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Adaptive Control for Student Grading System: A Linear Control Approach

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***Abstract*—In the realm of the academic performance improvement study delves into the implementation of an adaptive Control mechanism within a student grading system. The background underscores the critical need for a system to optimize student grades by dynamically adjusting study Efforts and improving teaching methodologies. The research aims to address the primary question of how Adaptive systems can positively influence student performance through behavioural and control education. The Methodology employs a Linear Control Approach utilizing Matlab simulations to model student academic performance and faculty guidance mechanisms. Results indicate that the adaptive control system effectively enhances student grades by tailoring educational experiences to individual needs and promoting continuous improvement. Ultimately, this study concludes that adaptive systems play a Pivotal role in guiding student development, fostering academic success, and facilitating a culture of educational excellence.**

***Index Terms*—Adaptive systems, Behavioural systems, Control education, Grade, Matlab Simulation, Feedback Control, Academic Success**

I. Introduction

The future of our country rests in the hands of today's children, who will become tomorrow's citizens. To prepare them for the challenges of an ever-evolving world, it's essential that students not only study hard but also develop the skills to navigate emerging technologies. To support this, we need a system that effectively guides students along their academic journey. In this system, the students' study efforts serve as the input, their grades represent the output, and the faculty act as controllers providing essential guidance on what to study, how to study, and when to focus on specific tasks. Through a combination of both open-loop and closed-loop feedback responses, we can better understand and improve student performance.

This academic grade system is designed to monitor students' progress closely, adjusting strategies based on their unique challenges and needs. It goes beyond just assigning grades by offering continuous feedback to students, parents, and educators. By tracking performance over time, the system helps identify areas where students may need extra support, fostering a path toward continuous improvement. It acknowledges that factors like health, personal challenges, or study habits can affect performance, and works to address those issues in real time.

For instance, if a student struggles with a particular subject, instead of just reflecting a low score, the system adjusts by providing tailored interventions, like additional practice or guidance. This feedback-driven approach is like a coach fine-tuning training for an athlete, ensuring that each student's strengths and weaknesses are considered, helping them to achieve their full potential academically.



Fig. 1: Grades of a Student

II. Literature Survey

Many developments are diving deep into student academics that studies into an in-depth analysis of the intricate factors that influences academic performance among students, while also proposing an effective strategies for enhancing student grades [3]. It gives a high light on the differential impacts of variables such as geographic and psychographics, characteristics on academic outcomes, suggesting an advantage for students stopping from urban environments over their rural counterparts [5]. It underscores the significant role of motivational interventions in elevating student grades, with empirical evidence showcasing notable improvements compared to historical performance metrics [6].

Moreover, the discourse expands to annotate the multifaceted nature of attributes that contribute to academic success, spanning demographic, academic, social, and psychological dimensions. While, the influence of psychological variables is noted to be marginal [4], the text underscores the potential of predictive analytics leveraging methodologies to forecast future academic Performance.

The rendering articulates that the refined influence of so-

cial media, particularly facebook, on academic performance, revealing divergent impacts observed among different student cohorts [12].

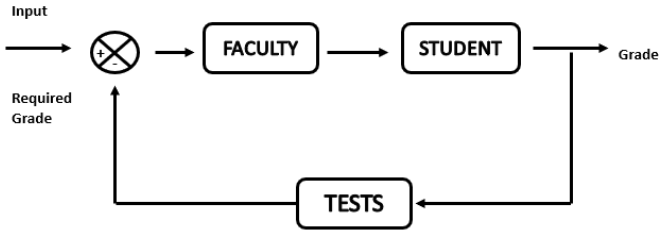


Fig. 2: Block Diagram of the System

The discourse digs into the application of sophisticated fuzzy logic algorithms in discerning the determinants of academic performance, [14] alongside the conceptualization of predictive models tailored categorically for online studying environments. The limitations of the existing models of the current academic system in government and private sector schools include a uniform approach that overlooks individual learning needs of a student, heavy dependency on standardized testing leading to exam-oriented study, a limited scope for personalized learning paths, an inflexible structure that stops the adaptation of evolving methodologies and technology.

