Prediction of Life Expectancy in Indonesia by Implementing Website-Based Lagrange Polynomial Interpolation

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Abstract

Life Expectancy (AHH) is a measurement of the average human lifespan accepted and used to assess the quality of health and welfare of a country's population. Accepted to develop a prediction system that can be easily accessed by the general public via a web platform. The method used to predict is the Lagrange polynomial interpolation method. The Lagrange polynomial interpolation method was chosen because it can model irregular numerical data with a fairly high level of accuracy. The data used to predict AHH comes from the Indonesian Central Statistics Agency (BPS). Known data on life expectancy in Indonesia for men from 2020 to 2023 shows 69.59, 69.67, 69.93 and 70.17. Predictions for 2024, 2025 and 2026 respectively show 70.19, 69.79, 68.77 with a Root Mean Squared Error result of 0.085875 or around 8.58% of the total data tested. The results of implementing the Lagrange polynomial interpolation method into an application in the form of this website show that this method is able to provide accurate predictions for life expectancy in Indonesia and can make it easier to use.

Keywords: Interpolasi, Polinom Langrange, Life Expectancy, prediction, lifespan

1   Introduction

Life Expectancy (AHH) is an important indicator used to assess the quality of health and welfare of a country's population. However, understanding and predicting life expectancy trends remains a challenge [1], especially in the context of public policy planning and data-based decision making [2] Developments in the social, economic and technological fields play an important role in determining a country's Life Expectancy

(AHH). According to Sihaloho, life expectancy is a measurement of the expected average human lifespan.

According to data from the World Health Organization (WHO) in 2024, Indonesia is ranked 115th in the world AHH list with an average age of 71.3 years, which is still below the global average of 73.3 years [3]. However, compared with Population Reference Bureau (PPB) data in 2022, Indonesia's AHH experienced a significant increase from 46.45 years in 1960 to 68.25 years in 2022. However, this figure is still relatively low when compared to countries in Southeast Asia.

Along with technological developments, data analysis for AHH predictions can be carried out more accurately and efficiently using various mathematical and computational methods. One method that can be used is Lagrange polynomial interpolation. This method is an interpolation technique that is suitable for estimating unknown values in a data range based on known values. Lagrange polynomial interpolation is an effective mathematical method for making predictions based on existing data.

The Lagrange polynomial interpolation method has several advantages, including its ability to produce accurate results with a limited amount of data and simplicity in implementation. However, this method also has limitations, especially when applied to large datasets or to highly volatile data [2], where the resulting polynomials may become too complex or less accurate [7].

To overcome this challenge, an application was created that uses the Lagrange Polynomial Interpolation method to predict AHH in Indonesia. One system that can be used is a website-based system [9]. The development of a website-based system for implementing the Lagrange polynomial interpolation method in predicting life expectancy offers several advantages [10-12]. The interactive and easily accessible website allows users from various groups, including policy makers, academics, and the general public, to make practical use of this prediction tool. In addition, integration with dynamic databases and user-friendly interfaces can increase the effectiveness of using this method on a wider scale [14].

To overcome this challenge, a website-based application is needed that uses the Lagrange polynomial interpolation method to predict AHH in Indonesia [15]. Website-based system development offers several advantages, including easy and interactive

access for users from various circles, as well as integration with dynamic databases and a user-friendly interface. With this system, it is hoped that it can help in providing more accurate and up-to-date information regarding AHH, thus supporting better decision making in various sectors.

2 Material and Methods

There are two methods used to implement Lagrange Polynomial Interpolation to Predict Life Expectancy in Indonesia Based on Province and Gender. The first method is the literature study method and the second method is the Lagrange polynomial interpolation method.

Literature Study Method

The library study method, also known as library research, is a data collection technique used to understand and study theories from various literature related to the research [16]. This method is used to look for references related to the research to be carried out and becomes a benchmark in carrying out the research stages [17]. This method is also used in collecting test data related to research.

Lagrange Polynomial Interpolation Method

Lagrange polynomial interpolation comes from a numerical analysis of interpolation. Interpolation is the process of finding and calculating the value of a function whose graph passes through a certain set of points [7]. Because it uses functions in polynomial form, Lagrange interpolation is a polynomial interpolation that is very well known in numerical methods [8]. Lagrange interpolation is used to obtain a polynomial function (x) of a certain degree that passes through a number of data points [18]. For example, look for a polynomial function of degree one or order 1 that will pass through two points [19], namely (x_2, y_2) and (x_1, y_1), then it can be [21] written with the linear equation in equations 1 and 2.

