Predicting Housing Prices with Machine Learning

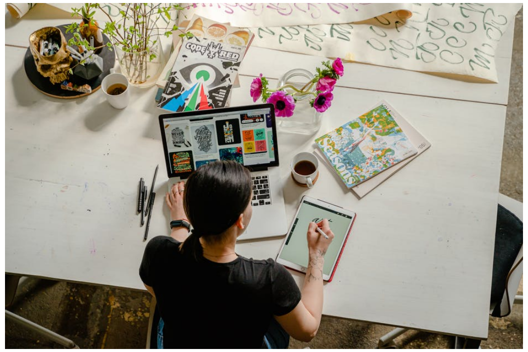
JOHN KOSMICKE, CHERIE WANG, TYLER KIM

Introduction

1. Buying a home is likely the largest and most important purchase a typical American would make in their life. Using data science and machine learning techniques, we will make predictions of home prices in Ames, Iowa according to several different methodologies.
2. Specifically, we consider a couple different linear methods and tree-based methods, and evaluate and adjust them based on the particulars of each methodology.
    - We do L1-regularization of the standard multiple linear regression (LASSO), with the intention of preventing model overfitting.
    - We also add a term structure adjustment to a standard Random Forest again hoping to improve the model accuracy.
    - We also compare accuracy and feature importance of a Gradient Boost tree model with a standard Random Forest
3. In addition, we also look use some neighborhood distance-based aggregation methods to get a sense of the demographic history of Ames housing development.

