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A SURVEY ON USED VEHICLE PRICE ESTIMATION SYSTEMS USING ARTIFICIAL INTELLIGENCE METHODS

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ABSTRACT

Recently, due to the high cost of new cars, which most buyers cannot afford, the market for used car transactions in the Kingdom of Saudi Arabia has been rapidly expanding. Several e-commerce websites offer intermediary services between buyers and dealers of used automobiles. However, it is very helpful to have information about the correct vehicle price for many buyers and sellers before making any decision about selling or buying a used car. Therefore, there is a great demand to develop an accurate vehicle price estimation system through the employment of machine learning (ML) and deep learning (DL) approaches. However, a large number of significant factors influence the price of a vehicle, making vehicle price estimation a challenging task. In general, the standard regression methods might not be efficient for high-dimensional data. This paper aims to investigate the recently developed vehicle price estimation systems that are based on the employment of ML and DL approaches. The recently developed systems are discussed and criticized in detail. In addition, we present a set of evaluation metrics to assess the efficiency of any vehicle price prediction system.

Keywords: *Vehicle Price Estimation, Deep Learning, Feature Extraction, Machine Learning, Used Cars.*

1. INTRODUCTION

Recently, the term Artificial Intelligence (AI) has been used widely in diverse types of applications and approaches [1, 2, 3]. In general, the AI landscape spreads across a collection of technologies including: Machine Learning (ML), Deep Learning (DL), Computer Vision, Natural Language Processing (NLP), and many others. These technologies allow the machine to understand human language, make a prediction, and learn from example [4].

Mainly, the AI system accepts data from an input unit (for instance, text, image, speech, etc.). The AI system then processes the received data through applying different rules and algorithms, predicting, interpreting, and acting upon the input data. After the processing task is completed, the system provides an outcome (for instance, success or fail). The final result is then assessed through analyzing, discovering, and obtain feedback. Finally, the AI system employs its assessments to maintain the input data, rules, and algorithms. Usually, this loop is repeated till the desired result is achieved [5].

Recently, the used vehicle price estimation issue has been considered as a high research interest, as it necessitates obvious effort and background in the field. In 2021, almost 557,000 used cars were sold to customers in the Kingdom of Saudi Arabia [6], this number has increased in the last few years due to several reasons, including the increasing in exportation and transportation fees, as the prices of used cars have gone by 20% [7].

Therefore, there is a high demand for developing an efficient used car price estimation system using the advances in ML and DL technologies, where this kind of systems will benefit the car buyers in several ways: minimize the time needed for estimating such cars, minimize the required effort for checking up the vehicle, and save buyers' expenses [8].

According to the research study conducted in this paper, the problem of used vehicle predicting prices has not been studied intensively in the Kingdom of

Saudi Arabia, although this kind of tasks is considered as a critical task for vehicle buyers and even for sellers. Based on our research investigation, there is no single study that has focused on the problem of vehicle price estimation is Saudi arabia. Therefore, the presented work in this paper is considered as a new research work, and provides a set of evaluation metrics to assess the performance of any vehicle price estimation system.

This paper aims to discuss and analyze the problem of used vehicle price estimation in the Kingdom of Saudi Arabia, and summarizes the recent developed AI-based vehicle price estimation approaches. The primary contributions of this paper lies on the following aspects:

1. Research the recent developed AI-based used vehicle price estimation systems.
2. Discuss and analyze the recent developed systems.
3. Present a set of assessment metrics for evaluating the efficiency of any developed used vehicle price estimation system.

The remainder of this paper is structured as follows: In Section 2, we discuss the recent developed vehicle price estimation systems. In Section 3, we discuss and analyze the developed systems in terms of regression accuracy and the employed machine learning or deep learning models. Section 4 presents several evaluation metrics which are required to be taken into consideration when developing an efficient vehicle price estimation system. And Finally, Section 5 summarizes the work presented in this paper and draws a list of future works.

