Regression Analysis of the Ames, Iowa Dataset

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1   Introduction

What is the price of a home in Ames Iowa? Our inaugural project in the program curriculum had us competing in an online competition utilizing the linear regression techniques that we've learned up to this point. Our team chose R as the preferred analysis platform as the consensus was that it had more applicable uses in industry. The objective was to apply various predictive models in order to assess the suitability of our parameter selections. The measure of accuracy was logged in terms of the Root Mean Square Error, or RMSE, as well as other comparison models such as cross-validation and the adjusted R-squared. Our approach was limited in that we not permitted to use more advanced algorithms that we will be exposed to later on, but the exploratory data analysis and data cleaning methods that we've learned and made use of here will surely be of use to us in our future personal and academic endeavors.

2   Ames, Iowa Data Set

The Ames, Iowa Data Set describes the sale of individual residential properies from 2006-2010 in Ames, Iowa[1]. The data was retreved from the dataset hosting site Kaggle, where it is listed under a machine learning competition named *House Prices: Advanced Regression Techniques*[2]. The data is comprised of 37 numeric features, 43 non-numeric features and an observation index split between a training set and a testing set, which contain 1460 and 1459 observations, respectively. The response variable (`SalePrice`) is only provided for the training set. The output of a model on the test set can be submitted to the Kaggle competition for scoring the performance of the model in terms of RMSE. The first analysis models property sale prices (`SalePrice`) as the response of living room area (`GrLivArea`) of the property and neighborhood (`Neighborhood`) where it is located. **Add some details on the question 2 variables?**

3   Analysis Question I

3.1   Question of Interest

Century 21 has commissioned an analysis of this data to determine how the sale price of property is related to living room area of the property in the Edwards, Northwest Ames, and Brookside neighborhoods of Ames, IA.

3.2   Modeling

Linear regression will be used to model sale price as a response of the living room area. From the initial exploratory data analysis, it was determined that sale prices should be log-transformed to meet the model assumptions for linearity (see section 5.1), thus improving our models fit and reducing standard error.

Additionally, two observations were removed as they appeared to be from a different population than the other observations in the dataset (see section 5.2); therefore, analysis only considers properties with living rooms less than 3500 sq. ft. in area.

We will consider two models: the logarithm of sale price as the response of living room area (1), the reduced model, and the logarithm of sale price as the response of living room area accounting for differences in the three neighborhood of interest (Brookside, Northwest Ames, and Edwards) where Edwards will be used as the reference (2), the full model. An extra sums of square (ESS) test will be used to verify that the addition of `Neighborhood` improves the model.

Reduced Model

$$\mu\{log(SalePrice)\} = \beta_0 + \beta_1(LivingRoomArea) \tag{1}$$

Full Model

$$\mu\{log(SalePrice)\} = \beta_0 + \beta_1(LivingRoomArea) + \beta_2(Brookside) + \beta_3(NorthwestAmes) +$$
$$\beta_3(Brookside)(LivingRoomArea) + \beta_4(NorthwestAmes)(LivingRoomArea) \tag{2}$$

The ESS test provides convincing evidence that the interaction terms are useful for the model (p-value < 0.0001); thus, we will continue with the full model.

```
## Analysis of Variance Table
##
## Model 1: log(SalePrice) ~ (GrLivArea) + Neighborhood_BrkSide + Neighborhood_NAmes
## Model 2: log(SalePrice) ~ (GrLivArea) + Neighborhood_BrkSide + Neighborhood_NAmes +
##     (GrLivArea) * Neighborhood_BrkSide + (GrLivArea) * Neighborhood_NAmes
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1    377 14.824
## 2    375 13.441  2    1.3834 19.299 1.053e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

3.3 Model Assumptions Assessment

The following assessments for model assumptions are made based on Figure 1 and Figure 3:

- The residuals of the model appear to be approximately normally distrubited based on the QQ plot of the residuals and histogram of the residuals, suggesting the assumption of normality is met.
- No patterns are evident in the scatter plots of residuals and studentized residuals vs predicted value, suggesting the assumption of constant variance is met.
- While some observations appear to be influential and have high leverage, removing these observations does not have a significant impact on the result of the model fit.

- Based on the scatter plot of the log transform of `SalePrice` vs `GrLivArea`, it appears that a linear model is reasonable (see section 5.1).

The sampling procedure is not known. We will assume the independence assumption is met.
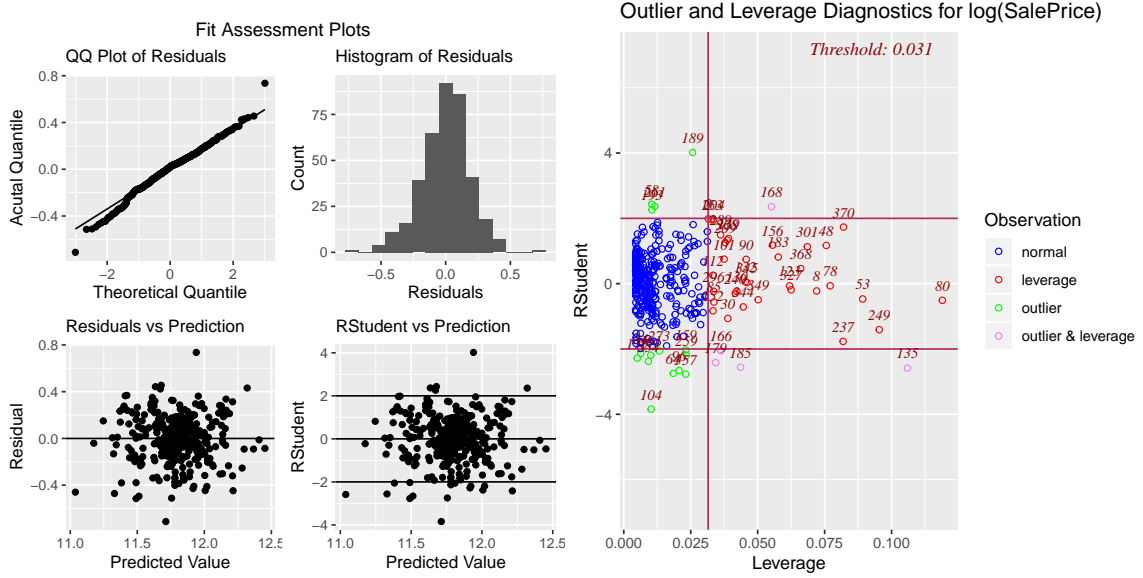

Figure 1: Diagnostic Plots

3.4 Comparing Competing Models

The two models were trained and validated on the training dataset using 10-fold cross validation. The table below summarizes the performance of the models with RMSE, adjusted R^2, and PRESS. These results show that the full model is an improvement over the reduced model, which is consistent with the result of the ESS test.

Model	RMSE	CV.Press	Adjused.R.Squared
Full Model	0.1906429	12.46260	0.5321848
Reduced Model	0.1972251	13.33804	0.4731396

3.5 Parameters

The following table summarizes the parameter estimates for the full model.

Parameter	Estimate	CI.Lower	CI.Upper
Intercept	11.0254845	10.8861855	11.1647836
GrLivArea	0.0005387	0.0004324	11.1647836
Neighborhood_BrkSide	-0.2338906	-0.4468114	-0.0209698
Neighborhood_NAmes	0.4178562	0.2558923	0.5798200
GrLivArea:Neighborhood_BrkSide	0.0001996	0.0000336	0.0003656
GrLivArea:Neighborhood_NAmes	-0.0002145	-0.0003366	-0.0000924

Where `Intercept` is β_0, `GrLivArea` is β_1, `Neighborhood_BrkSide` is β_2, `Neighborhood_NAmes` is β_3, `GrLivArea:Neighborhood_BrkSide` is β_4, and `GrLivArea:Neighborhood_NAmes` is β_5

3.6   Model Interpretation

We estimate that for increase in 100 sq. ft., there is associated multiplicative increase in median price of

- 1.055 for the Edwards neighborhood with a 95% confidence interval of [1.044 , 1.066]
- 1.033 for the Northwest Ames neighorhood with a 95% confidence interval of [1.026 , 1.040]
- 1.077 for the Brookside neighorhood with a 95% confidence interval of [1.063 , 1.090]

Since the sampling procedure is not known and this is an observational study, the results only apply to this data.

3.7   Conclusion

In response to the analysis commissioned by Century 21, the log transform of property sale price was modeled as a linear response to the property living room area for residential properties in Ames, IA. It was determined that it was necessary to include interaction terms to allow for the influence of neighborhood on sale price. Based on the model, there is strong evidence of an associated multiplicative increase in median sale price for an increase in living room area (p-vlue < 0.0001, overall F-test).

4   Analysis Question II

4.1   Question of Interest

Century 21 has commissioned a second analysis using the same data set, expanded to include as many of the 80 total features, plus the index split, as required to determine the sale price of residential properties across all neighborhoods of Ames, Iowa, beyond only the three - Edwards, Northwest Ames, and Brookside - previously commissioned for analysis.

4.2   Modeling

Restatement of Problem

Through analyzing our variable selection and cross-validation processes - along with our nascent domain knowledge of residential real estate - we ultimately arrived at a multiple linear regression model featuring 11 linear predictor variables and three interaction terms. Specifically, our variable selection process included direct analysis of a correlation plot and a correlation matrix as well as performing forward selection, backward elimination, and stepwise regression. Because many variables contained zeroes that were significant to the factor (for example, bathrooms), we elected to perform logarithmic transformation only to variable `LotArea`, representative of the area of the real estate lot.

In addition to the transformation of `LotArea`, we imputed NA values for 19 variables using a combination of the Data Dictionary provided by Century 21 as well as our domain knowledge.

Type of selection

Forward Selection

Forward selection is a variable selection methodology that begins with a constant mean and adds explanatory variables one-by-one until no further additonal predictor variables significantly improve the model's fit. This employess the "F-to-enter" method from the extra-sum-of-squares F-statistic. This was the first method we employed. For this process, we provided the test a starting model with no predictor variables and a model from which terms can be selected, which included all predictor variables available. The process worked forward with selecting one parameter. The suggested model is output below.

```r
# Initial Model - Forward Selection
model2.forward.Start <- lm(log(SalePrice)~1,data = train2)

# All Variables Model - Forward Selection
model2.Allvar <- lm(log(SalePrice) ~ Id + MSSubClass + MSZoning + LotFrontage + LotArea + Street +
                    Alley + LotShape + LandContour + Utilities + LotConfig + LandSlope +
                    Neighborhood + Condition1 + Condition2 + BldgType + HouseStyle + OverallQual +
                    OverallCond + YearBuilt + YearRemodAdd + RoofStyle + RoofMatl + Exterior1st +
                    Exterior2nd + MasVnrType + MasVnrArea + ExterQual + ExterCond + Foundation +
                    BsmtQual + BsmtCond + BsmtExposure + BsmtFinType1 + BsmtFinSF1 + BsmtFinType2
                    + BsmtFinSF2 + BsmtUnfSF + TotalBsmtSF + Heating + HeatingQC + CentralAir +
                    Electrical + `1stFlrSF` + `2ndFlrSF` + LowQualFinSF + GrLivArea + BsmtFullBath
                    + BsmtHalfBath + FullBath + HalfBath + BedroomAbvGr + KitchenAbvGr + KitchenQual
                    + TotRmsAbvGrd + Functional + Fireplaces + FireplaceQu + GarageType +
                    GarageYrBlt + GarageFinish + GarageCars + GarageArea + GarageQual + GarageCond
                    + PavedDrive + WoodDeckSF + OpenPorchSF + EnclosedPorch + `3SsnPorch` +
                    ScreenPorch + PoolArea + PoolQC + Fence + MiscFeature + MiscVal + MoSold +
                    YrSold + SaleType + SaleCondition, data = train2
                    )

model2.Forward <- stepAIC(model2.forward.Start, direction = "forward", trace = F, scope = formula(model2

summary(model2.Forward)
```

```
##
## Call:
## lm(formula = log(SalePrice) ~ OverallQual + Neighborhood + GrLivArea +
##     BsmtFinType1 + GarageCars + OverallCond + RoofMatl + TotalBsmtSF +
##     YearBuilt + LotArea + Condition2 + MSZoning + BsmtUnfSF +
##     SaleCondition + Functional + CentralAir + Condition1 + KitchenQual +
##     Fireplaces + Exterior1st + Heating + ScreenPorch + YearRemodAdd +
##     BsmtQual + PoolQC + Foundation + KitchenAbvGr + SaleType +
##     GarageArea + HeatingQC + BsmtExposure + EnclosedPorch + WoodDeckSF +
##     LotConfig + Street + BsmtFullBath + PoolArea + LandSlope +
##     GarageCond + HalfBath + FullBath + TotRmsAbvGrd + `3SsnPorch` +
##     ExterCond + GarageQual + GarageYrBlt + Utilities, data = train2)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.72243 -0.04585  0.00175  0.05406  0.72243
##
## Coefficients: (2 not defined because of singularities)
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)          1.156e+00  9.003e-01   1.284 0.199342
## OverallQual          4.534e-02  4.267e-03  10.625  < 2e-16 ***
## NeighborhoodBlueste -1.828e-02  8.177e-02  -0.224 0.823149
## NeighborhoodBrDale  -6.383e-02  4.388e-02  -1.455 0.146044
## NeighborhoodBrkSide  1.077e-02  3.669e-02   0.294 0.769178
## NeighborhoodClearCr -1.217e-02  3.774e-02  -0.322 0.747241
## NeighborhoodCollgCr -4.672e-02  2.923e-02  -1.599 0.110164
## NeighborhoodCrawfor  8.022e-02  3.486e-02   2.301 0.021539 *
## NeighborhoodEdwards -1.037e-01  3.226e-02  -3.215 0.001337 **
## NeighborhoodGilbert -4.801e-02  3.121e-02  -1.538 0.124258
## NeighborhoodIDOTRR  -4.462e-02  4.267e-02  -1.046 0.295897
## NeighborhoodMeadowV -1.632e-01  4.637e-02  -3.520 0.000446 ***
## NeighborhoodMitchel -9.451e-02  3.349e-02  -2.822 0.004844 **
## NeighborhoodNAmes   -5.862e-02  3.138e-02  -1.868 0.061937 .
## NeighborhoodNoRidge  1.077e-02  3.408e-02   0.316 0.752018
## NeighborhoodNPkVill -1.274e-02  4.704e-02  -0.271 0.786616
## NeighborhoodNridgHt  3.664e-02  3.044e-02   1.204 0.228936
## NeighborhoodNWAmes  -6.179e-02  3.293e-02  -1.877 0.060793 .
## NeighborhoodOldTown -5.731e-02  3.739e-02  -1.533 0.125636
## NeighborhoodSawyer  -5.556e-02  3.313e-02  -1.677 0.093742 .
## NeighborhoodSawyerW -4.766e-02  3.233e-02  -1.474 0.140677
## NeighborhoodSomerst  8.423e-03  3.675e-02   0.229 0.818755
## NeighborhoodStoneBr  8.120e-02  3.506e-02   2.316 0.020696 *
## NeighborhoodSWISU   -2.141e-02  3.892e-02  -0.550 0.582229
## NeighborhoodTimber  -3.348e-02  3.364e-02  -0.995 0.319801
## NeighborhoodVeenker -9.409e-03  4.540e-02  -0.207 0.835861
## GrLivArea            2.140e-04  1.608e-05  13.311  < 2e-16 ***
## BsmtFinType1ALQ     -5.270e-02  1.096e-01  -0.481 0.630830
## BsmtFinType1BLQ     -6.157e-02  1.096e-01  -0.562 0.574543
## BsmtFinType1GLQ     -4.235e-02  1.098e-01  -0.386 0.699892
## BsmtFinType1LwQ     -7.859e-02  1.100e-01  -0.715 0.474988
## BsmtFinType1Rec     -6.949e-02  1.097e-01  -0.634 0.526454
## BsmtFinType1Unf     -7.221e-02  1.092e-01  -0.661 0.508643
## GarageCars           2.050e-02  9.942e-03   2.062 0.039387 *
## OverallCond          3.719e-02  3.726e-03   9.982  < 2e-16 ***
## RoofMatlCompShg      2.517e+00  1.986e-01  12.671  < 2e-16 ***
## RoofMatlMembran      2.730e+00  2.311e-01  11.815  < 2e-16 ***
```

```
## RoofMatlMetal          2.592e+00  2.307e-01  11.236  < 2e-16 ***
## RoofMatlRoll           2.562e+00  2.283e-01  11.223  < 2e-16 ***
## RoofMatlTar&Grv        2.496e+00  2.042e-01  12.228  < 2e-16 ***
## RoofMatlWdShake        2.542e+00  2.055e-01  12.371  < 2e-16 ***
## RoofMatlWdShngl        2.545e+00  2.023e-01  12.585  < 2e-16 ***
## TotalBsmtSF            1.477e-04  1.523e-05   9.694  < 2e-16 ***
## YearBuilt             2.039e-03  3.156e-04   6.458 1.49e-10 ***
## LotArea                8.909e-02  1.000e-02   8.908  < 2e-16 ***
## Condition2Feedr        7.729e-02  9.623e-02   0.803 0.422021
## Condition2Norm         4.081e-02  8.255e-02   0.494 0.621127
## Condition2PosA         2.971e-01  1.541e-01   1.929 0.053972 .
## Condition2PosN        -8.390e-01  1.171e-01  -7.163 1.31e-12 ***
## Condition2RRAe        -1.399e-01  1.347e-01  -1.039 0.299064
## Condition2RRAn        -8.032e-02  1.343e-01  -0.598 0.549881
## Condition2RRNn        -1.358e-02  1.146e-01  -0.119 0.905654
## MSZoningFV             4.209e-01  5.158e-02   8.160 7.82e-16 ***
## MSZoningRH             4.154e-01  5.135e-02   8.089 1.37e-15 ***
## MSZoningRL             4.019e-01  4.368e-02   9.203  < 2e-16 ***
## MSZoningRM             3.711e-01  4.088e-02   9.078  < 2e-16 ***
## BsmtUnfSF             -5.325e-05  1.291e-05  -4.123 3.97e-05 ***
## SaleConditionAdjLand   1.243e-01  5.779e-02   2.150 0.031734 *
## SaleConditionAlloca    4.331e-02  3.720e-02   1.164 0.244486
## SaleConditionFamily    1.532e-02  2.691e-02   0.569 0.569387
## SaleConditionNormal    7.074e-02  1.268e-02   5.580 2.93e-08 ***
## SaleConditionPartial  -5.574e-02  6.543e-02  -0.852 0.394473
## FunctionalMaj2        -2.367e-01  5.882e-02  -4.024 6.05e-05 ***
## FunctionalMin1         4.359e-02  3.581e-02   1.217 0.223685
## FunctionalMin2         4.480e-02  3.535e-02   1.267 0.205325
## FunctionalMod         -4.948e-02  4.315e-02  -1.147 0.251792
## FunctionalSev         -2.619e-01  1.175e-01  -2.229 0.025995 *
## FunctionalTyp          7.740e-02  3.052e-02   2.536 0.011340 *
## CentralAirY            6.380e-02  1.591e-02   4.011 6.38e-05 ***
## Condition1Feedr        4.539e-02  2.158e-02   2.103 0.035674 *
## Condition1Norm         8.223e-02  1.785e-02   4.608 4.47e-06 ***
## Condition1PosA         4.391e-02  4.284e-02   1.025 0.305519
## Condition1PosN         8.746e-02  3.193e-02   2.739 0.006243 **
## Condition1RRAe        -4.912e-02  3.987e-02  -1.232 0.218225
## Condition1RRAn         4.088e-02  2.981e-02   1.371 0.170510
## Condition1RRNe         2.394e-02  7.837e-02   0.305 0.760077
## Condition1RRNn         8.546e-02  5.481e-02   1.559 0.119156
## KitchenQualFa         -5.620e-02  2.582e-02  -2.177 0.029690 *
## KitchenQualGd         -5.437e-02  1.439e-02  -3.779 0.000165 ***
## KitchenQualTA         -5.434e-02  1.644e-02  -3.306 0.000973 ***
```

