Visual Analysis of Student Performance

Visual Analytics Course Project - Fall 2025

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Project Goal

Problem: **Traditional 'Black Box' Grade Reports.**
Hide the root causes of failure

Solution: **Interactive Exploratory Environment.**
Uncovers hidden patterns and relationships

Goal: **Develop a Visual Analytics System.**
To support educational decision-making

Key Capability: **Understand Multidimensional Risks.**
Empower experts with integrated Social + Academic insights

Potential Users

1. School Counselors:

- Need to identify at-risk students before they fail.
- Use the tool to differentiate between behavioral issues and academic struggles.

2. Educational Policymakers:

- Need to validate hypotheses (e.g., ‘Does affect grades more than study time?’).
- Design broader intervention strategies based on data clusters.

The Dataset

Source:
UCI Machine Learning Repository (Student Performance Data Set)

Volume & Subject:
Volume: 395 Students | Subject: Mathematics (Secondary School)

Dimensions:
33 Attributes per student

Type:
Mixed data (Numerical grades, Categorical demographics, Ordinal surveys)

Data Structure (4 Pillars)

1. Demographics:

Age, Sex, Address (Urban/Rural), Family Size

2. Social Context:

Parent's Job, Relationships, Alcohol consumption (Walc/Dalc)

3. School Habits:

Study time, Travel time, Absences, Failures

4. Performance (Targets):

G1 (1st Period), G2 (2nd Period), G3 (Final Grade)

Data Preprocessing

Parsing: → Custom CSV parsing implemented in D3.js.

Encoding: → Converting categorical strings (e.g., 'yes'/'no') to binary integers.

Normalization: → Scaling numerical features to ensure ensure fair weighting.

Dim. Reduction: PCA calculation to condense 33 features into 2 principal components.

Visualization Strategy

Approach: Coordinated Multiple Views (CMV)

1. Macro View:
PCA Projection
(Global clustering)

2. Correlation View:
Scatter Plot
(Grade progression)

3. Micro View:
Parallel Coordinates
(Individual profiles)

4. Context View:
Bar/Histograms
(Distribution analysis)

1. Parallel Coordinates

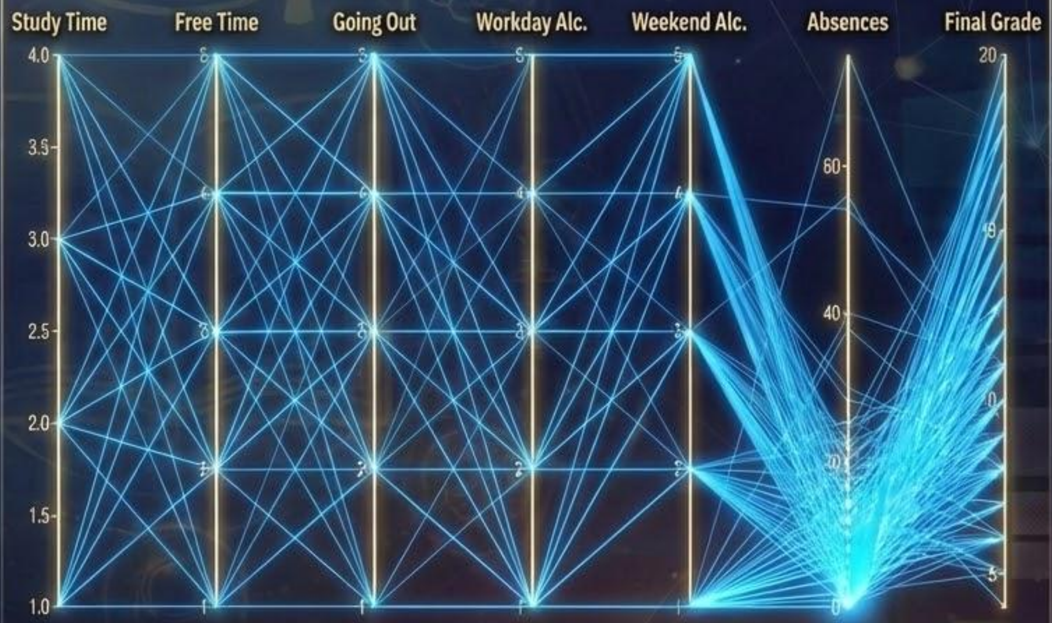
Key Features & Insights

Purpose: Multidimensional Profiling

Function: Each student is a line crossing multiple axes (Grades, Alcohol, Study Time)

