STAT 444 FINAL PROJECT PROPOSAL

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This paper contains our proposal for the STAT 444 final project. It outlines our dataset, performs some brief exploratory data analysis, then outlines our approach to fitting regression models to predict a final sale price of a house given its physical attributes.

1. Introduction to our chosen dataset.

Our proposal primarily aims to assess the feasibility of utilizing regression techniques for interpolating and modeling housing prices. To achieve this objective, we have selected a dataset from the Journal of Statistics, which includes housing prices in Ames, Iowa, along with other pertinent features. In today's dynamic real estate market, precise and dependable house price predictions hold immense significance for homeowners, buyers, and real estate professionals alike. By delving into the potential of these advanced modeling techniques, our goal is to augment the accuracy and reliability of house price predictions, contributing to more informed decision-making in the industry.

2. Exploratory Data Analysis.

2.1. *Summary Statistics.*

- The dataset contains 2930 rows and 82 columns
- There are 80 explanatory variables, including 23 nominal, 23 ordinal, 14 discrete, and 20 continuous variables.

2.2. *Missing/duplicate Values.*

- There are four columns where missing values are extensive and need to be dropped as they are not critical to our analysis.
  - Pool.QC has only 13 observations
  - Misc.Feature has only 106 observations
  - Pool.QC has only 198 observations
  - Fence has only 572 observations
- There are no duplicates rows

2.3. *Distribution of dependent variable.*

- The distribution of Sale Price looks very right-skewed with most values clustered around the left tail and a significantly longer right tail, signifying extreme high values
- The sale prices range from \$12,789 to \$755,000 with a mean of \$180,796 and a standard deviation of \$79,886.69
- To achieve a more normal distribution, we will apply log transformation on the dependent variable

Keywords and phrases: We love regression.

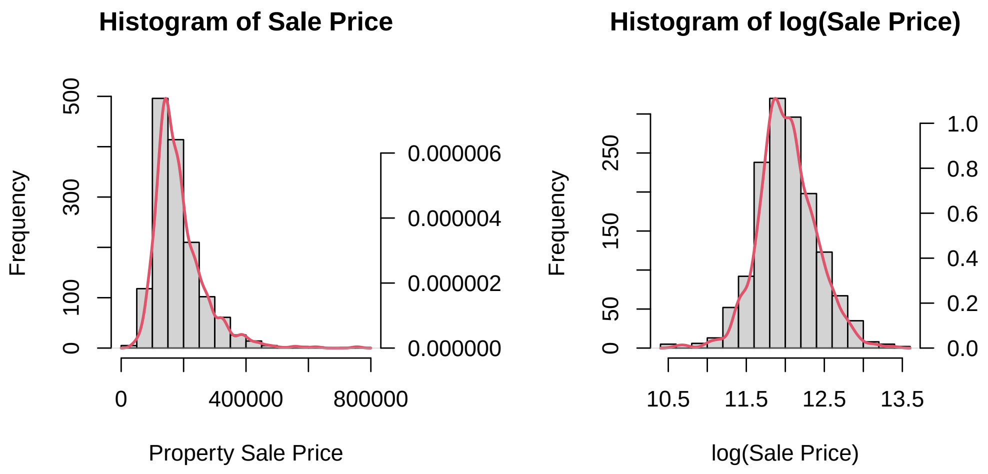


FIGURE 1. *Histograms of the response variable, Sale Price*

2.4. *Correlations with the dependent variable.*

- Based on our correlation analysis, the top 5 numeric variables with the highest correlations with our dependent variable are:
  - Overall.Qual: Rates the overall material and finish of the house
  - Gr.Liv.Area: Above grade (ground) living area square feet
  - Garage.Cars: Size of garage in car capacity
  - Garage.Area: Size of garage in square feet
  - Total.Bsmt.SF: Total square feet of basement area

2.5. *Check if there is a high degree of correlation or linear association among independent variables.*

- Some independent variables exemplify a strong correlation, which are to be expected because they essentially provide similar informaion.
  - For example, the high correlation between the variable **Garage Area** (size of garage in square feet) and **Garage Cars** (size of garage in car capacity) is not surprising.
  - To address this issue of redundancy, we will select one of them and exclude the other from the analysis.