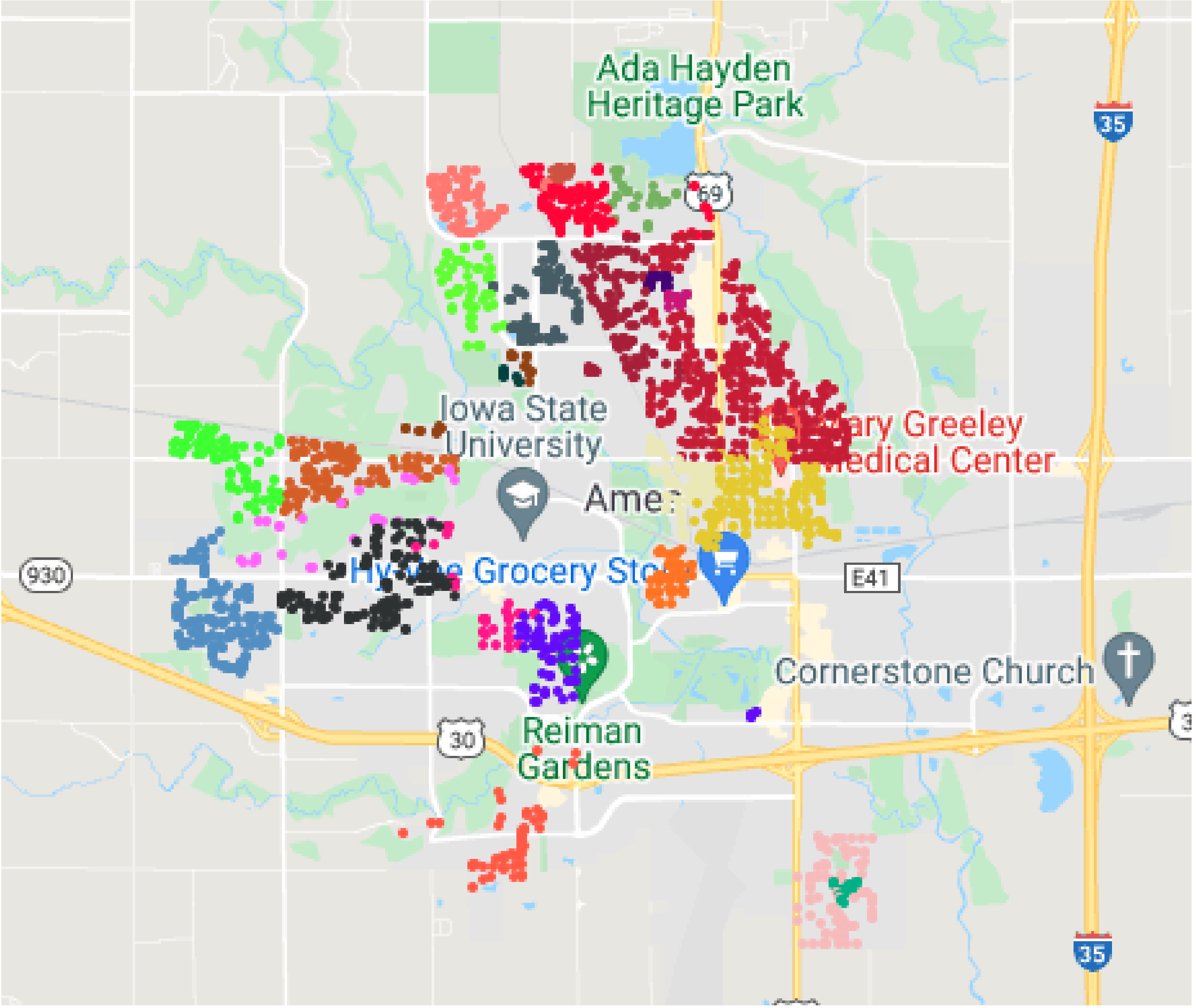
Predict home prices in Ames, Iowa

Identify the best methodologies



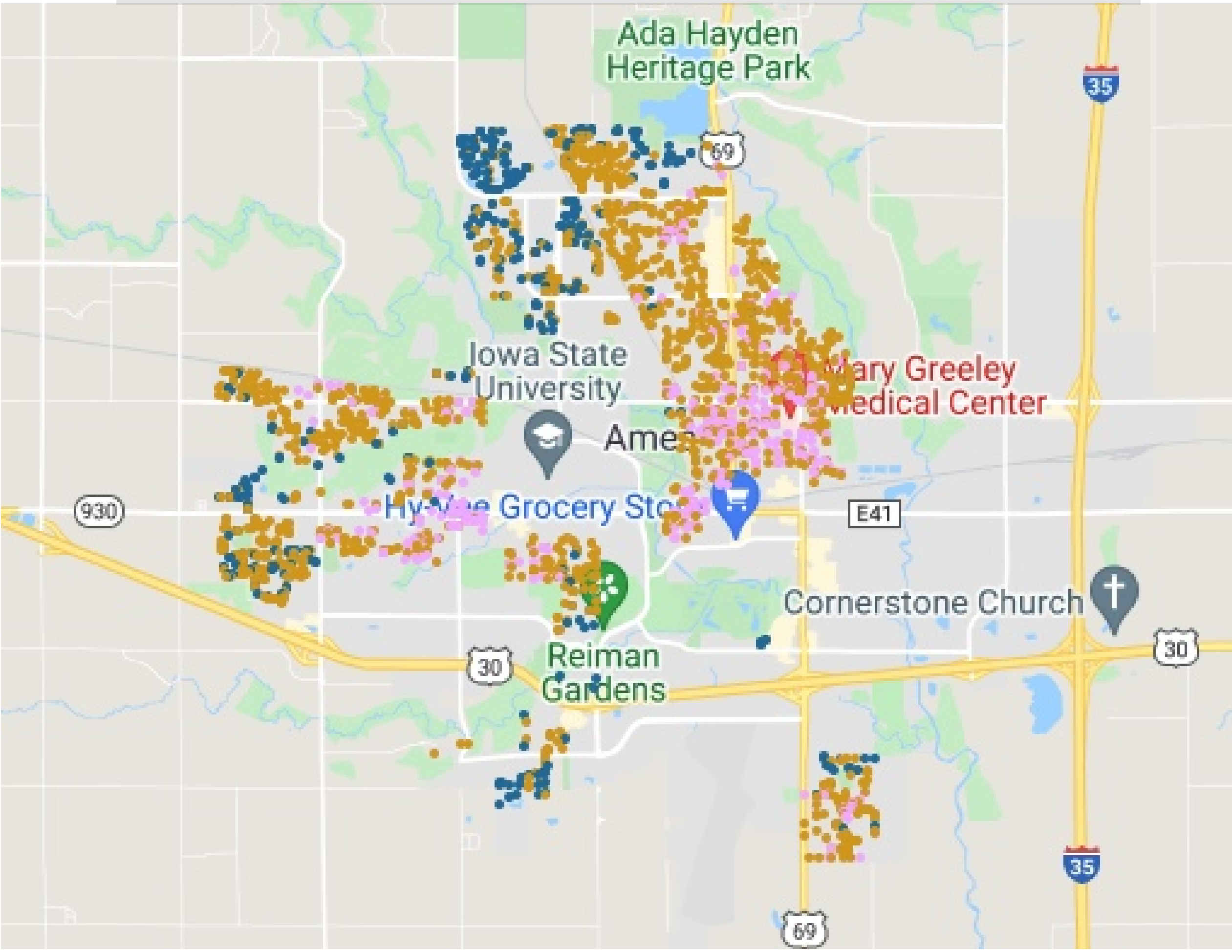
Implement machine learning models

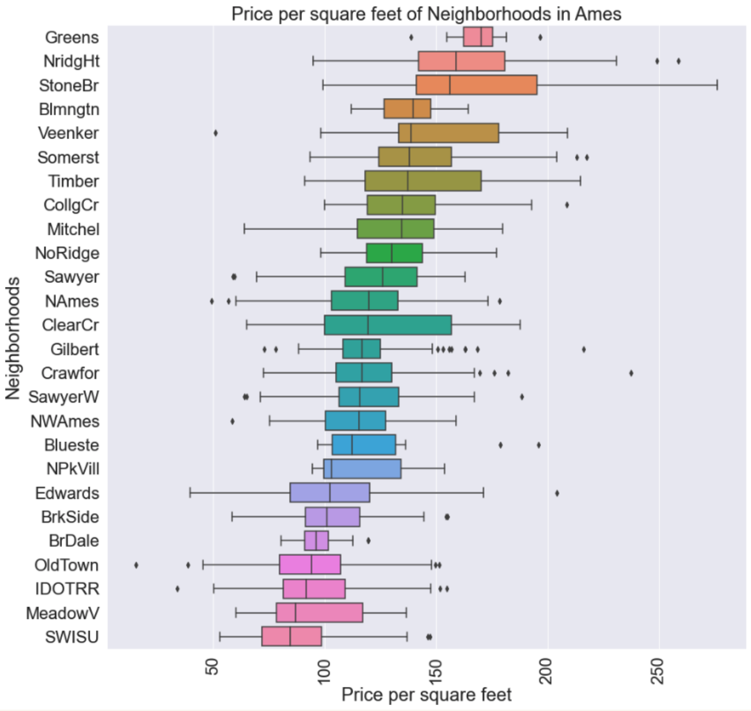
Ames Neighborhood Demographics

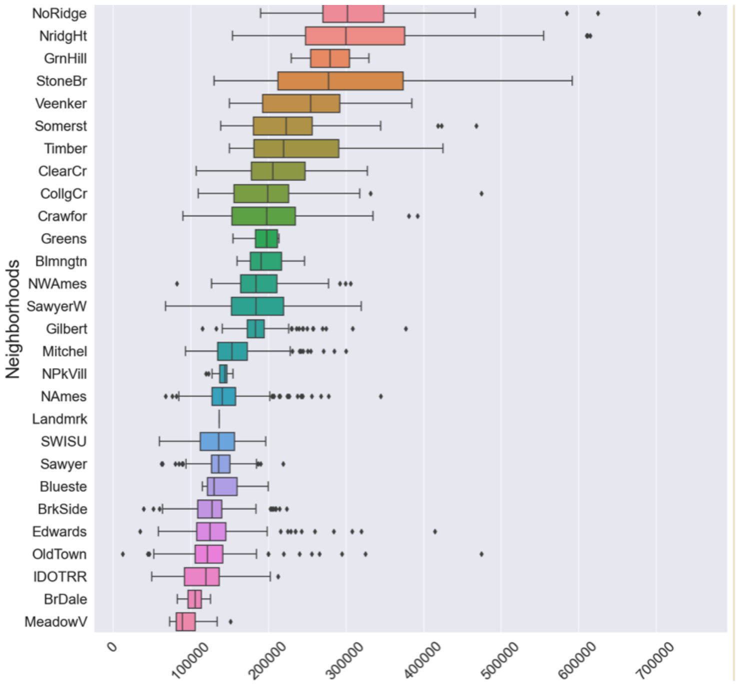


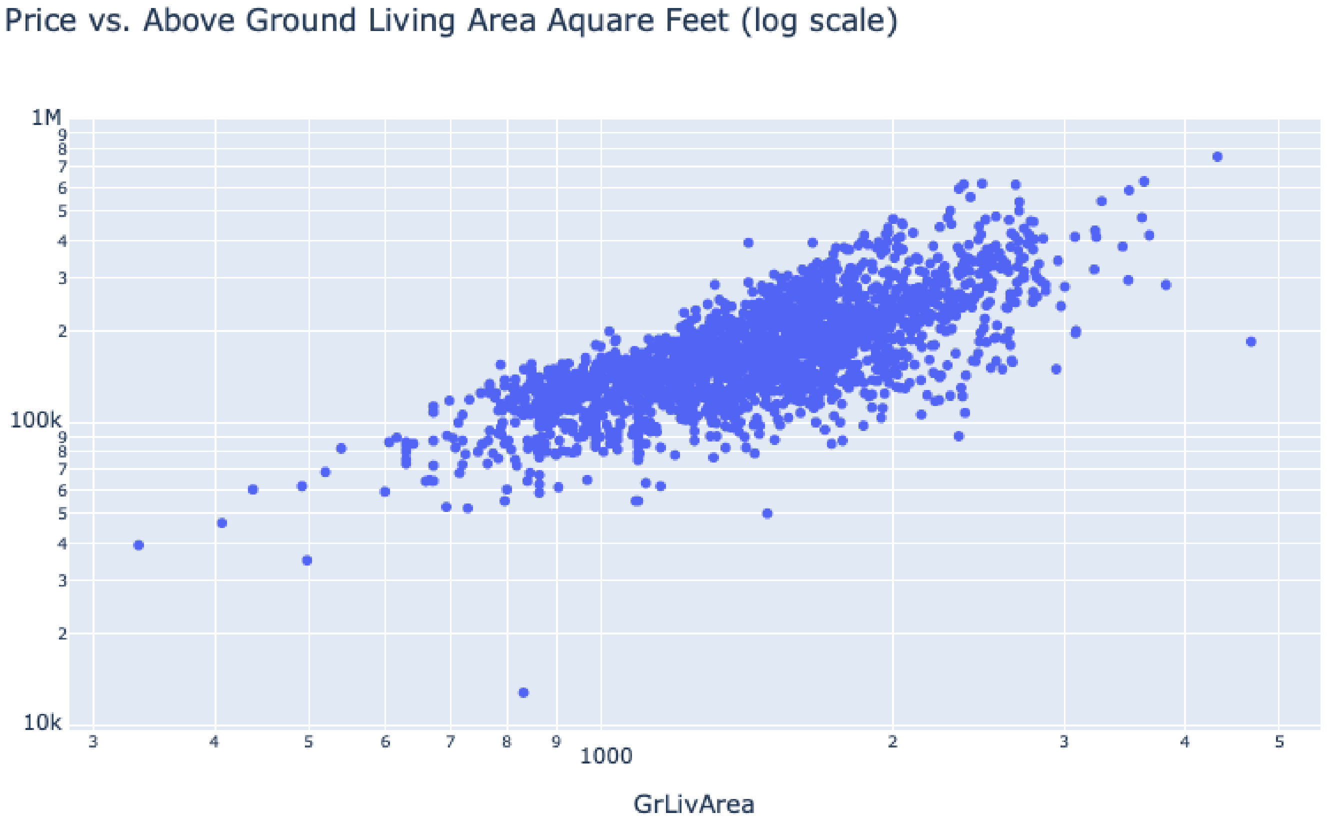
Exploratory Data Analysis

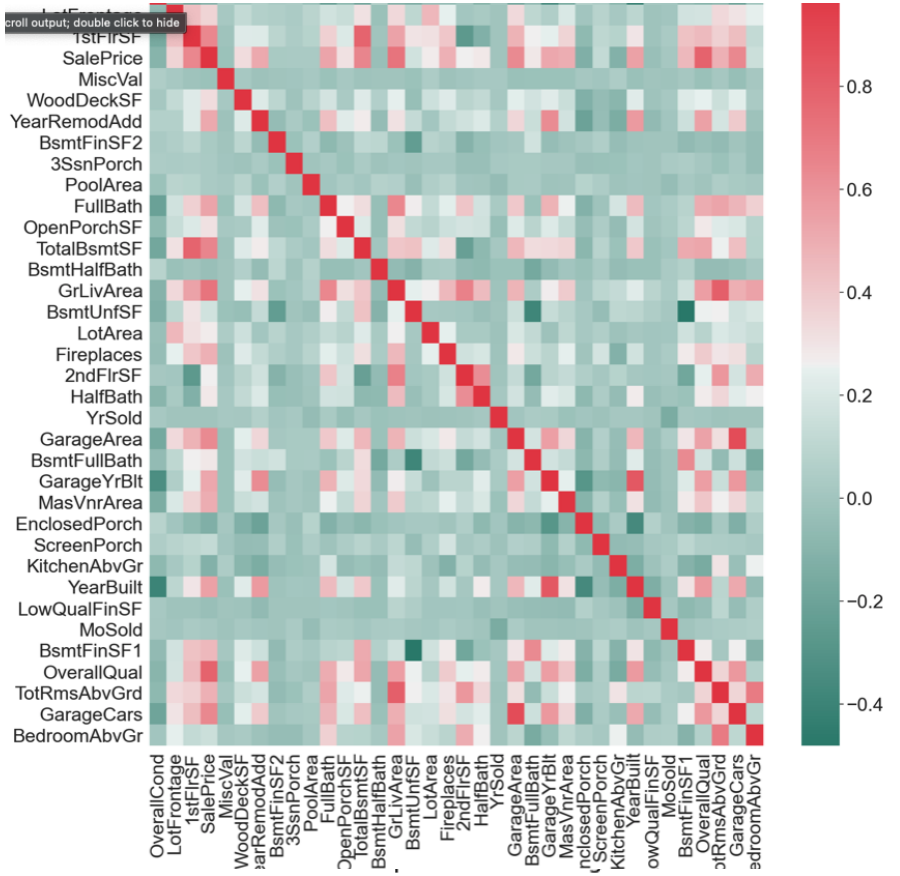
Neighborhood Housing Age

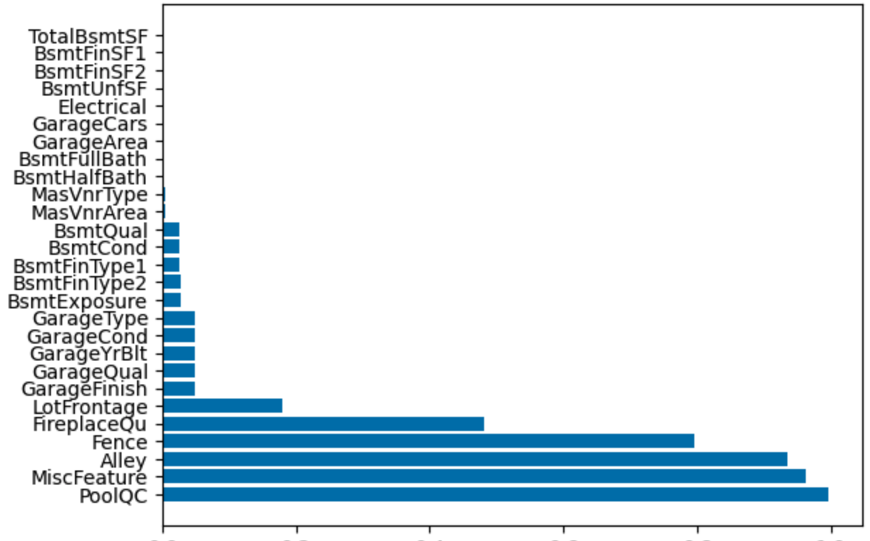







Price vs. Above Ground Living Area Aquare Feet (log scale)
