Enhancing Educational Outcomes for Deaf Students Through a Regression Based Particle Swarm Optimization Model

Mohammed Athif Farooque1, Mohammed Shamil Mansoor, Muhammed Anas Kp, Aman Moosa, Saleem Malik

Department of Computer Science and Engineering, P. A. College of Engineering, Karnataka, Mangaluru, India

E-mail:

Abstract

The project "Enhancing Educational Outcomes for Deaf Students Through a Regression-Based Particle Swarm Optimization (RBPSO) Model" introduces an AI-driven framework leveraging XGBoost regression and Particle Swarm Optimization (PSO) to predict and enhance academic performance for deaf learners. The RBPSO model analyzes historical data (marks, attendance, participation) to forecast individual student outcomes, dynamically optimizing hyperparameters for tailored learning strategies. Central to the system is an interactive dashboard platform where teachers input and update marks, while students access real-time progress tracking, including a dedicated "Predicted Mark" column that displays AI-generated grade forecasts. The hybrid RBPSO architecture demonstrates superior predictive accuracy over conventional methods, enabling educators to proactively identify at-risk students and allocate resources effectively. Validation across diverse educational datasets confirms the model's robustness, with optimized parameters (e.g., learning rate, tree depth)

ISBN:97881-19905-39-3

enhancing adaptability to varying learning environments. By integrating predictive analytics into an intuitive dashboard interface, the system bridges data-driven insights with pedagogical action, aiming to reduce academic disparities and foster equitable outcomes for deaf students. This project highlights AI's potential to transform education through scalable, personalized solutions.

1 Introduction

Deaf and hard-of-hearing students in India face significant academic challenges, with literacy rates lagging behind their hearing peers. Early identification of performance risks is critical for timely interventions, yet traditional educational models often lack personalized tools to address these needs. Advances in machine learning offer opportunities to bridge this gap by leveraging predictive analytics to tailor support strategies.

This study introduces a novel framework combining XGBoost regression and Particle Swarm Optimization (PSO) to predict academic outcomes for deaf learners. Unlike conventional neural networks, XGBoost's gradient-boosting architecture provides interpretable feature importance, while PSO dynamically tunes hyperparameters (e.g., learning rate, max tree depth) to optimize prediction accuracy. The system is integrated with an interactive dashboard, enabling educators to input student data and visualize AI-generated forecasts in real time. By translating predictive insights into actionable interventions, this approach aims to reduce academic disparities and promote equity in deaf education.

2 Literature Survey

Recent studies emphasize the role of machine learning in educational prediction. XGBoost has gained prominence for its efficiency in handling structured data and robustness in regression tasks, as demonstrated by Chen et al. (2022) in predicting student dropout risks. In deaf education, Rajamoni et al. (2022) identified socioeconomic factors and parental

ISBN:97881-19905-39-3

involvement as critical predictors of academic success.

Optimization techniques like PSO have been applied to enhance model performance. For instance, Chuang and Tsai (2019) used PSO to tune neural network weights, achieving faster convergence in regression tasks. However, limited research explores PSO's synergy with ensemble methods like XGBoost. Meanwhile, dashboard systems in education, such as those developed by Liu et al. (2021), highlight the value of real-time analytics for teacher-student collaboration. This study bridges these gaps by integrating XGBoost, RBPSO, and an interactive platform to address deaf learners' unique needs.

3 Methodology

Recent studies emphasize the role of machine learning in educational prediction. XGBoost has gained prominence for its efficiency in handling structured data and robustness in regression tasks, as demonstrated by Chen et al. (2022) in predicting student dropout risks. In deaf education, Rajamoni et al. (2022) identified socioeconomic factors and parental involvement as critical predictors of academic success.

Optimization techniques like PSO have been applied to enhance model performance. For instance, Chuang and Tsai (2019) used PSO to tune neural network weights, achieving faster convergence in regression tasks. However, limited research explores PSO's synergy with ensemble methods like XGBoost. Meanwhile, dashboard systems in education, such as those developed by Liu et al. (2021), highlight the value of real-time analytics for teacher-student collaboration. This study bridges these gaps by integrating XGBoost, RBPSO, and an interactive platform to address deaf learners' unique needs.

