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# 1. Introduction

# 2. Project Scope

## 2.1 Literature Review

### 2.1.1 Used Car Valuation Review

Selling used cars is generally a hard metric to gauge as unlike with brand-new cars there is no Manufacture Suggested Retail Price (MSRP) to give the seller an idea of how much the item is worth. This means that private sellers need to balance many different factors which could affect the value, factors such as condition, age, accident history etc. This means there is no real metric to which a seller can easily price their car to.

The selling of used cars has also become increasingly complex in recent years, with prices fluctuating due to factors such as the COVID-19 Pandemic chip shortage (Sillars 2021) or the new Ultra-Low Emission Zone (ULEZ) (Simpson 2023). Historically, there were resources such as the Parkers monthly car valuation book (Adams 2022) or the Kelley Blue Book (KBB) (Kelley Blue Book 2023) in which they publish books which advise readers on what price to expect for used cars. The problem with paper published books is that the books are out of date the moment they are printed, and so cannot keep updated with rapid changing prices. KBB state on their website that the used car valuation they offer is not based on a formula or algorithm instead based on vast knowledge of the industry (Kelley Blue Book 2019). This method of pricing is vague, as with no insight to the actual valuation process it cannot be said that the KBB is an un-bias party, and so prices may be swayed.

In 2021, the UK was recovering from the economic impact of the COVID-19 pandemic lockdown, with the economy growing 7.6% that year (Clark 2023). This recovery helped lead to the number of used car sales exploding like never seen before. The Society of Motor Manufactures and Traders (SMMT) said that “April saw growth of 307.4%, followed by the best May and June since records began.”(SMMT 2021). This explosion in demand lead to prices soaring that year, with the average used car price increasing by 30% over the previous year (Muir 2023). This rise in used car sales and prices could not have been predicted, and so sellers would find gauging used car prices extremely difficult.

New measures being implemented by the UK government have also affected used car sales. The Ultra-Low Emissions Zone in London was rolled out to improve the air quality (Transport for London 2023b) with fines of £12.50 per day to Internal Combustion Engine (ICE) cars that don’t meet the set criteria. Most petrol cars manufactured after 2005 and diesel cars from 2015 are exempt (Transport for London 2023a). BBC News states that ULEZ compliant car prices have increased on AutoTrader by over 40%, they state that the median price beforehand was “£12,989” and afterwards was “£18,295” (Rufo 2023). Factors such as the ULEZ’s or rising fuel prices (Race 2023) could be reasons to why used Battery Electric Vehicles (BEV) sales are up by 81.8% as of Q2 2023 (SMMT 2023).

To make it easier for sellers to value their cars, there are many online free valuation tools available. Some of the most popular of these tools are RAC Cars Online Valuation (RAC Cars 2021), We Buy Any Car (We Buy Any Car 2023), AutoTrader UK (AutoTrader 2023) and Parkers UK (Parkers 2023). These tools work by collecting data about the vehicle such as the car brand, model, model variant, year, and condition, and then the details are processed through an undisclosed algorithm with a price estimation given back to the user.

The main problem with this process is that there is no transparency or justification in their pricing, as these tools are closed source. Many of these online tools offer to buy the car from the user at the end of the valuation process offering a quick process (See Figure 1.).

A screenshot of a computer

Description automatically generated

Figure 1 - Screenshot of WeBuyAnyCar's car valuation offer webpage

This means that these car valuation tools could be affected by alternative motives, such as valuing the car lower on purpose to increase resale profits. My problem would solve this problem by making a free and open-source car price prediction tool for anyone to value cars with. It would allow a fair and transparent estimation process as the goal is to create a highly accurate value estimation tool that also justifies the pricing, so the value is properly understood.

### 2.1.2 Car prediction papers

Due to car price prediction being a complex metric to gauge, there is much previous work done on car prediction models using machine learning. Most of these papers are using regression-based algorithms, such as Linear Regression, Lasso Regression and Random Forrest. Others are based off using the K-Nearest Neighbours algorithm, Neural Networks or Deep Learning.

In (Ashok Kumar and Samruddhi 2020) the K-Nearest Neighbours (KNN) algorithm is applied to a dataset obtained named “The Used Cars dataset” with the goal of analysing used car prices. To compare their results, a Linear Regression algorithm was used as a benchmark. KNN ended up achieving an 85% accuracy, 14% higher than the benchmark set by linear regression.

The conclusion on further work is brief in its suggestions for accuracy improvement however it is stated that “advanced machine learning techniques” would be applied and validating the model with different methods. This however is very vague and would benefit from more specific future goals such as defining what machine learning techniques could be applied to this problem. Techniques such as Deep Metric Learners would be an ideal to use for future as to my knowledge this has not been applied to price prediction before.