2. RELATED WORKS

This section discusses the recent developed machine-learning and deep-learning approaches for the used vehicle estimation prices. There are several artificial intelligence approaches that have been developed for the purpose of vehicle estimation, however, in this section, we discuss the most relevant and recent approaches.

2.1 Used Vehicle Price Estimation Systems

The study presented by Lavanya et al. [9] involves the design and development of vehicle price prediction system using ML. Three different machine learning approaches have been employed: linear regression, decision tree, and random forest to predict the vehicles prices in Mauritius. The obtained results revealed that the random forest classifier offers the best means absolute error and mean square error among its competitors. On the other hand, authors showed that the lack of results referred to the short number of records that have been utilized.

Chandak et al. [10] developed a supervised machine learning model for estimating the value of a vehicle based on the employment of several attributes. The developed system consists of several machine learning models including the K-Nearest Neighbor (KNN) and decision tree. This work includes a correlation study among the employed attributes, for instance, the obtained results revealed that there is a positive correlation between the prices and the milage, year of registration and milage, whereas a negative correlation is presented between the prices and the year of registration. In conclusion, authors revealed that the KNN classifier offers the best mean square error.

The work presented by Gegic et al. [11] involves a development of a vehicle price estimation system using the employment of 3 different ML approaches: Artificial Neural Networks, Support Vector Machine, and Random Forest. The developed system ensembled multiple machine learning algorithm to increase the vehicle price estimation accuracy. The obtained accuracy was close to 92.38% using the developed ensemble system, where this is a substantial improvement over employing single machine learning models.

The work presented by Gajera et al. [12] includes the design and development of a smart vehicle price estimation system using the employment of ML technology, through adopting 5 different supervised machine learning algorithms, including: Linear regression, KNN, Random Forest, XB boost and Decision tree. According to the obtained results, the presented results analyzed the performance of the employed machine learning models through assessing the root mean squared error rate for each one. Random Forest achieves the best vehicle price estimation with the minimum root means squared error of 3702.34.

Samruddhi et al. [13] presented a supervised ML model using the K-Nearest Neighbor regression algorithm in order to analyse the prices of the used vehicles. The developed model was trained using a dataset containing three distinct ratios for k values between 2 and 10. The obtained accuracy result is close to 85% with Root Mean Squared Error of 4.01 and Mean Absolute Error rate of 2.01 with the K value of 4.

The work presented by Mammadov [14] involves the design and development of a linear regression method to estimate the car prices in the United States (US) market, to assist customers to

understand the most significant features in the US automobile industry. In this work, several data analysis techniques have been employed, including data cleaning, exploration, data visualization, and feature selection through the adoption of the Recursive Feature Elimination (RFE).

A ML algorithm based on employment of linear regression model has been proposed by Asghar et al. [15] to estimate the price of cars. Different data cleaning and processing methods have been employed in order to overcome the problems exist in the employed vehicle price dataset. The found results showed an enhancement over the existing research working with RMSE of 0.919.

Karakoc et al. [16] developed two distinct artificial neural network models for predicting car prices and verified them using a dataset from car sales website. The designed neural network model consists of two hidden layers with 30 and 25 neurons for the first hidden and second hidden layers respectively. The developed neural network model offers high prediction accuracy with 91.38%.

The work presented by Xia et al. [17] includes the design, development and an assessment of ForeXGBoost model that takes the advantage of carefully-designed data filling algorithms for the recovery of missing data. A sliding window has been employed in order to extract the historical sales and production data features. ForeXGBoost can enhance the car prediction accuracy. In addition, this work analyzed the impact of different attributes and data correlation among features on the overall prediction accuracy.

Three different ML algorithms based on the kind of regression, have been implemented by Gegic et al. [18], in order to estimate the used cars' prices. Three different supervised ML algorithms have been employed as follows: linear regression, lasso regression and ridge regression. The obtained results from employing the aforementioned three machine learning models, are as follows: 83.65% for linear regression, 87.09% for the lasso regression, and 84.00% for the ridge regression models.