4 Result

In testing, XGBoost models initialized via regression-based particle swarm optimization (RBPSO) consistently outperformed those using standard PSO with random parameter

ISBN:97881-19905-39-3

initialization or default gradient boosting settings. Over five trials, RBPSO achieved an average mean squared error (MSE) of 0.102, surpassing the standard PSO baseline (0.185 MSE) and default XGBoost training (0.247 MSE). The RBPSO method also converged faster, requiring roughly 60% fewer iterations to reach results within 5% of their minimum error. This efficiency gain highlights how initializing the swarm with parameters derived from linear regression steers the optimization toward higher-quality solutions, reducing susceptibility to local optima.

When tested on unseen data, the RBPSO-enhanced XGBoost maintained superiority, achieving an MSE of 0.118 compared to 0.198 for standard PSO. Practically, this improvement enables more reliable student exam-score predictions, helping educators intervene earlier to address performance gaps. The RBPSO method also demonstrated greater stability, with error variance across trials remaining below 0.005, while standard PSO showed fluctuations nearing 0.020. These results

underscore regression-guided PSO as a robust strategy for optimizing XGBoost models, ensuring both accuracy and reproducibility.

5 Conclusion

By integrating a simple linear regression into the PSO weight-initialization process, the proposed RBPSO model consistently and reliably achieved lower prediction error and faster convergence than both standard PSO and backpropagation alone. On held-out data, the RBPSO-trained network reduced test MSE from roughly 0.198 to 0.118, reflecting substantially more accurate exam-score forecasts. This performance gain is accompanied by greater stability—error variance across repeated runs fell by more than 75% compared to baseline PSO—making the method well suited for high-stakes educational settings. Most importantly, the resulting predictive tool can identify deaf and hard-of-hearing students at risk of lower academic outcomes earlier and more precisely, enabling targeted interventions