```
## Fireplaces            2.164e-02  5.782e-03   3.743 0.000190 ***
## Exterior1stAsphShn     3.372e-02  1.122e-01   0.301 0.763724
## Exterior1stBrkComm    -1.500e-01  8.675e-02  -1.729 0.084059 .
## Exterior1stBrkFace     8.658e-02  3.098e-02   2.795 0.005271 **
## Exterior1stCBlock     -2.912e-02  1.110e-01  -0.262 0.793151
## Exterior1stCemntBd     3.653e-02  3.249e-02   1.124 0.261090
## Exterior1stHdBoard     4.786e-03  2.832e-02   0.169 0.865811
## Exterior1stImStucc     1.779e-03  1.091e-01   0.016 0.986992
## Exterior1stMetalSd     3.256e-02  2.735e-02   1.190 0.234082
## Exterior1stPlywood     1.015e-02  2.972e-02   0.342 0.732706
## Exterior1stStone      -1.733e-02  8.554e-02  -0.203 0.839534
## Exterior1stStucco      4.550e-02  3.497e-02   1.301 0.193459
## Exterior1stVinylSd     2.773e-02  2.759e-02   1.005 0.315019
## Exterior1stWd Sdng     2.130e-03  2.740e-02   0.078 0.938050
## Exterior1stWdShing     1.068e-02  3.421e-02   0.312 0.754861
## HeatingGasA            1.306e-01  1.138e-01   1.147 0.251487
## HeatingGasW            2.122e-01  1.171e-01   1.812 0.070189 .
## HeatingGrav           -2.092e-02  1.230e-01  -0.170 0.864987
## HeatingOthW            1.733e-01  1.388e-01   1.248 0.212090
## HeatingWall            1.888e-01  1.291e-01   1.462 0.143934
## ScreenPorch            2.478e-04  5.473e-05   4.527 6.52e-06 ***
## YearRemodAdd           7.768e-04  2.340e-04   3.319 0.000929 ***
## BsmtQualEx             5.017e-02  1.753e-02   2.862 0.004274 **
## BsmtQualFa             1.652e-02  2.069e-02   0.799 0.424585
## BsmtQualGd             7.765e-03  1.067e-02   0.728 0.466730
## BsmtQualTA                    NA         NA      NA       NA
## PoolQCFa              -1.186e-01  1.182e-01  -1.003 0.316025
## PoolQCGd               8.872e-02  1.413e-01   0.628 0.530171
## PoolQCNone             9.036e-01  4.108e-01   2.200 0.027989 *
## FoundationCBlock       1.872e-02  1.369e-02   1.367 0.171852
## FoundationPConc        3.742e-02  1.498e-02   2.497 0.012637 *
## FoundationSlab        -2.317e-03  4.301e-02  -0.054 0.957042
## FoundationStone        1.037e-01  4.668e-02   2.222 0.026426 *
## FoundationWood        -1.163e-01  6.419e-02  -1.812 0.070191 .
## KitchenAbvGr          -5.693e-02  1.724e-02  -3.302 0.000985 ***
## SaleTypeCon            4.102e-02  7.839e-02   0.523 0.600868
## SaleTypeConLD          1.264e-01  4.199e-02   3.011 0.002654 **
## SaleTypeConLI         -3.210e-02  5.071e-02  -0.633 0.526833
## SaleTypeConLw          1.291e-02  5.215e-02   0.248 0.804473
## SaleTypeCWD            5.621e-02  5.681e-02   0.989 0.322668
## SaleTypeNew            1.558e-01  6.784e-02   2.297 0.021787 *
## SaleTypeOth            5.535e-02  6.437e-02   0.860 0.390039
## SaleTypeWD            -1.896e-02  1.830e-02  -1.036 0.300280
```

```
## GarageArea              1.014e-04  3.410e-05   2.974 0.002993 **
## HeatingQCFa            -3.036e-02  2.005e-02  -1.514 0.130261
## HeatingQCGd            -2.151e-02  9.049e-03  -2.377 0.017589 *
## HeatingQCPo            -4.834e-02  1.141e-01  -0.424 0.671941
## HeatingQCTA            -3.692e-02  8.979e-03  -4.112 4.18e-05 ***
## BsmtExposureAv          6.546e-02  1.039e-01   0.630 0.528649
## BsmtExposureGd          1.043e-01  1.043e-01   1.000 0.317348
## BsmtExposureMn          6.107e-02  1.041e-01   0.586 0.557645
## BsmtExposureNo          5.632e-02  1.037e-01   0.543 0.587153
## EnclosedPorch           1.198e-04  5.360e-05   2.236 0.025549 *
## WoodDeckSF              6.805e-05  2.572e-05   2.646 0.008240 **
## LotConfigCulDSac        1.137e-02  1.372e-02   0.829 0.407341
## LotConfigFR2           -4.420e-02  1.748e-02  -2.529 0.011562 *
## LotConfigFR3           -9.740e-02  5.591e-02  -1.742 0.081705 .
## LotConfigInside        -1.580e-02  7.682e-03  -2.057 0.039888 *
## StreetPave              1.106e-01  4.844e-02   2.284 0.022545 *
## BsmtFullBath            2.162e-02  8.120e-03   2.663 0.007845 **
## PoolArea                1.679e-03  7.539e-04   2.228 0.026072 *
## LandSlopeMod            1.755e-02  1.515e-02   1.158 0.247052
## LandSlopeSev           -7.623e-02  3.792e-02  -2.011 0.044573 *
## GarageCondFa            1.826e-01  1.443e-01   1.265 0.205988
## GarageCondGd            2.152e-01  1.480e-01   1.454 0.146055
## GarageCondNone         -7.047e-02  7.739e-02  -0.911 0.362683
## GarageCondPo            3.425e-01  1.551e-01   2.208 0.027399 *
## GarageCondTA            2.231e-01  1.426e-01   1.564 0.117963
## HalfBath                2.271e-02  8.330e-03   2.726 0.006496 **
## FullBath                1.935e-02  9.364e-03   2.066 0.039000 *
## TotRmsAbvGrd            6.493e-03  3.671e-03   1.769 0.077166 .
## `3SsnPorch`             1.477e-04  9.884e-05   1.494 0.135342
## ExterCondFa            -6.253e-02  7.903e-02  -0.791 0.429005
## ExterCondGd            -5.048e-02  7.515e-02  -0.672 0.501919
## ExterCondPo            -6.132e-02  1.365e-01  -0.449 0.653358
## ExterCondTA            -2.644e-02  7.504e-02  -0.352 0.724688
## GarageQualFa           -3.025e-01  1.229e-01  -2.461 0.013967 *
## GarageQualGd           -2.405e-01  1.255e-01  -1.916 0.055587 .
## GarageQualNone                 NA         NA      NA       NA
## GarageQualPo           -3.614e-01  1.519e-01  -2.379 0.017502 *
## GarageQualTA           -2.645e-01  1.212e-01  -2.183 0.029243 *
## GarageYrBlt            -4.060e-04  2.587e-04  -1.569 0.116882
## UtilitiesNoSeWa        -1.608e-01  1.094e-01  -1.471 0.141567
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.1028 on 1299 degrees of freedom
## Multiple R-squared:  0.941,  Adjusted R-squared:  0.9337
## F-statistic: 129.5 on 160 and 1299 DF,  p-value: < 2.2e-16
```

model2.Forward$anova

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## log(SalePrice) ~ 1
##
## Final Model:
## log(SalePrice) ~ OverallQual + Neighborhood + GrLivArea + BsmtFinType1 +
##     GarageCars + OverallCond + RoofMatl + TotalBsmtSF + YearBuilt +
##     LotArea + Condition2 + MSZoning + BsmtUnfSF + SaleCondition +
##     Functional + CentralAir + Condition1 + KitchenQual + Fireplaces +
##     Exterior1st + Heating + ScreenPorch + YearRemodAdd + BsmtQual +
##     PoolQC + Foundation + KitchenAbvGr + SaleType + GarageArea +
##     HeatingQC + BsmtExposure + EnclosedPorch + WoodDeckSF + LotConfig +
##     Street + BsmtFullBath + PoolArea + LandSlope + GarageCond +
##     HalfBath + FullBath + TotRmsAbvGrd + `3SsnPorch` + ExterCond +
##     GarageQual + GarageYrBlt + Utilities
##
##
##                 Step Df    Deviance Resid. Df Resid. Dev       AIC
## 1                                        1459  232.80066 -2678.573
## 2    + OverallQual  1 155.46203888      1458   77.33862 -4285.477
## 3   + Neighborhood 24  20.64653490      1434   56.69209 -4690.893
## 4      + GrLivArea  1  14.83069906      1433   41.86139 -5131.669
## 5   + BsmtFinType1  6   4.03327119      1427   37.82811 -5267.583
## 6     + GarageCars  1   3.26135246      1426   34.56676 -5397.217
## 7    + OverallCond  1   2.68083808      1425   31.88592 -5513.079
## 8       + RoofMatl  7   2.27800530      1418   29.60792 -5607.299
## 9    + TotalBsmtSF  1   2.90424457      1417   26.70367 -5756.030
## 10     + YearBuilt  1   1.54304245      1416   25.16063 -5840.930
## 11       + LotArea  1   1.79077988      1415   23.36985 -5946.728
## 12    + Condition2  7   1.46488205      1408   21.90497 -6027.238
## 13      + MSZoning  4   0.95147479      1404   20.95350 -6084.074
## 14     + BsmtUnfSF  1   0.67072280      1403   20.28277 -6129.573
## 15 + SaleCondition  5   0.84137276      1398   19.44140 -6181.429
## 16    + Functional  6   0.73550628      1392   18.70589 -6225.735
## 17    + CentralAir  1   0.46022681      1391   18.24567 -6260.106
## 18    + Condition1  8   0.53482973      1383   17.71084 -6287.542
```

```
## 19    + KitchenQual  3   0.37132218    1380    17.33951 -6312.477
## 20     + Fireplaces  1   0.26880260    1379    17.07071 -6333.288
## 21   + Exterior1st 14   0.54350008    1365    16.52721 -6352.528
## 22         + Heating  5   0.27522498    1360    16.25199 -6367.046
## 23    + ScreenPorch  1   0.15569020    1359    16.09630 -6379.100
## 24  + YearRemodAdd  1   0.15411911    1358    15.94218 -6391.146
## 25       + BsmtQual  3   0.18403447    1355    15.75814 -6402.098
## 26          + PoolQC  3   0.15215182    1352    15.60599 -6410.264
## 27     + Foundation  5   0.18551221    1347    15.42048 -6417.723
## 28  + KitchenAbvGr  1   0.10252599    1346    15.31795 -6425.463
## 29        + SaleType  8   0.24240360    1338    15.07555 -6432.752
## 30      + GarageArea  1   0.09371674    1337    14.98183 -6439.856
## 31        + HeatingQC  4   0.15007917    1333    14.83175 -6446.555
## 32   + BsmtExposure  4   0.13705578    1329    14.69470 -6452.109
## 33 + EnclosedPorch  1   0.06780557    1328    14.62689 -6456.862
## 34     + WoodDeckSF  1   0.06736739    1327    14.55953 -6461.602
## 35       + LotConfig  4   0.11722845    1323    14.44230 -6465.405
## 36          + Street  1   0.05761598    1322    14.38468 -6469.241
## 37   + BsmtFullBath  1   0.05359166    1321    14.33109 -6472.690
## 38        + PoolArea  1   0.04846687    1320    14.28262 -6475.636
## 39       + LandSlope  2   0.06762462    1318    14.21500 -6478.565
## 40      + GarageCond  5   0.12893599    1313    14.08606 -6481.869
## 41        + HalfBath  1   0.04484913    1312    14.04121 -6484.525
## 42        + FullBath  1   0.04414227    1311    13.99707 -6487.122
## 43   + TotRmsAbvGrd  1   0.02713930    1310    13.96993 -6487.955
## 44      + `3SsnPorch`  1   0.02428567    1309    13.94565 -6488.496
## 45       + ExterCond  4   0.07902859    1305    13.86662 -6488.793
## 46      + GarageQual  4   0.08008028    1301    13.78654 -6489.249
## 47      + GarageYrBlt  1   0.02479572    1300    13.76174 -6489.877
## 48        + Utilities  1   0.02288193    1299    13.73886 -6490.307
```

```r
final.Forward.Model <- lm(log(SalePrice) ~ OverallQual + Neighborhood + GrLivArea + BsmtFinType1 +
                GarageCars + OverallCond + RoofMatl + TotalBsmtSF + YearBuilt +
                LotArea + Condition2 + MSZoning + BsmtUnfSF + SaleCondition +
                Functional + CentralAir + Condition1 + KitchenQual + Fireplaces +
                Exterior1st + Heating + ScreenPorch + YearRemodAdd + BsmtQual +
                PoolQC + Foundation + KitchenAbvGr + SaleType + GarageArea +
                HeatingQC + BsmtExposure + EnclosedPorch + WoodDeckSF + LotConfig +
                Street + BsmtFullBath + PoolArea + LandSlope + GarageCond +
                HalfBath + FullBath + TotRmsAbvGrd + `3SsnPorch` + ExterCond +
                GarageQual + GarageYrBlt + Utilities, data = train2
                )
```

