STEVENS
INSTITUTE of TECHNOLOGY
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SYS-660

Decision and Risk Analysis

Final Project Report

Investment Portfolio Decision Support System (DSS)

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1. Introduction

Problem Statement

Investors often face challenges in making data-driven decisions when allocating investments between stocks and bonds. These decisions become more complex when considering factors such as risk tolerance, investment horizon, and market volatility. The **Investment Portfolio Decision Support System (DSS)** is designed to assist users in determining optimized stock and bond allocations based on user-specific inputs and risk profiles.

Motivation and Context

Investing involves balancing risk and reward while considering long-term objectives and uncertainties. Many investors struggle to:

1. Identify suitable investment alternatives.
2. Quantify risk tolerance and returns.
3. Incorporate evolving market conditions.

The DSS provides a structured solution by integrating utility models, Monte Carlo simulations, and portfolio optimization techniques.

Targeted Users

The primary users of this DSS include:

- Individual investors seeking optimized portfolios.
- Financial analysts providing investment recommendations.
- Retirees planning long-term savings.

2. Objectives and Needs

The DSS aims to provide:

1. **Personalized Portfolio Allocation**: Generate optimized investment allocations for stocks and bonds based on risk tolerance.
2. **Monte Carlo Simulations**: Model portfolio growth and uncertainties over time.
3. **Usability and Flexibility**: Allow users to input personalized parameters (e.g., age, horizon, risk tolerance).

Goals and Challenges

Goal	Challenge
Optimize portfolio allocation	Handling data for diverse stock/bond tickers
Model investment uncertainties	Simulating market fluctuations
Incorporate user preferences	Customizing utility models dynamically
Ensure usability and flexibility	Designing an intuitive user interface

3. Alternatives and Attributes

Available Alternatives

The DSS incorporates alternatives for both **stocks** and **bonds**:

- **Stocks**: Top 50 stocks based on historical performance.
- **Bonds**: Top 20 bonds selected for risk-averse options.
- **ETFs**: Sector-specific ETFs for balanced investment.

Defined Attributes

Attribute	Description
Mean Return	Average daily returns derived from historical data
Volatility	Standard deviation of daily returns
Horizon	Number of years to invest

4. Development Process

Data Understanding

The **financial_data_last_year.csv** dataset includes:

- Historical stock and bond price data.
- Attributes like `mean_return`, `volatility`, and `utility_score` derived using Python.

Example Data Columns
AAPL.3 (Closing Prices)
TSLA.3
SPY.3

Model and Utility Function Development

The utility function incorporates three key components:

1. **Return Utility (u_r)**: Based on mean returns.
2. **Risk Utility (u_σ)**: Inverse of volatility.
3. **Horizon Utility (u_h)**: Weighted based on the time horizon.

Utility Function Formula:

$$U\_Total = w\_r * u\_r + w\_\sigma * u\_\sigma + w\_h * u\_h$$

Where:

- **w_r** = Weight for returns
- **w_σ** = Weight for risk
- **w_h** = Weight for horizon

5. Utility Model and Weighting

Utility Function and Calculations

The **utility function** forms the backbone of the DSS as it quantifies the value of different investment alternatives based on the user's risk tolerance, expected return, and investment horizon. It assigns a weighted score to each investment option, allowing for optimal selection.

Utility Function Formula

The total utility U_Total for each investment is calculated as:

$$U\_Total = w\_r * u\_r + w\_\sigma * u\_\sigma + w\_h * u\_h$$

Where:

- U_Total: The overall utility score.
- u_r: **Return utility** — Utility derived from the mean return of the investment.
- U_σ: **Risk utility** — Utility inversely proportional to the volatility (risk) of the investment.
- u_h: **Horizon utility** — Utility derived from the time horizon (number of years) for investment.
- W_r, w_σ, w_h: Weights assigned based on the user's **risk tolerance**.

Components of the Utility Function

1. **Return Utility (u_r)**:
   Return utility is proportional to the mean return of the investment. It rewards investments with higher expected returns.

   U_r = Mean Return

2. **Risk Utility (u_σ)**:
   Risk utility penalizes investments with high volatility. It is modeled as the **inverse of volatility** to reflect risk aversion:

   U_σ = 1 / Volatility (if Volatility > 0)

   If volatility equals zero (rare in practice), the risk utility is assigned a value of zero to avoid computational errors.