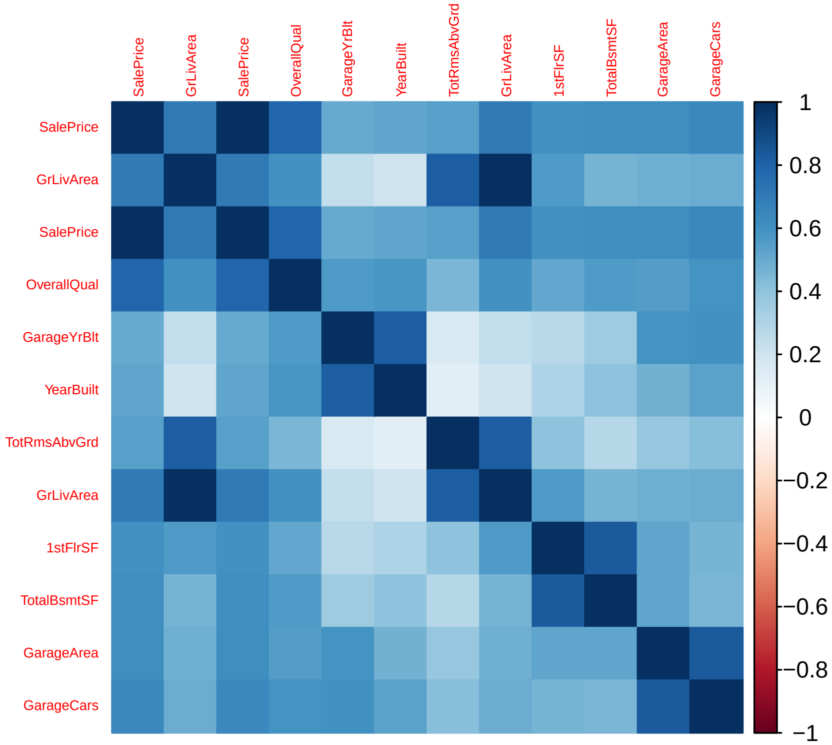
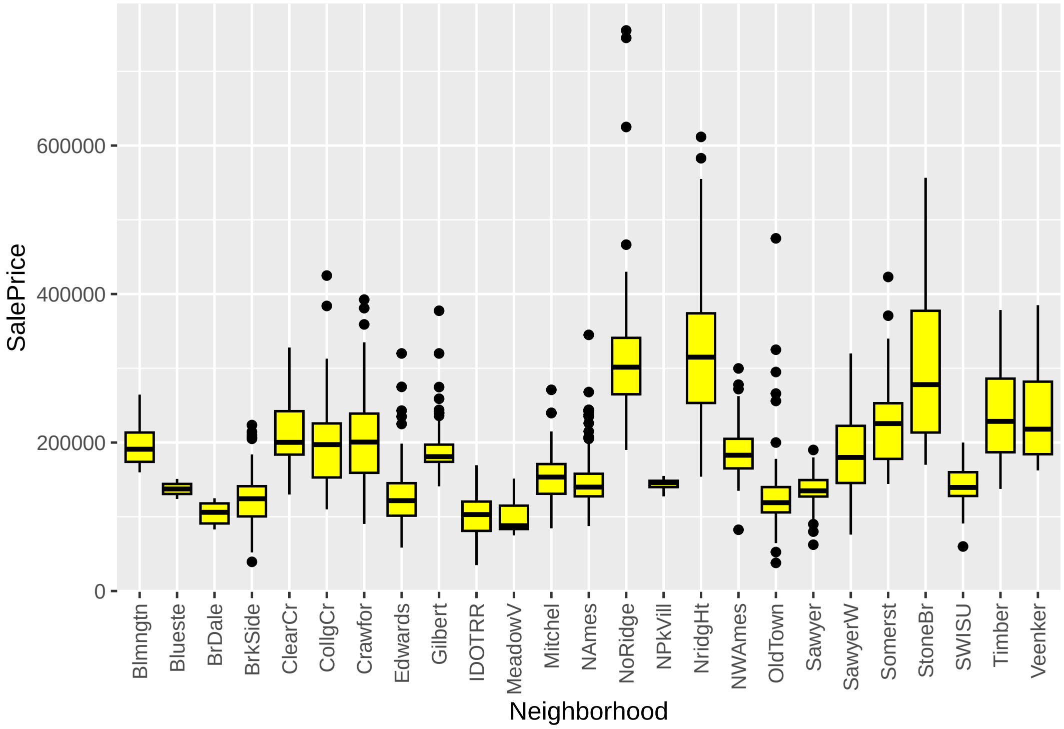