Liu et al. [19] considered the performance issue of a car prediction system, through analyzing the linear correlation between vehicle conditions, vehicle parameters, transaction factors, and used car price. A system for predicting automobile prices using the PSO-GRA-BPNN architecture has been proposed. Used car costs have a correlation of over 0.70 with variables like the original sticker price, mileage, gearbox, displacement, fuel consumption, and registration time. The suggested PSO-GRA-BPNN model has a prediction error of 30.041%, which is lower than the three other models (linear regression, random forest, and support vector machine).

The work presented by Hankar et al. [20] involves the employment of several regression methods based on supervised machine learning in order to predict the vehicle price of used cars through considering many factors including: milage, fuel type, mark, model, fiscal, and the production year of the vehicle. The experiments conducted revealed that gradient boosting regression exhibited a high R-squared score and a low root mean square error.

A comparative analysis on the performance of regression has been conducted by Monburinon et al. [21] based on supervised machine learning models using car market dataset collected from German E-commerce website. The presented work analyzed the performance of three different machine learning models: Gradient Boosted, Random Forest, and Multiple Linear Regression. As a result, the gradient boosted regression model achieves the best Mean Absolute Error (MAE) with 0.28, whereas the Random Forest Regression model offers MAE with 0.35, and the Multiple Linear Regression with MAE of 0.55.

Pudaruth [22] investigated the application of supervised machine learning methods to estimate the used vehicle prices in Mauritius. Different machine learning techniques have been employed, including: k-nearest neighbors, naïve bayes, and decision trees, through the adoption of data from daily newspapers. After considering several experiments, the mean error for the linear regression was 51,000, whereas the mean error was around 27,000 using the KNN.

A used vehicle price prediction system is presented by Noor & Jan [23] using the adoption of supervised machine learning algorithms. Multiple linear regression models have been adopted that offered 98% estimation precision. In addition, a prediction system with the price as the dependent variable has been proposed. The price attribute is derived from a number of variables, including the vehicle's model, city, manufacturer, color, version, mileage, and power steering.

Peerun et al. [24] in their study includes an investigation on assessing where it is reliable to predict the used vehicle's price using artificial neural networks. Four machine learning models have been trained using data featuring 200 unique automobiles from a variety of sources. Authors

conclude that Support Vector Machine provides marginally superior outcomes compared to neural network and linear regression. However, authors recommend to employ a large dataset in order to conduct more experimentation with different network types and structures to perform better prediction accuracy.

Sun et al. [25], a vehicle price evaluation model has been developed based on big data analysis that exploits the advantages of broadly circulated vehicle data and a huge number of vehicle transaction data to investigate the price data for each vehicle through adopting the optimized BP neural network algorithm. The optimized BP neural network model is utilized to determine the optimal number of hidden neurons in the BP neural network, thereby improving the convergence speed of the network topology and the precision of the prediction model.

A modern data mining method has been employed by Listiani [26] that is independent of input dimension namely the Support Vector Regression, that has been used to overcome the problem of used vehicle price estimation. Authors compared the estimation accuracy against the statistical regression model. The work presented involves a fully automatic approach for turning and implementing the SVR.

The work presented by Wu et al. [27] involves an expert system for used vehicle prices using adaptive neuro-fuzzy inference system. The developed system comprises three major phases: a data acquisition function, a price estimator algorithm, and a system for analyzing performance. Authors disclosed that the price of a vehicle is primarily determined by its make, production year, and engine type. A comparison has been made between the developed system and a conventional artificial neural network model with a back-propagation network. This study revealed that the proposed expert system improves the accuracy of the vehicle's price prediction.

3. DISCUSSION

As presented in the previous section, more than 18 research studies discussed the problem of used vehicle price estimation. However, the presented works differ in terms of efficiency, employed dataset, number of employed features, and the total number of records in the adopted dataset. Therefore, this section discusses the recent developed systems in terms of the total number of records in the selected dataset, total number of features, and the employment frequency of the ML model.