Backward Elimination

Backward elimination is a variable selection methodology that begins with all possible predictor variables and works backward, eliminating variables using all possible combinations until only the best for the fit are provided. This employees the "F-to-remove" method from the extra-sum-of-squares F-statistic. For this process, we provided the test a model with all available predictor variables from which insignificant variables were eliminated. The output is as follows below.

```
##
## Call:
## lm(formula = log(SalePrice) ~ MSZoning + LotArea + Street + LotConfig +
##      LandSlope + Neighborhood + Condition1 + Condition2 + OverallQual +
##      OverallCond + YearBuilt + YearRemodAdd + RoofMatl + Exterior1st +
##      ExterCond + Foundation + BsmtQual + BsmtExposure + BsmtFinSF1 +
##      BsmtFinSF2 + BsmtUnfSF + Heating + HeatingQC + CentralAir +
##      `1stFlrSF` + `2ndFlrSF` + LowQualFinSF + BsmtFullBath + FullBath +
##      HalfBath + KitchenAbvGr + KitchenQual + TotRmsAbvGrd + Functional +
##      Fireplaces + GarageCars + GarageArea + GarageQual + GarageCond +
##      WoodDeckSF + EnclosedPorch + `3SsnPorch` + ScreenPorch +
##      PoolArea + PoolQC + SaleType + SaleCondition, data = train2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.73120 -0.04561  0.00172  0.05490  0.73120
##
## Coefficients: (1 not defined because of singularities)
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          4.266e-01  8.405e-01   0.508 0.611822
## MSZoningFV           4.232e-01  5.158e-02   8.205 5.48e-16 ***
## MSZoningRH           4.156e-01  5.135e-02   8.092 1.33e-15 ***
## MSZoningRL           4.046e-01  4.366e-02   9.267  < 2e-16 ***
## MSZoningRM           3.720e-01  4.087e-02   9.102  < 2e-16 ***
## LotArea              8.957e-02  9.910e-03   9.038  < 2e-16 ***
## StreetPave           1.092e-01  4.837e-02   2.257 0.024168 *
## LotConfigCulDSac     8.514e-03  1.366e-02   0.623 0.533289
## LotConfigFR2        -4.098e-02  1.747e-02  -2.346 0.019108 *
## LotConfigFR3        -9.211e-02  5.588e-02  -1.648 0.099509 .
## LotConfigInside     -1.436e-02  7.645e-03  -1.878 0.060599 .
## LandSlopeMod         1.609e-02  1.517e-02   1.060 0.289200
## LandSlopeSev        -7.893e-02  3.793e-02  -2.081 0.037631 *
## NeighborhoodBlueste -1.262e-02  8.181e-02  -0.154 0.877419
## NeighborhoodBrDale  -6.156e-02  4.393e-02  -1.401 0.161392
## NeighborhoodBrkSide  1.229e-02  3.675e-02   0.335 0.738051
## NeighborhoodClearCr -8.026e-03  3.819e-02  -0.210 0.833565
## NeighborhoodCollgCr -4.798e-02  2.940e-02  -1.632 0.102904
## NeighborhoodCrawfor  8.246e-02  3.486e-02   2.366 0.018151 *
```

```
## NeighborhoodEdwards  -1.052e-01  3.244e-02  -3.242 0.001218 **
## NeighborhoodGilbert  -5.301e-02  3.135e-02  -1.691 0.091071 .
## NeighborhoodIDOTRR   -3.864e-02  4.270e-02  -0.905 0.365690
## NeighborhoodMeadowV  -1.558e-01  4.615e-02  -3.376 0.000758 ***
## NeighborhoodMitchel  -9.347e-02  3.359e-02  -2.782 0.005472 **
## NeighborhoodNAmes    -5.696e-02  3.145e-02  -1.811 0.070346 .
## NeighborhoodNoRidge   1.011e-02  3.435e-02   0.294 0.768597
## NeighborhoodNPkVill  -3.641e-03  4.683e-02  -0.078 0.938041
## NeighborhoodNridgHt   3.511e-02  3.064e-02   1.146 0.252054
## NeighborhoodNWAmes   -5.784e-02  3.292e-02  -1.757 0.079192 .
## NeighborhoodOldTown  -5.305e-02  3.751e-02  -1.414 0.157462
## NeighborhoodSawyer   -5.567e-02  3.318e-02  -1.678 0.093665 .
## NeighborhoodSawyerW  -4.701e-02  3.243e-02  -1.450 0.147364
## NeighborhoodSomerst   7.367e-03  3.683e-02   0.200 0.841496
## NeighborhoodStoneBr   8.119e-02  3.514e-02   2.311 0.021015 *
## NeighborhoodSWISU    -1.314e-02  3.927e-02  -0.335 0.738011
## NeighborhoodTimber   -4.081e-02  3.363e-02  -1.214 0.225115
## NeighborhoodVeenker  -1.408e-02  4.534e-02  -0.311 0.756160
## Condition1Feedr       4.537e-02  2.158e-02   2.103 0.035651 *
## Condition1Norm        8.266e-02  1.781e-02   4.640 3.83e-06 ***
## Condition1PosA        4.460e-02  4.303e-02   1.036 0.300227
## Condition1PosN        8.432e-02  3.194e-02   2.640 0.008387 **
## Condition1RRAe       -4.973e-02  3.993e-02  -1.245 0.213264
## Condition1RRAn        3.845e-02  2.969e-02   1.295 0.195581
## Condition1RRNe        2.909e-02  7.831e-02   0.371 0.710405
## Condition1RRNn        8.423e-02  5.477e-02   1.538 0.124342
## Condition2Feedr       6.606e-02  9.613e-02   0.687 0.492029
## Condition2Norm        2.643e-02  8.243e-02   0.321 0.748548
## Condition2PosA        2.720e-01  1.537e-01   1.769 0.077131 .
## Condition2PosN       -8.582e-01  1.170e-01  -7.334 3.92e-13 ***
## Condition2RRAe       -1.247e-01  1.347e-01  -0.926 0.354563
## Condition2RRAn       -9.775e-02  1.343e-01  -0.728 0.466739
## Condition2RRNn       -2.677e-02  1.143e-01  -0.234 0.814942
## OverallQual           4.580e-02  4.226e-03  10.838  < 2e-16 ***
## OverallCond           3.795e-02  3.678e-03  10.319  < 2e-16 ***
## YearBuilt             2.027e-03  3.084e-04   6.574 7.05e-11 ***
## YearRemodAdd          7.533e-04  2.328e-04   3.236 0.001242 **
## RoofMatlCompShg       2.588e+00  1.971e-01  13.133  < 2e-16 ***
## RoofMatlMembran       2.815e+00  2.313e-01  12.172  < 2e-16 ***
## RoofMatlMetal         2.664e+00  2.294e-01  11.611  < 2e-16 ***
## RoofMatlRoll          2.643e+00  2.256e-01  11.718  < 2e-16 ***
## RoofMatlTar&Grv       2.576e+00  2.029e-01  12.697  < 2e-16 ***
## RoofMatlWdShake       2.608e+00  2.047e-01  12.739  < 2e-16 ***
```

```
## RoofMatlWdShngl      2.619e+00  2.007e-01  13.049  < 2e-16 ***
## Exterior1stAsphShn    2.942e-02  1.129e-01   0.261 0.794465
## Exterior1stBrkComm   -1.445e-01  8.688e-02  -1.664 0.096402 .
## Exterior1stBrkFace    9.118e-02  3.097e-02   2.945 0.003292 **
## Exterior1stCBlock    -1.595e-02  1.107e-01  -0.144 0.885434
## Exterior1stCemntBd    3.761e-02  3.241e-02   1.161 0.246001
## Exterior1stHdBoard    8.831e-03  2.824e-02   0.313 0.754530
## Exterior1stImStucc    1.300e-03  1.092e-01   0.012 0.990507
## Exterior1stMetalSd    3.632e-02  2.737e-02   1.327 0.184723
## Exterior1stPlywood    1.240e-02  2.968e-02   0.418 0.676177
## Exterior1stStone     -2.733e-03  8.633e-02  -0.032 0.974753
## Exterior1stStucco     4.735e-02  3.477e-02   1.362 0.173503
## Exterior1stVinylSd    3.047e-02  2.761e-02   1.104 0.269907
## Exterior1stWd Sdng    4.887e-03  2.736e-02   0.179 0.858277
## Exterior1stWdShing    1.371e-02  3.417e-02   0.401 0.688369
## ExterCondFa          -6.467e-02  7.898e-02  -0.819 0.413026
## ExterCondGd          -5.206e-02  7.505e-02  -0.694 0.487999
## ExterCondPo          -6.700e-02  1.369e-01  -0.489 0.624675
## ExterCondTA          -2.915e-02  7.494e-02  -0.389 0.697347
## FoundationCBlock      1.752e-02  1.366e-02   1.282 0.200095
## FoundationPConc       3.701e-02  1.497e-02   2.472 0.013555 *
## FoundationSlab       -2.874e-03  4.305e-02  -0.067 0.946783
## FoundationStone       1.067e-01  4.661e-02   2.288 0.022287 *
## FoundationWood       -1.198e-01  6.406e-02  -1.870 0.061658 .
## BsmtQualEx           -2.908e-02  1.117e-01  -0.260 0.794559
## BsmtQualFa           -6.214e-02  1.116e-01  -0.557 0.577654
## BsmtQualGd           -6.800e-02  1.107e-01  -0.614 0.539034
## BsmtQualTA           -7.552e-02  1.102e-01  -0.685 0.493427
## BsmtExposureAv        7.904e-02  1.039e-01   0.760 0.447130
## BsmtExposureGd        1.170e-01  1.044e-01   1.121 0.262442
## BsmtExposureMn        7.427e-02  1.042e-01   0.713 0.476110
## BsmtExposureNo        6.757e-02  1.038e-01   0.651 0.515072
## BsmtFinSF1            1.557e-04  1.985e-05   7.845 9.00e-15 ***
## BsmtFinSF2            1.206e-04  2.533e-05   4.763 2.12e-06 ***
## BsmtUnfSF             8.636e-05  1.877e-05   4.602 4.60e-06 ***
## HeatingGasA           1.307e-01  1.140e-01   1.147 0.251499
## HeatingGasW           2.143e-01  1.171e-01   1.830 0.067509 .
## HeatingGrav          -2.660e-02  1.232e-01  -0.216 0.829129
## HeatingOthW           1.609e-01  1.387e-01   1.160 0.246275
## HeatingWall           1.894e-01  1.293e-01   1.464 0.143413
## HeatingQCFa          -2.893e-02  2.005e-02  -1.443 0.149300
## HeatingQCGd          -2.236e-02  9.056e-03  -2.469 0.013670 *
## HeatingQCPo          -4.023e-02  1.137e-01  -0.354 0.723556
```

```
## HeatingQCTA        -3.656e-02  8.978e-03   -4.072 4.94e-05 ***
## CentralAirY          6.087e-02  1.587e-02    3.835 0.000132 ***
## `1stFlrSF`           2.238e-04  2.272e-05    9.850  < 2e-16 ***
## `2ndFlrSF`           2.162e-04  1.685e-05   12.833  < 2e-16 ***
## LowQualFinSF         1.297e-04  6.816e-05    1.902 0.057393 .
## BsmtFullBath         2.738e-02  7.869e-03    3.479 0.000520 ***
## FullBath             1.824e-02  9.390e-03    1.943 0.052277 .
## HalfBath             2.186e-02  8.739e-03    2.501 0.012497 *
## KitchenAbvGr        -5.919e-02  1.726e-02   -3.428 0.000626 ***
## KitchenQualFa       -5.581e-02  2.585e-02   -2.159 0.031019 *
## KitchenQualGd       -5.422e-02  1.441e-02   -3.762 0.000176 ***
## KitchenQualTA       -5.442e-02  1.643e-02   -3.311 0.000954 ***
## TotRmsAbvGrd         6.363e-03  3.677e-03    1.730 0.083815 .
## FunctionalMaj2      -2.252e-01  5.885e-02   -3.826 0.000137 ***
## FunctionalMin1       4.374e-02  3.574e-02    1.224 0.221224
## FunctionalMin2       4.267e-02  3.545e-02    1.204 0.228910
## FunctionalMod       -5.044e-02  4.325e-02   -1.166 0.243773
## FunctionalSev       -2.672e-01  1.174e-01   -2.277 0.022965 *
## FunctionalTyp        7.897e-02  3.060e-02    2.581 0.009962 **
## Fireplaces           2.138e-02  5.793e-03    3.691 0.000233 ***
## GarageCars           2.013e-02  9.945e-03    2.024 0.043127 *
## GarageArea           8.607e-05  3.289e-05    2.617 0.008978 **
## GarageQualFa        -3.258e-01  1.274e-01   -2.557 0.010681 *
## GarageQualGd        -2.733e-01  1.307e-01   -2.091 0.036747 *
## GarageQualNone      -7.169e-02  7.735e-02   -0.927 0.354153
## GarageQualPo        -3.830e-01  1.558e-01   -2.459 0.014073 *
## GarageQualTA        -2.944e-01  1.261e-01   -2.334 0.019758 *
## GarageCondFa         2.199e-01  1.488e-01    1.477 0.139890
## GarageCondGd         2.534e-01  1.534e-01    1.653 0.098652 .
## GarageCondNone             NA         NA       NA       NA
## GarageCondPo         3.811e-01  1.595e-01    2.389 0.017040 *
## GarageCondTA         2.579e-01  1.472e-01    1.753 0.079892 .
## WoodDeckSF           6.553e-05  2.561e-05    2.559 0.010601 *
## EnclosedPorch        1.192e-04  5.379e-05    2.217 0.026793 *
## `3SsnPorch`          1.523e-04  9.865e-05    1.544 0.122869
## ScreenPorch          2.403e-04  5.450e-05    4.409 1.12e-05 ***
## PoolArea             1.583e-03  7.561e-04    2.093 0.036509 *
## PoolQCFa            -1.379e-01  1.187e-01   -1.162 0.245592
## PoolQCGd             7.035e-02  1.415e-01    0.497 0.619033
## PoolQCNone           8.269e-01  4.132e-01    2.001 0.045570 *
## SaleTypeCon          4.728e-02  7.847e-02    0.603 0.546873
## SaleTypeConLD        1.297e-01  4.196e-02    3.091 0.002037 **
## SaleTypeConLI       -3.534e-02  5.079e-02   -0.696 0.486647
```

```
## SaleTypeConLw            2.282e-02  5.216e-02    0.438 0.661784
## SaleTypeCWD              6.391e-02  5.687e-02    1.124 0.261366
## SaleTypeNew              1.574e-01  6.784e-02    2.321 0.020462 *
## SaleTypeOth              5.663e-02  6.433e-02    0.880 0.378874
## SaleTypeWD              -1.480e-02  1.822e-02   -0.812 0.416828
## SaleConditionAdjLand     1.275e-01  5.783e-02    2.205 0.027595 *
## SaleConditionAlloca      3.651e-02  3.738e-02    0.977 0.328772
## SaleConditionFamily      9.440e-03  2.690e-02    0.351 0.725671
## SaleConditionNormal      7.030e-02  1.266e-02    5.553 3.40e-08 ***
## SaleConditionPartial    -5.668e-02  6.552e-02   -0.865 0.387139
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.103 on 1303 degrees of freedom
## Multiple R-squared:  0.9406, Adjusted R-squared:  0.9335
## F-statistic: 132.3 on 156 and 1303 DF,  p-value: < 2.2e-16

## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## log(SalePrice) ~ Id + MSSubClass + MSZoning + LotFrontage + LotArea +
##     Street + Alley + LotShape + LandContour + Utilities + LotConfig +
##     LandSlope + Neighborhood + Condition1 + Condition2 + BldgType +
##     HouseStyle + OverallQual + OverallCond + YearBuilt + YearRemodAdd +
##     RoofStyle + RoofMatl + Exterior1st + Exterior2nd + MasVnrType +
##     MasVnrArea + ExterQual + ExterCond + Foundation + BsmtQual +
##     BsmtCond + BsmtExposure + BsmtFinType1 + BsmtFinSF1 + BsmtFinType2 +
##     BsmtFinSF2 + BsmtUnfSF + TotalBsmtSF + Heating + HeatingQC +
##     CentralAir + Electrical + `1stFlrSF` + `2ndFlrSF` + LowQualFinSF +
##     GrLivArea + BsmtFullBath + BsmtHalfBath + FullBath + HalfBath +
##     BedroomAbvGr + KitchenAbvGr + KitchenQual + TotRmsAbvGrd +
##     Functional + Fireplaces + FireplaceQu + GarageType + GarageYrBlt +
##     GarageFinish + GarageCars + GarageArea + GarageQual + GarageCond +
##     PavedDrive + WoodDeckSF + OpenPorchSF + EnclosedPorch + `3SsnPorch` +
##     ScreenPorch + PoolArea + PoolQC + Fence + MiscFeature + MiscVal +
##     MoSold + YrSold + SaleType + SaleCondition
##
## Final Model:
## log(SalePrice) ~ MSZoning + LotArea + Street + LotConfig + LandSlope +
##     Neighborhood + Condition1 + Condition2 + OverallQual + OverallCond +
##     YearBuilt + YearRemodAdd + RoofMatl + Exterior1st + ExterCond +
##     Foundation + BsmtQual + BsmtExposure + BsmtFinSF1 + BsmtFinSF2 +
##     BsmtUnfSF + Heating + HeatingQC + CentralAir + `1stFlrSF` +
```

```
##      `2ndFlrSF` + LowQualFinSF + BsmtFullBath + FullBath + HalfBath +
##      KitchenAbvGr + KitchenQual + TotRmsAbvGrd + Functional +
##      Fireplaces + GarageCars + GarageArea + GarageQual + GarageCond +
##      WoodDeckSF + EnclosedPorch + `3SsnPorch` + ScreenPorch +
##      PoolArea + PoolQC + SaleType + SaleCondition
##
##
##                Step Df    Deviance Resid. Df Resid. Dev        AIC
## 1                                      1207    12.84597 -6404.415
## 2     - GrLivArea  0 0.0000000000      1207    12.84597 -6404.415
## 3   - TotalBsmtSF  0 0.0000000000      1207    12.84597 -6404.415
## 4   - MiscFeature  4 0.0071184283      1211    12.85309 -6411.607
## 5     - BldgType  4 0.0090739655      1215    12.86217 -6418.576
## 6  - Exterior2nd 14 0.1907005136      1229    13.05287 -6425.088
## 7   - FireplaceQu  5 0.0330714087      1234    13.08594 -6431.394
## 8     - ExterQual  3 0.0058939959      1237    13.09183 -6436.737
## 9    - Electrical  4 0.0280797229      1241    13.11991 -6441.608
## 10 - BsmtFinType2  6 0.0660817875      1247    13.18599 -6446.273
## 11 - BsmtFinType1  5 0.0628798476      1252    13.24887 -6449.328
## 12     - RoofStyle  5 0.0646479063      1257    13.31352 -6452.221
## 13      - LotShape  3 0.0295479478      1260    13.34307 -6454.984
## 14 - GarageFinish  2 0.0105103125      1262    13.35358 -6457.834
## 15    - GarageType  5 0.0697782736      1267    13.42336 -6460.225
## 16    - MasVnrType  3 0.0309574363      1270    13.45432 -6462.862
## 17       - MiscVal  1 0.0001161084      1271    13.45443 -6464.849
## 18        - Alley  2 0.0187499370      1273    13.47318 -6466.816
## 19    - HouseStyle  7 0.1103233581      1280    13.58351 -6468.910
## 20         - Fence  4 0.0540626339      1284    13.63757 -6471.110
## 21      - BsmtCond  3 0.0340658341      1287    13.67163 -6473.468
## 22  - LotFrontage  1 0.0004633675      1288    13.67210 -6475.419
## 23 - BedroomAbvGr  1 0.0020604596      1289    13.67416 -6477.199
## 24        - YrSold  1 0.0026936553      1290    13.67685 -6478.911
## 25 - BsmtHalfBath  1 0.0031955268      1291    13.68005 -6480.570
## 26   - OpenPorchSF  1 0.0039191081      1292    13.68397 -6482.152
## 27        - MoSold  1 0.0036593326      1293    13.68763 -6483.761
## 28    - PavedDrive  2 0.0240231991      1295    13.71165 -6485.201
## 29           - Id  1 0.0064771694      1296    13.71813 -6486.512
## 30    - MSSubClass  1 0.0110326193      1297    13.72916 -6487.338
## 31    - MasVnrArea  1 0.0122577100      1298    13.74142 -6488.035
## 32   - LandContour  3 0.0519387656      1301    13.79336 -6488.527
## 33     - Utilities  1 0.0144669027      1302    13.80782 -6488.996
## 34   - GarageYrBlt  1 0.0168317755      1303    13.82465 -6489.218
```

