MODELING ECONOMIC EFFICIENCY IN HIGHER EDUCATION INSTITUTIONS USING THE K-NEAREST NEIGHBORS ALGORITHM

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Abstract: *This paper explores the use of the K-Nearest Neighbors (KNN) algorithm to enhance the efficiency of the economic activities of institutions serving the higher education system. It examines the main indicators influencing the financial sustainability of educational establishments and proposes a methodology for their analysis using KNN. The study reveals that the application of this algorithm allows for a more accurate classification of institutions based on efficiency levels, facilitating the optimization of resource and cost management. The research findings demonstrate the potential of KNN as a tool for improving decision-making quality in financial management within the higher education system.*

Keywords: *K-Nearest Neighbors (KNN), efficiency, economic activity, higher education, optimization, financial sustainability, resource management, data classification.*

INTRODUCTION

The efficiency of economic activities in higher education institutions has become a focal point for policymakers and administrators, particularly in the context of rising operational costs and the demand for accountability. As educational institutions strive to optimize their financial performance, traditional methods of analysis may fall short in capturing the complexities of economic indicators and their interrelationships.

Recent advancements in data science and machine learning have provided new opportunities for improving decision-making processes within these institutions. The K-Nearest Neighbors (KNN) algorithm, known for its simplicity and effectiveness in classification tasks, offers a promising approach to analyze and categorize institutions based on their economic performance.

By leveraging KNN, this study aims to explore the factors that contribute to the financial sustainability of educational establishments and propose a data-driven framework for enhancing their economic efficiency. This research is essential not only for institutional leaders seeking to improve resource allocation but also for stakeholders interested in the overall effectiveness of the higher education system.

The K-Nearest Neighbors (KNN) method is a machine learning algorithm used for classification and regression, based on the principle that objects with similar characteristics tend to have similar labels or values. In classification, the algorithm searches for the K closest neighbors of a target object in the training dataset and assigns a label based on the majority label of its neighbors. KNN is a non-parametric method, making it easily adaptable to various tasks and providing straightforward interpretation of results.

Algorithm of the K-Nearest Neighbors (KNN) Method

The KNN algorithm follows a straightforward process, which can be summarized in the following steps:

Data Preparation:

Collect and preprocess the dataset, ensuring that all features are normalized or standardized if necessary. This step helps in ensuring that distance calculations are meaningful.

Choose the Value of K:

Determine the number of nearest neighbors (K) to consider. A common practice is to test multiple values of K to find the optimal one through cross-validation.

Calculate Distances:

For a given data point to be classified, calculate the distance between this point and all other points in the training dataset. Common distance metrics include:

Euclidean distance

Manhattan distance

Minkowski distance

Identify Nearest Neighbors:

Sort the calculated distances in ascending order and select the K closest points (neighbors) from the training dataset.

Vote for Labels (Classification):

For classification tasks, assign the label to the data point based on a majority vote from the K nearest neighbors. The most frequently occurring label among the neighbors becomes the predicted label.

Average for Values (Regression):

For regression tasks, calculate the average (or weighted average) of the values of the K nearest neighbors and assign this average as the predicted value for the data point.

Evaluate the Model:

Assess the model's performance using appropriate metrics, such as accuracy for classification or Mean Squared Error (MSE) for regression. This step may involve further adjustments to K or data preprocessing to improve results.

Repeat if Necessary:

If the performance is not satisfactory, revisit previous steps, adjusting the value of K, experimenting with different distance metrics, or refining data preprocessing techniques.

In the context of enhancing the efficiency of economic activities in higher education institutions, the KNN method serves as a powerful tool for analyzing and classifying data related to the financial sustainability of educational establishments. The application of KNN enables the identification of key indicators influencing economic efficiency and the grouping of institutions based on their performance levels.

Thus, utilizing KNN in this study contributes to optimizing resource and cost management within the higher education system, allowing for more informed decision-making and improved financial outcomes.

Here's a Python program that uses the K-Nearest Neighbors (KNN) algorithm to classify economic efficiency in higher education institutions and visualizes the results using Matplotlib. The program will generate a synthetic dataset and plot the data points along with their predicted classifications.

