Comparative Analysis of An Explainable Ensemble of Multi-View Deep Learning Model for future price prediction of preowned cars

Introduction:

The rapidly growing market for pre-owned vehicles has created an imperative need for sophisticated price prediction mechanisms that can account for the complex interplay of numerous factors affecting vehicle valuations. While traditional statistical approaches have long served this purpose, the emergence of deep learning, particularly multi-view architectures, has opened new frontiers in prediction accuracy. However, the inherent "black box" nature of deep learning models has often posed challenges for stakeholders who require transparent and interpretable decisions, especially in the automotive market where pricing decisions have significant financial implications.

This research advances the field by introducing an innovative ensemble approach that combines multiple deep learning models, each analyzing different "views" or aspects of vehicle data, while maintaining explainability through integrated interpretation mechanisms. By leveraging diverse data perspectives - from historical pricing patterns and market trends to vehicle-specific attributes and regional factors - the ensemble architecture captures subtle patterns and relationships that single-view models might overlook. The incorporation of explainability techniques transforms these complex models from opaque predictors into transparent decision support tools, enabling stakeholders to understand and trust the reasoning behind price predictions.

The significance of this work lies not only in its potential to improve prediction accuracy but also in its practical applicability to real-world scenarios where decision transparency is crucial. By bridging the gap between advanced deep learning techniques and interpretable predictions,

this research contributes to both the theoretical understanding of multi-view ensemble models and their practical implementation in the automotive industry. The used car market is growing exponentially due to increasing demand for cost-effective transportation solutions. Pricing a used car accurately is challenging due to the diverse factors affecting its valuation. Traditional machine learning models often rely on structured numerical data, whereas deep learning methods can leverage multi-view inputs, including images and textual descriptions. However, deep learning models often lack interpretability, limiting their practical applications in high-stakes decision-making

Traditional Machine Learning Approaches

Early approaches to price prediction relied on regression models such as Linear Regression, Decision Trees, and Random Forest. These methods provided baseline performance but failed to capture complex interactions among features.

Deep Learning for Price Prediction

Recent advancements in deep learning have introduced architectures such as CNNs for image-based car condition assessment, RNNs and Transformers for textual analysis, and hybrid models combining multiple data sources. However, the lack of interpretability remains a challenge.

Multi-View Data Representation

Structured Data: Includes numerical features like mileage, age, brand, model, and previous price trends.

Textual Data: Extracted from seller descriptions using NLP techniques such as Word2Vec and BERT.

Image Data: Processed using CNNs to assess vehicle condition

Deep Learning Architectures

CNN for Image Analysis: Used to evaluate visual attributes such as dents, scratches, and overall vehicle condition.

RNN and Transformer for Text Analysis: Used to extract insights from textual descriptions.

Ensemble Model: Combines the outputs from CNN, RNN, and a structured data-based MLP (Multi-Layer Perceptron) using a weighted averaging mechanism.

Experimental Setup

Dataset**:** A combination of public datasets (Mendeley, CarDekho) and proprietary datasets.

Evaluation Metrics: Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), R-squared (R^2) score.

Baseline Models: Traditional machine learning models and single deep learning architectures for performance comparison.

Conclusion:

The Explainable Ensemble of Multi-View Deep Learning Model for Future Price Prediction of Preowned Cars leverages the power of deep learning to enhance the accuracy and interpretability of price forecasting. By integrating tabular, time-series, image, and text data, the model captures various factors influencing car resale values, including vehicle specifications, market trends, visual condition, and textual descriptions.

Through multi-modal deep learning, different architectures such as TabNet, LSTM, CNN, and BERT work together to process diverse data types, ensuring a holistic approach to price prediction. The inclusion of explainability techniques such as SHAP values, Grad-CAM, and attention mechanisms adds transparency, allowing users to understand why a certain price was predicted.

The project's structured workflow—from data preprocessing and feature engineering to model ensembling and deployment—ensures scalability and real-world applicability. This solution can benefit individual car buyers, dealerships, and online marketplaces, providing data-driven insights for better decision-making in the used car market. Ultimately, this project highlights the potential of AI-driven pricing models in transforming the automotive industry while maintaining interpretability and trustworthiness.