1M
100k
10k
1000
GrLivArea


LotFrontage
1stFlrSF
SalePrice
MiscVal
WoodDeckSF
YearRemodAdd
BsmtFinSF2
3SsnPorch
PoolArea
FullBath
OpenPorchSF
TotalBsmtSF
BsmtHalfBath
GrLivArea
BsmtUnfSF
LotArea
Fireplaces
2ndFlrSF
HalfBath
YrSold
GarageArea
BsmtFullBath
GarageYrBlt
MasVnrArea
EnclosedPorch
ScreenPorch
KitchenAbvGr
YearBuilt
LowQualFinSF
MoSold
BsmtFinSF1
OverallQual
TotRmsAbvGrd
GarageCars
BedroomAbvGr
OverallCond
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4


TotalBsmtSF
BsmtFinSF1
BsmtFinSF2
BsmtUnfSF
Electrical
GarageCars
GarageArea
BsmtFullBath
BsmtHalfBath
MasVnrType
MasVnrArea
BsmtQual
BsmtCond
BsmtFinType1
BsmtFinType2
BsmtExposure
GarageType
GarageCond
GarageYrBlt
GarageQual
GarageFinish
LotFrontage
FireplaceQu
Fence
Alley
MiscFeature
PoolQC

Pre-Processing

START

IMPUTATION OF MISSING DATA: 27 FEATURES HAD MISSING VALUES

DROP VARIABLES THAT ARE NOT USEFUL:

FEATURE TRANSFORMATION:

Bathroom = n full bath + 0.5*n half bath

Added Neighborhoods class*:

N, NE, W, S

ONE HOT ENCODING

TRANSFORM TARGET

START BENCHMARK MODEL

* N: NridgHt, NoRidge, Veenker, StoneBr;
NE: Blmngtn,Gilbert,OldTown, NWAmes, NAmes, Blmngtn,BrDale,Somerst, BrkSide, Greens, NPkVill;
W: CollgCr,SWISU, Edward,SawyerW,SawyerClearCr;
S: Crawfor,MeadowV,Timber,Mitchel,IDOTRR

Machine Learning Models

Linear Regression Models

- Multiple linear regression
- Lasso Regularization

Tree-Based Models

- Random Forest
- Gradient Boosting

Random Forest

- Ensemble of Decision Trees
- Random Selection of Rows and Columns
- Creates Statistical Independence of Trees
- Mitigates Overfitting