FIGURE 2. *Correlation matrix of independent variables*

2.6. *Other interesting but non-numeric variables.* We also assessed some of the non-numeric variables in the dataset and discovered some interesting results. * Neighborhood + There appears to be a significant difference in the average property sale price from neighborhood to neighborhood. * The dataset contains a good number of categorical variables with little variability in distribution and likely holds no predictive power + Street: Type of road access to property + Utilities: Type of utilities available + Roof.Matl: Roof material



3. Plan.

The primary objective of this feasibility study is to determine the viability and effectiveness of employing additive models, splines, and polynomial regression for predicting house prices. Specifically, we will evaluate the following:

- **Accuracy**: Assess the predictive accuracy of additive models, splines, and polynomial regression in comparison to traditional regression models commonly used in the real estate domain.
- **Flexibility**: Analyze the ability of these techniques to capture complex relationships between house price predictors, such as square footage, location, number of bedrooms, and other relevant features.
- **Interpretability**: Evaluate the interpretability and explainability of the models, ensuring that the predictions can be easily understood and justified by stakeholders.

To achieve our objective, we propose the following methodology as an outline:

- **Initial Benchmark**: We will investigate the accuracy of using linear regression with simple categorical encoding using the fulls et of features as an initial benchmark
- **Data Preprocessing**: Perform necessary data preprocessing tasks, including cleaning, feature engineering, and handling missing values or outliers to ensure the data quality. In an attempt to determine meaningful covariates, we are proposing to usage of clustering techniques such as Principal Component Analysis to remove extremely collinear covariates.
- **Model Implementation**: Develop additive models, splines, and polynomial regression models using appropriate algorithms and frameworks, such as generalized additive models (GAMs) and polynomial regression libraries in R. We will also apply penalization techniques to prevent overfitting such as forward/backward selection or LASSO/Ridge regression while scaling up the number of covariates to include interaction terms in an attempt to model any non-linear relationships

- **Model Evaluation**: Assess the performance of the models using appropriate evaluation metrics, such as mean squared error (MSE), root mean squared error (RMSE), and R-squared values and compare the results with benchmark models.
- **Interpretation and Explainability**: Analyze the interpretability of the models, examining the contributions of each feature and the underlying relationships identified by the models. Utilize visualization techniques to present the results in a comprehensive and understandable manner.

4. Introduction. This template helps you to create a properly formatted LaTeX 2$_\varepsilon$ manuscript. Prepare your paper in the same style as used in this sample .pdf file. Try to avoid excessive use of italics and bold face. Please do not use any LaTeX 2$_\varepsilon$ or TeX commands that affect the layout or formatting of your document (i.e., commands like `\textheight`, `\textwidth`, etc.).

5. Section headings.

Here are some sub-sections:

5.1. *A sub-section.*

Regular text.

5.1.1. *A sub-sub-section.*

Regular text.

6. Text.

6.1. *Lists.*

The following is an example of an *itemized* list, two levels deep.

- This is the first item of an itemized list. Each item in the list is marked with a "tick." The document style determines what kind of tick mark is used.
- This is the second item of the list. It contains another list nested inside it.
  - This is the first item of an itemized list that is nested within the itemized list.
  - This is the second item of the inner list. LaTeX
    allows you to nest lists deeper than you really should.
- This is the third item of the list.

