:
D = Fractal Dimension
H = *Hurst's* Exponent Value
From equation (9), the value of fractal dimensions (D) can be concluded that:

a. Time series data with fractal dimensions $1,5 < D < 2$ is considered *anti-persistence.*
b. Time series data with fractal dimensions $1 < D < 1,5$ is considered *persistence*.
c. The fractal dimension of 1,5 shows randomness in the time series data.

3. Result and Discussion

The outcomes of the studies had been acquired from the facts series technique to records evaluation. in the records evaluation technique, there are manual of completion steps and the process of constructing graphs from regression equations to acquire *Hurst* exponent values and fractal dimensions is finished with the help of the Matlab programming language.

Data analysis is an analysis used to find out the overall data on cases of TB as one of the infectious diseases in North Sumatra. In this descriptive analysis, a table is used to describe data on cases of TB from July 2023 to December 2023. Data from the North Sumatra Provincial Health Office will be used entirely in determining the *Hurst* exponent value and fractal dimension value from this calculation which will be a prediction of the number of TB patients in North Sumatra. The following is the data on cases of TB patients to be analyzed shown in Table 1 namely:

Table 1. Data on TB Cases for the July-December 2023 Period

Date	Month					
	July	August	September	October	November	December
1	12		166	156	41	53
2	10	14		73	215	58
3	12	7	118	27	208	78
4	4	9	66	134	184	7
5	9	1	3	203	206	119
6	15	138	131	103	29	157
7	8	17	116	88	134	125
8		9	118	19	136	95
9	12	11	87	45	118	67
10	14	9	140	110	91	214
11	13	5	124	93	91	59
12	12	5	110	112	53	117
13	15	14	123	112	55	90
14	5	15	95	111	120	105

Date	Month					
	July	August	September	October	November	December
15	1	14	119	72	126	120
16	11	51	128	32	115	76
17	10	11	130	72	23	203
18	10	7	42	145	134	10
19	12		210	78	100	102
20	86	13	104	30	190	89
21	5	14	106	180	134	87
22		10	23	145	127	137
23	4	5	113	180	113	69
24	19	36	106	56	84	29
25	10	24	57	21	127	58
26	10	4	6	170	156	116
27	10	103	136	76	80	126
28	6	7	136	68	114	100
29	3		115	108	115	242
30	16		81		94	201
31	13	149				

(Source: data obtained from the Provincial Health Office. North Sumatra, 2023)

Information:

: Dates not included in the month

: There is no data on that date (empty) and it is not used in this research

The following is the application of the *Hurst* exponential fractal dimension method for the analysis of case patterns of TB patients.

3.1. Determination of *Hurst* Exponent Value Using the *Hurst* Exponent Method

The *Hurst* exponent method is a method of calculating time series data where the *Hurst* exponent value is in the range of 0 and 1. In Table 1., the data on cases of TB observed is denoted by X_t, where i is the smallest date sequence of the last month, namely July 2023. In the case data of TB patients whose *Hurst* exponent value will be determined which is 174 days, the following are explained the calculation steps:

1. Determining the mean value (μ) for n = 174, using equation (4): $\mu = \frac{1}{n}\sum_{i=1}^{n} X_i$, then the result of the calculation is obtained, namely:
   $\mu_{174} = \frac{1}{174}\sum_{i=1}^{174} X_i = \frac{13.519}{174} = 77{,}695$
2. Determine the cumulative deviation series value at each time point (Z_t) from the data on the number of cases of TB whose process is shown in Table 2. the following:

Table 2. Total Cumulative Deviation Series Calculation (1)

Z_t	Calculation of Cumulative Deviation Series Value $\left(Z_t = \sum_{i=1}^{t}(X_t - \mu)\right)$	$(Z_t)^2$
Z_1	$12 - 77{,}695 = (-65{,}695)$	4.315,833
Z_2	$(-65{,}695) + 10 - 77{,}695 = (-133{,}39)$	17.792,892
Z_3	$(-133{,}39) + 12 - 77{,}695 = (-199{,}085)$	39.634,,837
Z_4	$(-199{,}085) + 4 - 77{,}695 = (-272{,}78)$	74.408,928
Z_5	$(-272{,}78) + 9 - 77{,}695 = (-341{,}475)$	116.605,176
.	.	.
.	.	.
.	.	.
Z_{170}	$(-396{,}455) + 116 - 77{,}695 = (-358{,}15)$	128.271,42
Z_{171}	$(-358{,}15) + 126 - 77{,}695 = (-309{,}845)$	96.003,92
Z_{172}	$(-309{,}845) + 100 - 77{,}695 = (-287{,}54)$	82.679,25
Z_{173}	$(-287{,}54) + 242 - 77{,}695 = (-123{,}235)$	15.186,86
Z_{174}	$(-123{,}235) + 201 - 77{,}695 = 0$	0