III. System

The basic problem addressed in this paper is Optimization of student academic performance by firmly adjusting study efforts and enhancing teaching methodologies. We would like to include a software that could analyse the tests of the student and identify in which topics is the student is weak and strong. Also this software linked will provide the personalized suggestions like what topics to be covered to improve themselves and provides weekly plan and monthly plan for studying dedicatedly for a student. We could also give inputs to software like what kind of a student they are so that it could prepare a customized plan for them. This software is linked to both student as well as the faculty, so that they can monitor them and also add their solutions and experiences for helping the students to become better to best in their studies. Faculty can also add their advice for helping children improve and advance in their studies, tests and exams.

In Fig.1 We can see the grade sheets of a student.This is a typical grade sheet of most of the students. This System mainly aims at studying behaviour of the student how a student refers the faculty and tests are the feedback of system. In Fig.2 we can see block diagram of the system. This block diagram Represents an educational feedback loop system designed to achieve a required grade. The process begins with an Input, which likely refers to the educational materials or instructions provided. This input is processed through an initial control mechanism, which is symbolizes a quality check or standard-setting step, where we fix the standards or grades needs to be achieved by the student is given here . The processed input is then directed to the Faculty, who are responsible for delivering the educational content and support to the Student.

The Student then works to achieve a certain Grade. If the grade achieved meets the Required Grade, the process completes successfully. If not, Feedback is provided. This feedback loop involves analyzing the student's performance and identifying areas for improvement. The feedback is then communicated back to the faculty and the control mechanism to adjust the teaching methods or input standards. This cycle continues until the required grade is achieved, ensures continuous improvement and adaptation in the educational process. Lets us see the equations describing the system : basic equation for the system

$$S(t) + M + c = MU \left[\frac{dG(t)}{dt} + \frac{d^2G(t)}{dt^2} \right] \quad (1)$$

- S(t) is the effort of the student
- G(t) is the grade of the student
- M is the internal motivation of the student
- U is the understanding skill of the student regarding academics.
- dG/dt is the rate of change of student grade for change in the input and teaching methods and efforts of the students

U(t) =

$$K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt} + K_s S_g(t) + K_c C(t) \quad (2)$$

Where:

- $U(t)$: Teacher's effort (input).
- $e(t) = G_{\text{ref}}(t) - G(t)$: Error (difference between desired and actual grades).
- $\int_0^t e(\tau)\, d\tau$: Integral of the error, representing cumulative feedback and advice over time.
- $\frac{de(t)}{dt}$: Derivative of the error, representing the rate of change in the student's performance.
- $S_g(t)$: Suggestion and advice term, representing targeted feedback on weak areas.
- $C(t)$: Clarification term, representing effort to clear doubts and enhance understanding.
- K_p: Proportional gain.
- K_i: Integral gain.
- K_d: Derivative gain.
- K_s: Suggestion and Advice gain.
- K_c: Clarification gain.

$$e(t) = G_{\text{ref}}(t) - G(t) \quad (3)$$

Where:

- $e(t)$: Error at time t, representing the difference between the Desired grade and the actual grade.
- $G_{\text{ref}}(t)$: Reference grade or the target grade set by the parents or the desired outcome.
- $G(t)$: Actual grade obtained by the student at time t.