The following is an example of an *enumerated* list of one level.

(i) This is the first item of an enumerated list.
(ii) This is the second item of an enumerated list.

The following is an example of an *enumerated* list, two levels deep.

1. This is the first item of an enumerated list. Each item in the list is marked with a "tick.". The document style determines what kind of tick mark is used.
2. This is the second item of the list. It contains another list nested inside of it.

   (i) This is the first item of an enumerated list that is nested within.
   (ii) This is the second item of the inner list. LaTeX allows you to nest lists deeper than you really should.

This is the rest of the second item of the outer list.

3. This is the third item of the list.

ird item of the list. \end{longlist}

6.2. *Punctuation.*

Dashes come in three sizes: a hyphen, an intra-word dash like "U-statistics" or "the time-homogeneous model"; a medium dash (also called an "en-dash") for number ranges or between two equal entities like "1–2" or "Cauchy–Schwarz inequality"; and a punctuation dash (also called an "em-dash") in place of a comma, semicolon, colon or parentheses—like this.

Generating an ellipsis . . . with the right spacing around the periods requires a special command.

6.3. *Citation.*

Simple author and year cite: Billingsley (1999). Multiple bibliography items cite: Billingsley (1999); Bourbaki (1966) or (Billingsley, 1999; Bourbaki, 1966). Author only cite: Ethier and Kurtz. Year only cite: 1956 or (1956).

7. Fonts. Please use text fonts in text mode, e.g.:

Roman
Italic
Bold
Small Caps
Sans serif
Typewriter

Please use mathematical fonts in mathematical mode, e.g.:

$\mathrm{ABCabc123}$

$ABCabc123$

$\mathbf{ABCabc123}$

$\boldsymbol{ABCabc123\alpha\beta\gamma}$

$\mathcal{ABC}$

$\mathbb{ABC}$

$\mathsf{ABCabc123}$

$\mathtt{ABCabc123}$

$\mathfrak{ABCabc123}$

Note that `\mathcal, \mathbb` belongs to capital letters-only font typefaces.

8. Notes. Footnotes[1] pose no problem.[2]

9. Quotations. Text is displayed by indenting it from the left margin. There are short quotations

> This is a short quotation. It consists of a single paragraph of text. There is no paragraph indentation.

and longer ones.

> This is a longer quotation. It consists of two paragraphs of text. The beginning of each paragraph is indicated by an extra indentation.
>
> This is the second paragraph of the quotation. It is just as dull as the first paragraph.

10. Environments.

10.1. *Examples for* `plain`-style environments.

Axiom 1. *This is the body of Axiom 1.*

Proof. This is the body of the proof of the axiom above. □

Claim 2. *This is the body of Claim 2. Claim 2 is numbered after Axiom 1 because we used* `[axiom]` *in* `\newtheorem`.

Theorem 10.1. *This is the body of Theorem 10.1. Theorem 10.1 numbering is dependent on section because we used* `[section]` *after* `\newtheorem`.

[1] This is an example of a footnote.

[2] Note that footnote number is after punctuation.

THEOREM 10.2 (Title of the theorem). *This is the body of Theorem 10.2. Theorem 10.2 has additional title.*

LEMMA 10.3. *This is the body of Lemma 10.3. Lemma 10.3 is numbered after Theorem 10.2 because we used* `[theorem]` *in* `\newtheorem`*.*

PROOF OF LEMMA 10.3. This is the body of the proof of Lemma 10.3. □

10.2. *Examples for* `remark`*-style environments.*

DEFINITION 10.4. This is the body of Definition 10.4. Definition 10.4 is numbered after Lemma 10.3 because we used `[theorem]` in `\newtheorem`.

EXAMPLE. This is the body of the example. Example is unnumbered because we used `\newtheorem*` instead of `\newtheorem`.

FACT. This is the body of the fact. Fact is unnumbered because we used `\newtheorem*` instead of `\newtheorem`.

