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MATHEMATICAL MODELING OF LEARNING PROCESSES AND PREDICTION OF STUDENTS SUCCESS

This review explores key modeling approaches, including regression analysis, cluster analysis, neural networks, Bayesian networks, and machine learning methods. These techniques help educators assess student performance, identify academic risks, and implement tailored interventions. Predictive models use factors such as prior grades, study time, and engagement in digital learning systems. Machine learning algorithms, including decision trees and neural networks, enhance forecast accuracy by adapting to new data. While mathematical models provide valuable insights, challenges such as incomplete data, emotional factors, and overfitting can affect reliability.

Keywords: *mathematical modeling, student success prediction, machine learning, regression analysis, neural networks, Bayesian networks, academic performance.*

Background

In the modern educational environment, mathematical modeling is gradually becoming a powerful tool for analyzing and predicting student success. These models are based on mathematical methods and algorithms. They help identify key factors that can affect learning outcomes, and can also make predictions about the future success of students. As you can see, this will allow us to create and develop different individual approaches to learning and make important decisions regarding the improvement of the educational process.

It is quite well known that mathematical modeling in the field of education has quite different approaches. Namely, these are neural networks, regression analysis, Bayesian networks and, of course, machine learning methods. It is clear that these tools will allow us to analyze key indicators of success, to predict success and to analyze rather large educational losses.

My goal of this work is to review modern approaches to mathematical modeling of learning processes and predicting student

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success. I will also analyze their effectiveness and their ability to improve the quality of education.

Consider the essence of mathematical modeling in education. As is known from various information sources, mathematical modeling in education plays a key role based on data on student learning outcomes. This will allow us to build different models and be able to predict their success in the future. I would like to note that these models are able to take into account numerous factors, namely: attendance at classes, results of control classes, participation in various extracurricular activities and the level of immersion in the educational process. According to Kaiser, mathematical modeling is considered as a creative process of interpretation of results and input changes to the model in order to determine, control or optimize the situation in order to understand the real one situations (Cooper, & Heaverlo, 2013).

As you know, the main methods of modeling in education are regression analysis and the method of cluster analysis.

Regression analysis is an opportunity to determine the relationship between different variables (it can be the share of self-study material and the average score of the learning result).

Cluster analysis is a kind of opportunity to divide students according to similar characteristics and the opportunity to develop appropriate learning strategies for each group.

We will also consider other modeling methods:

- Neural networks – they imitate the work of the human brain, and can reveal complex dependencies between various factors of the educational process (Kuchynska et al., 2022).

- Bayesian networks – they will allow us to build such probabilistic models – of the initial process, and to make the process based on existing data.

- Machine learning methods – they automatically find patterns in large data sets and can improve their prediction accuracy with each new set of different information and improve their prediction accuracy with each new set of information.

Let's consider the prediction of students' success. Usually, predicting the success of students is a rather difficult task for ensuring the quality of education. Thanks to mathematical models, educators and the management of educational institutions can conduct an analysis in order to early identify students who cannot master the educational material at least at an elementary level, and can be excluded for negative academic results. It is clear that thanks to this prediction, a new opportunity opens up for us to implement preventive

measures, such as developing a different strategy for mastering the material and conducting other general and individual consultations.

Let's consider some basic criteria for predicting success:

- Previous grades – on the basis of grades for previous courses, you can build regression models predicting learning outcomes in future semesters.

- Time spent studying – you can use time series models that will allow you to predict and take into account the student's cognitive changes and influence his improvement in academic performance.

- Activity in educational systems. Data from electronic learning management systems can serve as a basis for modeling student engagement and academic achievement.

Results

Let's consider the effectiveness of mathematical models in predicting the success of students. Mathematical modeling shows us significant potential in predicting student success due to the ability to analyze a large amount of data. This will allow us to detect patterns that are difficult to notice using traditional methods. The models we use for forecasting range in complexity and accuracy, from simple linear regressions to complex neural networks. Let's consider each of them:

1. Machine learning algorithms are one of the most effective tools for predicting student success.

They are powerful enough to create adaptive models that automatically learn based on new data and constantly improve their predictions. Machine learning itself is based on large data sets, such as exam preparation time, achievement scores, and more.