The referencing is also poor, with claims such as “Most of the people prefer to buy the used cars because of the affordable price” without any sources. This would infer that the paper is a less reliable source. However, this fact could have been confirmed by a source such as (Armstrong 2022). Here from the Statista Global Consumer Survey about US Consumers when purchasing cars, a low-price rank third overall, only beaten by safety and fuel efficiency.

In (Ganesh and Venkatasubbu 2019) multiple machine learning algorithms are applied to a 2005 dataset made by the Kelly Blue Book that has 805 entries. The goal of the research was to prove the hypothesis of “Multiple and Lasso Regressions are better at

predicting price than the Regression Tree.” by applying these three different supervised learning techniques on predicting used car retail prices and comparing the accuracy of each. The hypothesis was found to be correct, with Mean Error Rates (MER) used to rate the accuracy. Multiple Regression was found to be the best with a MER of 3.48%, while Lasso Regression had a MER of 3.51% and Regression Trees with 3.78%. In the conclusion for future work, it is suggested that algorithms such as Random Forrest should be applied to this problem to improve accuracy, and that to select more data from more recent sources to increase reducibility.

There is no discussion on what data pre-processing was done before the experiment, which could lead to the results of this paper being less accurate and reliable (Maharana, Mondal and Nemade 2022).

In (Varshitha, Jahnavi and Lakshmi 2022) multiple algorithms are applied to a used car dataset from Kaggle. The goal of the paper was to create a model that can predict used car pricing, whilst ensuring that there is no bias to either the owner of the vehicle or buyer. The pre-processing of the dataset was well documented and improves the reproducibility of the experiment. 5 different models were used, Linear Regression, Ridge Regression, Lasso regression, Deep Neural Network and Random Forrest. Deep Neural Networks performed second best, with a Mean Absolute Error (MAE) of 0.766 and a Root Mean Error (RSE) of 0.842. Random Forrest gained the best accuracy rating, with a MAE of 0.746 and RSE of 0.917.

For future work, the paper mentions how the algorithms used to create the used car price prediction tool, could be adapted for use in selling other used goods such as electronics too. It also mentions that by training the model on parts of a larger dataset rather than one small one, it could increase accuracy furthermore.

The research paper (Enoch Li and Bradford Lin 2021) implements two deep learning algorithms and compares them to linear regression on used car price prediction. The goal of the research is to more accurately be able to predict the car prices over existing literature on the subject. The deep learning algorithms used are two Multilayer Perceptrons (MLP), one is a TurnKey solution from sklearn (MLP1) and the other is a customised version of TensorFLow’s Keras framework (MLP2). The dataset used is 16,000 used car data points scraped from the Kelly’s Blue Book website with a 90/10 train test split. Dropping features such as the car colour. As there is no industry standard for naming colours, there could be “Ice White” and “Artic White”. This however could have been standardised in data pre-processing instead of simplify removing the feature by banding similar colours together. By removing this, the model’s performance would be less accurate as it is widely accepted across the industry that the colour of a car can affect the value(We Buy Any Car 2022) (AA 2018).

In their findings, linear regression performed very poorly with a Mean Squared Log Error (MSLE) of 2.61, while both MLP’s performed much better with MLP1 scoring 0.16 and ML2 with 0.08. While these MLP’s outperformed the linear regression algorithm, they were beaten by (Patch 2018) implementation of Ridge Regression with a MSLE of 0.7 on the same dataset. The papers justification for this was Patch had done different dataset pre-processing, with the removal of outliers and the model was tested on a trimmed dataset. It was then speculated that the MLP1 and 2 would have performed better than Patch’s on the same processed dataset. Rather than speculating, it would have been more accurate to implement Patch’s solution into their own and test the results. Patch’s paper is available on GitHub and with all the code used, meaning it is open source and therefore straightforward to implement.

The paper (Enci Liu et al. 2022) uses 3 neural network-based algorithms Back Propagation Neural Network (BPNN), GRA-BPNN (GRA) and PSO-GRA-BPNN (PSO) to predict used car prices on data obtained from China’s largest online used car website. Extensive data pre-processing is used here, with a final dataset of size 10,620. The dataset includes a field for car location, which is a unique but important field as some locations are more desirable to buy from than others (Motorway 2022). By including this, the results of the paper are more likely to have a higher accuracy by taking this into account. PSO obtained the most accurate score of a MSE of 0.48, compared to Random Forrest’s 0.84 which gives a strong argument in the ability of Neural Networks to perform price prediction task better than more traditional algorithms. However, Random Forrest took just 21 seconds to complete the task with PSO taking over 4 times longer at 94 seconds. In the conclusion it’s mentioned that PSO while very accurate also was worse at price prediction for high market cars, meaning more features may need to be added to increase accuracy.