Gradient Boosting Machine

- Sequentially Adds Trees, Does Not Average
- Converts Weak Learners to Strong Learners

  Requires Aggressive Hyperparameter Tuning to Prevent Overfitting

Linear Models

Ordinary Least Squares

(Benchmark Model)

R^2 train set: 0.886059

R^2 test set: 0.960320 CV

R^2 train set: 0.90715 RMSE: 0.03249

Penalized Linear Model: Lasso

- Lasso Regression with regularization terms

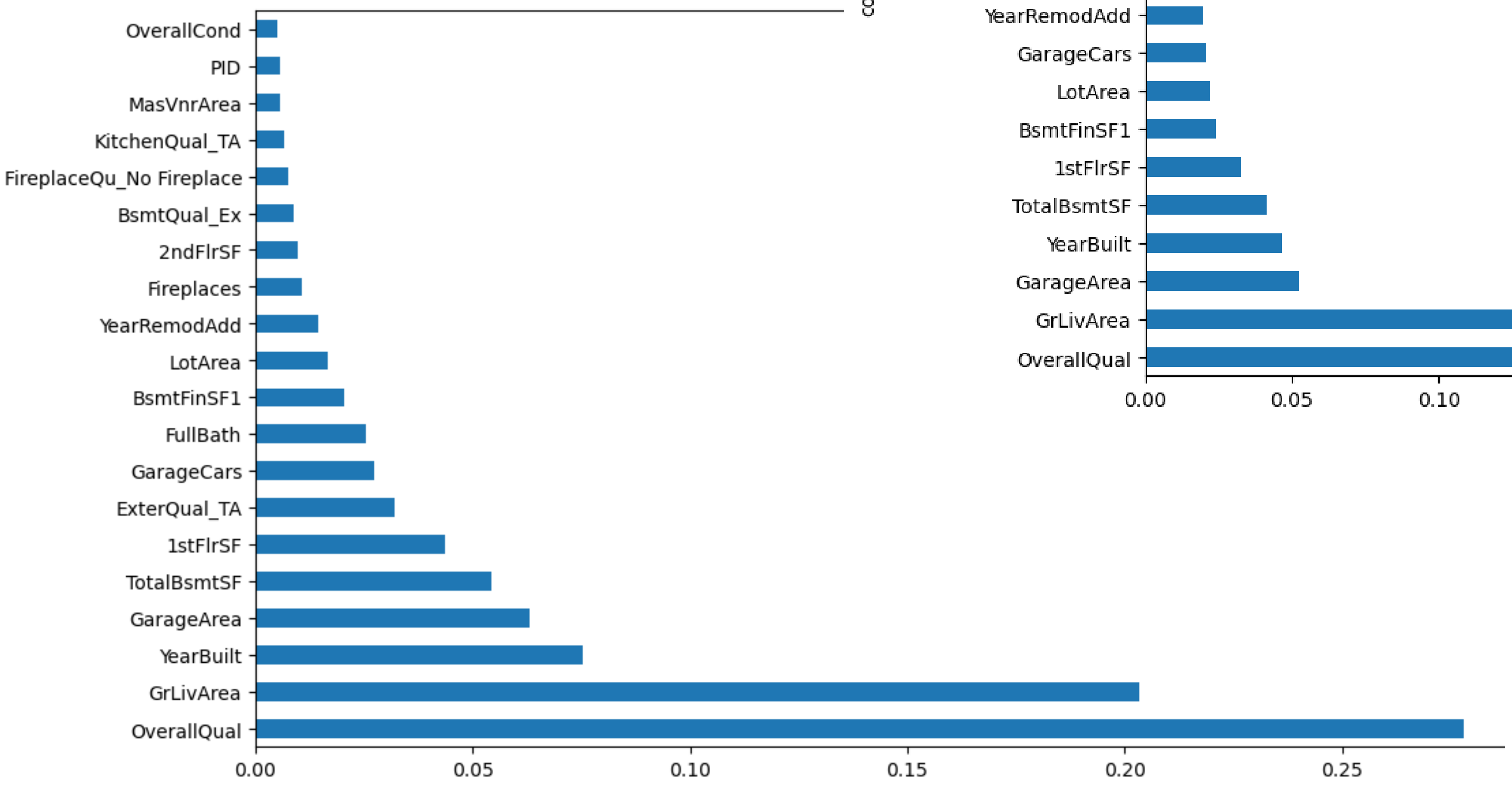
- Refit Multiple Linear Regression with Selected Features:
  - R^2 train set: 0.918851
  - R^2 test set: 0.932031
  - CV R^2 train set: 0.90888
  - RMSE: 0.0453
-