$$y_0 = a_0 + a_1 x_0 \tag{1}$$

$$y_1 = a_0 + a_1 x_1 \tag{2}$$

Equations (1) and (2) are then eliminated and produce equation 3

$$a_1 = \frac{y_1 - y_0}{x_1 - x_0} \tag{3}$$

The result of equation (1) is then substituted

$$y_0 = a_0 + a_1 x_0$$

$$y_0 - a_1 x_0 = a_0$$

$$a_0 = y_0 - \left(\frac{y_1 - y_0}{x_1 - x_0}\right) . x_0 \tag{4}$$

Then substitute equations (3) and (4) into linear functions

$$
\begin{aligned}
f(x) \; &= a_0 + a_1 x \\
&= \left(y_0 - \left(\frac{y_1 - y_0}{x_1 - x_0}\right) . x_0\right) + \left(\frac{y_1 - y_0}{x_1 - x_0}\right) . x \\
&= y_0 + \left(\frac{y_1 - y_0}{x_1 - x_0}\right) . (x - x_0) \\
&= \frac{y_0(x_1 - x_0) + (y_1 - y_0)(x - x_0)}{x_1 - x_0} \\
&= \frac{y_0 x_1 - y_0 x_0 + y_1 x - y_1 x_0 - y_0 x + y_0 x_0}{x_1 - x_0} \\
&= \frac{(x_1 - x) . y_0 + (x - x_0) . y_1}{x_1 - x_0} \\
&= \frac{(x_1 - x)}{(x_1 - x_0)} . y_0 + \frac{(x - x_0)}{(x_1 - x_0)} . y_1 \\
&= \frac{(x - x_0)}{(x_0 - x_1)} . y_0 + \frac{(x - x_1)}{(x_1 - x_0)} . y_1 \\
&= L_0(x) y_0 + L_1(x) y_1
\end{aligned}
$$

So equation 5 is a Lagrange polynomial of degree 1.

$$P_1(x) = \sum_{i=0}^{1} L_1(x) y_1 \tag{5}$$

And for equation 6 the degree is more than 1.

$$L_i(x) = \prod_{\substack{j=0 \\ j \neq 0}}^{x} \frac{(x - x_j)}{(x_i - x_j)} = \frac{(x - x_0)(x - x_1)...(x - x_{i-1})(x - x_{i+1})...(x - x_n)}{(x_i - x_0)(x_i - x_1)...(x_i - x_{i-1})(x_i - x_{i+1})...(x_i - x_n)} \tag{6}$$

Equations 5 and 6 are implemented in calculations using Excel [22]. If the prediction calculation results have a small mean error, then the Lagrange polynomial interpolation calculation will be implemented in the Java Script programming language to display in the form of an application in the form of a website.

3   Results and Discussions

Data collection

Data collection for the Life Expectancy Rate test was obtained from the Indonesian Central Statistics Agency (BPS), where three data were taken, namely based on gender, birth and national parameters. The data obtained will be categorized into four categories, namely:

a. Data on Indonesian Life Expectancy Rates for Male 2020-2023
b. Data on Indonesian Life Expectancy Rates for Female Gender 2020-2023
c. Data on Indonesian Life Expectancy at Birth, Male, 2020-2023
d. Data on Indonesian Life Expectancy at Birth, Female Gender, 2019-2023

Tabel 1 shows the highest value in 2023 of 70.17 and is likely to increase in the following year considering the development of media and the level of health awareness based on male gender, and of 74.18 on female gender in Tabel 2. Similarly, gender for birth prediction also has the highest level in 2023 for both males and females as shown in Tables 3 and 4.

Table 1. Data on Indonesian Life Expectancy Rates for Male

Year	Data on Life Expectancy for Men
2020	69.59
2021	69.67
2022	69.93
2023	70.17

Table 2. Data on Indonesian Life Expectancy Rates for Female

Year	Data on Life Expectancy for Woman
2020	73.46
2021	73.55
2022	73.86
2023	74.18

Table 3. Data on Life Expectancy for Birth Male genital

Year	Data on Life Expectancy for Birth Male genital
2020	71.25
2021	71.30
2022	71.46
2023	71.61

Table 4. Data on Life Expectancy on Life Expectancy for Birth Male genital

Year	Data on Life Expectancy for Birth Male genital
2020	75.60
2021	75.72
2022	76.05
2023	76.37

Data Processing

Based on the data that has been obtained, the data is then calculated using the Lagrange polynomial interpolation method to predict Life Expectancy in Indonesia from 2024 to 2026. To predict 2024, the Lagrange polynomial interpolation calculation uses Lagrange interpolation 4 or order 4. Table 5 is the result. AHH predictions in Indonesia in 2024 for males.

It can be seen that the AHH prediction for 2024 for male gender in Indonesia is at the age of 70.19 years. The results were obtained from the addition of Lagrange interpolation of orders 1 to 4 from the available data. To find the AHH prediction for 2025, the 2024 prediction results will be used as calculation data. And to find the AHH prediction for 2025, the 2024 and 2025 prediction data will also be used as calculation data.