In (Chuyang Jin 2021) 5 regression-based machine learning models are applied to a UK based user car dataset numbering 100,000 entries scraped from websites. However, the paper focuses on specifically the Mercedes part of the dataset numbering 13,120. This way of training a model on just a specific make could help negate the issue raised by (Enci Liu et al. 2022) of high market cars being harder to predict. Sufficient data pre-processing took place, with excellent data visualisation to show the effect this had.

Agreeing with the results of (Enoch Li and Bradford Lin 2021), (Varshitha, Jahnavi and Lakshmi 2022) and (Ashok Kumar and Samruddhi 2020) Linear regression performed the poorest with a R-Squared value of 0.72. This would back up that used car valuation is a complex factor and is not a linear scaling problem.

Of the 5 algorithms, Random Forrest performed the best with a R-Squared value of 0.90 however in the conclusion it is said that this could be improved upon by using a larger dataset or implementing other algorithms such as Naïve Bayes.

The paper (Varshitha, Jahnavi and Lakshmi 2022) was written with the goal of reducing fraud when buying a used car by the implementation of a highly accurate model with no bias to either the owner or the buyer. The algorithms used are a supervised learning artificial neural network based Keras Regression (using 10 layers), Random Forest, Linear, Lasso and Ridge Regression. The dataset used isn’t named, instead just referenced as from Kaggle. This is an acceptable method of referencing, however failing to detail the name of the specific dataset used causes an issue as there is many used car datasets on Kaggle (Kaggle 2023). The paper is a less reliable source as any reproduction of the work is not possible and so the claims and accuracy claimed cannot be verified.

In the results, Random Forest beat the Neural Network’s accuracy with a MAE of 0.75 and R-Squared of 0.92 compared to the MAE of 0.77 and R-Squared of 0.842 (with MAE generally the closer to 0 the better, and with R-Squared generally the closer to 1 the better). However, there is no explanation to why Random Forest is better, and no future improvements suggested that could improve the Neural Network to better predict used car prices. It is suggested that the models could be linked to a live web scraper, intaking current data about used cars. This would be a very useful idea, as the model would consistently be as up to date with prices as possible and increasing the dataset size consistently which would also help to improve the model’s accuracy.

Above, the suggestions made by the papers for future improvements are usually suggesting certain algorithms or frameworks that could be more accurate than current ones. Or by using a larger dataset which could improve performance by allowing the algorithm more references for the price prediction. Some papers mention impartiality and not ensuring no bias however, none of these papers focus on making the reasoning of the used car price prediction open. By adding some insight to the decision process made by the algorithm, the buyers and sellers could understand the features that are impacting the price the most.

To add insights to algorithms such as Random Forest would be near impossible, it works by combining multiple decision trees together (IBM 2023). This means that understanding what features are affecting the price prediction extremely difficult.

The paper (Martin, Wijekoon and Wiratunga 2020) while not related to used car price prediction, proves that DML’s can be very accurate especially when in comparison to algorithms such as KNN. (Ashok Kumar and Samruddhi 2020) found by using KNN in used car prediction an accuracy of 85% was obtained. If DML’s could be used here to further improve this accuracy, which is important as this would help make the tool a more reliable source for price predictions.

### 2.1.3 Deep Metric Learning papers

In the paper (Martin, Wijekoon and Wiratunga 2020) three different Deep Metric Learner (DML) algorithms are used with the goal of finding which is the highest performing in similarity-based return. The algorithms are used across three Human Activity Recognition datasets all of which are based on different activities called SelfBACK, Multi-Model Exercise Data (MEx) and a Physical Activity Monitoring dataset (PAMAP2). KNN was used as a benchmark model in which to compare the three DML algorithms against. Across all datasets, KNN was significantly outperformed by the DML’s across all datasets. The highest difference being in the MEx dataset, KNN scored 68.56% accuracy whilst highest performing DML was Matching Network (MN) using MLP with 94.19% and using Convolutional neural network (CNN) with 95.49%.

The paper (Wang et al. Oct 2017) aims to use Angular Loss (AL) to improve DML’s ability. The DML’s are used across three image-based datasets: a bird species dataset (CUB-200-2011), Stanford Car dataset and an online product-based dataset. There were 7 algorithms used, but the main comparison ones were the AL and N-Pair & Angular Loss (NP&AL). NP&AL was used to show that Angular Loss can also be applied to other frameworks such as N-Pair.

In the discussion about the results, it’s said that AL across all three datasets had increased performance over the baseline, however by applying it to NP&Al the best performance can be achieved across all tested algorithms. For future work it is stated that ideas such as implementing a clustering-based framework could be an improvement to performance.

The paper is well written with mathematical formulas, tables, and figures to help explain the narrative to the reader.