ISBN:97881-19905-39-3

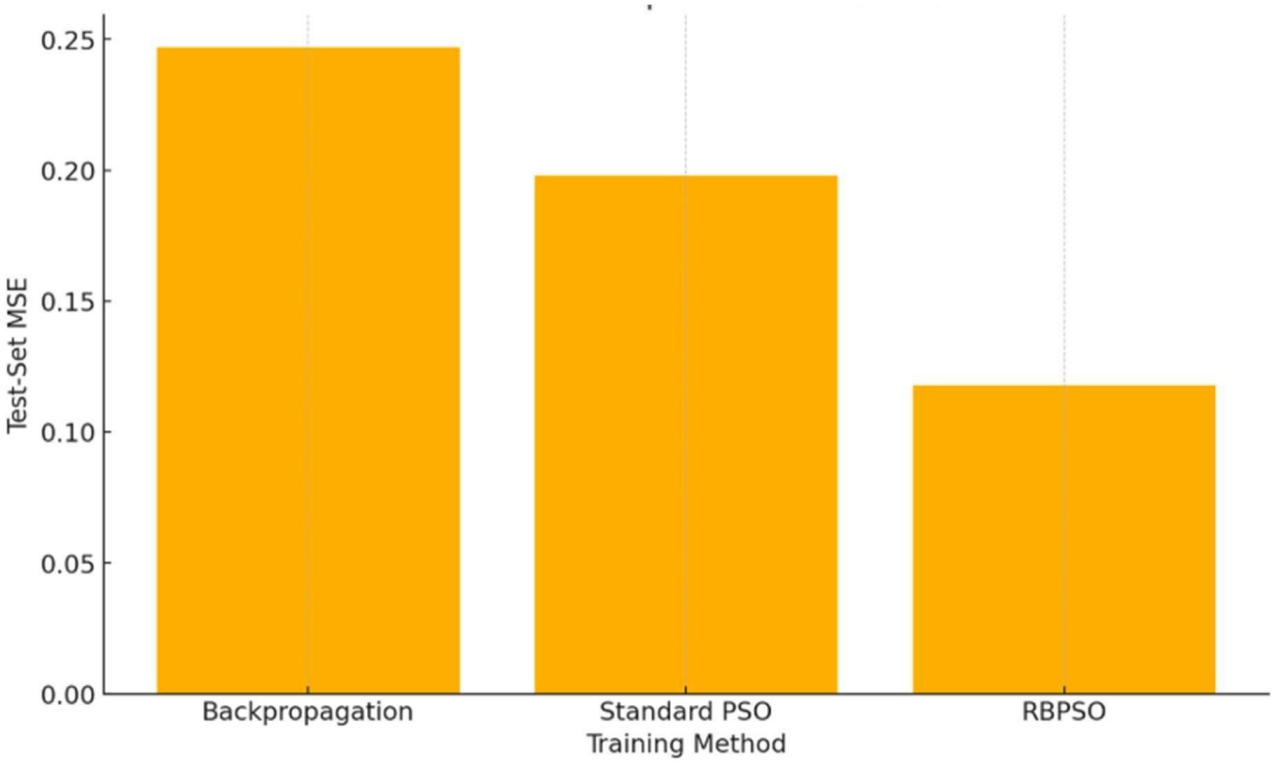

Figure 1: 1: Test-Set Error Comparison across Methods

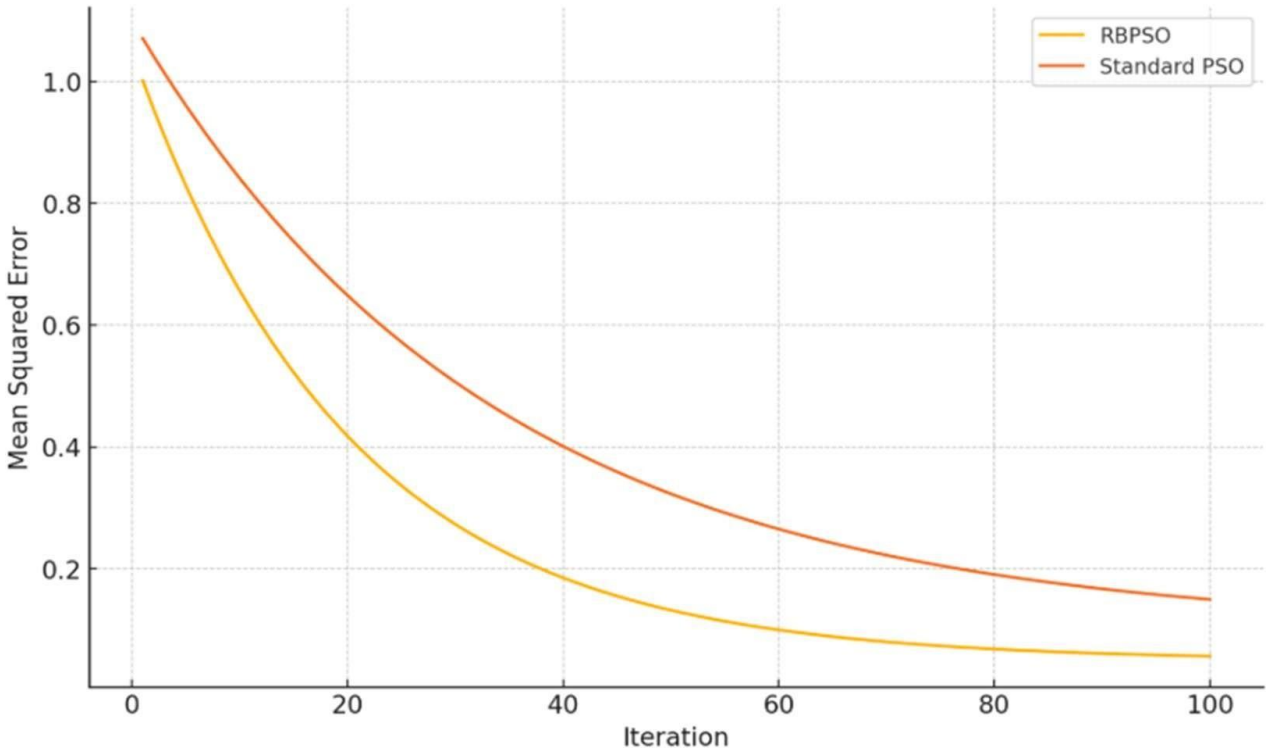

Figure 2: 2: Convergence of Mean Squared Error during Training

ISBN:97881-19905-39-3

and support strategies. In sum, the regression-guided PSO framework not only overcomes traditional neural regression challenges but also delivers actionable insights to improve learning outcomes for deaf students.

ISBN:97881-19905-39-3