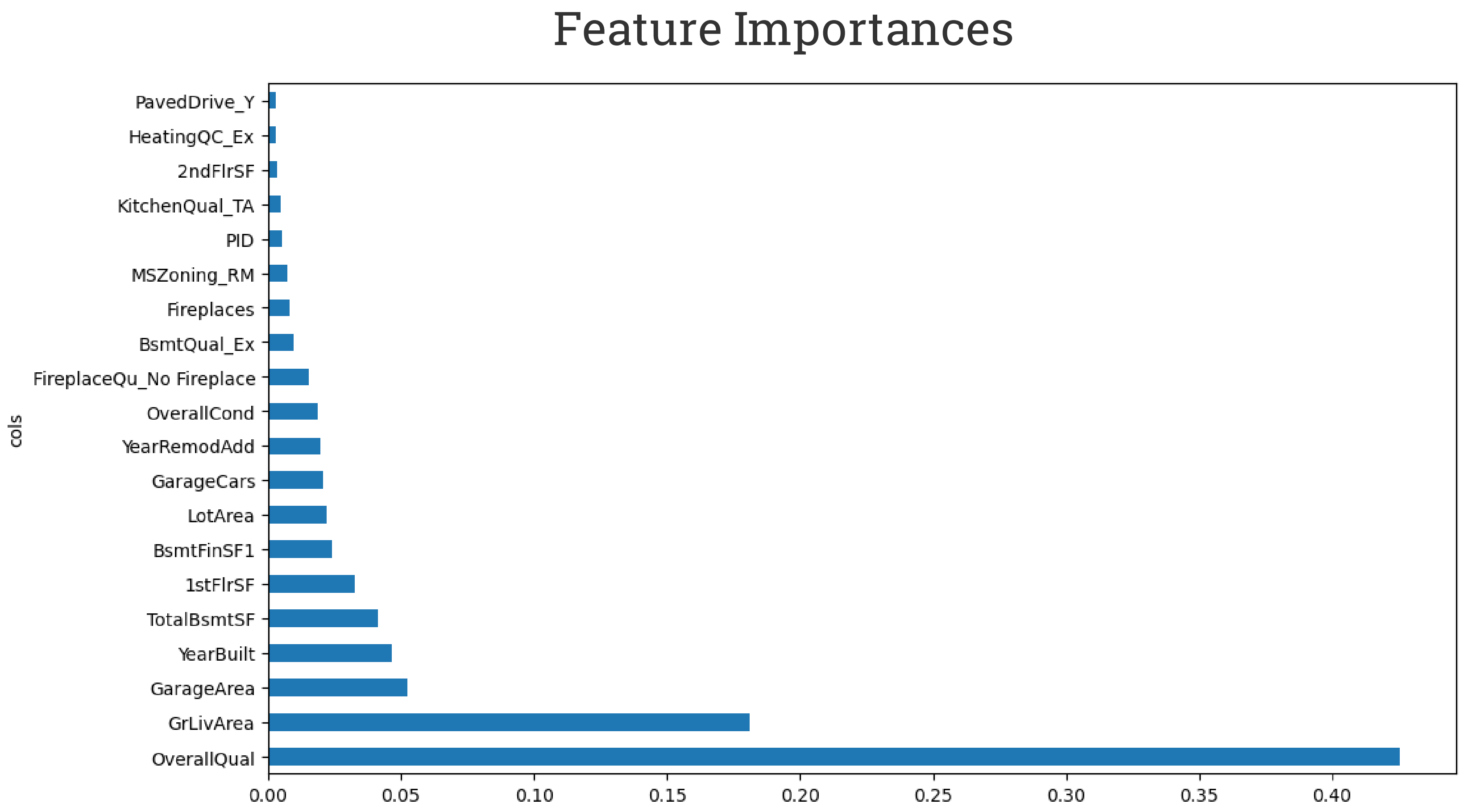
TREE MODELS

Random Forest

Log Root MSE (train) = .05639

Log Root MSE (valid) = .10619





Gradient Boosting Model

Log Root MSE (train) = .003419

Log Root MSE (valid) = .131497

Term Structure of Tree Model

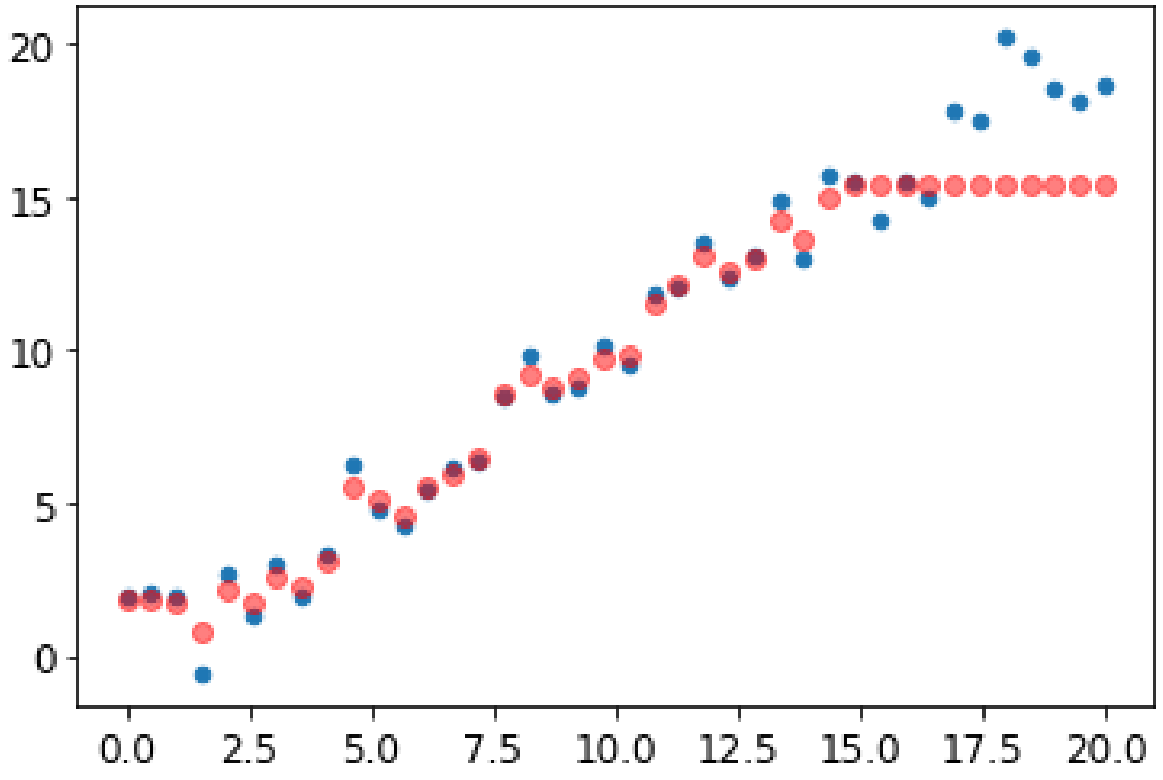
- Address Structural RF Problem
- Fit Linear Coefficient to Date-Only Data
- Transform Validation Set To One Year Earlier
- Evaluate Transformed Data Set
- Apply Term Structure Adjustment

Log Term Structure Adjustment = 0.0031734

Term Structure Adjustment = 1.007334