Table 5. AHH Prediction Results in Indonesia in 2024 for Male Gender

i	Year	x	f(xi)	L1	L2	L3	L4
0	2020	1	69.59				
1	2021	2	69.67	-69.59	278.68	-419.58	280.68
2	2022	3	69.93				
3	2023	4	70.17				
4	2024	5	70.19				

Table 6. Result prediction AHH Indonesia in 2025 for male gender

i	year	x	f(xi)	L1	L2	L3	L4	L5
0	2020	1	69.59					
1	2021	2	69.67					
2	2022	3	69.93	69.59	-348.35	699.3	-701.7	350.95
3	2023	4	70.17					
4	2024	5	70.19					
5	2025	6	69.79					

Based on Table 6, the prediction of AHH in Indonesia for male gender in 2025 shows AHH is 69.79 years old. And to find out the prediction of AHH in 2026, the prediction data obtained in 2025 will be used. Lagrange interpolation used in the calculation uses order 6.

By using Lagrange polynomial interpolation of order 4 to 6, you can find out the predicted life expectancy for men in Indonesia in 2024 to 2025 with respective prediction results of 70.19 for 2024, 69.79 for 2025 and 68.77 for 2026. These calculations apply to other test data and the following are the prediction results for other test data. AHH Prediction Results in Indonesia for Female Gender are shown in Fig. 1 and Male in Fig. 2. Fig. 3 shows AHH Prediction Results in Indonesia for Birth Female Genital.

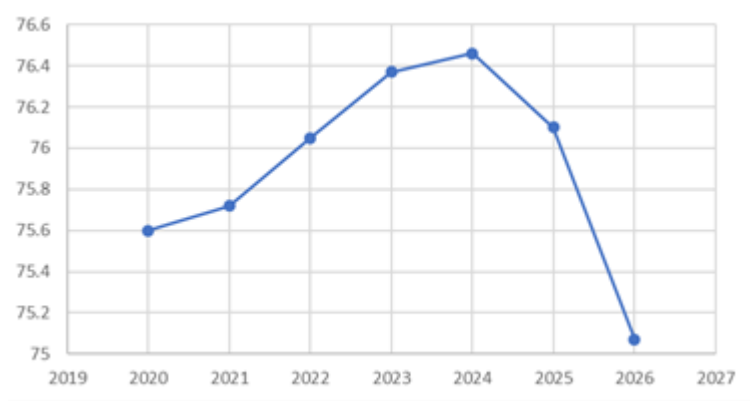**Table 7.** Result prediction AHH Indonesia in 2026 for male gender

i	year	x	f(xi)	L1	L2	L3	L4	L5	L6
0	2020	1	69.59						
1	2021	2	69.67						
2	2022	3	69.93	-69.59	418.02	-1048.95	1403.4	-1052.85	418.74
3	2023	4	70.17						
4	2024	5	70.19						
5	2025	6	69.79						
6	2026	7	68.77						
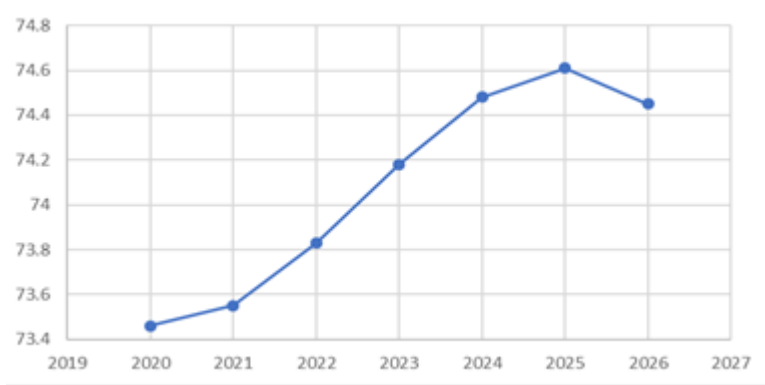
Figure 1. AHH Prediction Results in Indonesia for Female Gender
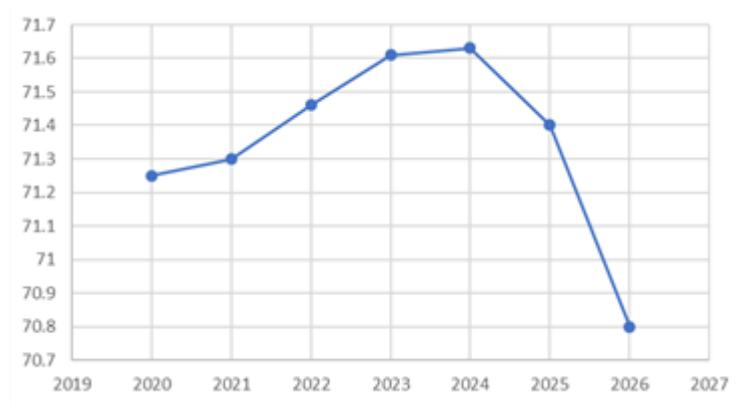
Figure 2. AHH Prediction Results in Indonesia for Male Gender