3. **Horizon Utility (u_h)**:
   Horizon utility reflects the benefit of long-term investments. It scales linearly with the investment horizon in years:

   U_h = Investment Horizon (years)

Weight Assignment

Weights w_r,w_σ,w_h are dynamically adjusted based on the user's **risk tolerance**. This ensures the utility function aligns with the user's preferences.

Risk Tolerance	Return Weight (w_r)	Risk Weight (w_σ)	Horizon Weight (w_h)
Low	0.3	0.5	0.2
Moderate	0.4	0.3	0.3
High	0.5	0.2	0.3

Utility Function in Action

The DSS calculates the utility score for each investment using the formula:

$$U_{Total} = w_r * \text{Mean Return} + w_\sigma * (1 / \text{Volatility}) + w_h * \text{Horizon}$$

For example:

- **Stock A** has a mean return of 0.002, volatility of 0.01, and the investment horizon is 10 years.
- User selects a **Moderate Risk Profile**: w_r = 0.4, w_σ = 0.3, w_h = 0. The utility components are:

$U_r = 0.002$, $u_\sigma = 1 / 0.01 = 100$, $u_h = 10$

The total utility score is:

$$U_{Total} = (0.4*0.002) + (0.3*100) + (0.3*10) = 0.0008 + 30 + 3 = 33.0008$$

Each investment alternative is scored using this methodology, and the DSS ranks investments based on their utility scores.

6. Risk Analysis

Uncertainty in Investments

The DSS evaluates uncertainty through **Monte Carlo simulations**. Results highlight:

- Mean expected portfolio value.
- Range of outcomes (5th and 95th percentiles).

Simulation Results

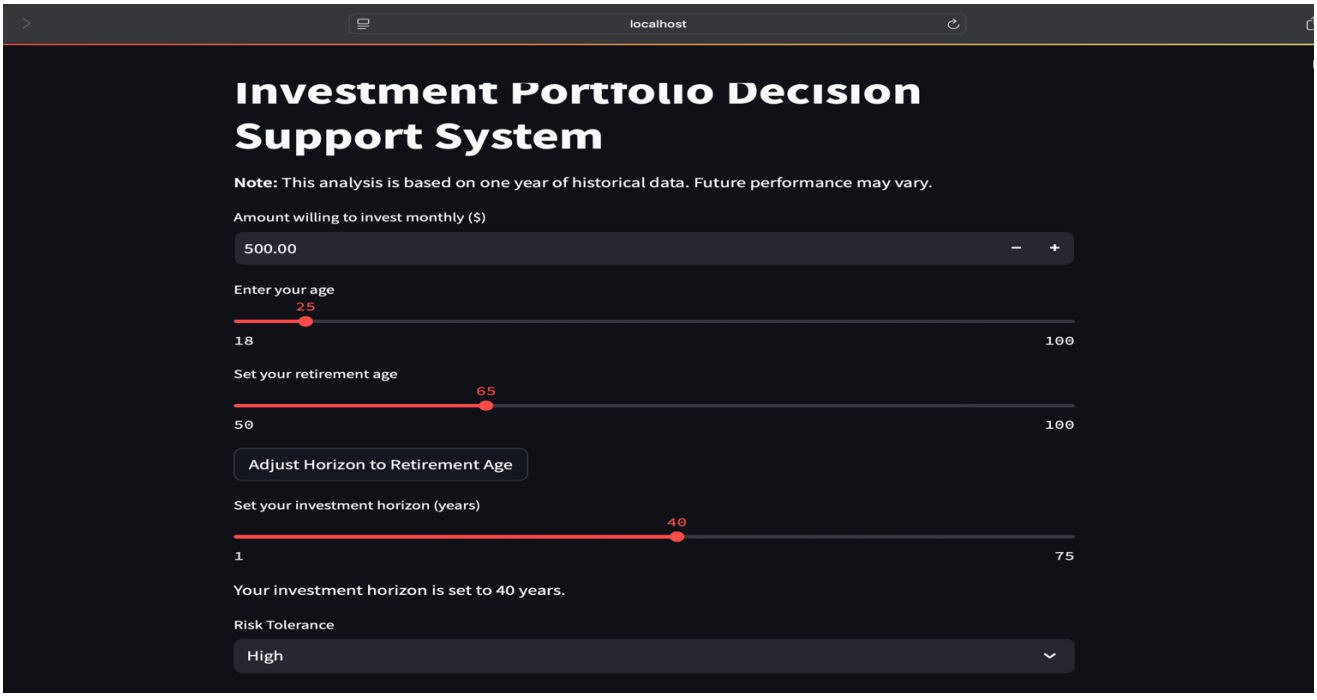
Example Output (40-year horizon):

