Predictive Analysis of SpaceX Falcon 9 Rocket Launch Success

Capstone Project: IBM Data Science

By

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1. Summary

This project focused on analyzing and predicting the success of SpaceX Falcon 9 rocket landings using historical launch data. By leveraging various data science techniques, including exploratory data analysis (EDA), interactive visualization, and predictive modeling, the goal was to determine the factors that influence the success of rocket landings. The project utilized data collected through APIs and web scraping, followed by data wrangling, EDA, and the application of machine learning algorithms to forecast landing outcomes. The findings provide actionable insights that could optimize rocket landing success rates, thereby reducing launch costs and increasing efficiency.

2. Background Information

SpaceX, a leading aerospace manufacturer, has revolutionized the space industry by reducing costs through the reuse of rocket components. The Falcon 9 rocket, known for its reusable first stage, is significantly cheaper than competitors, making it highly competitive in the market. However, the success of each launch is critical for cost-effectiveness. Understanding which factors contribute to successful landings can provide SpaceX with a competitive edge. This project explores historical data to predict whether a Falcon 9 first stage will successfully land, aiming to optimize operations and reduce expenses.

3. Statement of the Problem

The challenge SpaceX faces is ensuring the consistent success of the Falcon 9 rocket landings. Although they have achieved numerous successful missions, there are still instances of failures that result in increased costs. The main objectives of this project include:

- Predicting the success of Falcon 9 rocket landings.
- Identifying key factors that influence landing outcomes.
- Providing insights into how operational conditions affect landing success.
- Supporting decision-making for optimizing future launches.

By achieving these objectives, SpaceX can improve its cost efficiency and further establish itself as a leader in the space industry.

4. About the Dataset

Data Sources

The dataset was collected using a combination of:

- **SpaceX API**: Accessed using GET requests to gather data on historical launches.
- **Web Scraping**: Utilized BeautifulSoup to extract data from Wikipedia on Falcon 9 launches.

Data Features

The dataset includes variables such as:

- Launch site
- Booster version
- Payload mass
- Orbit type
- Launch date and time
- Landing outcome (success or failure)

The data was preprocessed to clean missing values, particularly in the `LandingPad` and `PayloadMass` columns, and filtered to include only Falcon 9 launches.

5. Methodology

Data Wrangling

- Cleaned and formatted data using **pandas**.
- One-hot encoding was applied to categorical variables such as `BoosterVersion`.
- Missing values were handled by replacing `PayloadMass` with the mean value where needed.

Exploratory Data Analysis (EDA)

- Used visualization tools like **matplotlib** and **seaborn** to examine relationships between variables.
- Analyzed launch success rates based on:
  - Launch site and orbit type.
  - Payload mass and flight number.

- Performed **SQL queries** to explore unique launch sites, total payload mass, and mission outcomes.
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Interactive Visual Analytics

- **Folium maps**: Created interactive maps to visualize launch sites and success rates.
- **Plotly Dash**: Built dashboards for exploring launch data, with filters for payload ranges and launch sites.

Predictive Analysis (Classification Models)

- Split data into training and testing sets for model evaluation.
- Applied machine learning models:
    - Decision Tree
    - Support Vector Machine (SVM)
    - Random Forest
    - K-Nearest Neighbors (KNN)
- Optimized models using **feature engineering** and **hyperparameter tuning**.
- Evaluated models based on accuracy, with **DecisionTree** achieving the best performance (accuracy: 87.3%).

6. Results and Discussion

Key Insights

- **Launch Site Analysis**: KSC LC-39A had the highest success rate (42%) among all launch sites.
- **Payload and Launch Success**: Higher payload masses generally resulted in more successful landings, particularly in orbits like LEO, ISS, and VLEO.
- **Orbit Success Rates**: Orbits such as ES-L1, GEO, HEO, and SSO demonstrated higher success rates.
- **Yearly Trends**: The success rate of launches has shown a significant increase from 2013 onwards, with the highest success rate recorded in 2019.
- **Predictive Model Performance**:
    - The **DecisionTree** model was found to be the most effective with an accuracy of 87.3%.

- The model performed well in distinguishing between successful and unsuccessful landings, though improvements could be made to reduce false positives.

Visual Results

- Interactive dashboards and Folium maps provided clear visualizations of the launch success distribution by site and payload.
- Scatter plots revealed a positive correlation between payload mass and successful outcomes.

7. Recommendations and Way Forward

Recommendations

- **Focus on High-Performing Launch Sites**: Investing in launches from sites like KSC LC-39A can yield higher success rates.
- **Optimize Payload Mass**: Maintaining payloads within optimal ranges could improve landing success, especially for orbits like LEO and ISS.
- **Leverage Predictive Models**: The DecisionTree model can be further refined to improve accuracy, helping SpaceX make informed decisions on launch conditions.

Way Forward

- **Incorporate Real-Time Data**: Integrate real-time data from future launches to continuously update and refine predictive models.
- **Advanced Feature Engineering**: Utilize additional features such as weather conditions, wind speed, and booster conditions to enhance model accuracy.
- **Expand Analysis to Other Rocket Models**: Apply the methodology to other SpaceX rockets (e.g., Falcon Heavy) to broaden insights and improve overall launch success rates.

8. References

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