11. Tables and figures. Cross-references to labeled tables: As you can see in Table1 and also in Table2. */%

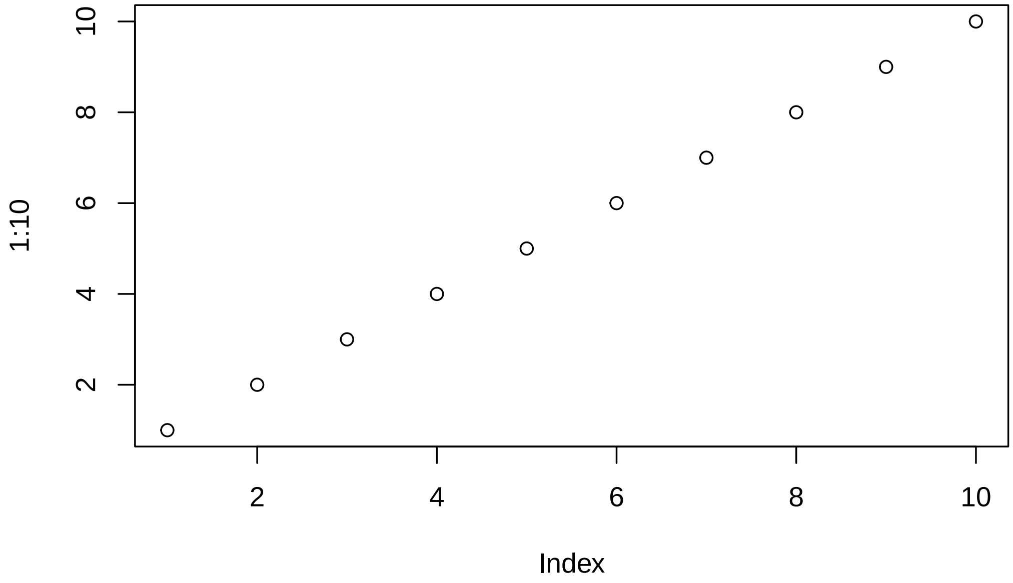


FIGURE 3. *Figure caption*

Sample of cross-reference to figure. Figure3 shows that it is not easy to get something on paper.

TABLE 1
Table caption

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160.0	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160.0	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108.0	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258.0	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360.0	175	3.15	3.440	17.02	0	0	3	2
Valiant	18.1	6	225.0	105	2.76	3.460	20.22	1	0	3	1
Duster 360	14.3	8	360.0	245	3.21	3.570	15.84	0	0	3	4
Merc 240D	24.4	4	146.7	62	3.69	3.190	20.00	1	0	4	2
Merc 230	22.8	4	140.8	95	3.92	3.150	22.90	1	0	4	2
Merc 280	19.2	6	167.6	123	3.92	3.440	18.30	1	0	4	4
Merc 280C	17.8	6	167.6	123	3.92	3.440	18.90	1	0	4	4
Merc 450SE	16.4	8	275.8	180	3.07	4.070	17.40	0	0	3	3
Merc 450SL	17.3	8	275.8	180	3.07	3.730	17.60	0	0	3	3
Merc 450SLC	15.2	8	275.8	180	3.07	3.780	18.00	0	0	3	3
Cadillac Fleetwood	10.4	8	472.0	205	2.93	5.250	17.98	0	0	3	4
Lincoln Continental	10.4	8	460.0	215	3.00	5.424	17.82	0	0	3	4
Chrysler Imperial	14.7	8	440.0	230	3.23	5.345	17.42	0	0	3	4
Fiat 128	32.4	4	78.7	66	4.08	2.200	19.47	1	1	4	1
Honda Civic	30.4	4	75.7	52	4.93	1.615	18.52	1	1	4	2
Toyota Corolla	33.9	4	71.1	65	4.22	1.835	19.90	1	1	4	1
Toyota Corona	21.5	4	120.1	97	3.70	2.465	20.01	1	0	3	1
Dodge Challenger	15.5	8	318.0	150	2.76	3.520	16.87	0	0	3	2
AMC Javelin	15.2	8	304.0	150	3.15	3.435	17.30	0	0	3	2
Camaro Z28	13.3	8	350.0	245	3.73	3.840	15.41	0	0	3	4
Pontiac Firebird	19.2	8	400.0	175	3.08	3.845	17.05	0	0	3	2
Fiat X1-9	27.3	4	79.0	66	4.08	1.935	18.90	1	1	4	1
Porsche 914-2	26.0	4	120.3	91	4.43	2.140	16.70	0	1	5	2
Lotus Europa	30.4	4	95.1	113	3.77	1.513	16.90	1	1	5	2
Ford Pantera L	15.8	8	351.0	264	4.22	3.170	14.50	0	1	5	4
Ferrari Dino	19.7	6	145.0	175	3.62	2.770	15.50	0	1	5	6
Maserati Bora	15.0	8	301.0	335	3.54	3.570	14.60	0	1	5	8
Volvo 142E	21.4	4	121.0	109	4.11	2.780	18.60	1	1	4	2

