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Modeling Student Performance Metrics in a University Course using Lagrange's Interpolation: A Preliminary Investigation

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Abstract

This study investigates students' academic performance in the university-level course MTM11022: Vector Algebra and Geometry using Lagrange polynomial interpolation. This research was conducted in a controlled academic environment with fixed teaching and syllabus variables; the objective was to model and predict student performance based on historical data from 2015 to 2021. MATLAB software was used for computation and visualization. Data from 2015-2019 were used for interpolation; 2017 was tested for interpolation accuracy, while 2020 and 2021 served as extrapolation cases. Key performance indicators such as Average Marks, Maximum and Minimum Marks, and Pass Rates were evaluated. The results affirm that Lagrange's interpolation offers meaningful insights into students' outcomes when applied within the data range, with moderate limitations in extrapolation. The model showed high accuracy within known data ranges but reduced performance during extrapolation. This study highlights the usefulness of mathematical modeling for educational data analysis and forecasting.

Keywords: Academic Performance, Lagrange's Interpolation Polynomial, MATLAB software, Predictive Modeling, Educational Data Analysis.

1. Introduction

Mathematical modeling in education helps quantify trends in student learning outcomes. Some approaches in this regard can be found in [1] to [5] in the literature. This study investigates academic performance in MTM 11022 and MTM 11222 (Same course under revised curriculum), a Level I, Semester I course, using historical student marks. Factors such as stable curriculum, fixed lecturer, and consistent evaluation methods provide a controlled environment suitable for interpolation-based modeling. The main objective is to explore the effectiveness of Lagrange interpolation in estimating academic indicators such as Average Marks, Maximum Marks, Minimum Marks and Pass Rate and forecasting future performance trends.

2. Methodology

The Lagrange polynomial interpolation method was employed to model academic data. Student marks from the years 2015 to 2019 were used to construct interpolation polynomials. The year 2017 was selected to test interpolation accuracy. Extrapolation was performed for 2020 and 2021 using the same polynomial model. MATLAB software was used to implement the Lagrange interpolation formula and generate academic performance indicators such as Average Marks, Maximum and Minimum Marks, and Pass Rate. Error analysis was performed by comparing predicted values with actual recorded values using absolute percentage error.

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2.1 Data Collection

The sorted data, without the index number of candidates to make sure the confidentiality of marks, used for this study was collected from the Department of Mathematical Sciences, Faculty of Applied Sciences, South Eastern University of Sri Lanka, and covers the period from year 2015 to 2021. The data set contains marks obtained by students in the level I semester I course MTM 11022 and MTM 11222 Vector Algebra and Geometry.

2.2 Lagrange's Interpolation Polynomial Method

The Lagrange polynomial was used to construct an interpolation model and it is obvious that this procedure is quite laborious and Lagrange developed a direct way to find the polynomial

$$P_n(x) = f(x_0)\, L_0(x) + f(x_1)\, L_1(x) + \cdots + f(x_n)\, L_n(x)$$
$$= \sum_{i=0}^{n} fi\; Li(x)$$

where the Lagrange coefficient polynomials

$L_i(x); i = 1, 2, \cdots, n$ are defined by

$$L_i(x) = \frac{(x - x_0)(x - x_1)\cdots(x - x_p)\cdots(x - x_n)}{(x_i - x_0)(x_i - x_1)\cdots(x_i - x_p)\cdots(x_i - x_n)};\ p \neq i.$$

and obviously:

$$L_i(x_k) = \delta_{ik} = \begin{cases} 1 & \text{if} \quad i = k \\ 0 & \text{if} \quad i \neq k \end{cases}$$

Where δ_{ik} is Kronecker's symbol

3. Results and Discussion

Interpolation (2017):

Table 1: The interpolated values closely approximated actual 2017 results

Metric	Actual Value	Predicted Value	Error (%)
Average Marks	45.70	60.67	32.74
Maximum Marks	95.00	99.00	4.21
Minimum Marks	3.00	17.50	483.33
Pass Rate (%)	77.66	86.43	11.29

The Lagrange's model gave a reasonably accurate estimate for Average Marks, Maximum Marks and Pass Rate but less accurate predictions for minimum marks due to greater variance. The Figure 1 graphically interpret the results. It demonstrates good fits for interpolation.

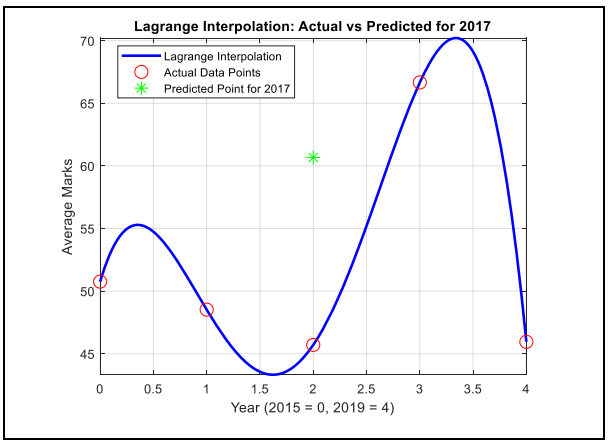

Figure 1: Interpolation curves for each factor.

Extrapolation (2020–2021):

Table 2: Extrapolated predictions showed increasing deviation due to high-order polynomial behaviour

Year	Metric	Actual Value	Predicted Value	Error (%)
2020	Average Marks	54	-171.70	417.9553>100
2020	Maximum Marks	96	-10	110.4167>100
2020	Minimum Marks	8	-126	1675>100
2020	Pass Rate (%)	80	-132.49	265.6155>100
2021	Average Marks	53.22	-831.36	1662.0763>100
2021	Maximum Marks	86	-241	380.2326>100
2021	Minimum Marks	13	-630	4946.1539>100
2021	Pass Rate (%)	92.62	-667.06	820.1912>100

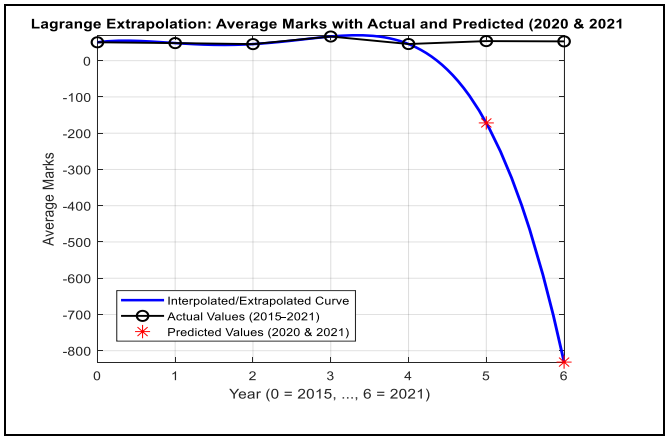

Figure 2: Extrapolation curves for each factor.

Actual vs predicted values (especially for minimum marks and pass rate) diverged significantly, confirming that extrapolation is less reliable.

Extrapolation curves in Figure 2 showed erratic behaviour outside known data boundaries, highlighting polynomial overfitting.

4. Conclusion

Lagrange interpolation is a valid tool for estimating academic performance within a historical dataset. While interpolation results were satisfactory, extrapolation proved less reliable. The study illustrates the potential of using simple mathematical models for academic forecasting, but recommends caution when predicting outside the training data range. Future work could explore spline methods or machine learning models for improved extrapolation accuracy.

5. References

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