**CSC3831 Predictive Analytics  
Machine Learning House Price Prediction**

**Introduction**

A grid search is used for each model to evaluate an exhaustive set of reasonable hyperparameters to find the optimal model settings for the dataset provided. The results from each grid search are displayed and discussed briefly in this report.

**First Model – Linear Regression (LR)**

For LR the following hyper-parameters were grid-searched; fit\_intercept, copy\_x, and n\_jobs. The results are as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fit Intercept** | **Copy X** | **N jobs** | **MSE** | **R^2** |
| TRUE | TRUE | 1 | 0.37206 | 0.621966 |
| TRUE | TRUE | 2 | 0.37206 | 0.621966 |
| TRUE | TRUE | 3 | 0.37206 | 0.621966 |
| TRUE | TRUE | 4 | 0.37206 | 0.621966 |
| TRUE | FALSE | -1 | 0.37206 | 0.621966 |
| TRUE | FALSE | 1 | 0.372047 | 0.621979 |
| TRUE | FALSE | 2 | 0.372047 | 0.621979 |
| TRUE | FALSE | 3 | 0.372047 | 0.621979 |
| TRUE | FALSE | 4 | 0.372047 | 0.621979 |
| FALSE | TRUE | -1 | 0.372046 | 0.621981 |
| FALSE | TRUE | 1 | 0.372046 | 0.621981 |
| FALSE | TRUE | 2 | 0.372046 | 0.621981 |
| FALSE | TRUE | 3 | 0.372046 | 0.621981 |
| FALSE | TRUE | 4 | 0.372046 | 0.621981 |
| FALSE | FALSE | -1 | 0.372046 | 0.621981 |
| FALSE | FALSE | 1 | 0.372046 | 0.621981 |
| FALSE | FALSE | 2 | 0.372046 | 0.621981 |
| FALSE | FALSE | 3 | 0.372046 | 0.621981 |
| FALSE | FALSE | 4 | 0.372046 | 0.621981 |

These results suggest that the choice of hyperparameters has a minimal impact on the model's performance. The MSE scores are relatively close together and the R^2 scores are all above 0.6, indicating that the model is performing relatively well, but there is still room for improvement.

**Second Model – Multi-Layer Perceptron (MLP)**  
For MLP the following hyper-parameters were explored; number of units, activation function, number of layers. 192 results were generated, 9 are shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *The nine best MLP model hyper-parameters and results* | | | | | | | |
| **Units Per Layer** | **Activation Function** | **Layers** | **Optimizer** | **Epochs** | **Batch Size** | **MSE** | **MAE** |
| 128 | relu | 3 | adam | 10 | 64 | 0.203492 | 0.30959 |
| 512 | relu | 2 | adam | 10 | 64 | 0.204488 | 0.308437 |
| 256 | relu | 5 | adam | 10 | 8 | 0.204824 | 0.306975 |
| 512 | relu | 5 | adam | 10 | 32 | 0.205468 | 0.317355 |
| 256 | relu | 2 | adam | 10 | 32 | 0.206546 | 0.311331 |
| 128 | relu | 4 | adam | 10 | 16 | 0.206783 | 0.306865 |
| 256 | relu | 5 | adam | 10 | 16 | 0.2072 | 0.312006 |
| 512 | relu | 2 | adam | 10 | 32 | 0.207466 | 0.306897 |
| 128 | relu | 3 | adam | 10 | 16 | 0.207523 | 0.308899 |

The results show increasing units, and layers do not necessarily lead to better performance. A second grid-search to improve upon the above results explored; optimizers, and epochs.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Units Per Layer** | **Activation Function** | **Layers** | **Optimizer** | **Epochs** | **Batch Size** | **MSE** | **MAE** |
| 128 | relu | 3 | adam | 10 | 64 | 0.203516 | 0.30981 |
| 128 | relu | 3 | adam | 10 | 64 | 0.214913 | 0.326542 |
| 128 | relu | 3 | adam | 25 | 64 | 0.215211 | 0.305607 |
| 128 | relu | 3 | adamax | 25 | 64 | 0.215381 | 0.321018 |
| 128 | relu | 3 | adam | 50 | 64 | 0.218082 | 0.303142 |
| 128 | relu | 3 | adamax | 10 | 64 | 0.219988 | 0.327635 |
| 128 | relu | 3 | rmsprop | 50 | 64 | 0.220686 | 0.304911 |
| 128 | relu | 3 | rmsprop | 10 | 64 | 0.23416 | 0.334149 |
| 128 | relu | 3 | rmsprop | 25 | 64 | 0.253742 | 0.348849 |
| 128 | relu | 3 | adagrad | 50 | 64 | 0.257711 | 0.35942 |
| 128 | relu | 3 | adagrad | 25 | 64 | 0.283529 | 0.379947 |
| 128 | relu | 3 | adagrad | 10 | 64 | 0.305943 | 0.395837 |

Unexpectedly, increasing the epochs and changing the optimizer did not increase performance as shown the MSE increased with the different variations.