Figure 3. AHH Prediction Results in Indonesia for Birth Female Genital

Root Mean Squared Error Testing

Based on the calculation results of the predicted life expectancy in Indonesia for 2024-2026, an error test was carried out using the Root Mean Squarred Error (RMSE) method. Where the RMSE value is used to measure the average size of the error to find out whether the calculation method used is working well or not. In RMSE testing, actual data and predicted data are needed so that it is based on the data obtained and [7] predictions that have been made. RMSE testing can only be carried out until 2023. For the following year, we must first wait for actual data on Indonesia's life expectancy, which uses Equation 7.

$$RMSE = \sqrt{\frac{\Sigma(Aktual-Prediksi)^2}{n}} \tag{7}$$

The results of the RMSE test for predicting life expectancy in Indonesia using the Lagrange polynomial interpolation method are shown in Table 8. Based on Table 8, it can be concluded that the RMSE value for predicting life expectancy in Indonesia using the Lagrange polynomial interpolation method based on four categories from 2019-2023 falls within the provisions of the RMSE test results, namely Moderate with an average RMSE of 0.085875 or around 8.58%.

Implementation

After carrying out calculations and testing errors using the RSME method, the next step is to implement the process that has been carried out into an application in the form of a website. Home and preview interfaces can be seen in Figs. 4 and 5, respectively.

Table 8. RMSE Test Results for Life Expectancy in Indonesia

AHH	RSME	RSME Mean
Data 1	0,124	
Data 2	0,082	0,085875
Data 3	0,045	
Data 4	0,0925	
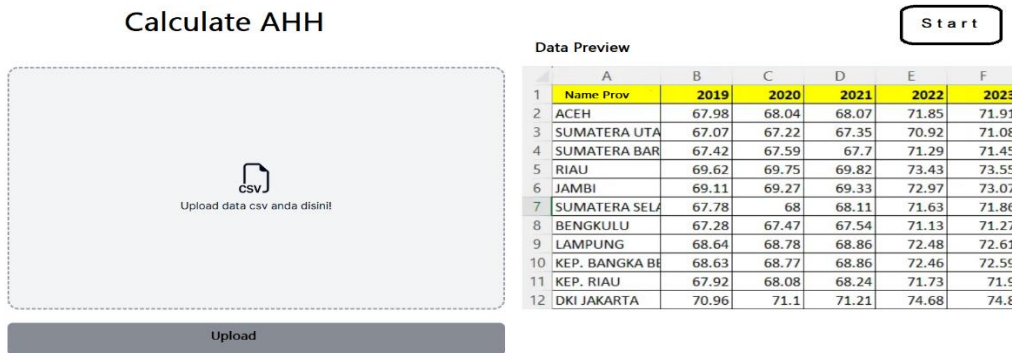
Figure 4. Home interface

Figure 5. Preview Interface

In the Home section, there is a Navbar that says "Numerical Analysis", and there is a footer that has 2 buttons "home" and "About". Next, there is an area for uploading the CSV file that you want to calculate, as well as a guide on how to use the application for users.

In the preview section, before the user performs calculations, there is a preview table sourced from the .csv file uploaded by the user. Users can perform calculations with the "Calculate" button, and there are options for the number of interpolations desired by the user.

In the calculation results section, there is a graph and table of results that will appear from the CSV file that has been calculated by the website. This website is able to calculate

Figure 6. Display graphs visualization of calculation results

predictions for more than 3 years in the future according to the number of predictions selected in the number of interpolation options. Display graphs visualization of calculation results are shown in Fig. 6.

4 Conclusions

It can be concluded that life expectancy in various provinces in Indonesia has increased consistently from 2019 to 2024. Although there are variations between provinces, data that frequently appears shows a significant increase in population life expectancy, reflecting improvements in overall health and quality of life. Based on the calculation results, it shows that women tend to have a higher life expectancy than men in each province, and this gender difference is relatively stable from year to year. The average prediction of AHH based on gender in Indonesia shows an increase and decrease. This increase and decrease occurs in every data used and also in every calculation tool used.

It can be concluded that in terms of the calculation tool used, the Lagrange polynomial interpolation method can be implemented to predict life expectancy in Indonesia because it has a Root Mean Squared Error with a value of 0.085875 or around

8.58%, which means it is included in the moderate category, which means the prediction results are included in the category which can be good [8]. And implementing Lagrange polynomial interpolation on an application in the form of a website can make it easier to carry out calculations automatically.

Acknowledgements

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