BigMart Sales Prediction

A comprehensive machine learning solution for retail sales prediction, demonstrating end-to-end data science methodology from exploratory analysis to production deployment.

Project Overview

This project implements a complete ML pipeline to predict `Item_Outlet_Sales` for a retail chain. The solution follows industry best practices and achieves a 12.5% improvement over baseline performance through systematic feature engineering, model optimization, and ensemble methods.

Key Results

- **Final Model Performance:** RMSE 1245.87 (12.4% improvement over baseline)
- **Feature Engineering:** 40+ derived features from statistical analysis
- **Production Ready:** Serialized pipeline with comprehensive validation
- **Statistical Rigor:** Hypothesis testing confirms feature significance

Technical Highlights

Data Science Methodology

1. **Exploratory Data Analysis** - Comprehensive statistical analysis and visualization
2. **Hypothesis Testing** - Statistical validation of feature relationships
3. **Feature Engineering** - Smart imputation and domain-specific feature creation
4. **Model Development** - Systematic algorithm comparison and optimization
5. **Ensemble Methods** - Advanced stacking with optimized weights
6. **Production Pipeline** - Deployment-ready artifacts with monitoring

Machine Learning Architecture

- **Ensemble Model:** LightGBM + CatBoost + Neural Network
- **Validation Strategy:** 5-fold Group Cross-Validation
- **Optimization:** Bayesian hyperparameter tuning with Optuna
- **Feature Count:** 40+ engineered features from 12 original features

Repository Structure

```
├── baseline_pipelines/          # EDA and hypothesis testing notebooks
├── finetuning_pipeline/         # Model development and optimization
├── production_models/           # Serialized model artifacts
├── bigmart_pipeline/           # Production deployment pipeline
├── BigMart_Report_Notebook.ipynb  # Complete interactive analysis
├── REPORT.md                   # Detailed technical documentation
└── Email_Report.md             # Executive summary for stakeholders
```

Quick Start

Prerequisites

```
pip install pandas numpy scikit-learn lightgbm catboost matplotlib seaborn
scipy
```

Run Analysis

```
# Complete interactive analysis
jupyter notebook BigMart_Report_Notebook.ipynb

# Individual pipeline components
jupyter notebook baseline_pipelines/EDA.ipynb
jupyter notebook finetuning_pipeline/final_version.ipynb
```

Generate Predictions

```
from finetuning_pipeline.BigMartpreprocessing import BigMartPreprocessor
import pickle

# Load trained pipeline
with open('bigmart_pipeline/bigmart_preprocessor.pkl', 'rb') as f:
    preprocessor = pickle.load(f)

# Process new data and predict
predictions = model.predict(new_data)
```

Key Features

Statistical Analysis

- **Missing Value Analysis:** Smart imputation strategies using hierarchical grouping
- **Hypothesis Testing:** Kruskal-Wallis and Spearman correlation tests
- **Feature Relationships:** Comprehensive correlation and effect size analysis

Feature Engineering

- **Statistical Features:** Item and outlet-level aggregated statistics
- **Business Logic:** Premium item flags, age calculations, ratio features
- **Categorical Encoding:** One-hot encoding with fallback handling
- **Target Engineering:** Log transformation for improved model stability

Model Development

- **Algorithm Comparison:** RandomForest, LightGBM, CatBoost, XGBoost
- **Hyperparameter Optimization:** Bayesian search with cross-validation
- **Ensemble Methods:** Stacking with optimized weight combinations
- **Validation:** Robust cross-validation preventing data leakage

Production Features

- **Serialization:** Complete pipeline saved as pickle artifacts
- **Input Validation:** Schema checking and error handling
- **Scalability:** Efficient batch processing capabilities
- **Monitoring:** Prediction confidence intervals and interpretability

Performance Summary

Model	RMSE	Improvement
Baseline RandomForest	1421.89	-
Optimized LightGBM	1287.65	9.4%
Final Ensemble	**1245.87**	**12.4%**

Documentation

- `REPORT.md` - Complete technical methodology and results
- `Email_Report.md` - Executive summary for stakeholders
- `BigMart_Report_Notebook.ipynb` - Interactive analysis with plots
- `baseline_pipelines/` - Step-by-step EDA and hypothesis testing
- `finetuning_pipeline/` - Model development and optimization

Business Impact

The model provides reliable sales predictions enabling:

- **Inventory Optimization:** Accurate demand forecasting
- **Revenue Planning:** Data-driven sales projections
- **Store Performance:** Outlet-specific insights and recommendations
- **Product Strategy:** Item-level performance analysis

Technical Skills Demonstrated

- **Statistics:** Hypothesis testing, correlation analysis, effect sizes
- **Machine Learning:** Feature engineering, ensemble methods, hyperparameter tuning
- **Software Engineering:** Object-oriented design, serialization, error handling
- **Data Science:** End-to-end pipeline development, model validation, production deployment

Contributing

This project demonstrates professional data science practices including:

- Reproducible analysis with clear documentation
- Production-ready code with proper error handling
- Comprehensive testing and validation
- Clean, maintainable codebase following best practices

License

This project is for educational and demonstration purposes.

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