The most common machine learning algorithms for predicting success are: decision trees, logistic regression, and neural networks.

2. Accuracy of models and factors affecting performance.

The accuracy of mathematical models in forecasting depends on several factors:

- Data quality. The more and more accurate the data, the more accurate the forecast.

- Model selection. Simpler models often lack the power to account for all possible relationships between variables. In contrast, more complex models, such as neural networks or ensemble methods, can provide more accurate results, but require larger amounts of data and computational resources.

- Model hyperparameters. The accuracy of the prediction also depends on the correct setting of the hyperparameters of the model.

3. Use of neural networks.

Neural networks are a powerful tool for analyzing complex relationships between various student performance indicators. They use multi-layer structures to process data and are able to recognize patterns that are difficult to detect with other methods. They can also predict whether a student will succeed in a particular course or predict his grade in a particular discipline based on data about his previous achievements. Most interested in using methods and tools of data analysis are commercial enterprises deploying their projects on the basis of information data warehouses (Chilukuri, 2020). Ensuring data integrity is one of the most important components of data analysis.

The main advantage of neural networks is their ability to learn from new data and adapt to changes in student behavior. However, they require a lot of computing power and lengthy training, which can be a limitation for educational institutions with limited resources.

4. Problems and limitations of mathematical models.

Despite their powerful effectiveness, mathematical models for predicting student success have some limitations.

Information gaps – data used for modeling may be incomplete or contain errors. This may be the case in some cases where students may not be using e-learning systems so actively that it may simply make it difficult to analyze their engagement.

Individual characteristics – these models often do not take into account emotional and motivational factors that can have a decisive influence on the student's success.

Overfitting – in these cases, when the model is too precisely adapted to the training data, it may not work effectively on new data sets. This means that the model may not be useful for changes in educational processes or student behavior.

5. Preventive measures based on forecasts – one of the key advantages of using mathematical models for predicting the success of students is the possibility of applying preventive measures. Educators can receive timely notifications about students who are at risk and take appropriate measures, such as individual consultations, adaptation of teaching materials or creation of individual study plans.

For example, if the model predicts that a student may have difficulty with a particular subject, additional resources or counseling can be offered. And, this already increases the chances of successfully completing the course and improving the overall quality of the educational process.

6. Development prospects.

Mathematical models continue to improve along with the development of artificial intelligence and big data processing technologies. New approaches, such as deep learning and ensemble methods, make it possible to increase the accuracy of forecasts and make models more flexible to changes in data.

Discussion and conclusions

So, after conducting the analysis, it can be stated that the mathematical modeling of learning processes and predicting the success of students is a promising direction in the development of educational technologies. It is thanks to the use of mathematical methods and algorithms that educational institutions get the opportunity to improve the quality of the educational process, identify problems at early stages and implement preventive measures to improve academic results.

I would like to note that despite certain limitations, the use of mathematical models allows us to make the educational process more effective and individualized.

I hope that in the future we can expect the further development of such technologies, which will contribute to the improvement of teaching methods and increase the level of success of students

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МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ПРОЦЕСІВ НАВЧАННЯ І ПРОГНОЗУВАННЯ УСПІШНОСТІ СТУДЕНТІВ

Розглянуто ключові підходи до моделювання, зокрема регресійний аналіз, кластерний аналіз, нейронні мережі, баєсові мережі та методи машинного навчання. Ці техніки допомагають освітянам оцінювати успішність студентів, визначати академічні ризики та впроваджувати адаптивні заходи. Прогнозні моделі враховують такі фактори, як попередні оцінки, витрачений на навчання час і рівень залученості до цифрових освітніх систем. Алгоритми машинного навчання, включаючи дерева рішень і нейронні мережі, підвищують точність прогнозування, адаптуючись до нових даних. Хоча математичні моделі забезпечують цінні аналітичні висновки, такі виклики, як неповні дані, емоційні фактори та перенавчання моделі, можуть впливати на їхню надійність.

Ключові слова: *математичне моделювання, прогнозування успішності студентів, машинне навчання, регресійний аналіз, нейронні мережі, баєсові мережі, академічна успішність.*

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