**Third Model – Random Forest Regressor (RFR)**

For RFR the following hyper-parameters were explored; n\_estimators, max\_depth, min\_samples\_split, and min\_samples\_leaf. 20 of the 600 results are shown below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *The ten best RFR model hyper-parameters and results* | | | | | |
| **N\_Estimators** | **Max Depth** | **Min Samples Split** | **Min Samples Leaf** | **MSE** | **R^2** |
| 300 | None | 2 | 2 | 0.192447 | 0.804463 |
| 300 | 30 | 2 | 2 | 0.192721 | 0.804184 |
| 100 | None | 2 | 2 | 0.193086 | 0.803814 |
| 100 | 50 | 2 | 2 | 0.193178 | 0.80372 |
| 300 | 30 | 5 | 2 | 0.19325 | 0.803647 |
| 300 | 40 | 2 | 2 | 0.193306 | 0.803591 |
| 200 | 50 | 2 | 2 | 0.193644 | 0.803246 |
| 300 | 50 | 5 | 1 | 0.193743 | 0.803146 |
| 300 | None | 5 | 2 | 0.193814 | 0.803074 |
| 300 | 50 | 5 | 2 | 0.193816 | 0.803072 |
| *The ten worst RFR model hyper-parameters and results* | | | | | |
| 10 | 10 | 2 | 8 | 0.244633 | 0.751439 |
| 10 | 10 | 15 | 4 | 0.244641 | 0.751431 |
| 10 | 10 | 10 | 2 | 0.246019 | 0.750031 |
| 10 | 10 | 5 | 1 | 0.24682 | 0.749217 |
| 10 | 10 | 5 | 8 | 0.247924 | 0.748095 |
| 10 | 10 | 20 | 4 | 0.248179 | 0.747836 |
| 10 | 10 | 20 | 1 | 0.249479 | 0.746516 |
| 10 | 10 | 15 | 2 | 0.250417 | 0.745562 |
| 10 | 10 | 2 | 1 | 0.252138 | 0.743814 |
| 10 | 10 | 10 | 1 | 0.252717 | 0.743225 |

These results show that a relatively high number of n\_estimators and low amount of min samples for both split and leaf are suitable hyper-parameters to fit an RFR to this dataset.

A second grid-search to improve upon the above results explored; ccp\_alpha, min\_impurity\_decrease, oob\_score, and warm\_start. From the 144 results the top 10 are shown:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Second grid-search: The ten best RFR model hyper-parameters and results* | | | | | | | | | | |
| **N estimators** | **Max Depth** | **Min Samples split** | **Min Sample Leaf** | **Bootstrap** | **OOB Score** | **Warm Start** | **Min Impurity decrease** | **CCP alpha** | **MSE** | **R^2** |
| 300 | None | 2 | 2 | TRUE | TRUE | FALSE | 0 | 0 | 0.192787 | 0.804118 |
| 300 | None | 2 | 2 | TRUE | FALSE | TRUE | 0 | 0 | 0.193311 | 0.803585 |
| 300 | None | 2 | 2 | TRUE | FALSE | FALSE | 0 | 0 | 0.194445 | 0.802433 |
| 300 | None | 2 | 2 | TRUE | TRUE | FALSE | 0.1 | 0 | 0.657525 | 0.331917 |
| 300 | None | 2 | 2 | TRUE | FALSE | FALSE | 0 | 0.1 | 0.662386 | 0.326978 |
| 300 | None | 2 | 2 | TRUE | TRUE | TRUE | 0.1 | 0.1 | 0.663693 | 0.32565 |
| 300 | None | 2 | 2 | TRUE | FALSE | TRUE | 0 | 0.1 | 0.664503 | 0.324827 |
| 300 | None | 2 | 2 | TRUE | TRUE | FALSE | 0.1 | 0.1 | 0.664552 | 0.324777 |
| 300 | None | 2 | 2 | TRUE | FALSE | TRUE | 0.1 | 0.1 | 0.665614 | 0.323698 |
| 300 | None | 2 | 2 | TRUE | TRUE | TRUE | 0 | 0.1 | 0.666029 | 0.323276 |

The top three results show no improvement whereas a majority of the results show deterioration in the accuracy of the model as shown by the high MSE score jumping from ~0.19 to ~0.66.