According to research work discussed in the previous section, there are 14 different vehicle price prediction datasets have been employed in the recent developed vehicle price prediction systems. Each dataset is different in size, parameters, and data types. Figure 1 presents the number of records (dataset size) that are exist in each dataset. As seen below, Alibaba Cloud Car Sales dataset is the one with the highest number of records with almost 1,000,000 records, whereas the E-commerce dataset includes the minimum number of records with 200 records in total.

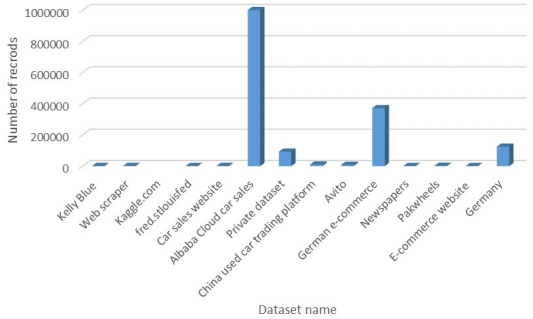

Figure 1: Total number of records for each dataset

Usually, the vehicle price prediction datasets with high number of records will achieve better prediction accuracy. Therefore, Alibaba Cloud Car Sales dataset may offer better prediction accuracy than other datasets. Therefore, it is significant to focus on a vehicle price prediction dataset with large number of records. However, large dataset requires an intensive data preprocessing including cleaning and maintaining missing data values.

In the context of evaluating ML/DL models, feature selection analysis is widely regarded as a crucial method for simplifying models and improving their performance in terms of fit, generalization, and forecast accuracy. Hence, it is significant to analyze the most significant features of the vehicle price dataset, to enhance the ML model accuracy and efficiency.

The number of features is also studies and analyzed for each dataset. The selected features in the training process have a high impact on the training accuracy. For instance, considering significant features in the training process will increase the prediction accuracy. Figure 2 shows the total number of features that have been employed for each vehicle price prediction dataset. As a result, the Germany dataset includes the largest number of employed features, with almost 179 features, whereas Alibaba Cloud Car Sales dataset came in the next place with a total number

of 33 features. The minimum number of employed features is exist in five different datasets: Kelly Blue book, Private dataset 2, Avito, Newspapers, and Pakwheels datasets.

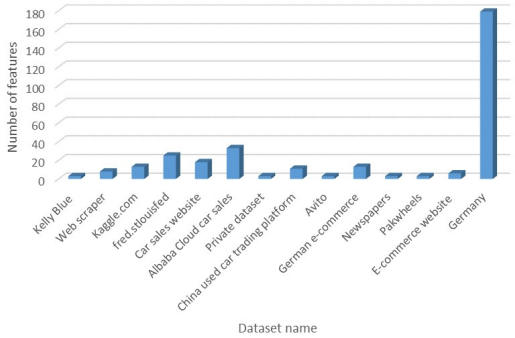

Figure 2: The number of features for each dataset

The Germany vehicle price prediction dataset is considered as unreliable with comparison to other datasets. As most of the existing vehicle price prediction datasets employed less than 15 features in the training process. Moreover, the mean of the employed features in the recent developed vehicle price predictions systems is almost 8 features. Therefore, it is important to choose the most significant features that affect the vehicle price prediction function, in order to allow for better vehicle price prediction accuracy.

The employment of ML or DL models have been studies and analyzed also. There are several machine learning and deep learning models have been employed with different requirements for the training process and complexity, and the prediction accuracy. Figure 3 shows the machine learning and deep learning models which have been employed in the vehicle price prediction. In addition, the frequency for employing each model is presented. As a result, Logistic Regression model has been employed in 6 different research works, with the maximum number of employments. On the other hand, XG, Naïve Bayes Ridge, and Lasso models have been employed only once.

Therefore, it is very important to select an efficient machine learning model with efficient parameters in order to allow for better used vehicle price prediction accuracy. An intensive research work is required to be accomplished in order to assess the performance of several machine learning and deep learning models, to pick the best model with the most efficient reliability and prediction accuracy.