Why?: Only way to visualize N dimensions simultaneously

Insight: Detects specific profiles (e.g., 'High Alcohol' + 'High Going Out Time' ->'Low G3')



2. Scatter Plot

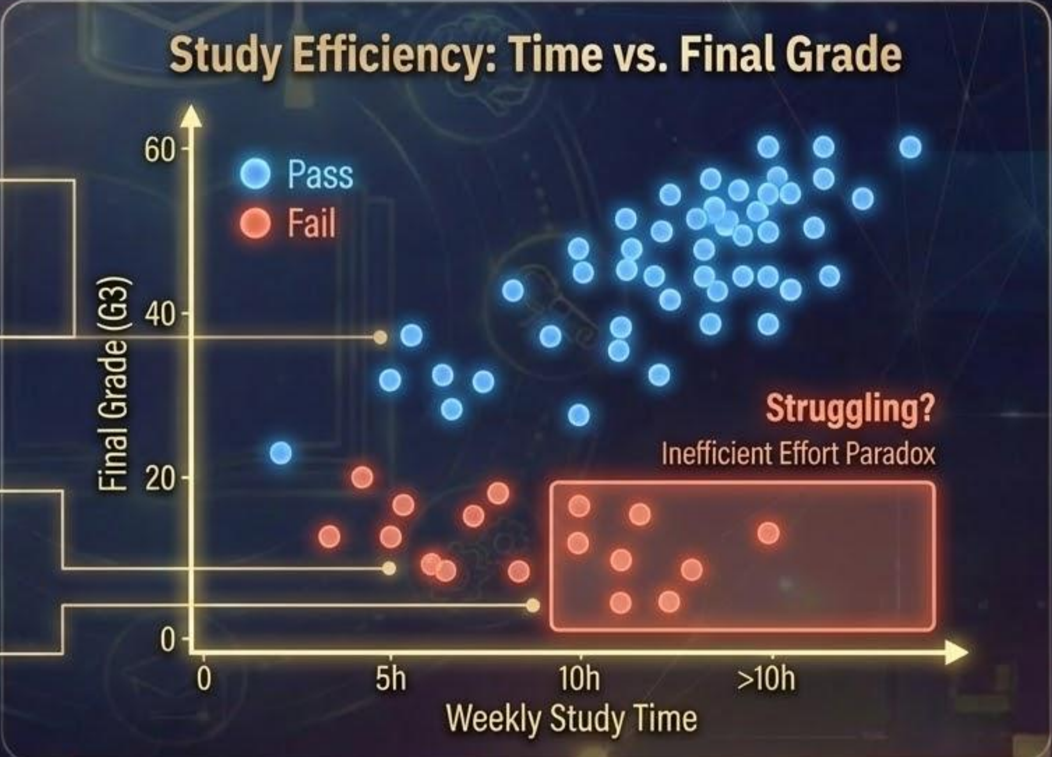
Key Features & Insights

Purpose:
Performance Correlation (Study Time vs. Final Grade)

Why?: Tests assumption: More study ≠ Better grades

Insight: Reveals 'Inefficient Effort' paradox (High study time, low grades)