**Fourth Model – Decision Tree Regressor (DTR)**

For DTR the following hyper-parameters were explored; fit\_intercept, copy\_x, and n\_jobs. 20 of the 2880 results are as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *The ten best DTR model hyper-parameters and results* | | | | | | |
| **Max Depth** | **Min Samples Split** | **Min Samples Leaf** | **Min Weight Fraction Leaf** | **Max Leaf Nodes** | **MSE** | **R^2** |
| 20 | 20 | 8 | 0 | None | 0.275792 | 0.719779 |
| 50 | 20 | 8 | 0 | None | 0.275795 | 0.719777 |
| None | 20 | 8 | 0 | None | 0.275797 | 0.719775 |
| 40 | 20 | 8 | 0 | None | 0.275809 | 0.719762 |
| 30 | 20 | 8 | 0 | None | 0.275891 | 0.719679 |
| 20 | 15 | 8 | 0 | None | 0.277281 | 0.718267 |
| 20 | 10 | 8 | 0 | None | 0.277293 | 0.718254 |
| 20 | 5 | 8 | 0 | None | 0.2773 | 0.718247 |
| 20 | 2 | 8 | 0 | None | 0.277375 | 0.718171 |
| 50 | 2 | 8 | 0 | None | 0.277416 | 0.718129 |
| *The ten worst DTR model hyper-parameters and results* | | | | | | |
| 50 | 20 | 4 | 0.3 | 10 | 0.634208 | 0.355609 |
| 50 | 20 | 4 | 0.3 | 20 | 0.634208 | 0.355609 |
| 50 | 20 | 4 | 0.3 | 30 | 0.634208 | 0.355609 |
| 50 | 20 | 4 | 0.3 | 40 | 0.634208 | 0.355609 |
| 50 | 20 | 4 | 0.3 | 50 | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | None | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | 10 | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | 20 | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | 30 | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | 40 | 0.634208 | 0.355609 |
| 50 | 20 | 8 | 0.3 | 50 | 0.634208 | 0.355609 |

All of the best models used the highest number of ‘min\_samples\_leaf’ passed to the grid search, based on this I explored a higher number of ‘min\_samples\_leaf’, and in a third grid-search different ‘max depths’ with ‘min\_samples\_leaf’.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Second Grid-Search: Testing ‘min\_samples\_leaf’ [8, 16, 32, 64]* | | | | | | |
| **Max Depth** | **Min Samples Split** | **Min Samples Leaf** | **Min Weight Fraction Leaf** | **Max Leaf Nodes** | **MSE** | **R^2** |
| 20 | 20 | 16 | 0 | None | 0.270174 | 0.725488 |
| 20 | 20 | 8 | 0 | None | 0.275696 | 0.719877 |
| 20 | 20 | 32 | 0 | None | 0.293371 | 0.701918 |
| 20 | 20 | 64 | 0 | None | 0.310895 | 0.684113 |
| *Third Grid-Search: Testing ‘min\_samples\_leaf’ [8, 16, 32, 64] and ‘max\_depths’ [20, 30, 40, 50]* | | | | | | |
| 20 | 20 | 16 | 0 | None | 0.270174 | 0.725488 |
| 30 | 20 | 16 | 0 | None | 0.270174 | 0.725488 |
| 40 | 20 | 16 | 0 | None | 0.270174 | 0.725488 |
| 50 | 20 | 16 | 0 | None | 0.270174 | 0.725488 |
| 20 | 20 | 8 | 0 | None | 0.275696 | 0.719877 |
| 30 | 20 | 8 | 0 | None | 0.275809 | 0.719762 |
| 50 | 20 | 8 | 0 | None | 0.275809 | 0.719762 |
| 40 | 20 | 8 | 0 | None | 0.275879 | 0.719692 |
| 20 | 20 | 32 | 0 | None | 0.293371 | 0.701918 |
| 30 | 20 | 32 | 0 | None | 0.293371 | 0.701918 |
| 40 | 20 | 32 | 0 | None | 0.293371 | 0.701918 |
| 50 | 20 | 32 | 0 | None | 0.293371 | 0.701918 |
| 20 | 20 | 64 | 0 | None | 0.310895 | 0.684113 |
| 30 | 20 | 64 | 0 | None | 0.310895 | 0.684113 |
| 40 | 20 | 64 | 0 | None | 0.310895 | 0.684113 |
| 50 | 20 | 64 | 0 | None | 0.310895 | 0.684113 |

Only a minor improvement of 0.005 was achieved with the second and third grid-search.