Stepwise Regression

Stepwise regression is a variable selection methodology that performs one step of forward selection for each step of backward elimination. The steps are repeated, concurrently, until no further predictor variables can be added or removed. This is the third model approach we used. The suggested model is output below.

```
##
## Call:
## lm(formula = log(SalePrice) ~ OverallQual + Neighborhood + GrLivArea +
##     GarageCars + OverallCond + RoofMatl + TotalBsmtSF + YearBuilt +
##     LotArea + Condition2 + MSZoning + BsmtUnfSF + SaleCondition +
##     Functional + CentralAir + Condition1 + KitchenQual + Fireplaces +
##     Exterior1st + Heating + ScreenPorch + YearRemodAdd + BsmtQual +
##     PoolQC + Foundation + KitchenAbvGr + SaleType + GarageArea +
##     HeatingQC + BsmtExposure + EnclosedPorch + WoodDeckSF + LotConfig +
##     Street + BsmtFullBath + PoolArea + LandSlope + GarageCond +
##     HalfBath + FullBath + BsmtFinSF1 + TotRmsAbvGrd + `3SsnPorch` +
##     LandContour, data = train2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.71707 -0.04587  0.00185  0.05454  0.71707
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)           2.628e-01  8.307e-01   0.316 0.751757
## OverallQual           4.637e-02  4.227e-03  10.969  < 2e-16 ***
## NeighborhoodBlueste  -2.465e-02  8.165e-02  -0.302 0.762785
## NeighborhoodBrDale   -6.171e-02  4.379e-02  -1.409 0.159041
## NeighborhoodBrkSide   6.700e-03  3.647e-02   0.184 0.854280
## NeighborhoodClearCr  -8.921e-03  3.795e-02  -0.235 0.814179
## NeighborhoodCollgCr  -5.029e-02  2.928e-02  -1.717 0.086143 .
## NeighborhoodCrawfor   6.945e-02  3.517e-02   1.975 0.048484 *
## NeighborhoodEdwards  -1.073e-01  3.234e-02  -3.317 0.000936 ***
## NeighborhoodGilbert  -5.637e-02  3.129e-02  -1.801 0.071875 .
## NeighborhoodIDOTRR   -4.823e-02  4.256e-02  -1.133 0.257396
## NeighborhoodMeadowV  -1.566e-01  4.609e-02  -3.398 0.000700 ***
## NeighborhoodMitchel  -9.832e-02  3.345e-02  -2.939 0.003350 **
## NeighborhoodNAmes    -6.297e-02  3.150e-02  -1.999 0.045854 *
## NeighborhoodNoRidge   5.874e-03  3.410e-02   0.172 0.863265
## NeighborhoodNPkVill  -5.852e-03  4.680e-02  -0.125 0.900505
## NeighborhoodNridgHt   3.175e-02  3.050e-02   1.041 0.298177
## NeighborhoodNWAmes   -6.507e-02  3.294e-02  -1.975 0.048435 *
## NeighborhoodOldTown  -5.963e-02  3.740e-02  -1.595 0.111041
## NeighborhoodSawyer   -6.145e-02  3.321e-02  -1.850 0.064491 .
## NeighborhoodSawyerW  -4.722e-02  3.236e-02  -1.459 0.144711
```

```
## NeighborhoodSomerst     2.308e-03  3.681e-02   0.063 0.950024
## NeighborhoodStoneBr     7.817e-02  3.529e-02   2.215 0.026911 *
## NeighborhoodSWISU      -1.710e-02  3.921e-02  -0.436 0.662860
## NeighborhoodTimber     -4.740e-02  3.398e-02  -1.395 0.163222
## NeighborhoodVeenker    -2.386e-02  4.528e-02  -0.527 0.598316
## GrLivArea               2.169e-04  1.607e-05  13.499  < 2e-16 ***
## GarageCars              2.234e-02  9.923e-03   2.251 0.024556 *
## OverallCond             3.802e-02  3.528e-03  10.775  < 2e-16 ***
## RoofMatlCompShg         2.545e+00  1.974e-01  12.897  < 2e-16 ***
## RoofMatlMembran         2.796e+00  2.315e-01  12.081  < 2e-16 ***
## RoofMatlMetal           2.634e+00  2.298e-01  11.459  < 2e-16 ***
## RoofMatlRoll            2.624e+00  2.255e-01  11.637  < 2e-16 ***
## RoofMatlTar&Grv         2.534e+00  2.030e-01  12.481  < 2e-16 ***
## RoofMatlWdShake         2.566e+00  2.047e-01  12.540  < 2e-16 ***
## RoofMatlWdShngl         2.626e+00  2.005e-01  13.094  < 2e-16 ***
## TotalBsmtSF             1.264e-04  2.166e-05   5.836 6.74e-09 ***
## YearBuilt               2.063e-03  3.066e-04   6.728 2.56e-11 ***
## LotArea                 9.191e-02  9.973e-03   9.215  < 2e-16 ***
## Condition2Feedr         4.557e-02  9.422e-02   0.484 0.628716
## Condition2Norm          1.326e-02  8.074e-02   0.164 0.869596
## Condition2PosA          3.137e-01  1.351e-01   2.322 0.020378 *
## Condition2PosN         -8.621e-01  1.154e-01  -7.471 1.44e-13 ***
## Condition2RRAe         -1.362e-01  1.337e-01  -1.018 0.308692
## Condition2RRAn         -1.054e-01  1.333e-01  -0.791 0.429086
## Condition2RRNn         -6.525e-02  1.135e-01  -0.575 0.565507
## MSZoningFV              4.235e-01  5.188e-02   8.162 7.64e-16 ***
## MSZoningRH              4.134e-01  5.173e-02   7.990 2.93e-15 ***
## MSZoningRL              4.022e-01  4.401e-02   9.139  < 2e-16 ***
## MSZoningRM              3.694e-01  4.113e-02   8.982  < 2e-16 ***
## BsmtUnfSF              -3.551e-05  2.021e-05  -1.757 0.079124 .
## SaleConditionAdjLand    1.198e-01  5.765e-02   2.078 0.037943 *
## SaleConditionAlloca     3.942e-02  3.767e-02   1.046 0.295553
## SaleConditionFamily     6.711e-03  2.696e-02   0.249 0.803487
## SaleConditionNormal     7.036e-02  1.265e-02   5.561 3.25e-08 ***
## SaleConditionPartial   -4.825e-02  6.557e-02  -0.736 0.461915
## FunctionalMaj2         -2.377e-01  5.797e-02  -4.100 4.38e-05 ***
## FunctionalMin1          4.812e-02  3.561e-02   1.352 0.176764
## FunctionalMin2          4.509e-02  3.522e-02   1.280 0.200704
## FunctionalMod          -6.051e-02  4.225e-02  -1.432 0.152286
## FunctionalSev          -2.881e-01  1.172e-01  -2.458 0.014100 *
## FunctionalTyp           7.996e-02  3.033e-02   2.636 0.008482 **
## CentralAirY             5.903e-02  1.581e-02   3.734 0.000196 ***
## Condition1Feedr         3.994e-02  2.141e-02   1.866 0.062287 .
```

```
## Condition1Norm          8.078e-02  1.761e-02   4.588 4.91e-06 ***
## Condition1PosA          4.221e-02  4.274e-02   0.987 0.323595
## Condition1PosN          8.479e-02  3.173e-02   2.672 0.007636 **
## Condition1RRAe         -5.594e-02  3.992e-02  -1.401 0.161322
## Condition1RRAn          4.035e-02  2.955e-02   1.366 0.172313
## Condition1RRNe          2.782e-02  7.838e-02   0.355 0.722736
## Condition1RRNn          9.338e-02  5.484e-02   1.703 0.088835 .
## KitchenQualFa          -5.884e-02  2.563e-02  -2.295 0.021878 *
## KitchenQualGd          -5.425e-02  1.434e-02  -3.783 0.000162 ***
## KitchenQualTA          -5.542e-02  1.636e-02  -3.388 0.000725 ***
## Fireplaces              2.301e-02  5.734e-03   4.013 6.32e-05 ***
## Exterior1stAsphShn      2.427e-02  1.125e-01   0.216 0.829181
## Exterior1stBrkComm     -1.476e-01  8.588e-02  -1.719 0.085839 .
## Exterior1stBrkFace      9.226e-02  3.100e-02   2.976 0.002971 **
## Exterior1stCBlock      -7.147e-03  1.107e-01  -0.065 0.948547
## Exterior1stCemntBd      3.946e-02  3.240e-02   1.218 0.223470
## Exterior1stHdBoard      1.009e-02  2.820e-02   0.358 0.720593
## Exterior1stImStucc      3.089e-04  1.093e-01   0.003 0.997746
## Exterior1stMetalSd      3.739e-02  2.735e-02   1.367 0.171865
## Exterior1stPlywood      1.277e-02  2.969e-02   0.430 0.667113
## Exterior1stStone        6.297e-03  8.555e-02   0.074 0.941337
## Exterior1stStucco       4.070e-02  3.450e-02   1.180 0.238335
## Exterior1stVinylSd      3.115e-02  2.753e-02   1.132 0.258031
## Exterior1stWd Sdng      8.055e-03  2.739e-02   0.294 0.768739
## Exterior1stWdShing      1.778e-02  3.418e-02   0.520 0.603060
## HeatingGasA             1.127e-01  1.137e-01   0.992 0.321602
## HeatingGasW             1.954e-01  1.167e-01   1.674 0.094313 .
## HeatingGrav            -5.024e-02  1.230e-01  -0.408 0.682993
## HeatingOthW             1.192e-01  1.382e-01   0.862 0.388672
## HeatingWall             1.765e-01  1.291e-01   1.367 0.171888
## ScreenPorch             2.541e-04  5.369e-05   4.734 2.44e-06 ***
## YearRemodAdd            7.722e-04  2.306e-04   3.349 0.000833 ***
## BsmtQualEx             -4.385e-02  1.109e-01  -0.396 0.692489
## BsmtQualFa             -7.601e-02  1.109e-01  -0.685 0.493211
## BsmtQualGd             -8.122e-02  1.098e-01  -0.740 0.459607
## BsmtQualTA             -8.766e-02  1.094e-01  -0.801 0.423203
## PoolQCFa               -1.172e-01  1.181e-01  -0.993 0.321097
## PoolQCGd                8.973e-02  1.413e-01   0.635 0.525401
## PoolQCNone              8.888e-01  4.096e-01   2.170 0.030201 *
## FoundationCBlock        2.000e-02  1.356e-02   1.474 0.140696
## FoundationPConc         3.890e-02  1.482e-02   2.624 0.008796 **
## FoundationSlab         -8.396e-03  4.292e-02  -0.196 0.844928
## FoundationStone         9.513e-02  4.570e-02   2.082 0.037570 *
```

```
## FoundationWood        -1.108e-01  6.433e-02  -1.722 0.085350  .
## KitchenAbvGr          -5.446e-02  1.725e-02  -3.156 0.001635  **
## SaleTypeCon            5.404e-02  7.851e-02   0.688 0.491375
## SaleTypeConLD          1.292e-01  4.152e-02   3.113 0.001892  **
## SaleTypeConLI         -3.118e-02  5.069e-02  -0.615 0.538650
## SaleTypeConLw          2.957e-02  5.213e-02   0.567 0.570658
## SaleTypeCWD            6.911e-02  5.694e-02   1.214 0.225061
## SaleTypeNew            1.504e-01  6.792e-02   2.214 0.027004  *
## SaleTypeOth            6.342e-02  6.436e-02   0.985 0.324670
## SaleTypeWD            -1.282e-02  1.813e-02  -0.707 0.479555
## GarageArea             8.816e-05  3.280e-05   2.687 0.007291  **
## HeatingQCFa           -2.500e-02  2.009e-02  -1.244 0.213590
## HeatingQCGd           -2.231e-02  9.037e-03  -2.469 0.013680  *
## HeatingQCPo           -3.208e-02  1.139e-01  -0.282 0.778255
## HeatingQCTA           -3.356e-02  8.943e-03  -3.752 0.000183  ***
## BsmtExposureAv         8.136e-02  1.041e-01   0.782 0.434479
## BsmtExposureGd         1.167e-01  1.045e-01   1.117 0.264225
## BsmtExposureMn         7.635e-02  1.043e-01   0.732 0.464419
## BsmtExposureNo         6.941e-02  1.039e-01   0.668 0.504291
## EnclosedPorch          1.334e-04  5.358e-05   2.489 0.012928  *
## WoodDeckSF             5.686e-05  2.553e-05   2.227 0.026095  *
## LotConfigCulDSac       1.019e-02  1.367e-02   0.745 0.456363
## LotConfigFR2          -3.814e-02  1.747e-02  -2.183 0.029218  *
## LotConfigFR3          -8.344e-02  5.585e-02  -1.494 0.135386
## LotConfigInside       -1.146e-02  7.623e-03  -1.504 0.132870
## StreetPave             1.101e-01  4.836e-02   2.277 0.022944  *
## BsmtFullBath           2.550e-02  7.871e-03   3.240 0.001227  **
## PoolArea               1.648e-03  7.516e-04   2.192 0.028562  *
## LandSlopeMod           2.918e-02  1.702e-02   1.714 0.086763  .
## LandSlopeSev          -5.733e-02  3.955e-02  -1.450 0.147387
## GarageCondFa          -9.532e-02  7.822e-02  -1.219 0.223224
## GarageCondGd          -4.292e-02  8.396e-02  -0.511 0.609282
## GarageCondNone        -7.425e-02  7.731e-02  -0.960 0.337030
## GarageCondPo           2.708e-02  8.779e-02   0.309 0.757742
## GarageCondTA          -4.153e-02  7.539e-02  -0.551 0.581872
## HalfBath               2.145e-02  8.286e-03   2.588 0.009753  **
## FullBath               1.612e-02  9.349e-03   1.725 0.084813  .
## BsmtFinSF1             3.491e-05  1.953e-05   1.788 0.074073  .
## TotRmsAbvGrd           6.244e-03  3.677e-03   1.698 0.089716  .
## `3SsnPorch`            1.582e-04  9.861e-05   1.604 0.108984
## LandContourHLS         3.537e-02  2.222e-02   1.592 0.111598
## LandContourLow        -1.354e-02  2.691e-02  -0.503 0.614883
## LandContourLvl         2.458e-02  1.580e-02   1.555 0.120089
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1032 on 1310 degrees of freedom
## Multiple R-squared:  0.9401, Adjusted R-squared:  0.9333
## F-statistic:   138 on 149 and 1310 DF,  p-value: < 2.2e-16

## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## log(SalePrice) ~ 1
##
## Final Model:
## log(SalePrice) ~ OverallQual + Neighborhood + GrLivArea + GarageCars +
##     OverallCond + RoofMatl + TotalBsmtSF + YearBuilt + LotArea +
##     Condition2 + MSZoning + BsmtUnfSF + SaleCondition + Functional +
##     CentralAir + Condition1 + KitchenQual + Fireplaces + Exterior1st +
##     Heating + ScreenPorch + YearRemodAdd + BsmtQual + PoolQC +
##     Foundation + KitchenAbvGr + SaleType + GarageArea + HeatingQC +
##     BsmtExposure + EnclosedPorch + WoodDeckSF + LotConfig + Street +
##     BsmtFullBath + PoolArea + LandSlope + GarageCond + HalfBath +
##     FullBath + BsmtFinSF1 + TotRmsAbvGrd + `3SsnPorch` + LandContour
##
##
##                  Step Df     Deviance Resid. Df Resid. Dev       AIC
## 1                                          1459  232.80066 -2678.573
## 2       + OverallQual  1 155.46203888      1458   77.33862 -4285.477
## 3     + Neighborhood 24  20.64653490      1434   56.69209 -4690.893
## 4         + GrLivArea  1  14.83069906      1433   41.86139 -5131.669
## 5     + BsmtFinType1  6   4.03327119      1427   37.82811 -5267.583
## 6        + GarageCars  1   3.26135246      1426   34.56676 -5397.217
## 7       + OverallCond  1   2.68083808      1425   31.88592 -5513.079
## 8          + RoofMatl  7   2.27800530      1418   29.60792 -5607.299
## 9       + TotalBsmtSF  1   2.90424457      1417   26.70367 -5756.030
## 10        + YearBuilt  1   1.54304245      1416   25.16063 -5840.930
## 11          + LotArea  1   1.79077988      1415   23.36985 -5946.728
## 12       + Condition2  7   1.46488205      1408   21.90497 -6027.238
## 13         + MSZoning  4   0.95147479      1404   20.95350 -6084.074
## 14        + BsmtUnfSF  1   0.67072280      1403   20.28277 -6129.573
## 15 + SaleCondition  5   0.84137276      1398   19.44140 -6181.429
## 16       + Functional  6   0.73550628      1392   18.70589 -6225.735
## 17       + CentralAir  1   0.46022681      1391   18.24567 -6260.106
## 18       + Condition1  8   0.53482973      1383   17.71084 -6287.542
```

22

```
## 19    + KitchenQual  3   0.37132218      1380    17.33951 -6312.477
## 20     + Fireplaces  1   0.26880260      1379    17.07071 -6333.288
## 21    + Exterior1st 14   0.54350008      1365    16.52721 -6352.528
## 22        + Heating  5   0.27522498      1360    16.25199 -6367.046
## 23    + ScreenPorch  1   0.15569020      1359    16.09630 -6379.100
## 24   + YearRemodAdd  1   0.15411911      1358    15.94218 -6391.146
## 25       + BsmtQual  3   0.18403447      1355    15.75814 -6402.098
## 26         + PoolQC  3   0.15215182      1352    15.60599 -6410.264
## 27     + Foundation  5   0.18551221      1347    15.42048 -6417.723
## 28   + KitchenAbvGr  1   0.10252599      1346    15.31795 -6425.463
## 29       + SaleType  8   0.24240360      1338    15.07555 -6432.752
## 30      + GarageArea  1   0.09371674     1337    14.98183 -6439.856
## 31       + HeatingQC  4   0.15007917     1333    14.83175 -6446.555
## 32   + BsmtExposure  4   0.13705578      1329    14.69470 -6452.109
## 33  + EnclosedPorch  1   0.06780557      1328    14.62689 -6456.862
## 34      + WoodDeckSF 1   0.06736739      1327    14.55953 -6461.602
## 35       + LotConfig 4   0.11722845      1323    14.44230 -6465.405
## 36          + Street 1   0.05761598      1322    14.38468 -6469.241
## 37   + BsmtFullBath  1   0.05359166      1321    14.33109 -6472.690
## 38       + PoolArea  1   0.04846687      1320    14.28262 -6475.636
## 39      + LandSlope  2   0.06762462      1318    14.21500 -6478.565
## 40      + GarageCond 5   0.12893599      1313    14.08606 -6481.869
## 41       + HalfBath  1   0.04484913      1312    14.04121 -6484.525
## 42       + FullBath  1   0.04414227      1311    13.99707 -6487.122
## 43   - BsmtFinType1  5   0.08686145      1316    14.08393 -6488.089
## 44      + BsmtFinSF1 1   0.03205070      1315    14.05188 -6489.416
## 45    + TotRmsAbvGrd 1   0.02637498      1314    14.02551 -6490.159
## 46      + `3SsnPorch` 1  0.02698569      1313    13.99852 -6490.971
## 47    + LandContour  3   0.05866738      1310    13.93985 -6491.102
```