Data for suggestion and clarification term: Collecting data for these terms would likely involve using subjective metrics or performance-based evaluations. Suggestions could be about study strategies, focusing on specific topics, or improving learning habits. Data Collection: 1. Surveys or Questionnaires: Have students rate how often they receive targeted advice and how useful they find it. 2. Learning Management Systems (LMS): If the educational system uses digital platforms, the frequency and type of feedback provided in student submissions can be recorded automatically. 3. Feedback Forms or Reports: Record the nature and frequency of personalized feedback given to students. These could be from: Homework evaluations, Parent-teacher meetings, Exam reviews or progress reports

C(t) - Clarification Term: This term represents the teacher's effort to clarify doubts or explain concepts that the student finds difficult.Data collection: 1. Student Queries Tracking: Track the number of questions or clarification requests a student makes in class or through online platforms. This could be through: Question and answer sessions in class, Emails or chat logs between the student and teacher, Learning platforms with query-response functionalities (e.g., Moodle, Google Classroom) 2.Test Performance: Improvement in scores after a doubt-clearing session 3. Student Performance Logs: Record when and how often a student seeks help in office hours or study groups, especially when focused on clarifying specific topics. 4. One-on-One Interaction Logs: Teachers could maintain a record of how frequently they interact with each student to clarify concepts (e.g., during office hours, one-on-one sessions, or after-class help). For example: A teacher may provide written suggestions on a homework assignment, which could be logged as a feedback interaction. Similarly, every clarification provided by the teacher in office hours could be noted, with time stamps to show when they occurred.

Calculating constants:

M= We consider the values based on the Interest of a student in studies we can give values from 0.1 to 1. U= We consider the values based on the Understanding level of student. Some students grasp fastly, some will be slow in understanding concepts. We can consider giving the values from 0.1 to 1

values for any system is a key step in tuning a PID controller. These values determine how the system reacts to error, aiming to correct it efficiently and achieve stability without overshooting or oscillation. 5. Root Locus and Frequency Response Methods For more complex systems, root locus or frequency response (Bode plot) methods can be used to tune the PID controller. Kc = Clarification Gain Track how student performance improves after the teacher provides clarifications. Kc can be calculated using Calculating K_p, K_d, K_i

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Kc = C(t)/G(t) C(t) is the number of clarifications provided. Fine-tune based on how quickly the student's performance improves after each clarification. Fuzzy logic controllers often model human interactions (like clarifications) as qualitative inputs and then convert them into numeric gains for tuning.

IV. Transfer Function of the System

A. *Transfer Function*

The transfer function is given by :

$$G(s) = \frac{K_p + K_i\frac{1}{s} + K_d s}{1 + (K_p + K_i\frac{1}{s} + K_d s)MUs(1+s)} G_{\text{ref}}(s) \quad (4)$$

The state-space representation is given by:

$$\dot{\mathbf{x}}(t) = A\mathbf{x}(t) + B\mathbf{u}(t) \quad (5)$$

$$\mathbf{y}(t) = C\mathbf{x}(t) + D\mathbf{u}(t) \quad (6)$$

Where:

$$A = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{1}{MU(1+s)} \end{bmatrix}, \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

$$\text{B} = \begin{bmatrix} 0 \\ \frac{1}{MU(1+s)} \end{bmatrix}, \qquad \text{D} = \begin{bmatrix} 0 \end{bmatrix}$$

The state-space equation is given by:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -\frac{1}{MU(1+s)} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{MU(1+s)} \end{bmatrix} (S(t)+M+C)$$

B. *System Modelling*

The academic performance model is designed to support students in achieving their educational goals and adapting to challenges throughout their academic journeys. The presence of a pole at the origin in the system indicates that student stability can fluctuate, reflecting their susceptibility to external influences. This suggests that a student's performance may become unstable or marginally stable depending on the strength of these influences, emphasizing the need for effective interventions to maintain consistent academic success.

Continuous system: From a system perspective, we are assuming system to be a continuous one. Even though students take breaks, their learning and academic development don't stop during these rest periods. In the realm of academic

performance modeling, it's easy to think of learning as a discrete process, marked by specific events like exams, assignments, and formal assessments. However, if we take a closer look, we realize that a student's academic development is far more dynamic and continuous in nature. Learning is not limited to structured study sessions or exams; rather, it is an ongoing process influenced by a range of cognitive, environmental, and emotional factors that operate consistently, even during breaks or rest periods. Even when students pause active studying, their brain continues to consolidate knowledge, and external factors like feedback and daily experiences constantly influence their learning. This makes academic performance a continuously evolving process, not just limited to periods of active study. The continuous flow of learning, adaptation, and external influences makes it essential to model academic outcomes as a continuous-time system, capturing both active learning and passive cognitive processes. Despite discrete events like exams, the learning system is always active, supporting the continuous-time approach. System or the plant is the Student. They Study, do the work and write the exams they are main system where all the work is done.

