**Introduction**

(TODO) // keep at the end, the general description of our project

**Literature Review**

Housing price prediction has had its fair share of predictive methods thrown at it in the past decade. In 2008, a paper was released comparing hedonic regression (a popular method of housing price prediction) to artificial neural networks using a dataset from turkey. The results showed improved performance in the neural network compared to hedonic regression (Selim 2008). In 2014, another study was published reviewing data from Fairfield County, Virginia in which they tested several alternative methods from ours, finding error rates around 27% using decision trees and the Ripper algorithm (Park and Bae 2014). Beyond that they note the use of SVM’s, a model which was found to outperform ANNs in a 2019 study of Hong Kong housing prices by Abidoye et al., and which had the lowest MSE in a 2014 study by Mu, Wu, and Zhang (Abidoye et al. 2019; Mu, Wu, and Zhang 2014). These results make sense, since a SVM will find the global minimum while ANNs may get stuck at local minima (Abidoye et al. 2019).

More recently, a conference paper by Mangaleswaran and Vigneshwari carried out a test similar to ours, comparing ANNs, logistic regression, k-means clustering, and linear regression. While they only tried to predict if houses would be above or below the mean price, they still found ANNs to be the most accurate, standing at 85% with logistic regression at 80% (Mangaleswaran and Vigneshwari 2020). This was to be expected since the recommended the semi-logarithmic form is known to produce more accurate results (Selim 2009). Diving specifically into neural networks, a 2021 paper by Kalliola et al. tested hyperparameters for neural networks used in housing price prediction on a Helsinki dataset. They found 6 hidden layers to be ideal with each layer having anywhere from 150 to 950 nodes (Kalliola et al. 2021). While unable to meet this level of complexity in our network, we aim to compare neural network performance to some of the other models when it comes to housing price prediction.

Sources

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Kalliola, Jussiet et al. "Neural Network Hyperparameter Optimization for Prediction of Real Estate Prices in Helsinki." PeerJ Computer Science, 2021. ProQuest, <https://www.proquest.com/scholarly-journals/neural-network-hyperparameter-optimization/docview/2514869195/se-2>, doi:<http://dx.doi.org/10.7717/peerj-cs.444>.

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Selim, Hasan. “Determinants of House Prices in Turkey: Hedonic Regression Versus Artificial Neural Network.” Expert Systems with Applications, vol. 36, no. 2, Elsevier Ltd, 2009, pp. 2843–52, <https://doi.org/10.1016/j.eswa.2008.01.044>.

Over view of the data set // NEEDS FIXES

Our dataset is from kaggle.com URL: [*https://www.kaggle.com/ericpierce/austinhousingprices*](https://www.kaggle.com/ericpierce/austinhousingprices) by author/provider: Eric Pierce.

This dataset consists of 2018 to 2021 house transaction records from Austin, TX area. There are total 15171 samples in the dataset. Each sample has 47 attributes such as: cities' name, zip code, address, built years, amenities info, purchase price, etc. Because some of the attributes are irrelevant or difficult to deal with, we will drop some of them such as 'homeImage', 'description', etc. to make our machine learning models less complex when predicting house price.

Chart, pie chart

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The majority of samples are evenly from 2018 - 2020 along with few samples from 2021. // add more words

Chart, box and whisker chart

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When we show the 'price' in boxplot, we see the range of price is significatly spread out. There are a lot points above maximum tail, which is a sign of this our dataset may not normally distributed regardless of years.

Further exploring the housing prices, we extract middle 90% of the prices and plot them, there are still a lot of outliers. However, we can see the mean price for 2018 - 2020 is around 400,000 while the mean price of 2021 is little bit higher. Due to the fact that we only have few samples from 2021, we couldn't tell whether or not inflation impacts to 2021 price.

Graphical user interface, application, table, Teams

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Here we see that **numOfBathrooms** has the highest correlation with price of 0.5

Graphical user interface, application, Teams

Description automatically generated

Here we see that none of these are particularly noteworthy, with **hasSpa** having the highest correlation of 0.17.

Timeline

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Here we can see that **livingAreaSqFt** has the highest correlation of 0.47. The other closest correlations are 0.3 for **numOfBedrooms**, -0.2 for **numOfHighSchools**, and 0.2 for **medianStudentPerTeacher**.

Zipcode and hometype were determined to not have relevant correlation with the price, so they were ignored.

## Methodology and Data Pre-processing

Then, we started training our machine learning models. Since our goal is to predict the housing price, we use Simple Linear Regression, Multiple Linear Regression, Polynomial regression, and Artificial Neural Network(ANN) for this numerical response variables. For regression methods, the output should be directly numerical values. However, for ANN models, we divide price to several range of intervals to make them as classification problems with meaningful predictions.

In regression training processes, both linear and polynomial, we use the unscaled data to trianing the models since hether or not scaling data does not affect the accuracy of regression training. We tend to keep the data unscaled because the predicted outputs and Mean Squared Error (MSE) can directly explain how far away the predicted price from actual price.

In ANN training processes, scaled data is required because each neuron receives inputs from all attributes. We use MinMaxScaler to normalize our data to value between [0,1]. Also, since response variable latestPrice is numerical continuous variable, this implies that we could have at most N number of different price as N is the number of samples in the dataset. This will makes ANN hard to make useful prediction on such huge amount of numerical price. Therefor, we divide the price into several range of intervals such [100,000 - 149,999], [150,000 - 199,999], etc. With limited numbers of price range as output, the ANN models can predict with certain values of input attributes which price range the predicted output should fall into.

