A Comparative Study of Lagrange And Gregory Forward Interpolation Techniques For Estimating New Student Enrollment Trends In Faculty of Tarbiyah At IAIN Kediri

Ahmad Syamsudin[1], M. Syamsul Ma'arif[2]

[1]Tadris Matematika, IAIN Kediri
[2]Pendidikan Bahasa Arab, IAIN Kediri
***Correspondence**: syamsudin@iainkediri.ac.id

Abstract

Penelitian ini bertujuan untuk mengeksplorasi penggunaan metode interpolasi polinom Lagrange dan interpolasi polinom Newton-Gregory forward dalam mengestimasi tren pendaftaran mahasiswa baru di beberapa program studi di Fakultas Tarbiyah IAIN Kediri. Data historis pendaftaran mahasiswa baru selama lima tahun terakhir digunakan sebagai dasar analisis. Metode penelitian ini menggunakan pendekatan kuantitatif dengan desain deskriptif dan komparatif. Pendekatan deskriptif digunakan untuk menggambarkan tren pendaftaran mahasiswa baru, sedangkan pendekatan komparatif digunakan untuk membandingkan akurasi prediksi antara kedua metode interpolasi. Hasil penelitian menunjukkan bahwa interpolasi Gregory Forward umumnya memberikan hasil yang lebih akurat dibandingkan interpolasi Lagrange, terutama untuk program studi seperti Manajemen Pendidikan Islam dan Pendidikan Bahasa Arab, dengan nilai MAE, MAPE, dan RMSE yang lebih rendah. Namun, interpolasi Lagrange menunjukkan performa yang lebih baik pada beberapa program studi, seperti Tadris Bahasa Indonesia dan Tadris IPA. Misalnya, untuk program studi Tadris Bahasa Indonesia, interpolasi Lagrange memiliki MAE sebesar 6.8, MAPE 1%, dan RMSE 13.05, yang secara signifikan lebih rendah dibandingkan dengan metode Gregory Forward. Kesimpulan dari penelitian ini menunjukkan bahwa tidak ada satu metode yang selalu unggul untuk semua program studi. Oleh karena itu, pemilihan metode interpolasi yang paling sesuai harus didasarkan pada karakteristik data spesifik dari setiap program studi. Penelitian ini memberikan kontribusi penting dalam bidang perencanaan akademik dengan menyediakan model prediksi yang lebih akurat, yang diharapkan dapat meningkatkan efisiensi dan efektivitas pengelolaan sumber daya di Fakultas Tarbiyah IAIN Kediri.

This study was aim to explore the Lagrange polynomial and Newton Gregory Forward polynomial interpolation methods in estimating new student enrollment trends in several study programs at the Faculty of Tarbiyah, IAIN Kediri. Historical data on new student enrollments over the past five years was analyzed. This research employs a quantitative approach with descriptive and comparative designs. The descriptive approach is used to depict new student enrollment trends, while the comparative approach compares the prediction accuracy between the two interpolation methods. The results indicate that the Gregory Forward interpolation generally provides more accurate results than the Lagrange interpolation, particularly for study programs such as Islamic Education Management and Arabic Language Education, as evidenced by lower MAE, MAPE, and RMSE values. However, the Lagrange interpolation performs better in some study programs, such as Indonesian Language Teaching and Natural Sciences Teaching.

For example, the Lagrange interpolation for the Indonesian Language Teaching program has an MAE of 6.8, MAPE of 1%, and RMSE of 13.05, significantly lower than the Gregory Forward method. The conclusion of this study suggests that no single method is consistently superior for all study programs. Therefore, selecting the most appropriate interpolation method should be based on the specific data characteristics of each study program. This research contributes significantly to academic planning by providing a more accurate predictive model, which is expected to enhance the efficiency and effectiveness of resource management at the Faculty of Tarbiyah, IAIN Kediri.

INTRODUCTION

Estimating trends in new student enrollment is crucial in academic planning and resource management in higher education institutions. The ability to predict the number of new student enrolments allows institutions to manage budgets, faculty, and support facilities more effectively. For example, research by (Wang et al., 2017) Shows that accurate predictions can help institutions optimize classroom use and budget allocation.