Custom Variable Selection

To develop the custom model, we employed a combination of a correlation matrix for quantitative data, analysis of the summarization of the suggested model from stepwise selection, and through direct analysis of the pairs plots. As previously mentioned, our final model included 11 linear terms and three interaction terms. We removed all variables suggested to be removed by the stepwise regression and backward elimination tests, then reprocessed the updated models until forward selection, backward elimination, and stepwise regression were in agreeance with respect to the linear terms. Once this trial-and-error process was completed, we added interaction terms based on domain knowledge and re-applied the forward selection, backward elimination, and stepwise regression methods until only significant terms - both linear and interactive - remained. We then used graphical analysis to visually confirm interaction between the interactive terms remaining.

```
##               row       column        cor          p
## 378    GarageCars   GarageArea  0.8824754143 0.000000e+00
## 270     GrLivArea  TotRmsAbvGrd 0.8254893743 0.000000e+00
```

```
## 91    TotalBsmtSF      X1stFlrSF 0.8195299750 0.000000e+00
## 307    YearBuilt     GarageYrBlt 0.7946235492 0.000000e+00
## 671   OverallQual       SalePrice 0.7909816006 0.000000e+00
## 683     GrLivArea       SalePrice 0.7086244776 0.000000e+00
## 135      X2ndFlrSF       GrLivArea 0.6875010642 0.000000e+00
## 275 BedroomAbvGr    TotRmsAbvGrd 0.6766199357 0.000000e+00
## 146   BsmtFinSF1    BsmtFullBath 0.6492117536 0.000000e+00
## 693    GarageCars       SalePrice 0.6404091973 0.000000e+00
## 188     GrLivArea        FullBath 0.6300116463 0.000000e+00
## 308 YearRemodAdd    GarageYrBlt 0.6245045510 0.000000e+00
## 694    GarageArea       SalePrice 0.6234314389 0.000000e+00
## 268     X2ndFlrSF    TotRmsAbvGrd 0.6164226355 0.000000e+00
## 679   TotalBsmtSF       SalePrice 0.6135805516 0.000000e+00
## 205     X2ndFlrSF        HalfBath 0.6097073003 0.000000e+00
## 680     X1stFlrSF       SalePrice 0.6058521847 0.000000e+00
## 330   OverallQual      GarageCars 0.6006707166 0.000000e+00
## 125   OverallQual       GrLivArea 0.5930074300 0.000000e+00
## 28     YearBuilt    YearRemodAdd 0.5928549763 0.000000e+00
## 20    OverallQual       YearBuilt 0.5723227690 0.000000e+00
## 134     X1stFlrSF       GrLivArea 0.5660239689 0.000000e+00
## 356   OverallQual      GarageArea 0.5620217566 0.000000e+00
## 686      FullBath       SalePrice 0.5606637627 0.000000e+00
## 273      FullBath    TotRmsAbvGrd 0.5547842535 0.000000e+00
## 26    OverallQual    YearRemodAdd 0.5506839242 0.000000e+00
## 176   OverallQual        FullBath 0.5505997094 0.000000e+00
## 332     YearBuilt      GarageCars 0.5378500917 0.000000e+00
## 71    OverallQual     TotalBsmtSF 0.5378084986 0.000000e+00
## 305   OverallQual     GarageYrBlt 0.5348401548 0.000000e+00
## 690  TotRmsAbvGrd       SalePrice 0.5337231556 0.000000e+00
## 673     YearBuilt       SalePrice 0.5228973329 0.000000e+00
## 76    BsmtFinSF1     TotalBsmtSF 0.5223960520 0.000000e+00
## 227     GrLivArea    BedroomAbvGr 0.5212695109 0.000000e+00
## 351   GarageYrBlt      GarageCars 0.5208950873 0.000000e+00
## 377   GarageYrBlt      GarageArea 0.5123267593 0.000000e+00
## 674 YearRemodAdd       SalePrice 0.5071009671 0.000000e+00
## 225     X2ndFlrSF    BedroomAbvGr 0.5029006133 0.000000e+00
## 365     X1stFlrSF      GarageArea 0.4897816541 0.000000e+00
## 364   TotalBsmtSF      GarageArea 0.4866654638 0.000000e+00
## 692   GarageYrBlt       SalePrice 0.4853808733 0.000000e+00
## 358     YearBuilt      GarageArea 0.4789538199 0.000000e+00
## 83    OverallQual       X1stFlrSF 0.4762238291 0.000000e+00
## 320      FullBath     GarageYrBlt 0.4751286638 0.000000e+00
## 675     MasVnrArea       SalePrice 0.4726144990 0.000000e+00
```

```
## 345       FullBath     GarageCars 0.4696720433 0.000000e+00
## 368      GrLivArea     GarageArea 0.4689974773 0.000000e+00
## 178      YearBuilt       FullBath 0.4682707872 0.000000e+00
## 342      GrLivArea     GarageCars 0.4672474188 0.000000e+00
## 691     Fireplaces      SalePrice 0.4669288368 0.000000e+00
## 293      GrLivArea     Fireplaces 0.4616791338 0.000000e+00
## 133     TotalBsmtSF      GrLivArea 0.4548682025 0.000000e+00
## 88       BsmtFinSF1       X1stFlrSF 0.4458626561 0.000000e+00
## 82         LotArea       X1stFlrSF 0.4438691242 0.000000e+00
## 339      X1stFlrSF     GarageCars 0.4393168080 0.000000e+00
## 179   YearRemodAdd       FullBath 0.4390464839 0.000000e+00
## 338    TotalBsmtSF     GarageCars 0.4345848343 0.000000e+00
## 258    OverallQual   TotRmsAbvGrd 0.4274523433 0.000000e+00
## 186       X2ndFlrSF       FullBath 0.4213779829 0.000000e+00
## 333   YearRemodAdd     GarageCars 0.4206221549 0.000000e+00
## 207      GrLivArea       HalfBath 0.4157716361 0.000000e+00
## 78        BsmtUnfSF    TotalBsmtSF 0.4153596052 0.000000e+00
## 290       X1stFlrSF     Fireplaces 0.4105310847 0.000000e+00
## 267       X1stFlrSF   TotRmsAbvGrd 0.4095159789 0.000000e+00
## 33      OverallQual      MasVnrArea 0.4072521235 0.000000e+00
## 371       FullBath     GarageArea 0.4056562085 0.000000e+00
## 281    OverallQual     Fireplaces 0.3967650380 0.000000e+00
## 124        LotArea      GrLivArea 0.3945774471 0.000000e+00
## 73       YearBuilt    TotalBsmtSF 0.3914520021 0.000000e+00
## 670        LotArea      SalePrice 0.3885202679 0.000000e+00
## 129      MasVnrArea      GrLivArea 0.3880520522 0.000000e+00
## 676      BsmtFinSF1      SalePrice 0.3864198062 0.000000e+00
## 185       X1stFlrSF       FullBath 0.3806374950 0.000000e+00
## 359   YearRemodAdd     GarageArea 0.3715998095 0.000000e+00
## 360      MasVnrArea     GarageArea 0.3708841528 0.000000e+00
## 230       FullBath    BedroomAbvGr 0.3632519830 0.000000e+00
## 349   TotRmsAbvGrd     GarageCars 0.3622885708 0.000000e+00
## 334      MasVnrArea     GarageCars 0.3619445662 0.000000e+00
## 257        LotArea   TotRmsAbvGrd 0.3601291441 0.000000e+00
## 75       MasVnrArea    TotalBsmtSF 0.3600673681 0.000000e+00
## 70         LotArea    TotalBsmtSF 0.3518380024 0.000000e+00
## 274       HalfBath   TotRmsAbvGrd 0.3434148575 0.000000e+00
## 87       MasVnrArea       X1stFlrSF 0.3398504137 0.000000e+00
## 289     TotalBsmtSF     Fireplaces 0.3395193239 0.000000e+00
## 375    TotRmsAbvGrd     GarageArea 0.3378221206 0.000000e+00
## 423      GrLivArea    OpenPorchSF 0.3302239617 0.000000e+00
## 280        LotArea     Fireplaces 0.3277536789 0.000000e+00
## 300    TotRmsAbvGrd     Fireplaces 0.3261144802 0.000000e+00
```

```
## 695     WoodDeckSF     SalePrice  0.3244134446 0.000000e+00
## 184     TotalBsmtSF     FullBath  0.3237224136 0.000000e+00
## 355        LotArea    GarageArea  0.3220454756 0.000000e+00
## 313     TotalBsmtSF   GarageYrBlt  0.3219920228 0.000000e+00
## 681        X2ndFlrSF    SalePrice  0.3193338028 0.000000e+00
## 90         BsmtUnfSF     X1stFlrSF  0.3179874384 0.000000e+00
## 696     OpenPorchSF    SalePrice  0.3158562271 0.000000e+00
## 35         YearBuilt    MasVnrArea  0.3116001068 0.000000e+00
## 411     OverallQual   OpenPorchSF  0.3088188234 0.000000e+00
## 60      OverallQual     BsmtUnfSF  0.3081589269 0.000000e+00
## 93        MSSubClass     X2ndFlrSF  0.3078857208 0.000000e+00
## 149     TotalBsmtSF  BsmtFullBath  0.3073505537 0.000000e+00
## 350      Fireplaces    GarageCars  0.3007887663 0.000000e+00
## 361      BsmtFinSF1    GarageArea  0.2969703853 0.000000e+00
## 96      OverallQual     X2ndFlrSF  0.2954928792 0.000000e+00
## 74     YearRemodAdd   TotalBsmtSF  0.2910655826 0.000000e+00
## 183      BsmtUnfSF      FullBath  0.2888860555 0.000000e+00
## 128    YearRemodAdd     GrLivArea  0.2873885197 0.000000e+00
## 266     TotalBsmtSF  TotRmsAbvGrd  0.2855725637 0.000000e+00
## 687        HalfBath     SalePrice  0.2841076756 0.000000e+00
## 85         YearBuilt     X1stFlrSF  0.2819858587 0.000000e+00
## 233       MSSubClass  KitchenAbvGr  0.2817210403 0.000000e+00
## 262       MasVnrArea  TotRmsAbvGrd  0.2795678875 0.000000e+00
## 214         LotArea  BedroomAbvGr  0.2791763555 0.000000e+00
## 195     OverallQual      HalfBath  0.2734580986 0.000000e+00
## 180       MasVnrArea      FullBath  0.2729988557 0.000000e+00
## 329         LotArea     GarageCars  0.2720069723 0.000000e+00
## 376      Fireplaces    GarageArea  0.2691412381 0.000000e+00
## 6       LotFrontage       LotArea  0.2620210123 0.000000e+00
## 45        MasVnrArea    BsmtFinSF1  0.2612560549 0.000000e+00
## 286      BsmtFinSF1    Fireplaces  0.2600109202 0.000000e+00
## 426        FullBath   OpenPorchSF  0.2599774255 0.000000e+00
## 276     KitchenAbvGr  TotRmsAbvGrd  0.2560454085 0.000000e+00
## 309      MasVnrArea   GarageYrBlt  0.2538513431 0.000000e+00
## 265       BsmtUnfSF  TotRmsAbvGrd  0.2506470614 0.000000e+00
## 43         YearBuilt    BsmtFinSF1  0.2495031967 0.000000e+00
## 395        GrLivArea    WoodDeckSF  0.2474328205 0.000000e+00
## 419     TotalBsmtSF   OpenPorchSF  0.2472637463 0.000000e+00
## 285       MasVnrArea    Fireplaces  0.2470152774 0.000000e+00
## 81      LotFrontage     X1stFlrSF  0.2451809314 0.000000e+00
## 150       X1stFlrSF  BsmtFullBath  0.2446711042 0.000000e+00
## 296        FullBath    Fireplaces  0.2436705031 0.000000e+00
## 197        YearBuilt      HalfBath  0.2426559102 0.000000e+00
```

```
## 434    GarageArea    OpenPorchSF 0.2414346721 0.000000e+00
## 86    YearRemodAdd      X1stFlrSF 0.2403792676 0.000000e+00
## 132      BsmtUnfSF       GrLivArea 0.2402572683 0.000000e+00
## 41     OverallQual     BsmtFinSF1 0.2396659662 0.000000e+00
## 383    OverallQual      WoodDeckSF 0.2389233922 0.000000e+00
## 69     LotFrontage     TotalBsmtSF 0.2382736687 0.000000e+00
## 314      X1stFlrSF     GarageYrBlt 0.2372582793 0.000000e+00
## 392      X1stFlrSF      WoodDeckSF 0.2354586228 0.000000e+00
## 430    TotRmsAbvGrd    OpenPorchSF 0.2341915878 0.000000e+00
## 391    TotalBsmtSF      WoodDeckSF 0.2320186091 0.000000e+00
## 317      GrLivArea     GarageYrBlt 0.2318559767 0.000000e+00
## 40         LotArea     BsmtFinSF1 0.2309689215 0.000000e+00
## 404    GarageYrBlt      WoodDeckSF 0.2273885171 0.000000e+00
## 684    BsmtFullBath      SalePrice 0.2271222331 0.000000e+00
## 231       HalfBath    BedroomAbvGr 0.2266514842 0.000000e+00
## 405      GarageCars      WoodDeckSF 0.2263421385 0.000000e+00
## 414    YearRemodAdd    OpenPorchSF 0.2262976327 0.000000e+00
## 385      YearBuilt      WoodDeckSF 0.2248801423 0.000000e+00
## 406      GarageArea      WoodDeckSF 0.2246663072 0.000000e+00
## 335      BsmtFinSF1      GarageCars 0.2240535224 0.000000e+00
## 256    LotFrontage    TotRmsAbvGrd 0.2213962408 0.000000e+00
## 432    GarageYrBlt     OpenPorchSF 0.2206152551 0.000000e+00
## 123    LotFrontage       GrLivArea 0.2203472317 0.000000e+00
## 346       HalfBath      GarageCars 0.2191781522 0.000000e+00
## 678      BsmtUnfSF       SalePrice 0.2144791055 0.000000e+00
## 337      BsmtUnfSF       GarageCars 0.2141751898 0.000000e+00
## 433      GarageCars    OpenPorchSF 0.2135694456 0.000000e+00
## 420      X1stFlrSF     OpenPorchSF 0.2116712255 4.440892e-16
## 669    LotFrontage       SalePrice 0.2096239448 4.440892e-16
## 130      BsmtFinSF1       GrLivArea 0.2081711301 8.881784e-16
## 421      X2ndFlrSF     OpenPorchSF 0.2080260632 8.881784e-16
## 386    YearRemodAdd      WoodDeckSF 0.2057259205 1.998401e-15
## 388      BsmtFinSF1      WoodDeckSF 0.2043061452 3.108624e-15
## 297       HalfBath      Fireplaces 0.2036485081 3.996803e-15
## 354    LotFrontage      GarageArea 0.2014733532 7.771561e-15
## 403      Fireplaces      WoodDeckSF 0.2000187958 1.221245e-14
## 382         LotArea      WoodDeckSF 0.1998462802 1.287859e-14
## 427       HalfBath     OpenPorchSF 0.1997401475 1.332268e-14
## 199       MasVnrArea       HalfBath 0.1991075194 1.598721e-14
## 127       YearBuilt       GrLivArea 0.1990097137 1.665335e-14
## 253    BedroomAbvGr    KitchenAbvGr 0.1985967577 1.887379e-14
## 321       HalfBath     GarageYrBlt 0.1979949050 2.264855e-14
## 291      X2ndFlrSF      Fireplaces 0.1945608922 6.394885e-14
```

```
## 261 YearRemodAdd   TotRmsAbvGrd  0.1917398163 1.483258e-13
## 413   YearBuilt    OpenPorchSF   0.1886858400 3.623768e-13
## 312   BsmtUnfSF     GarageYrBlt   0.1879249397 4.518608e-13
## 398   FullBath      WoodDeckSF    0.1877032138 4.818368e-13
## 143   YearBuilt     BsmtFullBath  0.1875985500 4.964917e-13
## 521   Fireplaces    ScreenPorch   0.1845302695 1.195044e-12
## 340   X2ndFlrSF     GarageCars    0.1839255831 1.417977e-12
## 198 YearRemodAdd    HalfBath      0.1833306117 1.677547e-12
## 363   BsmtUnfSF     GarageArea    0.1833026977 1.690648e-12
## 63  YearRemodAdd    BsmtUnfSF     0.1811330871 3.104628e-12
## 369 BsmtFullBath    GarageArea    0.1791894804 5.316858e-12
## 175     LotArea     FullBath      0.1791873528 5.319967e-12
## 10      LotArea     OverallQual   0.1782154116 6.946888e-12
## 192   MSSubClass    HalfBath      0.1773543886 8.788081e-12
## 9    LotFrontage    OverallQual   0.1765610224 1.090283e-11
## 36  YearRemodAdd    MasVnrArea    0.1765291806 1.099743e-11
## 396 BsmtFullBath    WoodDeckSF    0.1753151901 1.526557e-11
## 100   MasVnrArea    X2ndFlrSF     0.1738000004 2.291234e-11
## 545    GrLivArea    PoolArea      0.1702053360 5.918421e-11
## 431   Fireplaces    OpenPorchSF   0.1694053271 7.290124e-11
## 688 BedroomAbvGr    SalePrice     0.1682131543 9.927481e-11
## 222   BsmtUnfSF     BedroomAbvGr  0.1666433170 1.485800e-10
## 402 TotRmsAbvGrd    WoodDeckSF    0.1659838837 1.758029e-10
## 328  LotFrontage    GarageCars    0.1652286072 2.129863e-10
## 372    HalfBath     GarageArea    0.1635493640 3.252643e-10
## 58   LotFrontage    BsmtUnfSF     0.1608292768 6.398495e-10
## 387   MasVnrArea    WoodDeckSF    0.1599905296 7.864733e-10
## 147  BsmtFinSF2    BsmtFullBath   0.1586780608 1.083814e-09
## 310  BsmtFinSF1    GarageYrBlt    0.1574262445 1.467971e-09
## 62     YearBuilt    BsmtUnfSF     0.1490403920 1.053186e-08
## 283    YearBuilt    Fireplaces    0.1477163994 1.423520e-08
## 410      LotArea   OpenPorchSF    0.1472237238 1.591339e-08
## 324 TotRmsAbvGrd   GarageYrBlt    0.1465408418 1.856019e-08
## 213  LotFrontage  BedroomAbvGr    0.1444936461 2.931307e-08
## 538  BsmtFinSF1    PoolArea       0.1404912863 7.033185e-08
## 99  YearRemodAdd   X2ndFlrSF      0.1400237788 7.777962e-08
## 366   X2ndFlrSF    GarageArea     0.1383469586 1.112964e-07
## 140      LotArea   BsmtFullBath   0.1382726671 1.130664e-07
## 294 BsmtFullBath   Fireplaces     0.1379277084 1.216474e-07
## 210     FullBath   HalfBath       0.1363805887 1.685130e-07
## 136 LowQualFinSF   GrLivArea      0.1346828130 2.399688e-07
## 251     FullBath   KitchenAbvGr   0.1331152142 3.313172e-07
## 343 BsmtFullBath   GarageCars     0.1318812244 4.259908e-07
```

```
## 173   MSSubClass      FullBath  0.1316082224 4.502112e-07
## 542     X1stFlrSF      PoolArea  0.1315249756 4.578571e-07
## 269  LowQualFinSF   TotRmsAbvGrd  0.1311847760 4.904240e-07
## 418     BsmtUnfSF    OpenPorchSF  0.1290054146 7.585232e-07
## 44   YearRemodAdd     BsmtFinSF1  0.1284505471 8.466431e-07
## 224     X1stFlrSF    BedroomAbvGr  0.1274007494 1.041034e-06
## 541    TotalBsmtSF      PoolArea  0.1260531321 1.354117e-06
## 318   BsmtFullBath    GarageYrBlt  0.1225899006 2.628877e-06
## 415     MasVnrArea    OpenPorchSF  0.1225283318 2.659639e-06
## 32        LotArea     MasVnrArea  0.1223499891 2.750708e-06
## 174   LotFrontage       FullBath  0.1205478702 3.855272e-06
## 144  YearRemodAdd   BsmtFullBath  0.1194698791 4.707216e-06
## 159   OverallCond   BsmtHalfBath  0.1178209151 6.367488e-06
## 531   LotFrontage       PoolArea  0.1141063586 1.239367e-05
## 64      MasVnrArea      BsmtUnfSF  0.1138621631 1.293922e-05
## 284  YearRemodAdd      Fireplaces  0.1125813184 1.619633e-05
## 416    BsmtFinSF1    OpenPorchSF  0.1117606134 1.867889e-05
## 699    ScreenPorch      SalePrice  0.1114465711 1.972140e-05
## 141    OverallQual   BsmtFullBath  0.1110977861 2.094407e-05
## 399       HalfBath     WoodDeckSF  0.1080803027 3.498385e-05
## 298   BedroomAbvGr      Fireplaces  0.1075696810 3.810704e-05
## 226  LowQualFinSF   BedroomAbvGr  0.1056065685 5.275462e-05
## 31    LotFrontage     MasVnrArea  0.1050098330 5.817285e-05
## 77     BsmtFinSF2    TotalBsmtSF  0.1048095376 6.010660e-05
## 219     MasVnrArea   BedroomAbvGr  0.1027745161 8.352065e-05
## 215    OverallQual   BedroomAbvGr  0.1016763562 9.949911e-05
## 513      GrLivArea    ScreenPorch  0.1015103957 1.021512e-04
## 248      GrLivArea   KitchenAbvGr  0.1000631647 1.282743e-04
## 500        LotArea    ScreenPorch  0.0973810189 1.940828e-04
## 89     BsmtFinSF2      X1stFlrSF  0.0971174485 2.020319e-04
## 260      YearBuilt   TotRmsAbvGrd  0.0955891283 2.544833e-04
## 553      Fireplaces      PoolArea  0.0950735220 2.748854e-04
## 428   BedroomAbvGr    OpenPorchSF  0.0938095716 3.315593e-04
## 700       PoolArea      SalePrice  0.0924035495 4.073490e-04
## 49         LotArea     BsmtFinSF2  0.0922135123 4.187525e-04
## 393       X2ndFlrSF     WoodDeckSF  0.0921654176 4.216854e-04
## 532        LotArea      PoolArea  0.0917909418 4.451854e-04
## 507     BsmtFinSF2    ScreenPorch  0.0888712514 6.748802e-04
## 510      X1stFlrSF    ScreenPorch  0.0887580726 6.856868e-04
## 347   BedroomAbvGr     GarageCars  0.0861064377 9.897559e-04
## 509    TotalBsmtSF    ScreenPorch  0.0844889859 1.232141e-03
## 552   TotRmsAbvGrd       PoolArea  0.0837573495 1.358848e-03
## 145     MasVnrArea   BsmtFullBath  0.0830100478 1.500572e-03
```

```
## 543       X2ndFlrSF      PoolArea 0.0814868780 1.832442e-03
## 95          LotArea      X2ndFlrSF 0.0804654708 2.091386e-03
## 24      LotFrontage    YearRemodAdd 0.0786855146 2.624027e-03
## 59          LotArea      BsmtUnfSF 0.0772470168 3.142026e-03
## 39      LotFrontage     BsmtFinSF1 0.0766699970 3.374784e-03
## 122       MSSubClass       GrLivArea 0.0748531797 4.213734e-03
## 526      OpenPorchSF    ScreenPorch 0.0743039439 4.502235e-03
## 302       MSSubClass     GarageYrBlt 0.0741142186 4.605973e-03
## 27       OverallCond    YearRemodAdd 0.0737414981 4.816090e-03
## 557       WoodDeckSF       PoolArea 0.0733782070 5.029191e-03
## 315        X2ndFlrSF     GarageYrBlt 0.0733417224 5.051056e-03
## 517         HalfBath    ScreenPorch 0.0724258452 5.628839e-03
## 625      OpenPorchSF         MoSold 0.0712548848 6.454026e-03
## 164       BsmtFinSF2    BsmtHalfBath 0.0709481337 6.687445e-03
## 600       OverallQual         MoSold 0.0708151718 6.790956e-03
## 550      BedroomAbvGr       PoolArea 0.0707025836 6.879728e-03
## 441      OverallCond  EnclosedPorch 0.0703561845 7.159420e-03
## 409      LotFrontage     OpenPorchSF 0.0696049521 7.801296e-03
## 567      OverallCond         MiscVal 0.0687768061 8.568159e-03
## 245         X1stFlrSF    KitchenAbvGr 0.0681005882 9.243534e-03
## 389       BsmtFinSF2      WoodDeckSF 0.0678983264 9.454564e-03
## 546      BsmtFullBath       PoolArea 0.0676155562 9.756787e-03
## 163       BsmtFinSF1    BsmtHalfBath 0.0674184779 9.972479e-03
## 424      BsmtFullBath     OpenPorchSF 0.0673414614 1.005792e-02
## 648      BsmtFullBath         YrSold 0.0670491377 1.038816e-02
## 373      BedroomAbvGr      GarageArea 0.0652525299 1.263772e-02
## 533      OverallQual       PoolArea 0.0651658436 1.275642e-02
## 501      OverallQual    ScreenPorch 0.0648863605 1.314582e-02
## 120        X2ndFlrSF     LowQualFinSF 0.0633529501 1.547482e-02
## 584      KitchenAbvGr         MiscVal 0.0623407240 1.720427e-02
## 505        MasVnrArea    ScreenPorch 0.0622477112 1.737138e-02
## 544      LowQualFinSF       PoolArea 0.0621573723 1.753504e-02
## 506       BsmtFinSF1    ScreenPorch 0.0620206227 1.778535e-02
## 450        X2ndFlrSF  EnclosedPorch 0.0619886908 1.784425e-02
## 451      LowQualFinSF  EnclosedPorch 0.0610812378 1.959094e-02
## 556        GarageArea       PoolArea 0.0610472717 1.965912e-02
## 558      OpenPorchSF       PoolArea 0.0607621115 2.023972e-02
## 520      TotRmsAbvGrd    ScreenPorch 0.0593825996 2.326437e-02
## 246        X2ndFlrSF    KitchenAbvGr 0.0593057526 2.344382e-02
## 435       WoodDeckSF     OpenPorchSF 0.0586606086 2.499829e-02
## 181       BsmtFinSF1       FullBath 0.0585431369 2.529073e-02
## 325        Fireplaces     GarageYrBlt 0.0581759561 2.622396e-02
## 529              Id       PoolArea 0.0570439048 2.929065e-02
```

```
## 479       X1stFlrSF      X3SsnPorch  0.0561043745 3.206515e-02
## 615        FullBath         MoSold  0.0558721290 3.278470e-02
## 469         LotArea      X3SsnPorch  0.0556995619 3.332825e-02
## 502     OverallCond      ScreenPorch  0.0548105288 3.625216e-02
## 559  EnclosedPorch        PoolArea  0.0542025623 3.837511e-02
## 288        BsmtUnfSF      Fireplaces  0.0515748823 4.880435e-02
## 524       GarageArea      ScreenPorch  0.0514117624 4.952348e-02
## 561      ScreenPorch        PoolArea  0.0513073945 4.998823e-02
## 523       GarageCars      ScreenPorch  0.0504937919 5.373793e-02
## 223      TotalBsmtSF    BedroomAbvGr  0.0504499555 5.394645e-02
## 612        GrLivArea         MoSold  0.0502396808 5.495608e-02
## 108      LotFrontage    LowQualFinSF  0.0499814302 5.621755e-02
## 548        FullBath        PoolArea  0.0496038256 5.810530e-02
## 565         LotArea         MiscVal  0.0477906815 6.791680e-02
## 287       BsmtFinSF2      Fireplaces  0.0469207088 7.308663e-02
## 400     BedroomAbvGr      WoodDeckSF  0.0468537731 7.349738e-02
## 617     BedroomAbvGr         MoSold  0.0465438599 7.542378e-02
## 229     BsmtHalfBath    BedroomAbvGr  0.0465188484 7.558103e-02
## 107        MSSubClass    LowQualFinSF  0.0464737559 7.586521e-02
## 702          MoSold       SalePrice  0.0464322452 7.612758e-02
## 620       Fireplaces         MoSold  0.0463571025 7.660441e-02
## 473     YearRemodAdd     X3SsnPorch  0.0452858098 8.367071e-02
## 157         LotArea    BsmtHalfBath  0.0452181062 8.413444e-02
## 698      X3SsnPorch       SalePrice  0.0445836653 8.858170e-02
## 303     LotFrontage      GarageYrBlt  0.0443393840 9.034373e-02
## 263       BsmtFinSF1    TotRmsAbvGrd  0.0443156239 9.051661e-02
## 518     BedroomAbvGr     ScreenPorch  0.0442996911 9.063268e-02
## 279     LotFrontage      Fireplaces  0.0440176416 9.270736e-02
## 636     OverallCond          YrSold  0.0439497457 9.321243e-02
## 94       LotFrontage       X2ndFlrSF  0.0425492441 1.041311e-01
## 539       BsmtFinSF2        PoolArea  0.0417090547 1.111537e-01
## 457     BedroomAbvGr  EnclosedPorch  0.0415704345 1.123474e-01
## 511        X2ndFlrSF      ScreenPorch  0.0406064476 1.209302e-01
## 23         MSSubClass    YearRemodAdd  0.0405810448 1.211631e-01
## 622       GarageCars         MoSold  0.0405217301 1.217084e-01
## 255        MSSubClass    TotRmsAbvGrd  0.0403800648 1.230183e-01
## 51        OverallCond      BsmtFinSF2  0.0402291699 1.244256e-01
## 397     BsmtHalfBath      WoodDeckSF  0.0401612233 1.250634e-01
## 194         LotArea        HalfBath  0.0387168314 1.392324e-01
## 211              Id    BedroomAbvGr  0.0377185542 1.497254e-01
## 478      TotalBsmtSF     X3SsnPorch  0.0373837273 1.533766e-01
## 458     KitchenAbvGr  EnclosedPorch  0.0373123850 1.541632e-01
## 619     TotRmsAbvGrd         MoSold  0.0369070772 1.586904e-01
```