Value: Identifies students needing intervention in study methods



3. PCA Projection

Key Features & Insights

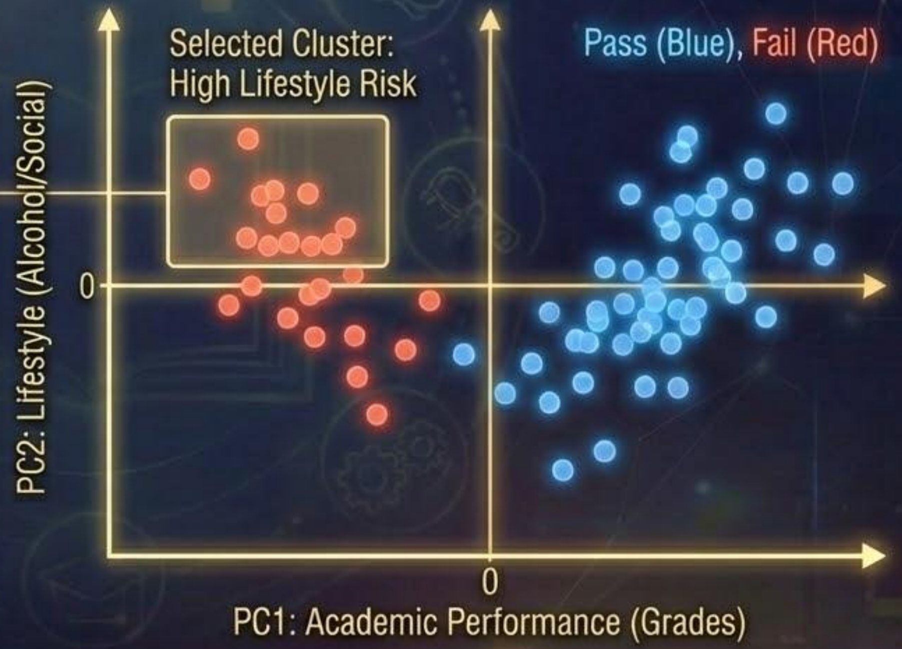
Purpose:
Cluster Analysis

Technique:
Principal Component Analysis
(2D Projection)

Why?: Reveals natural groupings based on similarity across ALL 33 variables

Interaction: 2D brushing allows selecting a ‘cluster’ to see their profile in other views

PCA Projection: Student Clusters

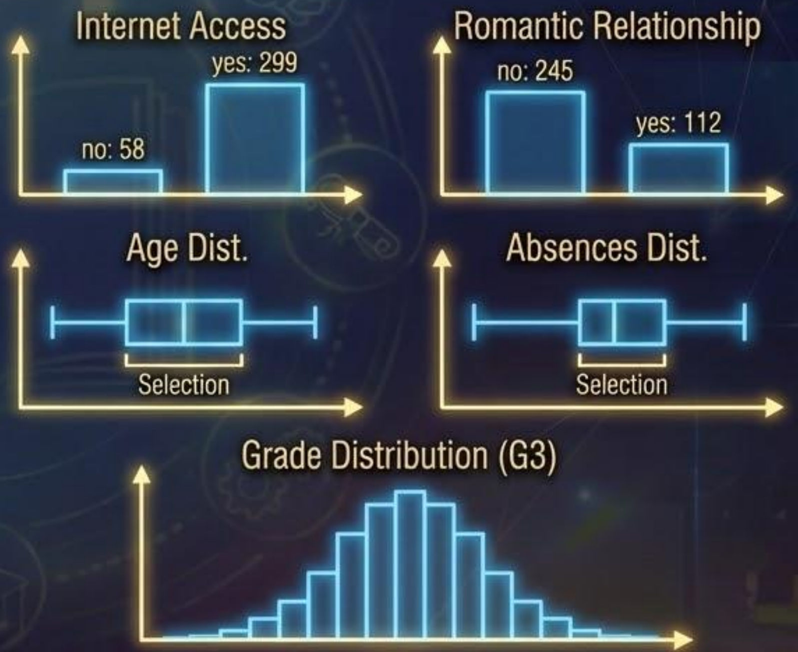


4. Context Charts

Key Features & Insights

- **Purpose:** Global Filtering & Distribution Analysis
- **Bar Charts:** Binary filters for 'Internet Access' and 'Romantic Relationships'
- **Box Plots:** Statistical summaries (Median/Quartiles) for 'Age' and 'Absences'
- **Histogram:** Visualizes the distribution of Final Grades (G3) to assess the 'shape' of performance
- **Interaction:** Acts as the controller; selecting bars or ranges here updates all other views

Context Charts: Data Distribution & Filtering



System Architecture

Frontend & Styling: HTML5, SASS (SCSS) for modular styling.

Visualization Engine: D3.js (Data-Driven Documents).

Logic: JavaScript (ES6+).

Specific Libraries: ‘pca-js’ used for real-time dimensionality reduction in the browser.

Case Studies & Insight

The 'Inefficient Effort' Paradox:

- Students studying >10h but failing (<10/20). Parallel plot reveals they are not drinkers/absentees. Problem is study method, not motivation.

The 'Gifted Underachiever' Risk:

- Students studying <2h with high grades (<15/20). High correlation with 'Going Out'. Risk of future failure when raw intellect is not sufficient.

Diminishing Returns of Study Volume

- Scatter plot reveals a saturation point. Studying >10h yields marginal gains over 5-10h, likely due to burnout.

The 'Unproductive Leisure' Trap

High Free Time is neutral on its own. However, when combined with high Going Out in the Parallel Plot, grades collapse. The risk is mismanaged leisure.

Conclusion

Summary: The system moves beyond static reporting to active exploration.

Value: Integrates statistical complexity (PCA) with interpretable details (Parallel Coords).

Impact: Allows detection of subtle student risks, such as the ‘Inefficient Effort’ paradox.