The Faculty of Tarbiyah IAIN Kediri, as one of the faculties with various study programs, faces challenges in forecasting the trend of new student registration every year (Syamsudin, 2020). Based on data from the Higher Education Database (PDDIKTI), the trend of new student registration at the Faculty of Tarbiyah IAIN Kediri shows significant variations between study programs in the last five years (Purnomo, 2022). This trend reflects the dynamics of demand for the study programs offered and the changing preferences of prospective students. (Kemdikbud, 2024).

Gregory Advance's Lagrange and Newtonian polynomial interpolation methods offer a mathematical approach to estimating registration trends based on historical data (Muhammad Julian et al., 2022). Lagrange interpolation has been used to estimate income generation from student fees, though enrollment trends can fluctuate, affecting income predictions (Kira, 2019). Research by Gautschi in his book Numerical Analysis: An Introduction highlights the effectiveness of the Lagrange method in a wide range of scientific applications. However, it also notes its weaknesses in dealing with large

fluctuations in data (Gautschi, 2012). Lagrange interpolation works by constructing a polygon that passes through all existing data points, making it particularly effective for data with a linear or slightly nonlinear trend.

The Gregory Forward interpolation method is relatively easy to understand and implement, especially for evenly distributed data (Almira et al., 2023). In many cases, the Newton-Gregory Forward method exhibits a relatively lower error rate compared to other interpolation methods, such as backward interpolation. For example, in population estimation studies, the average relative error for this method has been recorded as lower than that of the backward method (Firanto & Idayani, 2023). Research by (Bocher et al., 1994) Shows that Gregory Forward interpolation can reduce prediction errors in high-fluctuating data. Although more stable, this method may be more complex in its calculations than Lagrange interpolation. These two methods were chosen based on the need for a solution that could handle different types of historical data trends—from linear to significant fluctuations. By comparing these two methods, it is hoped that the most suitable table method can be applied at the Faculty of Tarbiyah IAIN Kediri.

Previous studies have shown the importance of selecting the proper interpolation method for predicting new student enrollment trends. According to research by (Chen, 2002) Using inappropriate interpolation methods can result in less accurate predictions, ultimately affecting academic planning and resource allocation. For example, research by (CHENG et al., 2008) Indicates that errors in enrollment predictions can lead to shortages or overuse of teaching staff, negatively impacting education quality. At the Faculty of Tarbiyah IAIN Kediri, inaccuracies in the prediction of new student enrollment can cause an imbalance in the allocation of resources between different study programs. Moreover, a unique method is required if each study program's conditions differ from what happened in the Tarbiyah faculty (Syamsudin, 2022).

This study explores how the Lagrange polypolation method and Newton-Gregory forward polynomial interpolation can be used to estimate the trend of new student enrollment in several study programs at the Faculty of Tarbiyah IAIN Kediri based on historical data analysis. It is hoped that obtaining accurate mathematical models from both methods can provide more reliable predictions. The prediction results of these two methods will be compared to determine the best model based on the error. This research is expected to provide recommendations for more accurate and reliable methods to be

used in academic planning at the Faculty of Tarbiyah IAIN Kediri so that it can improve the efficiency and effectiveness of faculty resource management.

METHODS

This study explores how the Lagrange interpolation method and the Newton-Gregory forward interpolation method can be used to estimate the trend of new student registrations in several study programs at the Faculty of Tarbiyah IAIN Kediri. This study uses a quantitative research design with descriptive and comparative (Ahadiyah & Dewi, 2022) and examines data from 2019 to 2023. The descriptive approach was used to describe the trend of new student enrollment based on historical data. In contrast, the comparative approach was used to compare the prediction accuracy between the Lagrange and Newton-Gregory forward interpolation methods.

Data Collection Methods

The data collection method in this study utilized secondary resource obtained from the Higher Education Database (PDDIKTI), which is the official source of higher education data in Indonesia. The data collected included the number of new student admissions in the Faculty of Tarbiyah at IAIN Kediri during the period from 2019 to 2023. This data encompasses the number of new students enrolled in each study program under the Faculty of Tarbiyah, such as Islamic Education Management, Arabic Language Education, Indonesian Language Education, and Science Education.