3. Determine the range value (R) at n=174 of the total value of the largest and smallest cumulative series through equation (6). Based on the calculation results from Table 2. obtained value:
   $maks\ (Z_{174}) = 0$
   $min\ (Z_{174}) = -3.353{,}225$
   So that the value of the range (R) = 3.353,225.
4. Calculate the standard deviation value (S) for n=174 by squaring the total value of the cumulative deviation series through equation (7). The results of the calculation of the total cumulative deviation series are shown in Table 2., so that the standard deviation value (S) is obtained:
   $S(n) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_t - \mu)^2}$
   $S(174) = \sqrt{\frac{1}{174}(679.026.052{,}049)}$
   $S = 1.975{,}462$
5. Determining the scaled range length ratio (R/S) for the value of the data range n=174 is as follows:
   $\frac{R}{S} = \frac{3.353{,}225}{1.975{,}462}$
   $\frac{R}{S} = 1{,}697$

The R/S value of n = 174 is 1,697.

Furthermore, to determine the R/S value for n = 87 and 29, the R/S value will be calculated with the same calculation steps as in n = 174. In the span of 174 days of the observed data there are three n. Values $\left(\frac{R}{S}\right)$ are determined in each sub n, for example in $n = 87$ there are two results in the column $\left(\frac{R}{S}\right)$ Table 3. because in the span of 174 days the data of cases of TB patients observed with the smallest divisor factor of 2, there will be 87 data from each n. Likewise, for $n = 29$ has a value $\left(\frac{R}{S}\right)$, which is six which is then taken as an average as shown in Table 3. If the value (R/S) is know n, then the log $\left(\frac{R}{S}\right)$ can be determined. For n that has more than one value $\left(\frac{R}{S}\right)$, the average value of the value (R/S) can be determined. Furthermore, from the results of the calculation of $\log(n)$ and $\log\left(\frac{R}{S}\right)$, a regression line is constructed as shown in Figure 1., where the $\log(n)$ is the x-axis and the $\log\left(\frac{R}{S}\right)$ is the y-axis.

Table 3. Summary of Calculation of Case Data of Tuberculosis Patients

N	Log n	(R/S)		Log (R/S)	H
		(R/S) every n	Average (R/S)		
174	2,241	1,697	1,697	0,230	0,475
87	1,940	1,702	2,384	0,377	
		3,065			
29	1,462	3,371	2,779	0,444	
		1,765			
		3,917			
		3,333			
		2,309			
		1,980			

From Table 3. above, the *Hurst* exponent value (H) can be found from the regression equation, namely $\log\left(\frac{R}{S}\right) = -0{,}543 + 0{,}475\log(n)$. The *Hurst* exponent value obtained from the regression equation is $H = 0{,}475$. Figure 1. is a graph formed from the log value $\left(\frac{R}{S}\right)$ and the $\log(n)$ which is the slope of the regression line.