V. ANALYSIS

- **Rise Time** (T_r): Approximately 30-50 days.
- **Settling Time** (T_s): Approximately 100-150 days
- **Steady-State Error** (e_{ss}): 5%

The rise time in this academic system is estimated to be around 30-50 days, reflecting the natural time it takes for noticeable improvement in student performance, which happens over weeks. The settling time is estimated at 100-150 days, as academic performance stabilizes gradually over months with consistent learning and feedback. Finally, a steady-state error of less than 5% accounts for the natural gap between desired and actual outcomes due to real-world factors like motivation or distractions. We can see the analysis of the matlab simulations in this part. Matlab simulations helps us in analysing our system in a better way before its being implemented in a practical way.

In the Fig.3 illustrates an open-loop system, where a student's academic progress increases steadily over time without any feedback or adjustments. In real life, this is like following a fixed study plan for an entire year without receiving any guidance or corrections, regardless of performance. The student continues to learn, but the lack of feedback means they can't identify or correct mistakes, and there's no opportunity to adapt the pace or focus on areas needing improvement. While progress is made, the system is less effective compared to a feedback-driven approach. In a normal academic system, this feedback through a software is lagging, whereas in our adaptive system faculty can provide the inputs, as well as software AI also provides some inputs for the students which are helpful for the students.

The impulse response graph in Fig. 4 tells how a, intense effort like cramming for an exam can lead to an immediate improvement in performance, but this effect fades over time without continuous reinforcement. It reflects real-life situations where students may see a sharp boost in knowledge after focused study, but if they don't keep up with regular learning, the benefits quickly diminish. This graph highlights the importance of sustained, consistent effort for lasting academic success, emphasizing that short bursts of intense work alone aren't enough to achieve long-term retention.

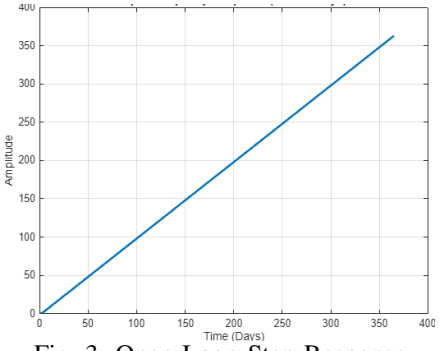


Fig. 3: Open Loop Step Response

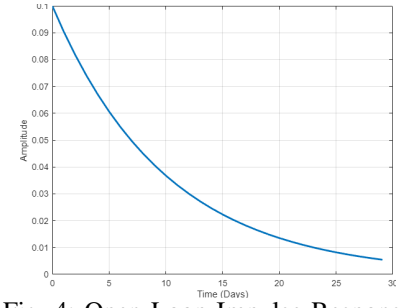


Fig. 4: Open Loop Impulse Response

A. *RootLocus*

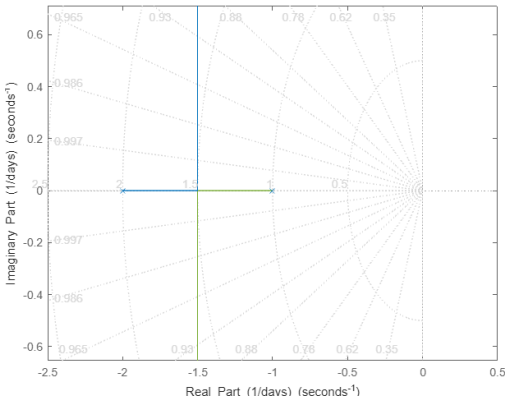


Fig. 5: Root locus Representation using continuous controller

The root locus plot in Fig. 5 visually shows the dynamics of student learning stability in relation to various influencing factors, such as feedback and study habits. A shift towards more improved study techniques can enhance stability, resulting in better academic performance. Conversely, negative feedback or distractions may destabilize learning, leading to poorer outcomes. This analysis emphasizes the