* Simple Linear Regression: using the highest correlation attribute **livingAreaSqFt** as explanatory variable (input) and **latestPrice** as response variable (output).
* Multiple Linear Regression: using all attributes from previous section **livingAreaSqFt**, **numOfBathrooms**, **avgSchoolRating**, **numOfBedrooms**, **numOfHighSchools**, **MedianStudentsPerTeacher** as inputs, and **latestPrice** as output.
* Artificial Neural Network: using the same attributes as multiple linear regression.

## Experimental Results

### Simple Linear Regression

The simple linear regression measures the correlation between the living area square footage and the latest price of the house. According to the linear regression model, the testing MSE was 0.0031034538994231665, while the training MSE was 0.0007533569972620845. Since the testing MSE was much higher than the training MSE, it can be concluded that the simple linear regression showed signs of overfitting. Note that all of the above assumes the outliers have not been removed. When the outliers were removed, the training and testing MSEs are 0.01683046917734069 and 0.017602933835473195, respectively. The regression model no longer shows signs of overfitting, but appeared to be much less accurate.

### Multivariate Linear Regression

The multivariate linear regression uses the living area square footage, the number of bathrooms, the average school rating, the number of bedrooms, the number of high schools, and the median number of students per teacher, as the dependent variables. Just like before, the dependent variable is the latest price of the house. Assuming the outliers have not been removed, the training and testing MSEs turned out to be 0.001161543841697301 and 0.0026126372082117054, which indicates that the model shows signs of overfitting. Once the outliers have been removed, the training and testing MSEs became 0.015228611447641035 and 0.016849382441537858, respectively. Just like the simple linear regression model, the multivariate linear regression model no longer shows signs of overfitting. The multivariate linear regression model seemed to be more accurate than the simple linear regression model, although it still remained relatively inaccurate.

### Polynomial Regression

The multivariate linear regression uses the living area square footage, the number of bathrooms, the average school rating, the number of bedrooms, the number of high schools, and the median number of students per teacher, as the dependent variables. Just like before, the dependent variable is the latest price of the house. The data for the polynomial regression is shown below:

![Table

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When the outliers are present, the 3rd-degree polynomial regression appeared to be the most accurate model out of all the polynomial models that were created, with a training MSE of 0.000320944 and a testing MSE of 0.002171320. After the outliers are removed, however, the best polynomial regression model turned out to be the 5th-degree polynomial model, with a training MSE of 0.009121448 and a testing MSE of 0.010224790. Furthermore, the regression model no longer shows signs of overfitting once the outliers have been removed. The 5th-degree polynomial regression model appears to be more accurate than the simple and multivariate linear regression models since it has a lower training and testing MSE than the linear regression models once the outliers have been removed.

### Artifical Neural Network

The artifical neural network uses the living area square footage, the number of bathrooms, the average school rating, the number of bedrooms, the number of high schools, and the median number of students per teacher, as the dependent variables. Just like before, the dependent variable is the latest price of the house. The prices themselves have been divided into 22 different ranges. The ANN itself is based off Keras' sequential model and three hidden dense layers with 100, 80, and 50 nodes. It uses stochastic-gradient descent as its optimizer and categorical\_crossentropy as its loss function. The output layer had 17 since there were 17 different price bucket classes.

//two dense layers. One layer has 12 units, while the other layer has 23 units. Both layers use the relu activation function. The training MSEs for this model range from 0.04 to 0.13. The accuracy for this model was approximately 20%. It is clear that the ANN leaves much to be desired, even when compared to the linear regression models.

### Overall Results

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Overall, it seemed that the 5th-degree polynomial degression was the most effective model at measuring the correlation between the price of the house and the other independent variables, especially if the outliers are removed. The linear regression models proved less effective than the 5th-degree polynomial regression model, but still had acceptably low training and testing MSEs. Curiously, the artifical neural network was by far the least accurate model when it came to predicting the housing price. A trend observed in almost all the models (except the polynomial regression model) was the fact that the training and testing MSEs increased substantially once the outliers have been removed.

### Error Analysis

One possible reason why the models were not as accurate as they could be is the fact that too many samples have been removed from the dataset during preprocessing. Removing too many samples reduced the sample size, which made it more difficult to properly train models. The accuracy of these models suffered as a result. Keep in mind that removing outliers from the dataset is supposed to increase the accuracy of the models, not decrease it. The fact that removing the outliers decreased the accuracy of these models indicates that too many legitimate samples have been removed from the dataset. To remedy this, the threshold used to remove the outliers needs to be increased so that fewer legitimate samples would be removed from the dataset. Besides that, bugs and other problems that have not been discovered in the models could have affected the accuracy of the models. These bugs and issues cause the models to be trained improperly. As such, the models are less capable of accurately predicting the housing price. A egregious example of this can be found in the artifical neural network, whose training MSE was high and whose accuracy was low. More rigorous checks and debugging techniques could mitigate the effects of these bugs. The code for the ANN would need to be rewritten in order to address this issue. Least but not least, the size of the dataset could have been increased. A larger dataset can further mitigate the effects of outliers and provide a more accurate picture regarding the relationship between the housing price and the other independent variables.

**Conclusions**