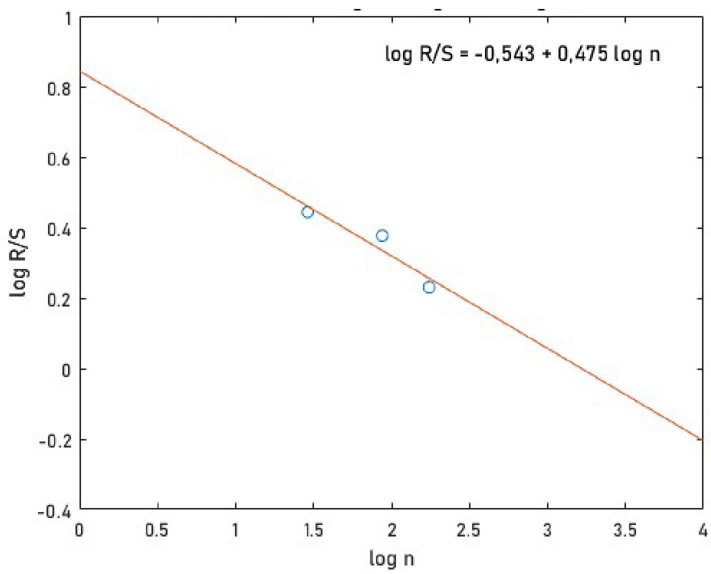

Figure 1. Graphic Regression Line log n and log R/S

From Figure 1. which has been obtained based on the log value of R/S as the y-axis and log n as the x-axis can be concluded that if the log value n is positive and the slope of the regression line is negative, it means that for every increment of one unit on the log n, the log value of R/S will decrease. This means that the log n value and the log R/S have a negative regression line relationship, where an increase in the log value n results in a decrease in the log value of the R/S.

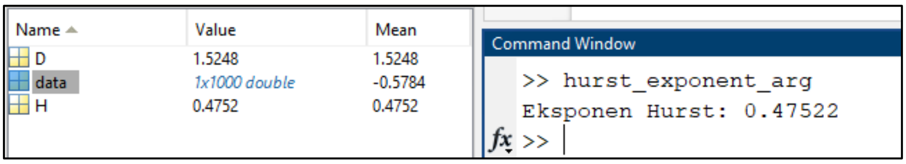

Figure 2. Results of *Hurst* exponential value calculation using Matlab Software

3.2. Determination of the Value of Fractal Dimension From the Calculation of *Hurst's* Exponent Value

The value of fractal dimensions can be calculated using equation (6) with the number of cases of TB as many as 174 (days). So that the value of the fractal dimension is obtained through equation (6), namely $D = 2 - H$, then $D = 2 - 0{,}475 = 1{,}525$. The value of this fractal dimension was obtained based on the results of the calculation of the *Hurst* exponent (H) value at 174 days, this data shows that the data is *anti-persistence*. Figure 3. is a graphical view of the data of TB cases for 174 days.

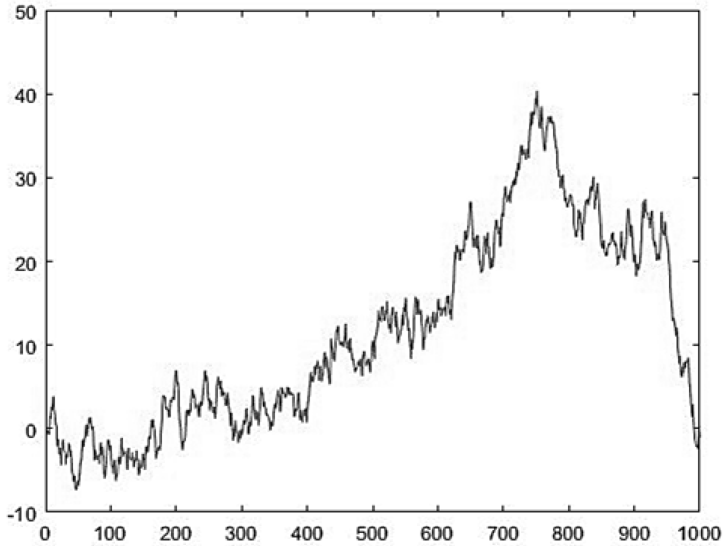

Figure 3. Graph of randomness of data on the time series of cases of TB for 174 days

The results obtained from the prediction model with the *Hurst* exponent fractal dimension method can be concluded that the two show a strong relationship. The mathematical approach of the *Hurst* exponent fractal dimension method can both be applied to predict the movement of the number of time series data in the form of cases of TB as one of the infectious diseases in Indonesia. The value of the *Hurst* exponent shown in Table 1, the value of the *Hurst* exponent is less than 0,5 which indicates that the data of TB cases in North Sumatra Province is *anti-persistence*. *Anti-persistence* means that the time series data of cases of TB patients which if the data increases at one time, it tends to decrease at the next time and if the data decreases at one time, it tends to increase at the next time. The fractal dimension value obtained from the calculation of the *Hurst* exponent value (H) $0 < \mathrm{H} < 0{,}5$, does not change the characteristics of the fractal object, namely *anti-persistence* because the fractal dimension value (D) resulting from the application of this method is $1{,}5 < D < 2$. The effects of the calculation of the *Hurst* exponent cost acquired in another way from the discovered data can also have an effect on the fee of the fractal dimension acquired. As explained in sub chapter 2.1 related to fractal dimensions, the higher the value of fractal dimensions can indicate that the process fluctuates more than the low value of fractal dimensions from the observed data of TB patients. The fluctuations from the observed data of TB cases are illustrated in Figure 2. The rise and fall in the number of TB cases for six months in 2023 occurred due to one of the factors, namely *Mycobacterium Tuberculosis* bacterial infection. *Mycobacterium Tuberculosis* bacteria can attack anyone so that it can increase the number of sufferers. With the increasing number of TB patients in North Sumatra in 2023, the local government is also still lacking in health service supplies so that each case of TB sufferers is lacking in the process of coping with it.

