Hypothesis Testing Techniques Project

# Introduction

In this project, we will demonstrate hypothesis testing techniques using a hypothetical study. The study investigates the effect of a new teaching method on students' test scores. We will generate a dataset, formulate hypotheses, conduct hypothesis testing, and interpret the results.

# Step 1: Generate a Dataset

We will create test scores for two groups of students: one group using the traditional method and another group using the new method.

Here's the code to generate the dataset:

```python  
import numpy as np  
import pandas as pd  
  
# Set random seed for reproducibility  
np.random.seed(42)  
  
# Generate data for two groups  
n\_students = 50  
traditional\_method\_scores = np.random.normal(loc=75, scale=10, size=n\_students)  
new\_method\_scores = np.random.normal(loc=78, scale=10, size=n\_students)  
  
# Create a DataFrame  
data = pd.DataFrame({  
 'Traditional\_Method': traditional\_method\_scores,  
 'New\_Method': new\_method\_scores  
})  
  
# Save dataset to CSV  
data.to\_csv('teaching\_methods\_test\_scores.csv', index=False)  
```

# Step 2: Formulate Hypotheses

Null Hypothesis (H₀): There is no difference in the mean test scores between students taught using the traditional method and those taught using the new method.

Alternative Hypothesis (H₁): There is a difference in the mean test scores between students taught using the traditional method and those taught using the new method.

# Step 3: Conduct Hypothesis Testing

We will perform a two-sample t-test to compare the means of the two groups. Here's the code:

```python  
import scipy.stats as stats  
  
# Perform two-sample t-test  
t\_stat, p\_value = stats.ttest\_ind(traditional\_method\_scores, new\_method\_scores)  
  
# Print results  
print(f"T-statistic: {t\_stat}")  
print(f"P-value: {p\_value}")  
```

# Step 4: Interpret the Results

The results of the two-sample t-test are as follows:

T-statistic: -3.003

P-value: 0.00339

Given that the p-value (0.00339) is less than the typical significance level of 0.05, we reject the null hypothesis. This suggests that there is a statistically significant difference in the mean test scores between students taught using the traditional method and those taught using the new method.

# Visualizing the Data

Here is the code to visualize the distribution of test scores for both teaching methods:

```python  
import matplotlib.pyplot as plt  
  
# Visualize the data  
plt.figure(figsize=(10, 6))  
plt.hist(traditional\_method\_scores, bins=10, alpha=0.7, label='Traditional Method')  
plt.hist(new\_method\_scores, bins=10, alpha=0.7, label='New Method')  
plt.legend(loc='upper right')  
plt.xlabel('Test Scores')  
plt.ylabel('Frequency')  
plt.title('Test Scores Distribution')  
plt.show()  
```

# Different Types of Hypothesis Testing Techniques

## 1. Z-Test

Purpose: Compare the sample mean to the population mean when the population variance is known.

Formula:  
Z = (X̄ - μ) / (σ / √n)  
  
Where:  
X̄ = sample mean  
μ = population mean  
σ = population standard deviation  
n = sample size

## 2. T-Test

Purpose: Compare the sample mean to the population mean when the population variance is unknown. Commonly used variants include one-sample t-test, two-sample t-test, and paired t-test.

Formula for one-sample t-test:  
t = (X̄ - μ) / (s / √n)  
  
Where:  
X̄ = sample mean  
μ = population mean  
s = sample standard deviation  
n = sample size

## 3. ANOVA (Analysis of Variance)

Purpose: Compare the means of three or more samples to see if at least one sample mean is different from the others.

Formula for F-statistic:  
F = (variance between groups) / (variance within groups)  
  
Where variance between groups = SSB / (k - 1)  
variance within groups = SSW / (N - k)  
SSB = sum of squares between groups  
SSW = sum of squares within groups  
k = number of groups  
N = total number of observations

## 4. Chi-Square Test

Purpose: Test the independence of two categorical variables.

Formula for Chi-Square statistic:  
χ² = Σ (Oᵢ - Eᵢ)² / Eᵢ  
  
Where:  
Oᵢ = observed frequency  
Eᵢ = expected frequency

## 5. Mann-Whitney U Test

Purpose: Compare differences between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

Formula for U statistic:  
U = n₁n₂ + (n₁(n₁ + 1) / 2) - R₁  
  
Where:  
n₁ = sample size of group 1  
n₂ = sample size of group 2  
R₁ = sum of ranks in group 1

## 6. Wilcoxon Signed-Rank Test

Purpose: Compare two related samples to assess whether their population mean ranks differ.

Formula:  
W = Σ (rank differences)  
  
Where:  
rank differences = differences between ranks of matched pairs

## 7. Kruskal-Wallis Test

Purpose: Compare more than two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

Formula for H statistic:  
H = (12 / (N(N + 1))) Σ (Rᵢ² / nᵢ) - 3(N + 1)  
  
Where:  
N = total number of observations  
Rᵢ = sum of ranks for group i  
nᵢ = number of observations in group i

## 8. F-Test

Purpose: Compare two population variances to determine if they are equal.

Formula for F statistic:  
F = σ₁² / σ₂²  
  
Where:  
σ₁² = variance of the first population  
σ₂² = variance of the second population

## 9. Correlation Tests

Purpose: Assess the strength and direction of the linear relationship between two continuous variables.

Formula for Pearson correlation coefficient (r):  
r = Σ [(Xᵢ - X̄)(Yᵢ - Ȳ)] / (√Σ (Xᵢ - X̄)² √Σ (Yᵢ - Ȳ)²)  
  
Where:  
Xᵢ = values of the first variable  
Yᵢ = values of the second variable  
X̄ = mean of the first variable  
Ȳ = mean of the second variable

## 10. Regression Analysis

Purpose: Determine the relationship between a dependent variable and one or more independent variables.

Formula for simple linear regression:  
Y = β₀ + β₁X + ε  
  
Where:  
Y = dependent variable  
X = independent variable  
β₀ = intercept  
β₁ = slope  
ε = error term