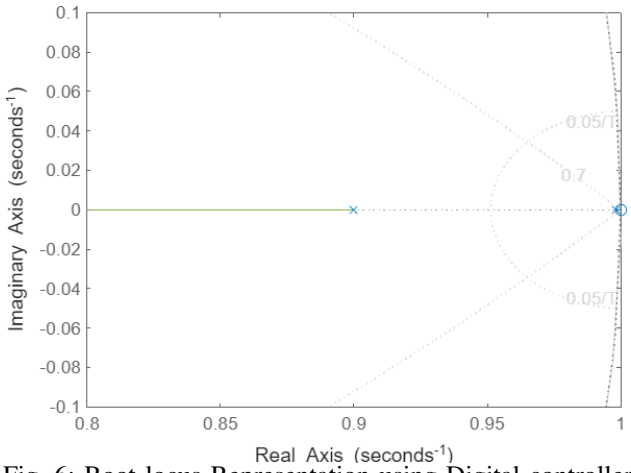


Fig. 6: Root locus Representation using Digital controller

importance of optimizing teaching methods and student engagement to foster a more stable and effective learning environment, ultimately guiding academic success.

B. *Frequency*

We would like to test our system and here we can see the frequency ressponses of our system. In this Fig.6 root locus plot shows a stable system with poles along the real axis, indicating overdamped behavior without oscillations. In a continuous controller, the system responds smoothly in real-time, with immediate adjustments to changes. In contrast, a digital controller operates in discrete steps with slight delays due to sampling, but with proper tuning, it can still achieve stability and effective control. Both controllers can stabilize the system, but the digital one introduces small delays while still maintaining overall system behavior.

In Fig. 7, the closed-loop step response illustrates how timely faculty feedback can accelerate student improvement. The input represents the feedback given to students, while the system symbolizes how they process and apply that feedback. Initially, student performance is low, but with continuous feedback, their progress accelerates, shown by the sharp rise in the graph. Over time, as they internalize the guidance, the rate of improvement slows and stabilizes, indicating a higher level of proficiency. The rapid improvement on the graph suggests an ideal learning process, where effective, timely feedback leads to efficient and lasting academic progress.

In the Fig.8 with the continuous controller, the system's response shows a gradual and smooth adjustment across different frequencies, much like a student receiving constant feedback and making steady progress over time. The phase shifts are smooth, indicating a more predictable learning pattern. In the Fig.9 with the digital controller, the system adjusts more abruptly, with sharper changes in both magnitude and phase. This is similar to a student who receives feedback at intervals (digital), leading to quicker, more noticeable improvements but with sudden shifts in understanding or performance. The continuous controller represents steady, ongoing development, while the digital controller reflects a more sporadic, stepwise improvement process, often seen in students who improve after specific interventions or assessments.