TABLE 2
Sample posterior estimates for each model

				Quantile		
Model	Parameter	Mean	Std. dev.	2.5%	50%	97.5%
Model 0	β_0	-12.29	2.29	-18.04	-11.99	-8.56
	β_1	0.10	0.07	-0.05	0.10	0.26
	β_2	0.01	0.09	-0.22	0.02	0.16
Model 1	β_0	-4.58	3.04	-11.00	-4.44	1.06
	β_1	0.79	0.21	0.38	0.78	1.20
	β_2	-0.28	0.10	-0.48	-0.28	-0.07
Model 2	β_0	-11.85	2.24	-17.34	-11.60	-7.85
	β_1	0.73	0.21	0.32	0.73	1.16
	β_2	-0.60	0.14	-0.88	-0.60	-0.34
	β_3	0.22	0.17	-0.10	0.22	0.55

12. Equations and the like. Two equations:

$$C_s = K_M \frac{\mu/\mu_x}{1-\mu/\mu_x} \tag{12.1}$$

and

$$G = \frac{P_{\text{opt}} - P_{\text{ref}}}{P_{\text{ref}}} 100(\%). \tag{12.2}$$

Equation arrays:

$$\frac{dS}{dt} = -\sigma X + s_F F, \tag{12.3}$$

$$\frac{dX}{dt} = \mu X, \tag{12.4}$$

$$\frac{dP}{dt} = \pi X - k_h P, \tag{12.5}$$

$$\frac{dV}{dt} = F. \tag{12.6}$$

One long equation:

$$\begin{aligned}
\mu_{\text{normal}} &= \mu_x \frac{C_s}{K_x C_x + C_s} \\
&= \mu_{\text{normal}} - Y_{x/s}\bigl(1 - H(C_s)\bigr)(m_s + \pi / Y_{p/s}) \\
&= \mu_{\text{normal}} / Y_{x/s} + H(C_s)(m_s + \pi / Y_{p/s}).
\end{aligned} \tag{12.7}$$

APPENDIX: TITLE

Appendices should be provided in `{appendix}` environment, before Acknowledgements.

If there is only one appendix, then please refer to it in text as ... in the Appendix.

APPENDIX A: TITLE OF THE FIRST APPENDIX

If there are more than one appendix, then please refer to it as ... in Appendix A, Appendix B, etc.

APPENDIX B: TITLE OF THE SECOND APPENDIX

B.1. First subsection of Appendix B. Use the standard LaTeX commands for headings in `{appendix}`. Headings and other objects will be numbered automatically.

$$\mathcal{P} = \bigl(j_{k,1}, j_{k,2}, \ldots, j_{k,m(k)}\bigr). \tag{B.1}$$

Sample of cross-reference to the formula (B.1) in Appendix B.

Acknowledgements. The authors would like to thank the anonymous referees, an Associate Editor and the Editor for their constructive comments that improved the quality of this paper.

The first author was supported by NSF Grant DMS-??-??????.

The second author was supported in part by NIH Grant ???????????.

SUPPLEMENTARY MATERIAL

Title of Supplement A
Short description of Supplement A.

Title of Supplement B
Short description of Supplement B.

REFERENCES

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