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## 18    LotFrontage      YearBuilt  0.0368534286 1.592971e-01
## 446   BsmtFinSF2 EnclosedPorch  0.0365433394 1.628382e-01
## 492     GarageCars     X3SsnPorch  0.0357652851 1.719841e-01
## 638   YearRemodAdd        YrSold  0.0357432471 1.722487e-01
## 485       FullBath     X3SsnPorch  0.0353530166 1.769833e-01
## 610       X2ndFlrSF        MoSold  0.0351644274 1.793059e-01
## 484   BsmtHalfBath     X3SsnPorch  0.0351136309 1.799353e-01
## 493     GarageArea     X3SsnPorch  0.0350867002 1.802697e-01
## 607       BsmtUnfSF        MoSold  0.0348884430 1.827454e-01
## 153       GrLivArea  BsmtFullBath  0.0348360495 1.834039e-01
## 234   LotFrontage   KitchenAbvGr  0.0344246581 1.886352e-01
## 614   BsmtHalfBath        MoSold  0.0328727052 2.093598e-01
## 8       MSSubClass   OverallQual  0.0326277075 2.127766e-01
## 515   BsmtHalfBath   ScreenPorch  0.0321214072 2.199645e-01
## 594    ScreenPorch       MiscVal  0.0319457608 2.224984e-01
## 641     BsmtFinSF2        YrSold  0.0317056370 2.259960e-01
## 653   KitchenAbvGr        YrSold  0.0316872065 2.262661e-01
## 609       X1stFlrSF        MoSold  0.0313715604 2.309272e-01
## 472       YearBuilt     X3SsnPorch  0.0313545131 2.311809e-01
## 470     OverallQual     X3SsnPorch  0.0303705671 2.461582e-01
## 243       BsmtUnfSF   KitchenAbvGr  0.0300858683 2.506158e-01
## 595        PoolArea       MiscVal  0.0296686509 2.572495e-01
## 627     X3SsnPorch        MoSold  0.0294737952 2.603891e-01
## 295   BsmtHalfBath    Fireplaces  0.0289755866 2.685363e-01
## 97      OverallCond     X2ndFlrSF  0.0289421160 2.690898e-01
## 117       BsmtUnfSF  LowQualFinSF  0.0281666881 2.821334e-01
## 623     GarageArea        MoSold  0.0279737998 2.854434e-01
## 17      MSSubClass     YearBuilt  0.0278501369 2.875793e-01
## 25          LotArea  YearRemodAdd  0.0276698773 2.907119e-01
## 162     MasVnrArea   BsmtHalfBath  0.0274026623 2.953977e-01
## 438   LotFrontage EnclosedPorch  0.0273661049 2.960426e-01
## 254            Id   TotRmsAbvGrd  0.0272387244 2.982973e-01
## 512   LowQualFinSF   ScreenPorch  0.0267994130 3.061609e-01
## 618   KitchenAbvGr        MoSold  0.0265889072 3.099771e-01
## 475     BsmtFinSF1     X3SsnPorch  0.0264505062 3.125032e-01
## 471     OverallCond     X3SsnPorch  0.0255036600 3.301473e-01
## 111     OverallCond  LowQualFinSF  0.0254943199 3.303245e-01
## 491     GarageYrBlt     X3SsnPorch  0.0254215000 3.317081e-01
## 585   TotRmsAbvGrd       MiscVal  0.0247628842 3.443919e-01
## 30      MSSubClass     MasVnrArea  0.0235729681 3.680801e-01
## 468   LotFrontage     X3SsnPorch  0.0234987244 3.695909e-01
## 628    ScreenPorch        MoSold  0.0232169918 3.753591e-01
## 514   BsmtFullBath   ScreenPorch  0.0231477258 3.767857e-01
```

```
## 499    LotFrontage    ScreenPorch  0.0229687320 3.804877e-01
## 549       HalfBath       PoolArea  0.0223814981 3.927890e-01
## 659     WoodDeckSF         YrSold  0.0222704510 3.951420e-01
## 19          LotArea      YearBuilt  0.0219366834 4.022653e-01
## 603   YearRemodAdd         MoSold  0.0214900022 4.119179e-01
## 596            Id         MoSold  0.0211721766 4.188687e-01
## 624     WoodDeckSF         MoSold  0.0210110443 4.224189e-01
## 555      GarageCars       PoolArea  0.0209335310 4.241329e-01
## 477       BsmtUnfSF     X3SsnPorch  0.0207640057 4.278958e-01
## 482       GrLivArea     X3SsnPorch  0.0206431897 4.305893e-01
## 547    BsmtHalfBath       PoolArea  0.0200246298 4.445328e-01
## 474       MasVnrArea    X3SsnPorch  0.0191437843 4.648259e-01
## 598    LotFrontage         MoSold  0.0189419430 4.695474e-01
## 662     X3SsnPorch         YrSold  0.0186449254 4.765432e-01
## 592  EnclosedPorch        MiscVal  0.0183606001 4.832932e-01
## 422    LowQualFinSF   OpenPorchSF  0.0182510391 4.859080e-01
## 352            Id      GarageArea  0.0176337785 5.007813e-01
## 326            Id      GarageCars  0.0165696771 5.269768e-01
## 576       X2ndFlrSF        MiscVal  0.0161968746 5.363168e-01
## 116      BsmtFinSF2  LowQualFinSF  0.0148069979 5.718554e-01
## 640      BsmtFinSF1         YrSold  0.0143589224 5.835463e-01
## 608      TotalBsmtSF        MoSold  0.0131961786 6.143911e-01
## 216     OverallCond   BedroomAbvGr  0.0129800601 6.202024e-01
## 109         LotArea  LowQualFinSF  0.0128104054 6.247810e-01
## 11             Id    OverallCond  0.0126089248 6.302373e-01
## 602       YearBuilt         MoSold  0.0123984706 6.359583e-01
## 537      MasVnrArea       PoolArea  0.0119283940 6.488149e-01
## 490       Fireplaces    X3SsnPorch  0.0112572390 6.673530e-01
## 1              Id       MSSubClass  0.0111564782 6.701541e-01
## 439         LotArea EnclosedPorch  0.0109514944 6.758666e-01
## 663     ScreenPorch         YrSold  0.0106941060 6.830660e-01
## 599         LotArea         MoSold  0.0105207039 6.879325e-01
## 139    LotFrontage   BsmtFullBath  0.0105143334 6.881116e-01
## 79             Id       X1stFlrSF  0.0104960410 6.886258e-01
## 98       YearBuilt       X2ndFlrSF  0.0103076596 6.939294e-01
## 452       GrLivArea EnclosedPorch  0.0091132103 7.278971e-01
## 530      MSSubClass       PoolArea  0.0082827076 7.518384e-01
## 121            Id       GrLivArea  0.0082727577 7.521268e-01
## 583    BedroomAbvGr        MiscVal  0.0077669720 7.668285e-01
## 247    LowQualFinSF  KitchenAbvGr  0.0075217443 7.739873e-01
## 191            Id       HalfBath  0.0067838113 7.956429e-01
## 621      GarageYrBlt        MoSold  0.0064638728 8.050822e-01
## 536    YearRemodAdd       PoolArea  0.0058293720 8.238849e-01
```

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## 92            Id       X2ndFlrSF  0.0055898489 8.310099e-01
## 172           Id        FullBath  0.0055874529 8.310812e-01
## 535     YearBuilt        PoolArea  0.0049497276 8.501179e-01
## 572     BsmtFinSF2         MiscVal  0.0049397812 8.504155e-01
## 665       MiscVal          YrSold  0.0049062625 8.514187e-01
## 103       BsmtUnfSF       X2ndFlrSF  0.0044690921 8.645239e-01
## 200      BsmtFinSF1        HalfBath  0.0042624244 8.707324e-01
## 459   TotRmsAbvGrd EnclosedPorch  0.0041512990 8.740741e-01
## 571      BsmtFinSF1         MiscVal  0.0035714735 8.915451e-01
## 138      MSSubClass BsmtFullBath  0.0034910258 8.939735e-01
## 417      BsmtFinSF2     OpenPorchSF  0.0030925622 9.060156e-01
## 232             Id     KitchenAbvGr  0.0029512364 9.102920e-01
## 436             Id EnclosedPorch  0.0028892179 9.121694e-01
## 137             Id    BsmtFullBath  0.0022885556 9.303768e-01
## 167       X1stFlrSF    BsmtHalfBath  0.0019556536 9.404841e-01
## 235         LotArea    KitchenAbvGr  0.0016780030 9.489212e-01
## 586      Fireplaces         MiscVal  0.0014086054 9.571131e-01
## 497             Id      ScreenPorch  0.0013302086 9.594979e-01
## 582        HalfBath         MiscVal  0.0012901448 9.607167e-01
## 301             Id      GarageYrBlt  0.0010008825 9.695195e-01
## 631             Id          YrSold  0.0007117940 9.783207e-01
## 593       X3SsnPorch         MiscVal  0.0003539653 9.892182e-01
## 483    BsmtFullBath      X3SsnPorch -0.0001060915 9.967684e-01
## 166       TotalBsmtSF BsmtHalfBath -0.0003145818 9.904177e-01
## 407             Id     OpenPorchSF -0.0004769113 9.854736e-01
## 187    LowQualFinSF        FullBath -0.0007095096 9.783903e-01
## 656      GarageYrBlt          YrSold -0.0017497095 9.467416e-01
## 534      OverallCond        PoolArea -0.0019849423 9.395944e-01
## 155      MSSubClass    BsmtHalfBath -0.0023325346 9.290423e-01
## 578        GrLivArea         MiscVal -0.0024156396 9.265212e-01
## 447       BsmtUnfSF EnclosedPorch -0.0025378546 9.228150e-01
## 384      OverallCond      WoodDeckSF -0.0033336993 8.987253e-01
## 601      OverallCond          MoSold -0.0035108386 8.933753e-01
## 577    LowQualFinSF         MiscVal -0.0037928708 8.848674e-01
## 481    LowQualFinSF      X3SsnPorch -0.0042956104 8.697349e-01
## 486        HalfBath      X3SsnPorch -0.0049724884 8.494369e-01
## 37              Id      BsmtFinSF1 -0.0050240490 8.478946e-01
## 390       BsmtUnfSF      WoodDeckSF -0.0053164243 8.391603e-01
## 169    LowQualFinSF    BsmtHalfBath -0.0058415048 8.235244e-01
## 495     OpenPorchSF      X3SsnPorch -0.0058424993 8.234948e-01
## 46              Id      BsmtFinSF2 -0.0059676720 8.197775e-01
## 408      MSSubClass     OpenPorchSF -0.0061001212 8.158485e-01
## 562             Id         MiscVal -0.0062424048 8.116329e-01
```