Primary data were obtained through interviews with academic staff to gather information on factors influencing fluctuations in admissions each year, new policies affecting enrollment, and their perspectives on future enrollment trends. This data was then used to explore trends in new student admissions and to predict future trends using the Lagrange polynomial interpolation method and the Newton-Gregory forward interpolation method. In data processing, a quantitative analysis method was used to compare the accuracy of the predictions from both interpolation methods. Indicators used to measure the accuracy of the predictions include MAE (Mean Absolute Error), MAPE (Mean Absolute Percentage Error), and RMSE (Root Mean Square Error).

Data Description

The data used in this study include the following variables:

- Number of New Student Registrations: The number of new students who register yearly for each study program at the Faculty of Tarbiyah IAIN Kediri. This data will be used as a dependent variable in the interpolation analysis.

- Year: The academic year in which new student enrollment occurs. This variable will be used as an independent variable in the interpolation analysis.

- Study Programs: Study programs at the Faculty of Tarbiyah IAIN Kediri, such as Manajemen Pendidikan Islam (Islamic Education Management), Pendidikan Agama Islam (Islamic Religious Education), Pendidikan Bahasa Arab (Arabic Language Education), Pendidikan Guru MI (Elementary School Teacher Education), Tadris Bahasa Indonesia (Indonesian Language Teaching), Tadris Bahasa Inggris (English Language Teaching), Tadris IPA (Science Teaching), Tadris Matematika (Mathematics Teaching). This variable will be used to group data and analyze per study program. Using these variables, this study will evaluate the accuracy of the prediction of the Lagrange and Newton-Gregory forward interpolation methods and provide recommendations for better academic planning at the Faculty of Tarbiyah IAIN Kediri.

Data Processing

The data that has been collected will be processed using two interpolation methods, namely Lagrange polynomial interpolation and Newton-Gregory forward polynomial interpolation. Additionally, the speed of convergence in terms of iterations for both methods will be compared to provide a more comprehensive analysis.

- Polinom Lagrange Interpolation
  Lagrange's polynomial interpolation is similar to Newton's polynomial, but it does not use a finite form of differentiation. Lagrange polynomial interpolation can be obtained from Newton's equations (Munir, 2006). This method is applied to find a specific degree polynomial function that passes through several data points. In general, the formula for Lagrange polynomial interpolation of degrees (requires points) is as follows:

$$P_n(x) = a_0 L_0(x) + a_1 L_1(x) + a_2 L_2(x) + \cdots + a_n L_n(x) \tag{1}$$

Where $a_i =$ y_i, $i = 0,1,2,3,\ldots n$

$$L_i(x_j) = \prod_{\substack{j=0 \\ j \neq i}}^{n} \frac{(x-x_j)}{(x_i-x_j)} = \frac{(x-x_0)(x-x_1)\ldots(x-x_{i-1})(x-x_{i+1})\ldots(x-x_n)}{(x_i-x)(x_i-x_i)\ldots(x_i-x_{i-1})(x_i-x_{i+1})\ldots(x_i-x_n)} \tag{2}$$

The data processing process with Lagrange interpolation goes through several steps: 1) Determining the Lagrange interpolation polynomial based on historical data. 2) Using the polynomial to predict the number of new student registrations in the following year.

● The polynomial of Newton and Gregory

Forward Gregory Interpolation is one of the polynomial interpolation methods used to estimate the value of a function based on several known data points. This method is also known as the forward Newtonian interpolation method because it uses Newton's formula for polynomials in the forward form (Laksono et al., 2018). The Basic Principle of Interpolation Gregory Forward uses a forward difference Table to construct interpolation polynomials. In Gregory Advance's interpolation, the interpolation polynomials are expressed in the equation:

$$P_n(x) = y_0 + \Delta y_0 \frac{(x-x0)}{h} + \frac{\Delta^2 y_0}{2!} \frac{(x-x0)(x-x1)}{h^2} + \cdots + \frac{\Delta^n y_0}{n!} \frac{(x-x0)(x-x1)\ldots(x-x_{n-1})}{h^n} \tag{2}$$

Or it can be written,

$$= f_0 + (x-x_0)\frac{\Delta f_0}{1!h} + (x-x_0)(x-x_1)\frac{\Delta^2 f_0}{2!h^2} + \ldots + (x-x_0)(x-x_1)\ldots(x-x_{n-1})\frac{\Delta^n f_0}{n!h^n} \tag{3}$$