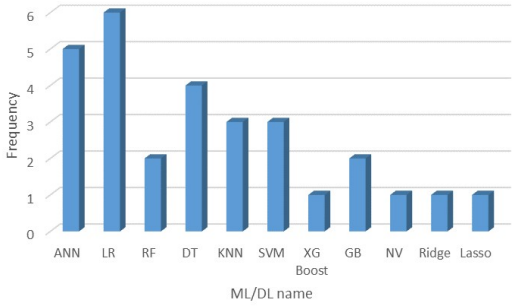

Figure 3: The employment frequency of ML/DL models in the existing systems

4. EVALUATION METRICS FOR USED VEHICLE PRICE ESTIMATION SYSTEMS

As discussed above, several used car price prediction systems have been developed recently with various datasets, factors, accuracy results, and the employed ML model. Therefore, it is significant to study and analyze the performance of such system through adopting a comparison mechanism. For this purpose, we presented five main parameters which can be adopted in assessing the recent developed vehicle price prediction systems. The suggested parameters are as follows:

1. Employed ML/DL model: many machine learning and deep learning models have been developed with different accuracy, memory requirements, and speed. Therefore, it is important to study and analyze the selected machine learning or deep learning models.
2. Car Price Dataset: as presented earlier in the literature, there are several car price datasets available online. However, it is significant to select an efficient car price dataset in order to develop an accurate car prediction system.
3. Dataset Size: the car prediction dataset size is a significant for developing a reliable car prediction system.
4. Number of Features: this presents the total number of features that have been employed to train the ML model.
5. Obtained Results: the performance of each developed system has been studied and analyzed, in order to present the car price prediction accuracy.

Table 1 shows a comparison between the recent developed used vehicle price prediction systems. As presented below, the existing systems have been analyzed based on five main factors as stated above.

TABLE 1: A COMPARISON AMONG THE EXISTING VEHICLE PRICE ESTIMATION SYSTEMS.

Research work	Authors	Employed ML/DL algorithm(s)	Dataset	Dataset size	# of features	Results
[9]	Lavanya et al. 2021	Linear regression, Random Forest, & Decision Tree regressions	Kelly Blue book	804	3	Random Forest RMSE: 5321.687 MAE: 1725.187
[10]	Chandak et al. 2019	K-Nearest Neighbour & Decision Tree	Private dataset	NA	NA	(KNN) RMSE: 5581.96 (Decision Tree) RMSE: 4961.64
[11]	Gegic et al. 2019	ANN, Support Vector Machine, & Random Forest	Web scraper	1,105	8	Best Accuracy: SVM 48.23% Minimum error: ANN 7.05%
[12]	Gajera et al. 2021	Linear regression, KNN, Random Forest, XG Boost, & Decision Tree	Private dataset 2	92,386	3	The best is the Random Forest with RMSE: 3702.34
[13]	Samruddhi et al. 2020	K-Nearest Neighbour	Kaggle.com	NA	13	Accuracy:85.00% RMSE: 4.73 MAE: 2.13
[14]	Mammadov 2021	Linear regression	fred.stlouisfed.org	205	25	RSME: 0.917
[15]	Asghar et al. 2021	Linear regression	fred.stlouisfed.org	205	25	RSME: 0.919
[16]	Karakoc et al. 2020	Artificial Neural Network	Car sales website	1,000	18	Success: 91.38%
[17]	Xia et al. 2020	ForeXGBoost	Alibaba Cloud car sales dataset	1,000,000	33	ForeXGBoost outperforms benchmark algorithms
[18]	Gegic et al. 2019	Linear regression, lasso regression, and ridge regression	Web scraper	1,105	8	Linear: 83.65% Lasso: 87.09% Ridge: 84.00%
[19]	Liu et al. 2022	PSO-GRA-BPNN	China used car trading platform https://www.iautos.cn	10,260	11	MAE: 0.475 R^2: 0.984
[20]	Hankar et al. 2022	Gradient Boosting	Avito	8,000	3	Gradient Boosting RMSE: 44516.20 R^2: 0.80
[21]	Monburinon et al. 2018	Gradient Boosting	German e-commerce website	371,528	13	MAE: 0.28
[22]	Pudaruth 2014	Multiple linear regression, Naïve bayes, k-nearest neighbour, and decision tree	Newspapers	400	3	MAE: 41,962
[23]	Noor & Jan 2017	Multiple linear regression	Pakwheels	2,000	3	Precision: 98%
[24]	Peerun et al. 2015	Support vector machine, Neural Network, Linear regression	E-commerce website	200	6	MAE: 30,605
[25]	Sun et al. 2017	Optimized BP neural network	E-commerce website	NA	NA	NA
[26]	Listiani 2009	Support Vector Regression	Germany	124,386	179	RMSE: 8.000
[27]	Wu et al. 2009	Adaptive Neuro-Fuzzy Inference System (ANFIS)	User car website in Taiwan	NA	3	NA