Log Root MSE (Train) = 0.05639

Log Root MSE (Valid) = .107604



Simulated Data - Deep Learning for Coders with fastai & Python

(Howard and Gugger, O'Reilly, 2020)

Conclusions

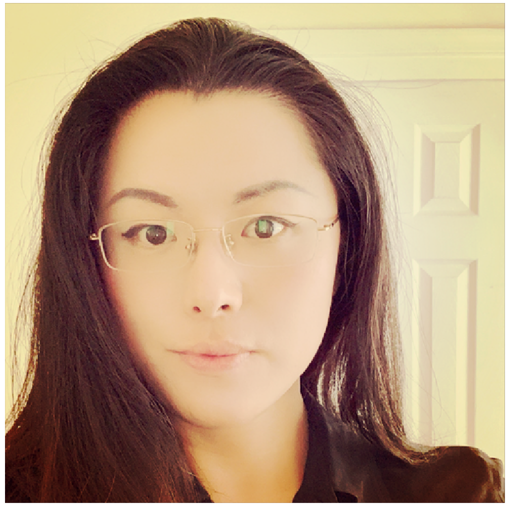
Future Work

ELIMINATE ONE-HOT ENCODING FOR THE CATEGORICAL FEATURES IN FAVOR OF LABEL ENCODING-ISH APPROACH

APPLY ADDITIONAL MACHINE LEARNING ALGORITHMS

IMPLEMENT MORE SPECIFIC MODELS TARGETING DEMOGRAPHICS AND AGE GROUPS TO GET A MORE ACCURATE ASSESSMENT OF HOME VALUES IN AMES, AND OTHER GEOGRAPHICAL REGIONS

Thank You



CHERIE WANG

TYLER KIM

JOHN KOSMICKE