In Table 2. summary of the calculation of data on TB cases from the North Sumatra Provincial Health Office, it can be seen that the results of 174 days of data starting from July 1-December 31, 2023 with the smallest prime factor divisors are 2, 3 and 29 with $n = 174, \frac{174}{2}, \frac{87}{3}, 29$. For $n = 174$, the $\log n$ value is $2{,}241$, the value $\left(\frac{R}{S}\right)$ is $1{,}697$ with an average of $1{,}697$, and the $\log\left(\frac{R}{S}\right)$ value is $0{,}230$. At $n = 174$ has a value $\left(\frac{R}{S}\right)$ only one because the value covers the entire data. Furthermore, at $n = 87$, the $\log n$ value is 1,940, the $\left(\frac{R}{S}\right)$ value is $1{,}702$ and $3{,}065$ with an average of $2{,}384$, and the $\log\left(\frac{R}{S}\right)$ value is $0{,}377$. When $n = 87$ has a value $\left(\frac{R}{S}\right)$ there are two because the value is the result of the divisor of the smallest prime factor, which is 2. Then at $n = 29$, the $\log n$ value is 1,462, the value $\left(\frac{R}{S}\right)$ is $3{,}371$, $1{,}765$, $3{,}917$, $3{,}333$, $2{,}309$ and $1{,}980$ with an average of $2{,}779$ and the $\log\left(\frac{R}{S}\right)$ value is $0{,}444$. When $n = 29$ has a value $\left(\frac{R}{S}\right)$, there are six because the value is the result of the divisor of the smallest prime factor, which is $2 \times 3 = 6$. It is clear that the value of $\left(\frac{R}{S}\right)$ for each n is found in Table 1. is obtained based on the results of manual calculations that have been carried out, the number of values is in accordance with the smallest prime factor that divides the data.

The final result obtained from the calculation to obtain the value of the *Hurst* exponent, namely from the $\log(n)$ value as the x-axis and $\log\left(\frac{R}{S}\right)$ as the y-axis is built the regression line seen in Figure 1. and the form of a randomness graph of time series data from the data of tuberculosis cases (TB) in Figure 3. with the help of Matlab software version R2024a. This shows that to determine the prediction value using the *Hurst* exponent fractal dimension method, it will obtain a value that is always changing (not fixed) because the research data used is also unstable and can change every certain period of time.

4. Conclusion

Primarily based on the consequences of research that has been accomplished at the prediction of the range of instances of TB in North Sumatra Province by way of making use of the *Hurst* exponent fractal size technique, it is able to be concluded that the effects of the calculation of the *Hurst* exponent price (H) might be used for the calculation of fractal dimensions due to the fact these techniques display a strong dating within the calculation of time series data. The rise and fall in the number of TB cases for six months in 2023 occurred because one of the factors was *Mycobacterium Tuberculosis* bacterial infection. *Mycobacterium Tuberculosis* bacteria can attack anyone so that it can increase the number of sufferers.

The results of the calculation for six months from July-December 2023, with 174 data used through the *Hurst* exponent fractal dimension method, obtained the *Hurst* exponent value $(H) = 0{,}475$ or $0 < H < 0{,}5$ and the fractal dimension value $(D) = 1{,}525$ or $1{,}5 < D < 2$. Where these values are classified based on the characteristics of time series data, which is *anti-persistence* which means that if the data increases at one time, it tends to decrease at the next time and if the data decreases at one time, it tends to increase at the next time. However, the predetermined period can change (unstable) due to factors that affect the fluctuations of TB patients.

Thus, the *Hurst* exponent fractal dimension method is able to predict the rate of TB as one of the infectious diseases in Indonesia using 3 data ranges (n), namely 174, 87 and 29. So it can be said that the *Hurst* exponent fractal dimension method can be used to predict the rate of tuberculosis patients in Indonesia.

5. References

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