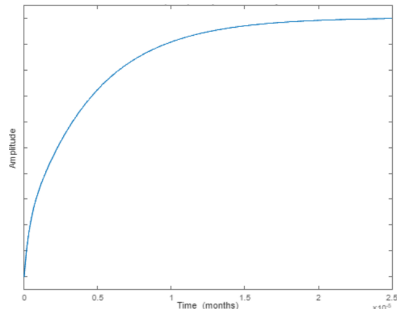


Fig. 7: Closed Loop Step Response of the System

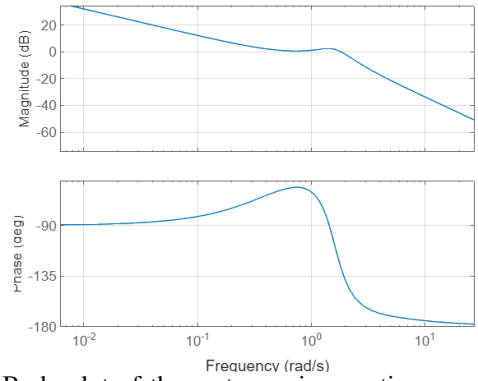


Fig. 8: Bode plot of the system using continuous controller

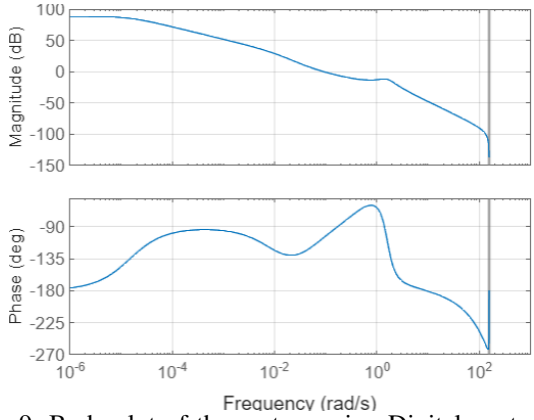


Fig. 9: Bode plot of the system using Digital controller

VI. Simulink

The Simulink block in the Fig.10 illustrates an academic grading system, student's performance is modelled as a Dynamic system influenced by the faculty's control efforts. It begins with a step input Block represents the desired academic target performance level for the student. The target is compared to the student's actual performance at the summing junction, producing an error signal that quantifies the difference. The PID Controller Block, symbolizes the faculty combined with a software. We have given unity negative feedback. This feedback is the tests conducted , tells us about the performance of student. The control signal, representing faculty guidance, adjusts the student's performance in a

feedback loop. By continuously monitoring and responding to the student's progress, the system dynamically improves performance over time.

The simulation shows that students' performance initially improves rapidly, overshooting the target due to strong faculty interventions. This reflects how, with the right support, students can temporarily exceed expectations, highlighting the impact of guidance and effort on achieving high performance.

In the Fig.11 following the peak, from 1 to 3 days, the performance drops below the desired level and oscillates before gradually stabilizing. These oscillations are a result of the system trying to find a balance, with the derivative component of the PID controller helping to Dampen these fluctuations over time. This phase could represent the student's performance fluctuating as they adjust to the new level of effort and assistance from faculty, experiencing periods of over-performance and under-performance. Finally, after a week, the performance stabilizes and converges to the desired level, indicating that the PID controller effectively minimizing the error, leading to a steady state where the student's performance matches the desired goal. In academic terms, this means that the student's grades stabilize and consistently meet the faculty's expectations and will achieve more grades.

In real-time, the shape of the curve is influenced by several factors. Initially, there is a burst of effort and enthusiasm from the student when receiving new goals and support from their Professors leading to rapid improvement. However, over correction can cause the student to Overshoot the target, much like the peak observed in the graph. As the student tries, to stabilize their performance, there may be some Periods of fluctuation, similar to the oscillations seen in the graph. Over time, the student finds a balanced routine, adjusting to the level of support and achieving a stable performance that meets the target. Thus, the graph demonstrates the Dynamic response of a student's academic performance to targeted interventions by the faculty, with initial rapid improvements, periods of adjustment, and eventual stabilization.