Or

$$p_n(x) = f_0 + \frac{s}{1!}\Delta f_0 + \frac{s(s-1)}{2!}\Delta^2 f_0 + \ldots + \frac{s(s-1)(s-2)\ldots(s-n+1)}{n!}\Delta^n f_0$$
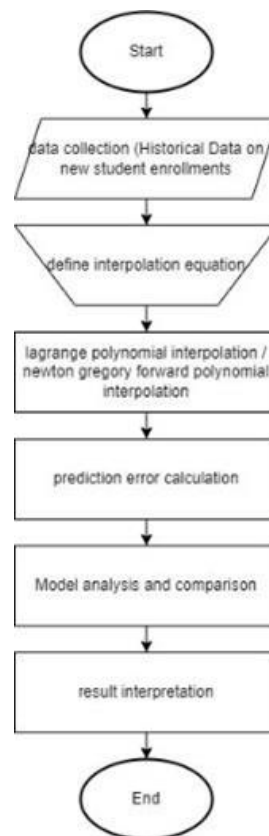
$$= \sum_{k=0}^{n}\binom{s}{k}\Delta^k f_0, \text{ while } \binom{s}{0} = 1, \binom{s}{k} = \frac{s(s-1)(s-2)\ldots(s-k+1)}{k!} \tag{4}$$

Table 1. Newton's Forward Gregory

i	X	f(x)	Δf	Δ²f	Δ³f	Δ⁴f
0	x_0	f_0	Δf_0	$\Delta^2 f_0$	$\Delta^3 f_0$	$\Delta^4 f_0$
1	x_1	f_1	Δf_1	$\Delta^2 f_1$	$\Delta^3 f_1$	
2	x_2	f_2	Δf_2	$\Delta^2 f_2$		
3	x_3	f_3	Δf_3			
4	x_4	f_4				

Where:

- $f_0 = f(x_0) = y_0$ is the value of the function at the starting point.
- y_0 is the difference between the first, second, and nth advances.
- h is the interval between data points.

Figure 1. Flowchart for Predicting New Student Enrollment Trends

The data processing process with Newton-Gregory forward interpolation begins with 1) determining the polynomial based on historical data. 2) Using the polynomial to predict the number of new student registrations in the following year.

Prediction Error Calculation

The prediction error calculation is a critical step in assessing the accuracy of the interpolation methods. This process involves comparing the predicted enrollment Figures generated by the Lagrange and Newton-Gregory Forward interpolation methods with the actual historical data. The primary indicators used for this comparison include Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Root Mean Squared Error (RMSE) are commonly used metrics (Sari et al., 2023); (Lodetti et al., 2022). (Khair et al., 2017) found MAPE useful for evaluating time series and trend data forecasts

MAE measures the average magnitude of the errors in a set of predictions without considering their direction with the MAE formula below

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}| \qquad (5)$$

where:

- n is the total amount of data,
- y_i Is the actual value,
- $\hat{y}_i$ is the predicted value.

MAPE calculates the relative error to provide a better view of the magnitude of the error.

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}}{y_i}\right| \qquad (6)$$

Mean Squared Error (MSE) is a common metric used to measure the average of the squared differences between the predicted values and the actual values. It indicates how well a model predicts an outcome by penalizing larger errors more heavily. MSE Formula

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \qquad (7)$$

RMSE, as the square root of MSE, offers a measure of the spread of the errors and maintains the same unit as the original data, making it easier to interpret. RMSE formula below

$$RMSE = \sqrt{MSE} \quad (7)$$

Statistical analysis

Statistical analysis plays a pivotal role in evaluating the predictive accuracy of each interpolation method. By analyzing the values of MAE, MSE, and RMSE, researchers can gauge which method yields predictions closer to the actual data. Lower values in these error metrics indicate a higher accuracy level. Comparing these error metrics across interpolation methods will help identify the superior method. This comparison is essential for providing reliable recommendations to the Faculty of Tarbiyah IAIN Kediri. The goal is to adopt the most accurate method to enhance academic planning, resource allocation, and overall management of student enrollment processes, thereby optimizing the institution's operational efficiency.