- **Total Investment**: $240,000
- **Mean Portfolio Value**: $931,525
- **5th Percentile**: $312,501
- **95th Percentile**: $2,025,203

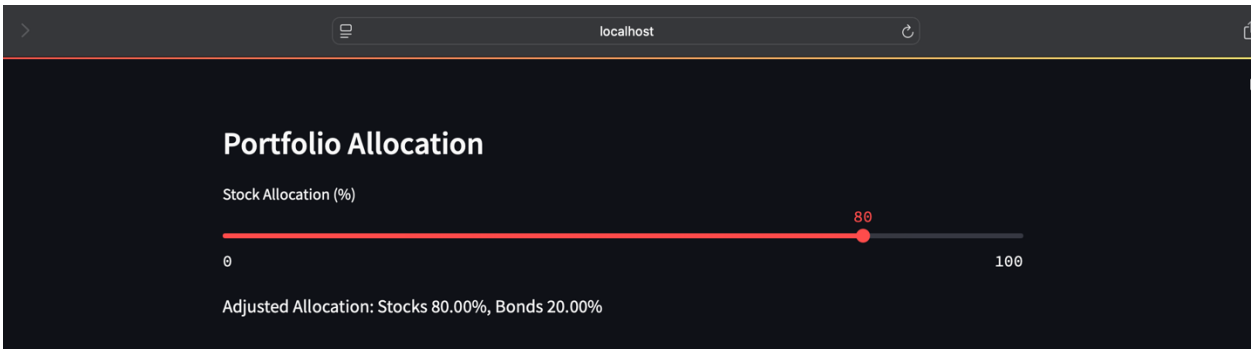
7. User Interface and Usability

Screenshots of DSS

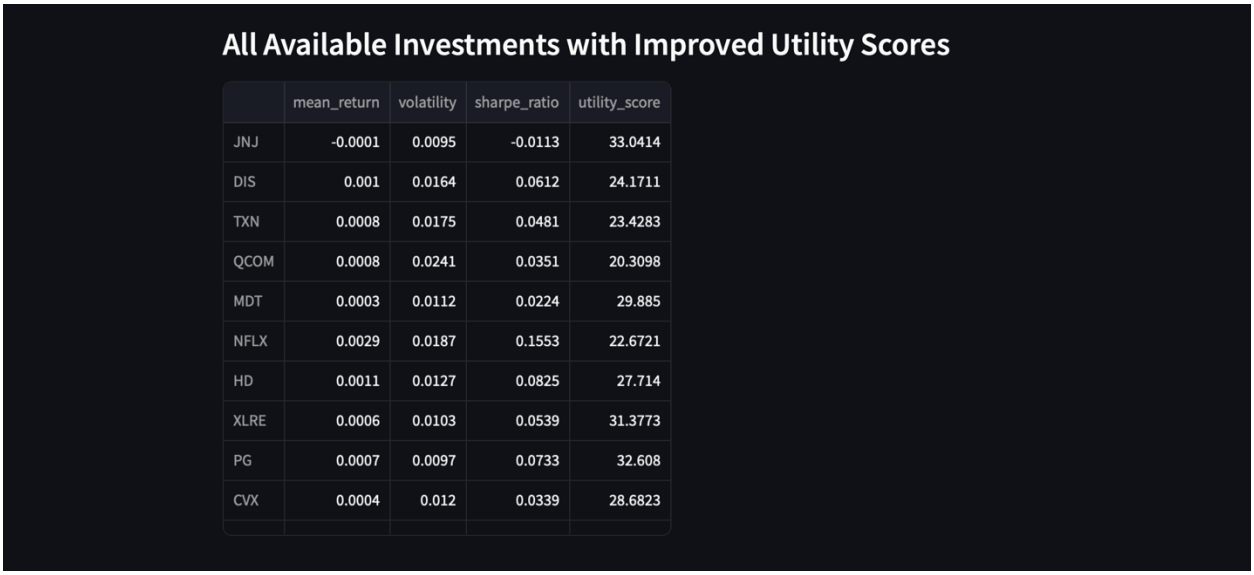
1. **Input Parameters**:
    - User inputs monthly investments, age, retirement horizon, and risk tolerance.