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## 14        LotArea    OverallCond -0.0063053353 8.097702e-01
## 630        MiscVal        MoSold -0.0064945502 8.041758e-01
## 489    TotRmsAbvGrd    X3SsnPorch -0.0066832410 7.986069e-01
## 604     MasVnrArea        MoSold -0.0067232039 7.974288e-01
## 580    BsmtHalfBath       MiscVal -0.0073665245 7.785284e-01
## 563      MSSubClass       MiscVal -0.0076832913 7.692691e-01
## 56             Id       BsmtUnfSF -0.0079397034 7.617980e-01
## 560      X3SsnPorch      PoolArea -0.0079915489 7.602900e-01
## 516       FullBath    ScreenPorch -0.0081060933 7.569616e-01
## 639     MasVnrArea        YrSold -0.0083166226 7.508559e-01
## 454    BsmtHalfBath EnclosedPorch -0.0085553339 7.439517e-01
## 616       HalfBath        MoSold -0.0090498882 7.297135e-01
## 48      LotFrontage    BsmtFinSF2 -0.0093123095 7.221957e-01
## 590      WoodDeckSF       MiscVal -0.0095512282 7.153744e-01
## 131      BsmtFinSF2      GrLivArea -0.0096398916 7.128488e-01
## 661   EnclosedPorch        YrSold -0.0099159370 7.050056e-01
## 304        LotArea    GarageYrBlt -0.0099695529 7.034858e-01
## 651       HalfBath        YrSold -0.0102686689 6.950290e-01
## 569    YearRemodAdd       MiscVal -0.0102862488 6.945331e-01
## 677      BsmtFinSF2     SalePrice -0.0113781215 6.639987e-01
## 437      MSSubClass EnclosedPorch -0.0120366219 6.458454e-01
## 633     LotFrontage        YrSold -0.0120939602 6.442745e-01
## 161    YearRemodAdd   BsmtHalfBath -0.0123370321 6.376325e-01
## 209    BsmtHalfBath      HalfBath -0.0123399001 6.375543e-01
## 508       BsmtUnfSF    ScreenPorch -0.0125792734 6.310420e-01
## 380      MSSubClass     WoodDeckSF -0.0125793582 6.310397e-01
## 16             Id      YearBuilt -0.0127127154 6.274240e-01
## 193     LotFrontage      HalfBath -0.0129521028 6.209559e-01
## 554     GarageYrBlt      PoolArea -0.0133168950 6.111556e-01
## 597      MSSubClass        MoSold -0.0135846432 6.040063e-01
## 644       X1stFlrSF        YrSold -0.0136037705 6.034971e-01
## 637      YearBuilt        YrSold -0.0136176800 6.031268e-01
## 119       X1stFlrSF   LowQualFinSF -0.0142406727 5.866501e-01
## 581       FullBath       MiscVal -0.0142898450 5.853585e-01
## 551     KitchenAbvGr      PoolArea -0.0145251160 5.791972e-01
## 643      TotalBsmtSF        YrSold -0.0149686480 5.676652e-01
## 606      BsmtFinSF2        MoSold -0.0152107380 5.614175e-01
## 67             Id     TotalBsmtSF -0.0154145661 5.561832e-01
## 605      BsmtFinSF1        MoSold -0.0157269483 5.482075e-01
## 221      BsmtFinSF2   BedroomAbvGr -0.0157281136 5.481779e-01
## 381     LotFrontage     WoodDeckSF -0.0167797589 5.217503e-01
## 685    BsmtHalfBath     SalePrice -0.0168441543 5.201536e-01
## 4              Id        LotArea -0.0174824669 5.044637e-01
```

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## 362    BsmtFinSF2      GarageArea -0.0182265919 4.864925e-01
## 574    TotalBsmtSF        MiscVal -0.0184789224 4.804779e-01
## 591    OpenPorchSF        MiscVal -0.0185837390 4.779915e-01
## 170      GrLivArea  BsmtHalfBath -0.0189184832 4.700979e-01
## 650       FullBath         YrSold -0.0196688407 4.526681e-01
## 2             Id    LotFrontage -0.0197613200 4.505455e-01
## 277           Id     Fireplaces -0.0197716324 4.503091e-01
## 154           Id  BsmtHalfBath -0.0201547452 4.415786e-01
## 344   BsmtHalfBath    GarageCars -0.0208910590 4.250739e-01
## 575      X1stFlrSF        MiscVal -0.0210957195 4.205511e-01
## 701        MiscVal      SalePrice -0.0211895796 4.184863e-01
## 292   LowQualFinSF    Fireplaces -0.0212721434 4.166751e-01
## 632      MSSubClass        YrSold -0.0214070378 4.137257e-01
## 667           Id      SalePrice -0.0219167194 4.026938e-01
## 22            Id   YearRemodAdd -0.0219976419 4.009586e-01
## 611   LowQualFinSF        MoSold -0.0221739606 3.971934e-01
## 579   BsmtFullBath        MiscVal -0.0230470249 3.788657e-01
## 212      MSSubClass  BedroomAbvGr -0.0234380285 3.708290e-01
## 282     OverallCond    Fireplaces -0.0238199778 3.630812e-01
## 272   BsmtHalfBath   TotRmsAbvGrd -0.0238363413 3.627516e-01
## 573       BsmtUnfSF        MiscVal -0.0238366451 3.627454e-01
## 168       X2ndFlrSF  BsmtHalfBath -0.0238547839 3.623802e-01
## 655     Fireplaces        YrSold -0.0240955650 3.575543e-01
## 480       X2ndFlrSF     X3SsnPorch -0.0243576484 3.523476e-01
## 487   BedroomAbvGr     X3SsnPorch -0.0244777964 3.499768e-01
## 370   BsmtHalfBath     GarageArea -0.0245355796 3.488402e-01
## 488   KitchenAbvGr     X3SsnPorch -0.0246003587 3.475688e-01
## 460     Fireplaces EnclosedPorch -0.0248218685 3.432435e-01
## 425   BsmtHalfBath   OpenPorchSF -0.0253237579 3.335712e-01
## 613   BsmtFullBath        MoSold -0.0253608943 3.328625e-01
## 394   LowQualFinSF     WoodDeckSF -0.0254436480 3.312869e-01
## 682   LowQualFinSF      SalePrice -0.0256061300 3.282073e-01
## 498      MSSubClass   ScreenPorch -0.0260301767 3.202578e-01
## 206   LowQualFinSF       HalfBath -0.0270800493 3.011219e-01
## 634        LotArea        YrSold -0.0271636631 2.996312e-01
## 635     OverallQual        YrSold -0.0273467083 2.963852e-01
## 658      GarageArea        YrSold -0.0273779404 2.958337e-01
## 589      GarageArea        MiscVal -0.0273999144 2.954461e-01
## 156    LotFrontage  BsmtHalfBath -0.0278556578 2.874837e-01
## 7             Id    OverallQual -0.0283647539 2.787617e-01
## 645       X2ndFlrSF        YrSold -0.0286999139 2.731188e-01
## 626   EnclosedPorch        MoSold -0.0288872657 2.699986e-01
## 646   LowQualFinSF        YrSold -0.0289208798 2.694414e-01
```

```
## 703        YrSold      SalePrice -0.0289225852 2.694132e-01
## 570     MasVnrArea        MiscVal -0.0295122487 2.597674e-01
## 379             Id     WoodDeckSF -0.0296431972 2.576582e-01
## 476      BsmtFinSF2      X3SsnPorch -0.0299933980 2.520757e-01
## 110     OverallQual   LowQualFinSF -0.0304292840 2.452458e-01
## 208    BsmtFullBath       HalfBath -0.0309049591 2.379416e-01
## 566     OverallQual        MiscVal -0.0314062105 2.304122e-01
## 528      X3SsnPorch    ScreenPorch -0.0314358470 2.299724e-01
## 587      GarageYrBlt        MiscVal -0.0321216929 2.199604e-01
## 201      BsmtFinSF2       HalfBath -0.0321478375 2.195850e-01
## 412     OverallCond    OpenPorchSF -0.0325888135 2.133227e-01
## 494      WoodDeckSF     X3SsnPorch -0.0327706336 2.107784e-01
## 118      TotalBsmtSF   LowQualFinSF -0.0332453873 2.042388e-01
## 629        PoolArea         MoSold -0.0337366403 1.976284e-01
## 568       YearBuilt        MiscVal -0.0343831387 1.891692e-01
## 654     TotRmsAbvGrd         YrSold -0.0345163543 1.874597e-01
## 540        BsmtUnfSF       PoolArea -0.0350922408 1.802008e-01
## 264      BsmtFinSF2    TotRmsAbvGrd -0.0352265479 1.785383e-01
## 652     BedroomAbvGr         YrSold -0.0360138928 1.690210e-01
## 647        GrLivArea         YrSold -0.0365258196 1.630401e-01
## 496   EnclosedPorch     X3SsnPorch -0.0373052828 1.542417e-01
## 250     BsmtHalfBath   KitchenAbvGr -0.0379443502 1.473008e-01
## 160       YearBuilt   BsmtHalfBath -0.0381618057 1.449943e-01
## 336      BsmtFinSF2      GarageCars -0.0382635129 1.439250e-01
## 240      MasVnrArea   KitchenAbvGr -0.0384501121 1.419789e-01
## 504     YearRemodAdd    ScreenPorch -0.0387400107 1.389957e-01
## 316    LowQualFinSF     GarageYrBlt -0.0390991542 1.353671e-01
## 657       GarageCars         YrSold -0.0391169041 1.351896e-01
## 327       MSSubClass     GarageCars -0.0401097931 1.255479e-01
## 158     OverallQual   BsmtHalfBath -0.0401501577 1.251676e-01
## 218     YearRemodAdd   BedroomAbvGr -0.0405809281 1.211642e-01
## 242      BsmtFinSF2   KitchenAbvGr -0.0407512364 1.196093e-01
## 202       BsmtUnfSF       HalfBath -0.0411175301 1.163181e-01
## 642       BsmtUnfSF         YrSold -0.0412581949 1.150733e-01
## 249    BsmtFullBath   KitchenAbvGr -0.0415025464 1.129357e-01
## 588       GarageCars        MiscVal -0.0430801281 9.987840e-02
## 467       MSSubClass     X3SsnPorch -0.0438245492 9.414954e-02
## 106             Id   LowQualFinSF -0.0442299581 9.114212e-02
## 278       MSSubClass     Fireplaces -0.0455693403 8.175110e-02
## 42       OverallCond     BsmtFinSF1 -0.0462308559 7.741099e-02
## 649     BsmtHalfBath         YrSold -0.0465238818 7.554936e-02
## 466             Id     X3SsnPorch -0.0466347889 7.485435e-02
## 152    LowQualFinSF   BsmtFullBath -0.0471434219 7.173346e-02
```

```
## 203    TotalBsmtSF      HalfBath -0.0488037386 6.227931e-02
## 52        YearBuilt     BsmtFinSF2 -0.0491068312 6.066983e-02
## 453  BsmtFullBath EnclosedPorch -0.0499106491 5.656746e-02
## 55      BsmtFinSF1     BsmtFinSF2 -0.0501174000 5.555041e-02
## 503      YearBuilt    ScreenPorch -0.0503644345 5.435519e-02
## 348  KitchenAbvGr     GarageCars -0.0506338924 5.307601e-02
## 29             Id      MasVnrArea -0.0510714013 5.105260e-02
## 519  KitchenAbvGr    ScreenPorch -0.0516133661 4.863597e-02
## 271  BsmtFullBath  TotRmsAbvGrd -0.0532752361 4.181608e-02
## 13     LotFrontage    OverallCond -0.0534569624 4.112193e-02
## 190  BsmtHalfBath       FullBath -0.0545358120 3.719872e-02
## 142    OverallCond  BsmtFullBath -0.0549415154 3.580810e-02
## 259    OverallCond  TotRmsAbvGrd -0.0575831661 2.779335e-02
## 660    OpenPorchSF         YrSold -0.0576193601 2.769526e-02
## 50     OverallQual     BsmtFinSF2 -0.0591186927 2.388567e-02
## 12      MSSubClass    OverallCond -0.0593158171 2.342025e-02
## 564    LotFrontage        MiscVal -0.0596057301 2.275005e-02
## 664       PoolArea         YrSold -0.0596889317 2.256081e-02
## 322  BedroomAbvGr     GarageYrBlt -0.0605729801 2.063300e-02
## 196    OverallCond       HalfBath -0.0607693268 2.022485e-02
## 113  YearRemodAdd  LowQualFinSF -0.0624191001 1.706456e-02
## 374  KitchenAbvGr     GarageArea -0.0644330472 1.379977e-02
## 115    BsmtFinSF1  LowQualFinSF -0.0645025969 1.369761e-02
## 189  BsmtFullBath       FullBath -0.0645120486 1.368378e-02
## 449       X1stFlrSF EnclosedPorch -0.0652917009 1.258441e-02
## 47      MSSubClass     BsmtFinSF2 -0.0656485792 1.210779e-02
## 367  LowQualFinSF     GarageArea -0.0676014132 9.772126e-03
## 53    YearRemodAdd     BsmtFinSF2 -0.0677585136 9.602936e-03
## 252        HalfBath  KitchenAbvGr -0.0682625489 9.077591e-03
## 114     MasVnrArea  LowQualFinSF -0.0686279799 8.712897e-03
## 244    TotalBsmtSF  KitchenAbvGr -0.0689006426 8.449365e-03
## 38      MSSubClass     BsmtFinSF1 -0.0698357492 7.598820e-03
## 429  KitchenAbvGr    OpenPorchSF -0.0700906099 7.380712e-03
## 522    GarageYrBlt    ScreenPorch -0.0705636275 6.990725e-03
## 217      YearBuilt  BedroomAbvGr -0.0706512169 6.920573e-03
## 54      MasVnrArea     BsmtFinSF2 -0.0713296276 6.398272e-03
## 319  BsmtHalfBath     GarageYrBlt -0.0735219994 4.943847e-03
## 525     WoodDeckSF    ScreenPorch -0.0741813512 4.569021e-03
## 182     BsmtFinSF2       FullBath -0.0764438620 3.470202e-03
## 672    OverallCond      SalePrice -0.0778558940 2.912351e-03
## 126    OverallCond       GrLivArea -0.0796858654 2.311138e-03
## 241     BsmtFinSF1  KitchenAbvGr -0.0810068508 1.950233e-03
## 527 EnclosedPorch    ScreenPorch -0.0828642448 1.529762e-03
```

```
## 311    BsmtFinSF2    GarageYrBlt -0.0841809875 1.284090e-03
## 668    MSSubClass      SalePrice -0.0842841351 1.266472e-03
## 237    OverallCond  KitchenAbvGr -0.0870008554 8.754658e-04
## 401   KitchenAbvGr    WoodDeckSF -0.0901302727 5.648741e-04
## 15     OverallQual   OverallCond -0.0919323426 4.361720e-04
## 465    OpenPorchSF  EnclosedPorch -0.0930793175 3.691033e-04
## 341    LowQualFinSF    GarageCars -0.0944795202 3.002847e-04
## 456       HalfBath EnclosedPorch -0.0953165257 2.650863e-04
## 448    TotalBsmtSF EnclosedPorch -0.0954777367 2.587670e-04
## 165      BsmtUnfSF  BsmtHalfBath -0.0958042882 2.463966e-04
## 353    MSSubClass      GarageArea -0.0986715432 1.592242e-04
## 102    BsmtFinSF2       X2ndFlrSF -0.0992603160 1.453587e-04
## 445    BsmtFinSF1  EnclosedPorch -0.1023033055 9.005496e-05
## 220    BsmtFinSF1   BedroomAbvGr -0.1073546768 3.949968e-05
## 444     MasVnrArea EnclosedPorch -0.1099067973 2.568539e-05
## 440    OverallQual EnclosedPorch -0.1139368586 1.276996e-05
## 455       FullBath EnclosedPorch -0.1150929635 1.040475e-05
## 323   KitchenAbvGr    GarageYrBlt -0.1178342163 6.352091e-06
## 204      X1stFlrSF       HalfBath -0.1199159088 4.334881e-06
## 463     GarageArea EnclosedPorch -0.1217767196 3.064133e-06
## 299   KitchenAbvGr     Fireplaces -0.1239362353 2.035535e-06
## 34     OverallCond     MasVnrArea -0.1256936336 1.451849e-06
## 464     WoodDeckSF EnclosedPorch -0.1259888880 1.371105e-06
## 697  EnclosedPorch      SalePrice -0.1285779579 8.255770e-07
## 689   KitchenAbvGr      SalePrice -0.1359073708 1.860426e-07
## 61     OverallCond      BsmtUnfSF -0.1368405699 1.530090e-07
## 101    BsmtFinSF1       X2ndFlrSF -0.1370789861 1.455247e-07
## 57     MSSubClass      BsmtUnfSF -0.1407594808 6.637589e-08
## 84     OverallCond      X1stFlrSF -0.1442027840 3.126348e-08
## 666        MoSold         YrSold -0.1457214127 2.230274e-08
## 171   BsmtFullBath  BsmtHalfBath -0.1478709605 1.374507e-08
## 239    YearRemodAdd KitchenAbvGr -0.1495975210 9.270323e-09
## 228   BsmtFullBath  BedroomAbvGr -0.1506728092 7.237186e-09
## 462     GarageCars EnclosedPorch -0.1514341600 6.067010e-09
## 357    OverallCond     GarageArea -0.1515213706 5.945338e-09
## 151      X2ndFlrSF  BsmtFullBath -0.1694939517 7.124079e-11
## 72     OverallCond    TotalBsmtSF -0.1710975146 4.685274e-11
## 104    TotalBsmtSF      X2ndFlrSF -0.1745119501 1.894085e-11
## 238      YearBuilt KitchenAbvGr -0.1748002456 1.753175e-11
## 112      YearBuilt   LowQualFinSF -0.1837843444 1.475930e-12
## 236    OverallQual KitchenAbvGr -0.1838822345 1.435740e-12
## 331    OverallCond     GarageCars -0.1857575106 8.424372e-13
## 443    YearRemodAdd EnclosedPorch -0.1939191471 7.771561e-14
```

```
## 177    OverallCond      FullBath -0.1941494887 7.238654e-14
## 105     X1stFlrSF      X2ndFlrSF -0.2026461810 5.329071e-15
## 66      BsmtFinSF2      BsmtUnfSF -0.2092944924 6.661338e-16
## 3        MSSubClass    LotFrontage -0.2150228858 0.000000e+00
## 68       MSSubClass    TotalBsmtSF -0.2385184093 0.000000e+00
## 80       MSSubClass       X1stFlrSF -0.2517583519 0.000000e+00
## 461     GarageYrBlt EnclosedPorch -0.2894607700 0.000000e+00
## 306     OverallCond   GarageYrBlt -0.3047730489 0.000000e+00
## 21      OverallCond      YearBuilt -0.3759831956 0.000000e+00
## 442        YearBuilt EnclosedPorch -0.3872677829 0.000000e+00
## 148       BsmtUnfSF  BsmtFullBath -0.4229004774 0.000000e+00
## 5        MSSubClass        LotArea -0.4626677157 0.000000e+00
## 65       BsmtFinSF1      BsmtUnfSF -0.4952514693 0.000000e+00
##
##
## Call:
## lm(formula = log(SalePrice) ~ (BsmtUnfSF) + CentralAir + HalfBath +
##     KitchenQual + Neighborhood + OverallCond + OverallQual +
##     RoofMatl + `1stFlrSF` + `2ndFlrSF` + YearBuilt + MSZoning:Neighborhood +
##     OverallQual:Neighborhood + YearBuilt:Neighborhood, data = train2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.10903 -0.05710  0.00340  0.06988  0.54783
##
## Coefficients: (86 not defined because of singularities)
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 9.113e+01  5.951e+01   1.531 0.125913
## BsmtUnfSF                  -7.036e-05  9.483e-06  -7.420 2.06e-13 ***
## CentralAirY                 1.133e-01  1.747e-02   6.485 1.24e-10 ***
## HalfBath                    2.557e-02  1.005e-02   2.543 0.011104 *
## KitchenQualFa              -1.283e-01  3.151e-02  -4.071 4.95e-05 ***
## KitchenQualGd              -4.918e-02  1.848e-02  -2.661 0.007883 **
## KitchenQualTA              -7.753e-02  2.058e-02  -3.767 0.000172 ***
## NeighborhoodBlueste        -1.145e+00  7.682e-01  -1.491 0.136311
## NeighborhoodBrDale         -1.013e+02  9.325e+01  -1.087 0.277415
## NeighborhoodBrkSide        -8.696e+01  5.959e+01  -1.459 0.144700
## NeighborhoodClearCr        -8.553e+01  5.956e+01  -1.436 0.151264
## NeighborhoodCollgCr        -9.405e+01  5.961e+01  -1.578 0.114875
## NeighborhoodCrawfor        -8.480e+01  5.954e+01  -1.424 0.154607
## NeighborhoodEdwards        -8.983e+01  5.951e+01  -1.509 0.131447
## NeighborhoodGilbert        -8.989e+01  5.961e+01  -1.508 0.131774
## NeighborhoodIDOTRR         -8.423e+01  5.959e+01  -1.414 0.157732
## NeighborhoodMeadowV        -1.338e+02  6.699e+01  -1.997 0.046046 *
```

```
## NeighborhoodMitchel              -8.464e+01  5.959e+01  -1.420 0.155747
## NeighborhoodNAmes                -8.952e+01  5.955e+01  -1.503 0.132966
## NeighborhoodNoRidge              -1.078e+02  6.166e+01  -1.748 0.080609 .
## NeighborhoodNPkVill              -7.003e+01  9.521e+01  -0.736 0.462130
## NeighborhoodNridgHt              -1.373e+02  6.200e+01  -2.215 0.026952 *
## NeighborhoodNWAmes               -9.219e+01  5.970e+01  -1.544 0.122798
## NeighborhoodOldTown              -8.697e+01  5.952e+01  -1.461 0.144172
## NeighborhoodSawyer               -8.858e+01  5.954e+01  -1.488 0.137081
## NeighborhoodSawyerW              -8.983e+01  5.964e+01  -1.506 0.132248
## NeighborhoodSomerst              -1.088e+02  6.031e+01  -1.804 0.071379 .
## NeighborhoodStoneBr              -1.169e+02  5.985e+01  -1.953 0.050984 .
## NeighborhoodSWISU                -8.570e+01  5.982e+01  -1.433 0.152192
## NeighborhoodTimber               -8.856e+01  5.963e+01  -1.485 0.137747
## NeighborhoodVeenker              -9.277e+01  6.086e+01  -1.524 0.127669
## OverallCond                       4.899e-02  4.049e-03  12.098  < 2e-16 ***
## OverallQual                       9.050e-02  9.185e-02   0.985 0.324637
## RoofMatlCompShg                   1.820e+00  1.518e-01  11.989  < 2e-16 ***
## RoofMatlMembran                   1.908e+00  2.070e-01   9.217  < 2e-16 ***
## RoofMatlMetal                     1.959e+00  2.039e-01   9.606  < 2e-16 ***
## RoofMatlRoll                      1.799e+00  2.021e-01   8.903  < 2e-16 ***
## RoofMatlTar&Grv                   1.817e+00  1.562e-01  11.627  < 2e-16 ***
## RoofMatlWdShake                   1.684e+00  1.635e-01  10.296  < 2e-16 ***
## RoofMatlWdShngl                   1.978e+00  1.620e-01  12.213  < 2e-16 ***
## `1stFlrSF`                        4.397e-04  1.490e-05  29.503  < 2e-16 ***
## `2ndFlrSF`                        2.534e-04  1.301e-05  19.479  < 2e-16 ***
## YearBuilt                        -4.108e-02  2.957e-02  -1.389 0.164955
## NeighborhoodBlmngtn:MSZoningFV          NA         NA      NA       NA
## NeighborhoodBlueste:MSZoningFV          NA         NA      NA       NA
## NeighborhoodBrDale:MSZoningFV           NA         NA      NA       NA
## NeighborhoodBrkSide:MSZoningFV          NA         NA      NA       NA
## NeighborhoodClearCr:MSZoningFV          NA         NA      NA       NA
## NeighborhoodCollgCr:MSZoningFV          NA         NA      NA       NA
## NeighborhoodCrawfor:MSZoningFV          NA         NA      NA       NA
## NeighborhoodEdwards:MSZoningFV          NA         NA      NA       NA
## NeighborhoodGilbert:MSZoningFV          NA         NA      NA       NA
## NeighborhoodIDOTRR:MSZoningFV           NA         NA      NA       NA
## NeighborhoodMeadowV:MSZoningFV          NA         NA      NA       NA
## NeighborhoodMitchel:MSZoningFV          NA         NA      NA       NA
## NeighborhoodNAmes:MSZoningFV            NA         NA      NA       NA
## NeighborhoodNoRidge:MSZoningFV          NA         NA      NA       NA
## NeighborhoodNPkVill:MSZoningFV          NA         NA      NA       NA
## NeighborhoodNridgHt:MSZoningFV          NA         NA      NA       NA
## NeighborhoodNWAmes:MSZoningFV           NA         NA      NA       NA
```

```
## NeighborhoodOldTown:MSZoningFV              NA         NA      NA        NA
## NeighborhoodSawyer:MSZoningFV               NA         NA      NA        NA
## NeighborhoodSawyerW:MSZoningFV              NA         NA      NA        NA
## NeighborhoodSomerst:MSZoningFV       -4.127e-02  3.617e-02  -1.141 0.254136
## NeighborhoodStoneBr:MSZoningFV              NA         NA      NA        NA
## NeighborhoodSWISU:MSZoningFV                NA         NA      NA        NA
## NeighborhoodTimber:MSZoningFV               NA         NA      NA        NA
## NeighborhoodVeenker:MSZoningFV              NA         NA      NA        NA
## NeighborhoodBlmngtn:MSZoningRH              NA         NA      NA        NA
## NeighborhoodBlueste:MSZoningRH              NA         NA      NA        NA
## NeighborhoodBrDale:MSZoningRH               NA         NA      NA        NA
## NeighborhoodBrkSide:MSZoningRH              NA         NA      NA        NA
## NeighborhoodClearCr:MSZoningRH              NA         NA      NA        NA
## NeighborhoodCollgCr:MSZoningRH              NA         NA      NA        NA
## NeighborhoodCrawfor:MSZoningRH       -2.891e-01  1.471e-01  -1.965 0.049566 *
## NeighborhoodEdwards:MSZoningRH       -1.153e-02  1.124e-01  -0.103 0.918275
## NeighborhoodGilbert:MSZoningRH              NA         NA      NA        NA
## NeighborhoodIDOTRR:MSZoningRH               NA         NA      NA        NA
## NeighborhoodMeadowV:MSZoningRH              NA         NA      NA        NA
## NeighborhoodMitchel:MSZoningRH              NA         NA      NA        NA
## NeighborhoodNAmes:MSZoningRH          1.311e-02  1.038e-01   0.126 0.899575
## NeighborhoodNoRidge:MSZoningRH              NA         NA      NA        NA
## NeighborhoodNPkVill:MSZoningRH              NA         NA      NA        NA
## NeighborhoodNridgHt:MSZoningRH              NA         NA      NA        NA
## NeighborhoodNWAmes:MSZoningRH               NA         NA      NA        NA
## NeighborhoodOldTown:MSZoningRH              NA         NA      NA        NA
## NeighborhoodSawyer:MSZoningRH               NA         NA      NA        NA
## NeighborhoodSawyerW:MSZoningRH       -3.157e-02  9.308e-02  -0.339 0.734508
## NeighborhoodSomerst:MSZoningRH              NA         NA      NA        NA
## NeighborhoodStoneBr:MSZoningRH              NA         NA      NA        NA
## NeighborhoodSWISU:MSZoningRH          8.997e-02  6.990e-02   1.287 0.198222
## NeighborhoodTimber:MSZoningRH               NA         NA      NA        NA
## NeighborhoodVeenker:MSZoningRH              NA         NA      NA        NA
## NeighborhoodBlmngtn:MSZoningRL        8.619e-02  1.439e-01   0.599 0.549170
## NeighborhoodBlueste:MSZoningRL              NA         NA      NA        NA
## NeighborhoodBrDale:MSZoningRL               NA         NA      NA        NA
## NeighborhoodBrkSide:MSZoningRL        1.002e-01  3.500e-02   2.862 0.004277 **
## NeighborhoodClearCr:MSZoningRL              NA         NA      NA        NA
## NeighborhoodCollgCr:MSZoningRL        8.415e-02  4.763e-02   1.767 0.077493 .
## NeighborhoodCrawfor:MSZoningRL       -1.794e-01  1.163e-01  -1.543 0.123078
## NeighborhoodEdwards:MSZoningRL        9.354e-02  5.700e-02   1.641 0.100993
## NeighborhoodGilbert:MSZoningRL              NA         NA      NA        NA
## NeighborhoodIDOTRR:MSZoningRL               NA         NA      NA        NA
```

```
## NeighborhoodMeadowV:MSZoningRL           NA         NA     NA       NA
## NeighborhoodMitchel:MSZoningRL   -3.520e-02  6.755e-02  -0.521 0.602408
## NeighborhoodNAmes:MSZoningRL             NA         NA     NA       NA
## NeighborhoodNoRidge:MSZoningRL           NA         NA     NA       NA
## NeighborhoodNPkVill:MSZoningRL           NA         NA     NA       NA
## NeighborhoodNridgHt:MSZoningRL    6.540e-03  1.343e-01   0.049 0.961163
## NeighborhoodNWAmes:MSZoningRL            NA         NA     NA       NA
## NeighborhoodOldTown:MSZoningRL    1.310e-01  1.374e-01   0.953 0.340596
## NeighborhoodSawyer:MSZoningRL     3.789e-01  9.603e-02   3.945 8.38e-05 ***
## NeighborhoodSawyerW:MSZoningRL           NA         NA     NA       NA
## NeighborhoodSomerst:MSZoningRL           NA         NA     NA       NA
## NeighborhoodStoneBr:MSZoningRL           NA         NA     NA       NA
## NeighborhoodSWISU:MSZoningRL             NA         NA     NA       NA
## NeighborhoodTimber:MSZoningRL            NA         NA     NA       NA
## NeighborhoodVeenker:MSZoningRL           NA         NA     NA       NA
## NeighborhoodBlmngtn:MSZoningRM           NA         NA     NA       NA
## NeighborhoodBlueste:MSZoningRM           NA         NA     NA       NA
## NeighborhoodBrDale:MSZoningRM            NA         NA     NA       NA
## NeighborhoodBrkSide:MSZoningRM           NA         NA     NA       NA
## NeighborhoodClearCr:MSZoningRM           NA         NA     NA       NA
## NeighborhoodCollgCr:MSZoningRM           NA         NA     NA       NA
## NeighborhoodCrawfor:MSZoningRM           NA         NA     NA       NA
## NeighborhoodEdwards:MSZoningRM           NA         NA     NA       NA
## NeighborhoodGilbert:MSZoningRM           NA         NA     NA       NA
## NeighborhoodIDOTRR:MSZoningRM     3.285e-01  6.078e-02   5.404 7.67e-08 ***
## NeighborhoodMeadowV:MSZoningRM           NA         NA     NA       NA
## NeighborhoodMitchel:MSZoningRM           NA         NA     NA       NA
## NeighborhoodNAmes:MSZoningRM             NA         NA     NA       NA
## NeighborhoodNoRidge:MSZoningRM           NA         NA     NA       NA
## NeighborhoodNPkVill:MSZoningRM           NA         NA     NA       NA
## NeighborhoodNridgHt:MSZoningRM           NA         NA     NA       NA
## NeighborhoodNWAmes:MSZoningRM            NA         NA     NA       NA
## NeighborhoodOldTown:MSZoningRM    9.159e-02  1.334e-01   0.687 0.492482
## NeighborhoodSawyer:MSZoningRM            NA         NA     NA       NA
## NeighborhoodSawyerW:MSZoningRM           NA         NA     NA       NA
## NeighborhoodSomerst:MSZoningRM           NA         NA     NA       NA
## NeighborhoodStoneBr:MSZoningRM           NA         NA     NA       NA
## NeighborhoodSWISU:MSZoningRM             NA         NA     NA       NA
## NeighborhoodTimber:MSZoningRM            NA         NA     NA       NA
## NeighborhoodVeenker:MSZoningRM           NA         NA     NA       NA
## NeighborhoodBlueste:OverallQual          NA         NA     NA       NA
## NeighborhoodBrDale:OverallQual   -1.765e-01  1.209e-01  -1.460 0.144598
## NeighborhoodBrkSide:OverallQual   5.238e-02  9.339e-02   0.561 0.574959
```

```
## NeighborhoodClearCr:OverallQual  2.198e-02  9.624e-02   0.228 0.819374
## NeighborhoodCollgCr:OverallQual -2.246e-02  9.310e-02  -0.241 0.809390
## NeighborhoodCrawfor:OverallQual -2.219e-02  9.423e-02  -0.236 0.813823
## NeighborhoodEdwards:OverallQual -8.933e-02  9.267e-02  -0.964 0.335226
## NeighborhoodGilbert:OverallQual -5.617e-02  9.435e-02  -0.595 0.551694
## NeighborhoodIDOTRR:OverallQual  -5.006e-02  9.477e-02  -0.528 0.597419
## NeighborhoodMeadowV:OverallQual -4.351e-02  1.134e-01  -0.384 0.701160
## NeighborhoodMitchel:OverallQual  8.362e-03  9.529e-02   0.088 0.930080
## NeighborhoodNAmes:OverallQual   -3.913e-02  9.257e-02  -0.423 0.672591
## NeighborhoodNoRidge:OverallQual -3.349e-02  9.536e-02  -0.351 0.725461
## NeighborhoodNPkVill:OverallQual        NA        NA      NA       NA
## NeighborhoodNridgHt:OverallQual  9.661e-03  9.293e-02   0.104 0.917221
## NeighborhoodNWAmes:OverallQual  -7.376e-02  9.485e-02  -0.778 0.436917
## NeighborhoodOldTown:OverallQual -1.110e-02  9.244e-02  -0.120 0.904433
## NeighborhoodSawyer:OverallQual  -3.677e-02  9.677e-02  -0.380 0.704025
## NeighborhoodSawyerW:OverallQual  2.947e-02  9.448e-02   0.312 0.755118
## NeighborhoodSomerst:OverallQual -7.485e-03  9.362e-02  -0.080 0.936292
## NeighborhoodStoneBr:OverallQual -1.822e-02  1.024e-01  -0.178 0.858829
## NeighborhoodSWISU:OverallQual   -4.943e-02  9.543e-02  -0.518 0.604545
## NeighborhoodTimber:OverallQual   3.304e-03  9.541e-02   0.035 0.972377
## NeighborhoodVeenker:OverallQual  1.644e-02  1.012e-01   0.162 0.871007
## NeighborhoodBlueste:YearBuilt          NA        NA      NA       NA
## NeighborhoodBrDale:YearBuilt     5.108e-02  4.699e-02   1.087 0.277191
## NeighborhoodBrkSide:YearBuilt    4.324e-02  2.961e-02   1.460 0.144418
## NeighborhoodClearCr:YearBuilt    4.268e-02  2.960e-02   1.442 0.149531
## NeighborhoodCollgCr:YearBuilt    4.701e-02  2.962e-02   1.587 0.112692
## NeighborhoodCrawfor:YearBuilt    4.251e-02  2.958e-02   1.437 0.150946
## NeighborhoodEdwards:YearBuilt    4.502e-02  2.957e-02   1.523 0.128094
## NeighborhoodGilbert:YearBuilt    4.509e-02  2.962e-02   1.522 0.128202
## NeighborhoodIDOTRR:YearBuilt     4.192e-02  2.961e-02   1.416 0.157054
## NeighborhoodMeadowV:YearBuilt    6.711e-02  3.347e-02   2.005 0.045127 *
## NeighborhoodMitchel:YearBuilt    4.223e-02  2.961e-02   1.426 0.154071
## NeighborhoodNAmes:YearBuilt      4.481e-02  2.959e-02   1.515 0.130100
## NeighborhoodNoRidge:YearBuilt    5.404e-02  3.066e-02   1.762 0.078224 .
## NeighborhoodNPkVill:YearBuilt    3.482e-02  4.790e-02   0.727 0.467477
## NeighborhoodNridgHt:YearBuilt    6.854e-02  3.082e-02   2.224 0.026319 *
## NeighborhoodNWAmes:YearBuilt     4.627e-02  2.967e-02   1.560 0.119071
## NeighborhoodOldTown:YearBuilt    4.335e-02  2.957e-02   1.466 0.142934
## NeighborhoodSawyer:YearBuilt     4.413e-02  2.958e-02   1.491 0.136067
## NeighborhoodSawyerW:YearBuilt    4.475e-02  2.963e-02   1.510 0.131263
## NeighborhoodSomerst:YearBuilt    5.440e-02  2.997e-02   1.815 0.069724 .
## NeighborhoodStoneBr:YearBuilt    5.855e-02  2.975e-02   1.968 0.049294 *
## NeighborhoodSWISU:YearBuilt      4.288e-02  2.974e-02   1.442 0.149534
```

```
## NeighborhoodTimber:YearBuilt      4.425e-02  2.963e-02    1.493 0.135647
## NeighborhoodVeenker:YearBuilt      4.633e-02  3.028e-02    1.530 0.126250
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1315 on 1355 degrees of freedom
## Multiple R-squared:  0.8993, Adjusted R-squared:  0.8916
## F-statistic: 116.4 on 104 and 1355 DF,  p-value: < 2.2e-16
```