RESULT AND DISCUSSION

Data Description

Based on data from PDDikti, a Table of historical data on new student registration at the Faculty of Tarbiyah IAIN Kediri for 2019 to 2023 was obtained. The following are details of registration data per study program as shown in Table 2 below (Kemdikbud, 2024)

Table 2. New Student Admission Data of the Faculty of Tarbiyah IAIN Kediri

No	Study Program	2019	2020	2021	2022	2023
1	Islamic Education Management	329	475	560	580	591
2	Islamic Religious Education	1822	1764	1756	1435	1191
3	Arabic Language Education	402	492	558	558	492
4	Elementary School Teacher Education	278	405	531	585	584
5	Indonesian Language Teaching	0	29	94	175	255
6	English Language Teaching	931	921	905	806	672
7	Science Teaching	0	23	71	125	175
8	Mathematics Teaching	262	344	411	406	400

Implementation Results

At this stage, the calculation of the interpolation of the Lagrange polynomial and Newton Gregory advances will be carried out using historical data from the period 2019 to 2023 that has been obtained previously from PDDikti. This stage is essential so that the accuracy of the calculation of the two interpolations using the Python programming language with Google Collaboration tools is known. This process uses the cross-validation method by deleting the actual data in the year you want to make the prediction.

Using Python, the results of applying the Lagrange interpolation method with new student admissions data of the Faculty of Tarbiyah IAIN Kediri can be observed in Table 4 below.

Table 4 Lagrange interpolation testing data

No	Study Program	2019	2020	2021	2022	2023	2024
1	Islamic Education Management	475	490	550	595	531	709
2	Islamic Religious Education	1764	1952.25	1630.5	1623.25	438	2167
3	Arabic Language Education	492	502.5	551	568.5	450	402
4	Elementary School Teacher Education	405	427	516.3333333	607	496	633
5	Indonesian Language Teaching	29	29.75	93.5	175.75	252	320
6	English Language Teaching	921	952.25	884.1666667	837.25	547	676
7	Science Teaching	23	25.25	69.5	127.25	166	220
8	Mathematics Teaching	344	376	389.6666667	438	272	592

From Table 4 above, the values generated from 2019-2023 are the prediction values generated by deleting data from the year to be predicted and calculated by Lagrange interpolation. Furthermore, the same thing is also done using advanced Gregory interpolation, as shown in Table 5, so that the accuracy of the data can be compared with actual data.

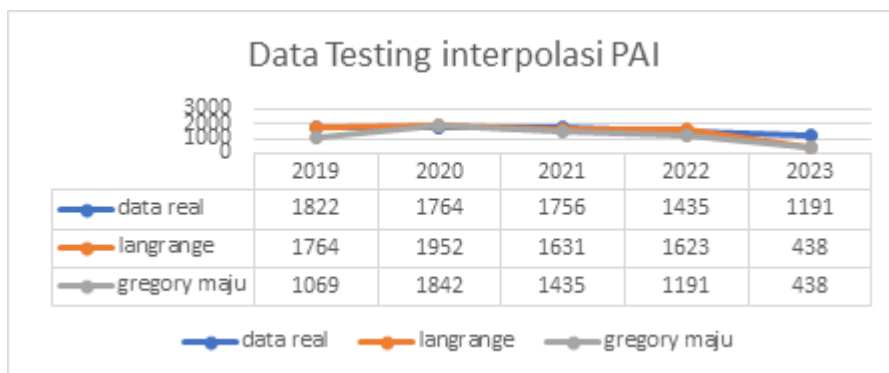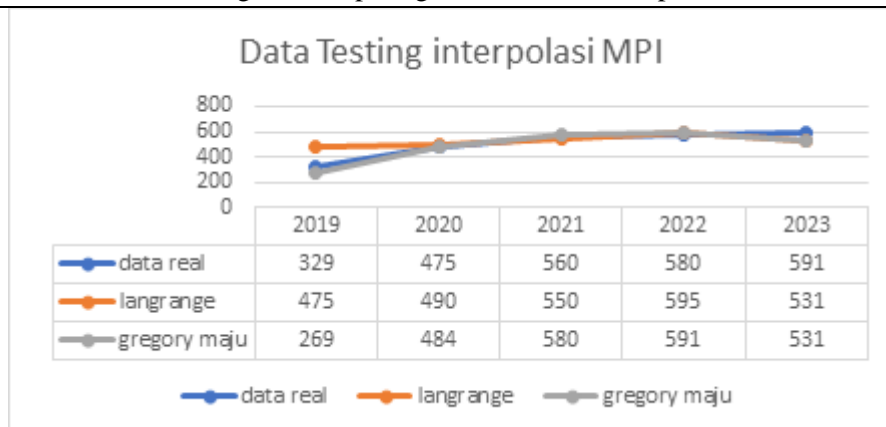**Table 5** Advanced Gregory interpolation testing data