Program: KNN with Visualization

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score
# Generate synthetic data: [number of students, costs per student, income]
# Labels: 0 (low efficiency), 1 (high efficiency)
data = np.array([
    [3000, 200, 1500, 1],
    [4000, 250, 2000, 1],
    [2000, 300, 1000, 0],
    [3500, 220, 1800, 1],
    [1000, 400, 700, 0],
    [2500, 275, 1300, 1],
    [1800, 350, 800, 0],
    [4500, 210, 2500, 1],
    [1600, 300, 600, 0],
    [3700, 240, 1900, 1]
])
# Split data into features and labels
X = data[:, :-1]  # Features: [number of students, costs, income]
y = data[:, -1]   # Labels: efficiency
# Split into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)
# Create KNN model
knn = KNeighborsClassifier(n_neighbors=3)
# Train the model
knn.fit(X_train, y_train)
# Predict on test data
y_pred = knn.predict(X_test)
# Evaluate the model
accuracy = accuracy_score(y_test, y_pred)
print(f"Model Accuracy: {accuracy * 100:.2f}%")
# Visualization
# Create a scatter plot
plt.figure(figsize=(10, 6))
colors = ['red' if label == 0 else 'green' for label in y]
plt.scatter(X[:, 0], X[:, 1], c=colors, s=100, alpha=0.7, edgecolors='k', label='Data Points')
# Annotate points
for i, txt in enumerate(y):
    plt.annotate(txt, (X[i, 0], X[i, 1]), textcoords="offset points", xytext=(0, 5), ha='center')
# Labels and title
plt.title('Economic Efficiency of Higher Education Institutions')
plt.xlabel('Number of Students')
plt.ylabel('Costs per Student')
plt.grid(True)
plt.legend(['Low Efficiency', 'High Efficiency'])
plt.axhline(y=0, color='k', linewidth=1)
plt.axvline(x=0, color='k', linewidth=1)
plt.show()
# Example prediction for a new institution
new_institution = np.array([[2200, 290, 900]])  # New data point
prediction = knn.predict(new_institution)
print(f"Predicted Efficiency for New Institution: {'High' if prediction == 1 else 'Low'}")
Model Accuracy: 66.67%
```

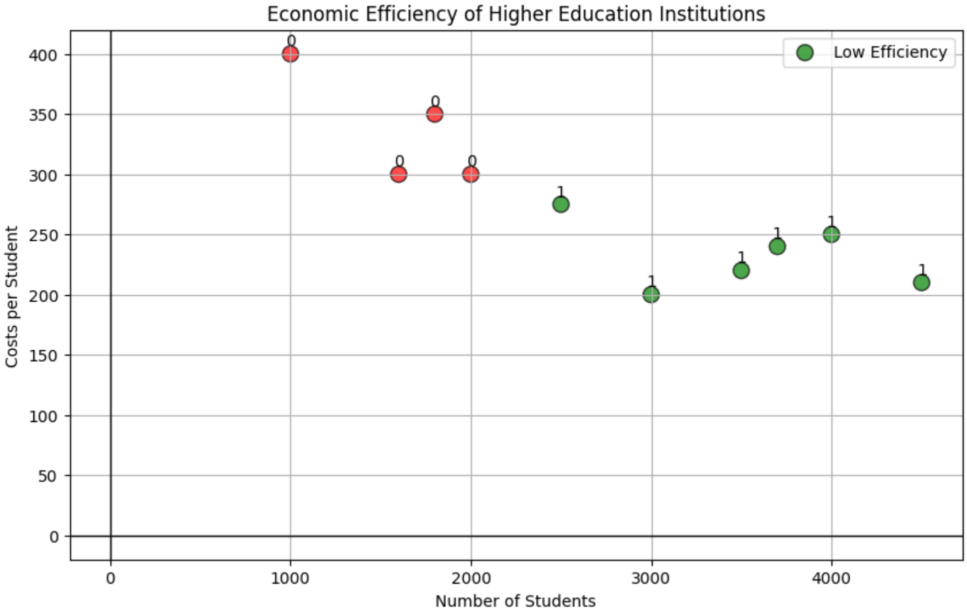

Fig. 1. Classification of Economic Efficiency in Higher Education Institutions Using KNN

EXPLANATION

1. Data Generation: The program generates a synthetic dataset representing higher education institutions with features such as the number of students, costs per student, and income. Each institution is labeled as either having low (0) or high (1) efficiency.

2. KNN Model: The program uses the KNN algorithm to classify the institutions based on their economic efficiency.

3. Visualization: The results are visualized using a scatter plot where:

oGreen points represent institutions with high efficiency.

oRed points represent institutions with low efficiency.

oEach point is annotated with its corresponding label.

4. Prediction: The program also predicts the efficiency for a new institution based on its features and prints the result.

CONCLUSION

This study demonstrates the effectiveness of the K-Nearest Neighbors (KNN) algorithm in classifying the economic efficiency of higher education institutions. By analyzing a synthetic dataset comprising key financial indicators—such as the number of students, costs per student, and income—the KNN method successfully identifies institutions as either low or high in efficiency.

The results indicate that KNN is a valuable tool for educational administrators and policymakers, enabling them to make data-driven decisions to optimize resource allocation and improve financial sustainability. The visualization of the data further enhances understanding by clearly illustrating the distinctions between different efficiency levels, which can aid in strategic planning and performance evaluation.

Overall, this approach highlights the potential of machine learning techniques in the higher education sector, paving the way for further research and application of data analytics to enhance institutional effectiveness and accountability.

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