4.3 Model Assumption Assessment

Address each assumption

4.4 Comparing Competing Models

- Adj R^2 The final adjusted R^2 of our model is 0.8916

- CV Press Our cross-validated PRESS statistic output is below.

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
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```

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## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading
```

```
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient
## fit may be misleading

## Linear Regression
##
## 1460 samples
##   12 predictor
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 1313, 1314, 1315, 1314, 1315, 1313, ...
## Resampling results:
##
##   RMSE      Rsquared   MAE
##   0.171943  0.8187467  0.1030658
##
## Tuning parameter 'intercept' was held constant at a value of TRUE
```

- Kaggle score

4.5 Conclusion

A short summary of the analysis

5 Appendix

5.1 Checking for Linearity in `SalePrice` vs `GrLivArea`

The scatter plot in Figure 2 shows relationship of `SalePrice` vs `GrLivArea` for all three neighborhoods of interest to Century 21. Based on this plot, it does not appear that this relationship meets the assumptions of linear regression, specifically the constant varaince assumption. The response will be transformed to attempt to handle the changing variance.

The images below show the scatter plots of log sale price vs living room area (Figure 3). In the image on the right, the scatter plot is shown for each neighborhood. In the image on the left the observations for all three neighborhoods are included. In all cases, a linear model appears to be reasonable to model this data.

5.2 Analysis of Influential points

The two outlying observations with living room areas greater than 4000 sq. ft. appear to be from a different distribution than the main dataset. Since these are partial sales, it is possible that the sale prices do not reflect market value. For this reason, we will limit the analysis to properies with less than 3500 sq. ft. 4

Figure 2: Scatter Plot of Sale Price vs Living Room Area

Figure 3: Scatter Plots of Log of Sale Price vs Living Room Area
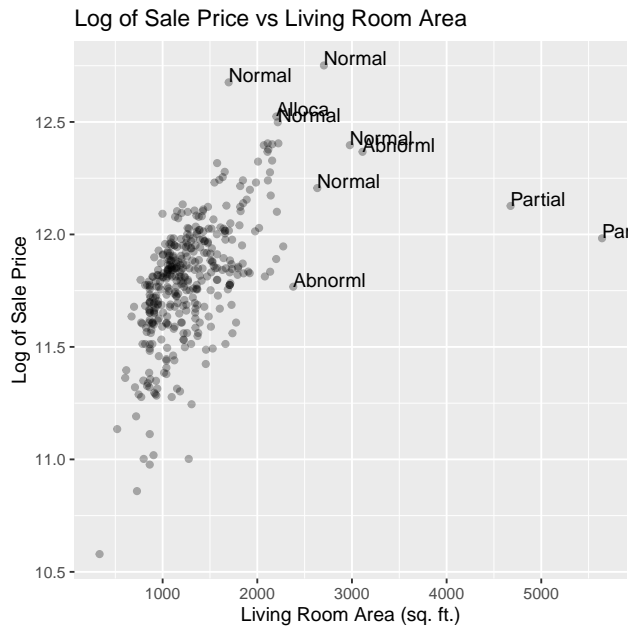
Figure 4: Influential Points

5.3 R Code For Analysis 1

```r
### Compuational Setup
# libraries
library(knitr)
library(kableExtra)
library(tidyverse)
library(olsrr)
library(gridExtra)
library(caret)
library(multcomp)


# load data
train <- read_csv('./data/train.csv')
test <- read_csv('./data/test.csv')


# set a random seed for repodicibility
set.seed(123)


### Helper Code


#' Print Typical Regression Fit Plots
#'
#' @description
#' Plots QQ plot of residuals, histogram of residuals,
```

```r
#' residuals vs predicted values, and studentized
#' residuals vs predicted values. Depends on tidyverse
#' and gridExtra packages being loaded.
#'
#' @param data The true values corresponding to the input.
#' @param model The predicted/fitted values of the model.
basic.fit.plots <- function(data, model) {

    # depends on
    require(tidyverse)
    require(gridExtra)

    # get predicted values
    data$Predicted <- predict(model, data)
    # get residuals
    data$Resid <- model$residuals
    # get studentized residuals
    data$RStudent <- rstudent(model = model)

    # create qqplot of residuals with reference line
    qqplot.resid <- data %>%
      ggplot(aes(sample = Resid)) +
      geom_qq() + geom_qq_line() +
      labs(subtitle = 'QQ Plot of Residuals',
           x = 'Theoretical Quantile',
           y = 'Acutal Quantile')

    # create histogram of residuals
    hist.resid <- data %>%
      ggplot(aes(x = Resid)) +
      geom_histogram(bins = 15) +
      labs(subtitle = 'Histogram of Residuals',
           x = 'Residuals',
           y = 'Count')

    # create scatter plot of residuals vs predicted values
    resid.vs.pred <- data %>%
      ggplot(aes(x = Predicted, y = Resid)) +
      geom_point() +
      geom_abline(slope = 0) +
      labs(subtitle = 'Residuals vs Prediction',
           x = 'Predicted Value',
           y = 'Residual')
```

```r
    # create scatter plot of studentized
    # residuals vs predicted values
    rStud.vs.pred <- data %>%
      ggplot(aes(x = Predicted, y = RStudent)) +
      geom_point() +
      geom_abline(slope = 0) +
      geom_abline(slope = 0, intercept = -2) +
      geom_abline(slope = 0, intercept = 2) +
      labs(subtitle = 'RStudent vs Prediction',
           x = 'Predicted Value',
           y = 'RStudent')


    # add all four plots to grid as
    # qqplot          histogram
    # resid vs pred    RStud vs pred
    grid.arrange(qqplot.resid,
             hist.resid,
             resid.vs.pred,
             rStud.vs.pred,
             nrow = 2,
             top = 'Fit Assessment Plots')
}


#' Creates dummy variables (columns) for given column
#'
#' @param data A dataframe.
#' @param column A categorical column in data.
#' @param reference A value in the column to use a reference.
#' @param as.onehot Set to TRUE to use onehot encoding.
#'
get.dummies <- function(data, column, reference, as.onehot = FALSE) {
  # get the levels of the factor in column
  lev <- levels(data[[column]])
  # do not remove reference for onehot encoding
  if (!as.onehot) {
    # remove the reference value
    lev <- lev[lev != reference]
  }
  # add encodings
  for (fct in lev){
    new_col <- paste(column, fct, sep = '_')
    data[new_col] <- as.numeric(data[, column] == fct)
```

```r
    print(new_col)
  }
  data
}


#' Calculates PRESS from `caret` CV model
#'
#' @param model.cv Calculates press from a model
#' produced by `caret`
#'
PRESS.cv <- function(model.cv) {
  meanN <- 0
  folds <- model.cv$control$index
  for (i in seq(1:length(folds))){
    meanN <- meanN + length(folds[[i]])
  }
  meanN <- meanN / length(folds)
  meanN * ((model.cv$results$RMSE)^2)
}


### plots of log of sale price ~ living room area

# create scatter plot for northwest ames
regplot.names <- train %>% filter(Neighborhood == 'NAmes') %>%
  ggplot(aes(x = (GrLivArea), y = log(SalePrice))) +
  geom_point(alpha = 0.3) +
  ylim(10, 13) +
  xlim(0, 3500) +
  labs(subtitle = 'Northwest Ames',
       y = 'Log of Sale Price', x = 'Living Room Area (sq. ft.)')

# create scatter plot for edwards
regplot.ed <- train %>%
  filter(GrLivArea < 4000) %>%
  filter(Neighborhood == 'Edwards') %>%
  ggplot(aes(x = (GrLivArea), y = log(SalePrice))) +
  geom_point(alpha = 0.3) +
  ylim(10, 13) +
  xlim(0, 3500) +
  labs(subtitle = 'Edwards',
       y = 'Log of Sale Price', x = 'Living Room Area (sq. ft.)')

# create regression plot for brookside
```

```r
regplot.brk <- train %>% filter(Neighborhood == 'BrkSide') %>%
  ggplot(aes(x = (GrLivArea), y = log(SalePrice))) +
  geom_point(alpha = 0.3) +
  ylim(10, 13) +
  xlim(0, 3500) +
  labs(subtitle = 'Brook Side',
       y = 'Log of Sale Price', x = 'Living Room Area (sq. ft.)')

# add the scatter plots for the neighborhood into a single plot
grid.arrange(regplot.names,regplot.ed,regplot.brk, nrow = 2,
             top = 'Regression Plots for Neighborhoods')

# scatter plot of observations from all three neighborhoods
train %>%
  filter(GrLivArea < 4000) %>%
  ggplot(aes(x = (GrLivArea), y = log(SalePrice))) +
  geom_point(alpha = 0.3) +
  labs(title = 'Log of Sale Price vs Living Room Area',
       y = 'Log of Sale Price', x = 'Living Room Area (sq. ft.)')

### Filter data for analysis 1

train <- train %>%
  filter(Neighborhood %in% c("Edwards", "BrkSide", "NAmes"))
train$Neighborhood <- as.factor(train$Neighborhood)

# create dummy variables with Neighborhood == 'Edwards' as reference
train <- get.dummies(train, "Neighborhood", reference = 'Edwards')

# remove suspect points from training data
train.mod <- train %>% filter(GrLivArea < 4000)

#### Extra Sum of Squares

# full model formula
model.formula = log(SalePrice) ~ (GrLivArea) +
    Neighborhood_BrkSide +
    Neighborhood_NAmes +
    (GrLivArea) * Neighborhood_BrkSide +
    (GrLivArea) * Neighborhood_NAmes
# reduced model formula
model.reduced.formula = log(SalePrice) ~ (GrLivArea) +
    Neighborhood_BrkSide +
```

```r
    Neighborhood_NAmes

# fit models
model <- lm(formula = model.formula, data = train.mod)
model.reduced <- lm(formula = model.reduced.formula, data = train.mod)
# ESS test on models
anova(model.reduced, model)


### Assessment plots

# create plots of residuals
basic.fit.plots(train.mod, model)
# create leverage / outlier plot
ols_plot_resid_lev(model)


### cross validation

## cross validate the full model

# Set up repeated k-fold cross-validation
train.control <- trainControl(method = "cv", number = 10)
# Train the model
model.cv <- train(model.formula,
                  data = train.mod,
                  method = 'lm',
                  trControl = train.control)
# print model summary
model.cv

# get the CV results
res <- model.cv$results

# get cross-validated PRESS statistic
PCV <- PRESS.cv(model.cv)

## cross validate the reduced model

# Set up repeated k-fold cross-validation
train.control <- trainControl(method = "cv", number = 10)
# Train the model
model.reduced.cv <- train(model.reduced.formula,
                  data = train.mod,
                  method = 'lm',
```

```r
                                 trControl = train.control)
# print model summary
model.reduced.cv


# get the CV results
res.red <- model.reduced.cv$results


# get cross-validated PRESS statistic
PCV.red <- PRESS.cv(model.reduced.cv)


# print accuracy metrics to md table
kable(data.frame('Model' = c('Full Model', 'Reduced Model'),
                  'RMSE'=c(res$RMSE, res.red$RMSE),
                  'CV Press'=c(PCV, PCV.red),
                  'Adjused R Squared'=c(res$Rsquared, res.red$Rsquared)),
      "latex", booktabs = T) %>%
  kable_styling(position = "center")


### get the parameters from the CV'ed model


# extract the model estimates from the model summary
sm <- summary(model)
sm.coe <- sm$coefficients
# get the CIs for the coefficients
model.conf <- confint(model)


# print model estimates to md / latex table
# extract the params and put into a dataframe
kable(data.frame('Parameter' = c('Intercept', 'GrLivArea',
                                 'Neighborhood_BrkSide', 'Neighborhood_NAmes',
                                 'GrLivArea:Neighborhood_BrkSide',
                                 'GrLivArea:Neighborhood_NAmes '),
                 'Estimate'=c(sm.coe[[1]],sm.coe[[2]],sm.coe[[3]],
                              sm.coe[[4]],sm.coe[[5]],sm.coe[[6]]),
                 'CI Lower' = c(model.conf[[1]],model.conf[[2]],model.conf[[3]],
                                model.conf[[4]],model.conf[[5]],model.conf[[6]]),
                 'CI Upper' = c(model.conf[[1,2]],model.conf[[1,2]],model.conf[[3,2]],
                                model.conf[[4,2]],model.conf[[5,2]],model.conf[[6,2]])),
      "latex", booktabs = T) %>%
  kable_styling(position = "center")


# summary of model to get overall test
summary(lm(model.formula, data = train.mod))
```

```r
## Calculate CIs of slopes not in standard table

# get CI for Northwest Ames
confint(glht(model, linfct = "GrLivArea + GrLivArea:Neighborhood_NAmes = 1"))

# get CI for Brookside
confint(glht(model, linfct = "GrLivArea + GrLivArea:Neighborhood_BrkSide = 1"))
```

5.4   R Code For Analysis 2

Include "well commented" `code` in the appendex!

```r
train %>% ggplot(aes(x = (GrLivArea), y = log(SalePrice))) +
  geom_point(alpha = 0.3) +
  labs(title = 'Log of Sale Price vs Living Room Area',
       y = 'Log of Sale Price', x = 'Living Room Area') +
  geom_text(aes(label = ifelse((log(GrLivArea) > 7.75 & log(SalePrice) > 11) |
                                  (log(SalePrice) > 12.45),
                               SaleCondition, '')), hjust=0, vjust=0)
```

References

[1] Cock, D. D. (2011). Ames, iowa: Alternative to the boston housing data as an end of semester regression project. *Journal of Statistics Education*, 19(3).

[2] Kaggle (2016). Ames housing dataset. Data retrieved from the Kaggle website, https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data.