2. **Portfolio Allocation**:
    - Adjust stock-bond allocations dynamically.

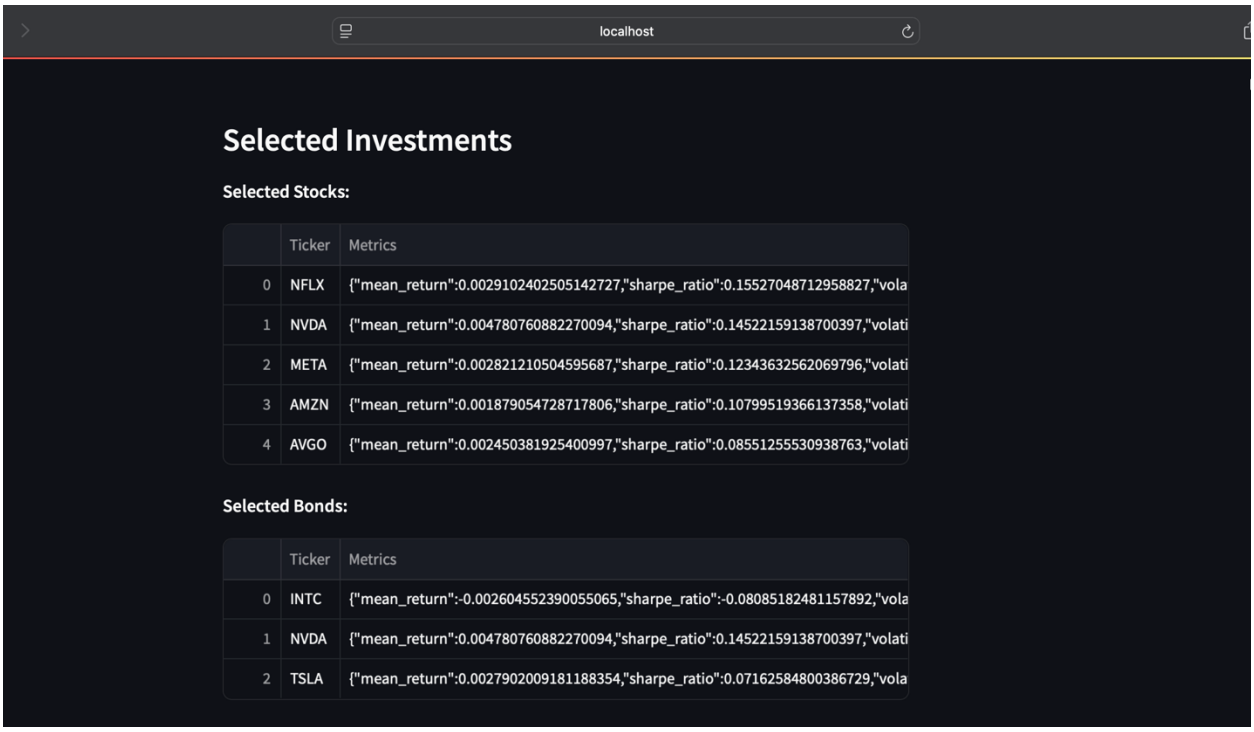


3. **Utility Scores**:
    - Table displaying mean return, volatility, and utility scores.