As presented in Table 1, there are different ML and DL models that have been adopted to predict the prices of used vehicles. For instance, linear regression model has been employed in diverse research works [9, 12, 14, 15, 22, 23, 24] and achieved reasonable regression accuracy.

On the other hand, the recent developed vehicle price prediction systems depend on various number of features, where the selected features range from 3 to 179. However, 3 features are considered as a very low number of features to estimate the used vehicle price which may minimize the prediction accuracy, whereas the number of 179 features is strongly very high number and may add complexity to the overall vehicle price estimation system. Therefore, there is a high demand to adopt the most important features

that would affect the vehicle price estimation accuracy in a positive way.

As presented in Section 2, there are several evaluation metrics that have been employed to estimate the developed system's efficiency. In a few research works, the RMSE and MAE parameters were evaluated. On the other hand, accuracy metric was adopted by several research works. Hence, the presented research works did not agree on a certain evaluation metrics, therefore, it was difficulty to compare the obtained results from the existing vehicle price estimation systems.

Finally, most of the existing vehicle price estimation approaches focused on the employment of ML models, with rear adoption of deep neural network models. Hence, it important to design and implement an efficient deep neural network model in order to enhance the vehicle price estimation.

5. OPEN RESEARCH ISSUES

This section presents a set of open research issues that may be addressed in the future research works which focus on the area of vehicle price estimation.

For instance, no single complete dataset is exist, since the available datasets are either old or uncomplete. Therefore, there is a great demand to build a web application that involves all the records for recent vehicle price operations. As this will improve the vehicle price prediction accuracy.

On the other hand, as presented in Section 2, none of the existing research studies focused on the issue of computer vision classification, as computer vision approaches may enhance the vehicle price estimation cost through classifying the vehicle brand and year.

Internal faulty systems or parts in the car might not be taken into consideration in the pricing task, and hence obtains inaccurate vehicle price estimation. Therefore, a database system is required in order to involve all the accidents that occur to each vehicle.

According to the discussed recent research works, we explored a number of research issues in the area of vehicle price estimation that are required to be covered in the future studies, as follows:

1. The requirement for online data records in order to improve the vehicle price prediction accuracy.
2. Obtain the necessary and the most significant features that affect the vehicle price prediction accuracy.
3. Explore the adoption of deep neural networks in the training and estimation process. The development of an efficient neural network model for efficient vehicle price prediction accuracy.
4. Set of evaluation metrics: researchers need to focus on a set of evaluation metrics instead for considering a single evaluation metric.

6. CONCLUSION AND FUTURE WORK

The used vehicle price estimation issue is considered as a significant task nowadays in the Kingdom of Saudi Arabia due to the high demand on used cars market. Therefore, it is important to study and analyze the recent developed systems in the same field. This paper discusses the used vehicle price estimation issue, and presents the recent developed approaches for used vehicle price estimation using the employment of ML and DL technologies. In addition, this paper presents a set of evaluation metrics that can be used to assess the efficiency of any ML/DL-based used vehicle price estimation system. For future work, we aim to develop an efficient and reliable used vehicle price estimation system through analyzing the efficiency of several ML and DL approaches, and the employment of an efficient feature extraction methods in order to enhance the system's accuracy.

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