### 2.1.4 Conclusion

According to my research, currently there are no Deep Metric Learner papers on price prediction, and certainly not any on used car price prediction so I feel this subject area is a gap in research. By using DMLs it has potential to outperform the most accurate algorithms in this research area, while also having the ability to share insights about the decision-making process not available by algorithms such as Random Forrest. To the best of my knowledge no car price prediction papers look at insights for the users about the algorithm, therefore this is also a gap in the research that my project aims to resolve.

## 2.2 Requirements

The requirements are for a regressor based problem, in which the requirement prioritisation technique MoSCoW (Agile n.d.) is used to sort requirements by must have, should have, could have and won’t have.

### 2.2.1 Functional Requirements

* Artificial Indigence Implementation
  + Must be using a Deep Metric Learner based algorithm for price prediction
  + Must use a dataset of used car selling data
  + Must process car input data given and give a price prediction
  + Must be an open-source tool with version control
  + Should manage an accuracy above 80% to ensure tool useability
  + Should be compared against a different machine learning algorithm
  + Could obtain a higher accuracy than the comparison algorithm as this would increase tool viability
  + Could use Random Forrest as this has shown to be one of the highest performers from the literature review
  + Won’t have any buyer or seller bias implemented as this tool is made to be completely impartial
  + Won’t perform a price prediction for anything other than a private car
* The dataset:
  + Must be populated with used car sales
  + Must pre-process the data to maximise the potential accuracy of the tool
  + Should combine multiple datasets. This could help to remove any bias one source may have.
* The output
  + Must contain a price prediction from the given dataset
  + Must contain at least one performance measure
  + Should use Mean Average Error
  + Could use additional performance error methodologies
  + Could use figures to display the performance differences
* Web Application
  + Could be implemented into a web application
  + Could use the Driver Vehicle and Licencing Agency (DVLA) dataset api to return a price based on a registration number input

### 2.2.2 Non-Function Requirements

* Security
  + No sensitive information will be stored or transmitted
  + Car information such as registration plates are public knowledge
  + The datasets obtained are from public data repositories such as Kaggle
* Capacity
  + System Requirements
    - If made into a web application the project should support modern browsers such as Chromium Based Browsers, Firefox
    - Safari support could be available
    - Mobile phone and tablet browsers will not be supported
    - Must be able to run on a 2020 MacBook Air M1 as that will be the development machine
    - Could also run on a windows-based Intel i5 Desktop as this would be the backup development machine
* Maintainability and Manageability
  + The project will be open sourced throughout the development of the project
  + This means that maintainability will be easier as bug reports, or improvements can be suggested by peers
* Scalability
  + It is only expected for this project there will be no more than one person using the application at a single time as this is a proof of concept
* Useability
  + The web application should be simple and clear which would help to increase accessibility by reducing clutter
* Accuracy
  + The application should be as accurate as possible as this would increase the reliability of the tool

# 3. Design

Marking Grid: There is in-depth and accurate design and planning process at professional level. The solution shows notable creativity and/or use advanced techniques, and clearly refers to the planning process. The student makes excellent use of appropriate techniques (such as, but not limited to wireframes, ER diagrams, use case diagrams, etc) to link the project scope with the implementation section

## 3.1 Methodology

## 3.2 Wireframes

## 3.3 Toolkits/Algorithms/Languages

* Python version 3.11.9
* Visual Studio Code
* Sklearn Random Forrest, K Nearest Neighbour,
* Custom Keras Siamese Model with a Triplet Loss Function [Image similarity estimation using a Siamese Network with a triplet loss (keras.io)](https://keras.io/examples/vision/siamese_network/)
* Custom Triplet Generator
* Pandas Dataframes

## 3.4. ER diagrams

Not Exhaustive List

# 4. Implementation

* What was interesting about what you did?
* Cool solutions you implemented

Marking Grid: The final project not only achieves all its set objectives but goes above and beyond, delivering additional value. The implemented artefact— be it code, or other media—is executed with exceptional craftsmanship and attention to detail, leading to a project that excels in fulfilling its intended purpose. Comprehensive documentation supports the work, clearly outlining the process and decisions made during the implementation phase, thereby evidencing professional skills and judgment within the field.

# 5. Testing and Evaluation

* How do you know that what you did
  + Works
  + Is it fit for purpose
* User surveys,
* Black box testing,
* Etc

Marking Grid: Comprehensive evaluation methods, appropriate to the project's goals and type, are employed strategically. These may range from software quality assurance methods like focus groups, user testing or black box testing to empirical experiments for theory validation. Results are meticulously analysed and used to inform suggestions for future work. The conclusion offers deep analysis of outcomes against initial objectives and a reflection on lessons learned.

# 6. Conclusion

Reflect!

Legal, social, ethical and professional issues

Commercial relevance Quality of your engineered solution

Your Planning and Achievement

Future Work

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