No	Study Program	2019	2020	2021	2022	2023	2024
1	Islamic Education Management	2019	2020	2021	2022	2023	709
2	Islamic Religious Education	269	483.5	580	591	531	2167

3	Arabic Language Education	1069	1841.625	1435	1191	438	402
4	Elementary School Teacher Education	360	505.125	558	492	450	633
5	Indonesian Language Teaching	190	438.375	585	584	496	320
6	English Language Teaching	-3	49.375	175	255	252	676
7	Science Teaching	806	929.5	806	672	547	220
8	Mathematics Teaching	-9	38.4375	125	175	166	592

By Table 2 as data testing, the data will be processed with Python code, and the results are presented in a line diagram as shown in the following table 6.

Table 6 Interpolated Data Testing

Line diagram comparing real data with interpolation

Data Testing interpolasi MPI

	2019	2020	2021	2022	2023
data real	329	475	560	580	591
langrange	475	490	550	595	531
gregory maju	269	484	580	591	531

Data Testing interpolasi PAI

	2019	2020	2021	2022	2023
data real	1822	1764	1756	1435	1191
langrange	1764	1952	1631	1623	438
gregory maju	1069	1842	1435	1191	438
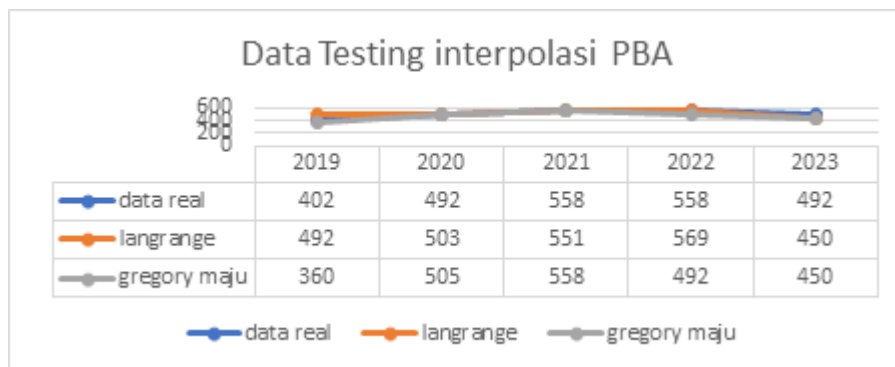
Prediction error calculation

The prediction error can be known using the MAE, MAPE, and RMSE indicators with Python code and the values in Table 7 below.

Table 7 Calculation of the second error of interpolation

No	Study Program	Lagrange Interpolation (			Gregory Forward Interpolation (		
		MAE	MAPE	RMSE	MAE	MAPE	RMSE
1	Manajemen Pendidikan Islam	49.2	12%	71.36666	31.9	7%	39.47974
2	Pendidikan Agama Islam	262.6	19%	362.4912	429.725	29%	510.4156
3	Pendidikan Bahasa Arab	32	7%	45.01888	32.625	7%	40.14042
4	Pendidikan Guru MI	54.73333	15%	70.78999	52.875	13%	62.48022
5	Tadris Bahasa Indonesia	6.8	1%	13.04895	37.475	51%	51.7574
6	Tadris Bahasa Inggris	43.66667	6%	60.18663	98.3	12%	108.7007
7	Tadris IPA	7.6	5%	11.15684	27.4875	47%	34.10665
8	Tadris Matematika	59.06667	17%	71.5697	57.6625	18%	81.58826

From the calculation of the total error in Table 7, for the Tadris Indonesian and Tadris Science study programs, data from the past four years (2020-2023) is used because the program only accepts new students in 2020.