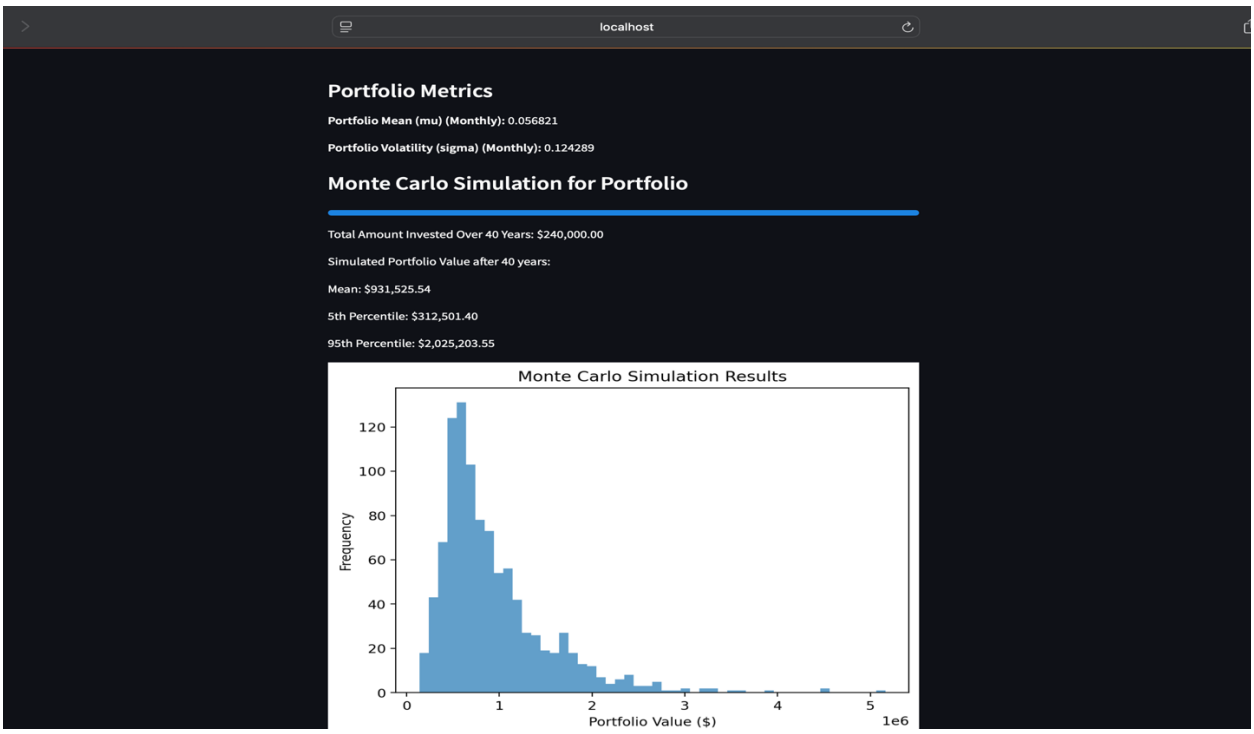


	mean_return	volatility	sharpe_ratio	utility_score
JNJ	-0.0001	0.0095	-0.0113	33.0414
DIS	0.001	0.0164	0.0612	24.1711
TXN	0.0008	0.0175	0.0481	23.4283
QCOM	0.0008	0.0241	0.0351	20.3098
MDT	0.0003	0.0112	0.0224	29.885
NFLX	0.0029	0.0187	0.1553	22.6721
HD	0.0011	0.0127	0.0825	27.714
XLRE	0.0006	0.0103	0.0539	31.3773
PG	0.0007	0.0097	0.0733	32.608
CVX	0.0004	0.012	0.0339	28.6823

4. **Optimized Investments**:
    - Selected stocks and bonds displayed with metrics.



5. **Monte Carlo Visualization**:
    - Histogram showing portfolio growth under uncertainty.



8. Results and Interpretation

Portfolio Optimization Outcomes

The DSS recommends a portfolio based on:

1. User's **risk profile**.
2. Utility scores for selecting top-performing assets.

Portfolio Metrics

Metric	Value
Portfolio Mean (Monthly)	0.0568
Portfolio Volatility	0.1242

Simulation Insights

- Monte Carlo simulation results indicate potential future portfolio values.
- The **5th and 95th percentiles** provide a range of possible outcomes.

9. Challenges and Limitations

Challenges Faced

1. **Yahoo Finance API Limitations**:
    - Limited data requests led to the use of a static dataset.
2. **Data Cleaning**:
    - Ensuring consistent and clean financial data for analysis.

Limitations

- Static dataset restricts real-time analysis.
- Simplified utility function may not capture all market behaviors.

10. Conclusion and Recommendations

The Investment Portfolio DSS effectively assists users in making data-driven investment decisions. By leveraging utility functions, portfolio optimization, and Monte Carlo simulations, the system:

- Provides personalized recommendations.
- Models investment uncertainties over time.

Future Enhancements:

1. Integrate live APIs for real-time data analysis.
2. Expand asset coverage beyond top 50 stocks and bonds.
3. Add advanced risk metrics for better decision-making.

11. References

1. [Markowitz, H. (1952). Portfolio Selection: Efficient Frontier]
2. [Monte Carlo Simulation: Geometric Brownian Motion]
3. [Python Libraries: Pandas, Numpy, Matplotlib, Streamlit]