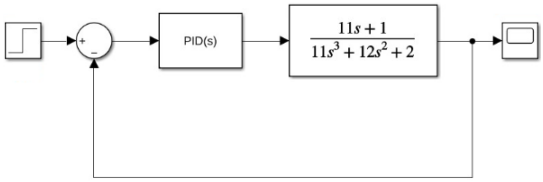


Fig. 10: Simulation

VII. Future Works and Conclusion

Adaptive Control mechanism helps students in guiding them, Faculty become more connected to the students in guiding and controlling. Students learn many new and effective things. Our project focuses on developing strategies to improve academic grades and enhance student Success. Through the implementation of various interventions such as personalized study plans, academic Resources, and feedback

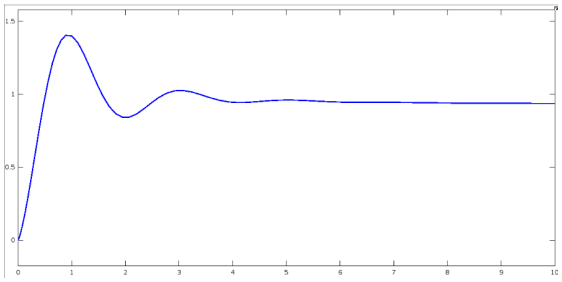


Fig. 11: Simulation Output

mechanisms, we aimed to address the diverse needs of students and promote a culture of continuous improvement.

We would like to extend our work by Personalized Learning Paths so as to improve the students grade, Collaboration with Educational Institutions in collecting the data. Personalized Learning helps in Tailoring Educational Experiences to individual student needs and preferences is an emerging trend in education. Future work could focus on leveraging academic grade data to develop personalized learning pathways, adaptive assessments, and targeted interventions that cater to diverse student populations.

References

[1] RA, K., Karunya, S., Rashmi, R. 2023. *"Student Academic Analyser and Career Guidance System using Data Analytics and Visualization Techniques,"* Chennai, India. Available: https://example-url.com.

[2] Tolle, H., Rokhmawati, R.I., Khoirunisa, E. 2023. *"Interaction Design of Academic Analysis Module Mobile App to Enhance Student Academic Performance Monitoring"* Malang, Indonesia. Available: https://example-url.com.

[3] P. Prasertisirikul, S. Laohakiat, R. Trakunphutthirak, S. Sukaphat, 2022, *"A Predictive Model for Student Academic Performance in Online Learning System,"* Bangkok, Thailand.

[4] S. Verma, 2020 *"Effect of Different Attributes on the Academic Performance of Engineering Students,"* B.T. Kumaon Institute of Technology, Dwarahat, Uttarakhand, India.

[5] Yaakub, T.N., Ahmad, W.R., Husaini, Y., Burham, N. (2018). "Influence Factors in Academic Performance Among Electronics Engineering Students," Shah Alam, Selangor. Available: https://example-url.com.

[6] Hashim, H., Salim, N.A., Sulaiman, A.A., Haris, H.C.M., Hussin, H. (2016). "An Effective Approach to Improve Students' Grade Point Average," in *IEEE 8th International Conference on Engineering Education (ICEED)*. Available: https://example-url.com.

[7] C.L. Sa, D.H. Abang Ibrahim, E.D. Hossain, M.B. Hossin, 2014 *"Student Performance Analysis,"* Kota Samarahan, Sarawak, Malaysia.

[8] M.J. Madar, O.B. Ibrahim, 2011 *"E-learning Towards Student Academic Performance,"* University Technology Malaysia (UTM), Johor, Malaysia.

[9] Nagrath, I.J. and Gopal, M. 2021 *Control Systems Engineering*.

[10] Kuo, B.C. and Golnaraghi, F. 2023 *Automatic Control Systems*.

[11] Ogata, K. *Modern Control Engineering*.

[12] Jamil, S., Zehra, F., Naqvi, R., Bhamani, S. (2013). "Impact of Facebook Intensity on Academic Grades," in *5th International Conference on Information and Communication Technologies*. Available: https://example-url.com.

[13] Salam, S.D., Paul, P., Tabassum, R., Mahmud, I., Ullah, M.A., Rahman, A., Rahman, R.M. (2018). "Determination of Academic Performance and Academic Consistency by Fuzzy Logic," in *International Conference on Intelligent Systems (IS)*. Available: https://example-url.com.

[14] CTMS "Online website CTMS," [Online] Available: https://ctms.engin.umich.edu/CTMS/index.php?example= CruiseControlsection=ControlFrequency.