Comparative Analysis of the Two Methods

From the results of the error comparison between Lagrange interpolation and Progressive Gregory interpolation, it can be seen that Progressive Gregory interpolation often gives more accurate results compared to Lagrange interpolation in some cases. For example, for the Islamic Education Management study program, Gregory Forward's interpolation has lower MAE (31.9) and RMSE (39.48) scores compared to Lagrange's interpolation (MAE 49.2 and RMSE 71.37). In addition, the MAPE for Gregory Forward interpolation was 7%, lower than 12% for Lagrange interpolation. This suggests that Gregory Forward's interpolation provides predictions closer to actual values, which means that this method may be more suitable for predicting the data of these study programs. These findings align with Pratiwi's research, which found that the Newton-Gregory Forward method consistently shows a smaller relative error than the Newton-Gregory Backward method, indicating that forward interpolation is more effective in data prediction (Pratiwi et al., 2017).

However, there are some exceptions where Lagrange interpolation is better, especially in the Tadris Indonesian and Tadris Science study programs. For Tadris Indonesian, the Lagrange interpolation has an MAE of 6.8 and an RMSE of 13.05, much lower than the Gregory Forward interpolation, which has an MAE of 37.475 and an RMSE of 51.76. The same goes for Tadris IPA, where the Lagrange interpolation has lower MAE and RMSE (7.6 and 11.16) than Gregory Forward interpolation (MAE 27.4875 and RMSE 34.11).

The Lagrange interpolating polynomial is a well-known method for estimating values within a given dataset, particularly effective for interpolating values based on known data points. However, when it comes to extrapolating future enrollment levels, several challenges arise, which can lead to unreliable predictions. Hal ini dapat terjadi karena The Lagrange polynomial is constructed using all available data points, which means that it can be heavily influenced by the specific values and distribution of these points. These findings are consistent with Hakimah's study, which suggests that while higher polynomial degrees in Gregory Forward interpolation can yield predictions closer to the actual values, they are not always superior to Lagrange interpolation at certain degrees (Hakimah et al., 2020).

CONCLUSION

The study aimed to explore the use of Lagrange polynomial interpolation and Newton Gregory Forward polynomial interpolation in estimating new student enrollment trends across several study programs at the Faculty of Tarbiyah, IAIN Kediri. By analyzing historical data, this research compared the predictive accuracy of both methods to identify the most suitable model based on error metrics. The results show that Gregory Forward interpolation generally provides more accurate predictions, particularly for the Islamic Education Management and Arabic Language Education programs, with lower MAE, MAPE, and RMSE values. These findings align with prior research by Pratiwi et al. (2017), which supports that Newton-Gregory Forward interpolation often yields smaller error rates than backward methods, reinforcing its effectiveness in trend prediction with stable or evenly distributed data.

Conversely, Lagrange interpolation demonstrated superior performance in the Indonesian Language Education and Science Education programs, achieving lower error metrics. This exception is consistent with research by Hakimah et al. (2020), who found that higher polynomial degrees in Gregory Forward interpolation might bring predictions closer to actual values but may not outperform Lagrange interpolation when data exhibits dynamic trend shifts.

This study significantly contributes to academic planning by providing a more accurate predictive model for estimating new student enrollments, enabling IAIN Kediri's Faculty of Tarbiyah to optimize resource management and enhance strategic decision-making. Moreover, it enriches the literature on interpolation applications in educational data analysis, affirming that the choice of interpolation method should match data characteristics for optimal accuracy (Gautschi, 2012; Berrut & Trefethen, 2004). The use of Gregory Forward interpolation may be preferred for data that follow stable trends, while Lagrange may be better suited to data with more dynamic trend patterns.

As a further application, the results of this study can be used by other educational institutions to estimate enrollment trends or other relevant trends based on their historical data. This research also opens up opportunities for further development, such as using other interpolation methods or combinations of methods to improve prediction accuracy. In the future, further research may focus on testing these predictive models with more extended data or on different educational contexts to test the reliability and generalization of the resulting models. The research can also explore using machine learning techniques as an alternative or complement to traditional interpolation methods for predicting educational data.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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