

## Problem Set #4

MACS 30100, Dr. Evans

Due Monday, Feb. 5 at 11:30am

1. **Multiple linear regression (4 points).** For this problem, you will use the 397 observations from the [Auto.csv](#) dataset.<sup>1</sup> This dataset includes 397 observations on miles per gallon (`mpg`), number of cylinders (`cylinders`), engine displacement (`displacement`), horsepower (`horsepower`), vehicle weight (`weight`), acceleration (`acceleration`), vehicle year (`year`), vehicle origin (`origin`), and vehicle name (`name`).
  - (a) Import the data using `pandas.read_csv()` function. Look for characters that seem out of place that might indicate missing values. Replace them with missing values using the `na_values=...` option.
  - (b) Produce a scatterplot matrix which includes all of the quantitative variables (`mpg`, `cylinders`, `displacement`, `horsepower`, `weight`, `acceleration`, `year`, `origin`). [Use the pandas scatterplot function in the code block below.]

```
from pandas.plotting import scatter_matrix
scatter_matrix(df_quant, alpha=0.3, figsize=(6, 6),
               diagonal='kde')
```

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  - (c) Compute the correlation matrix for the quantitative variables ( $8 \times 8$ ) using the `DataFrame.corr()` method.
  - (d) Estimate the following multiple linear regression model of `mpg` on all other quantitative variables, where  $u_i$  is an error term for each observation, using Python's `statsmodels.api.OLS()` function.

$$mpg_i = \beta_0 + \beta_1 cylinders_i + \beta_2 displacement_i + \beta_3 horsepower_i + \dots \\ \beta_4 weight_i + \beta_5 acceleration_i + \beta_6 year_i + \beta_7 origin_i + u_i$$

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  - i. Which of the coefficients is statistically significant at the 1% level?
    - ii. Which of the coefficients is NOT statistically significant at the 10% level?
    - iii. Give an interpretation in words of the estimated coefficient  $\hat{\beta}_6$  on  $year_i$  using the estimated value of  $\hat{\beta}_6$ .
  - (e) Looking at your scatterplot matrix from part (b), what are the three variables that look most likely to have a nonlinear relationship with  $mpg_i$ ?
    - i. Estimate a new multiple regression model by OLS in which you include squared terms on the three variables you identified as having a nonlinear relationship to  $mpg_i$  as well as a squared term on  $acceleration_i$ .

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<sup>1</sup>The [Auto.csv](#) dataset comes from [James et al. \(2017, Ch. 3\)](#) and is available at <http://www-bcf.usc.edu/~gareth/ISL/data.html>.

- ii. Report your adjusted R-squared statistic. Is it better or worse than the adjusted R-squared from part (d)?
  - iii. What happened to the statistical significance of the *displacement<sub>i</sub>* variable coefficient and the coefficient on its squared term?
  - iv. What happened to the statistical significance of the cylinders variable?
- (f) Using the regression model from part (e) and the `.predict()` function, what would be the predicted miles per gallon *mpg* of a car with 6 cylinders, displacement of 200, horsepower of 100, a weight of 3,100, acceleration of 15.1, model year of 1999, and origin of 1?

2. **Classification problem: KNN by hand and in Python (3 points).** The table below provides a training data set containing six observations, three predictors, and one qualitative response variable.

Obs.	$X_1$	$X_2$	$X_3$	$Y$	Eucl. Dist. from $X_1 = X_2 = X_3 = 0$
1	0	3	0	Red	
2	2	0	0	Red	
3	0	1	3	Red	
4	0	1	2	Green	
5	-1	0	1	Green	
6	1	1	1	Red	

Suppose we wish to use this data set to make a prediction for  $Y$  when  $X_1 = X_2 = X_3 = 0$  using  $K$ -nearest neighbors.

- (a) Compute the Euclidean distance between each observation and the test point  $X_1 = X_2 = X_3 = 0$ .

$$\text{dist}(\mathbf{p}, \mathbf{q}) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + (q_3 - p_3)^2}$$

- (b) What is our KNN prediction with  $K = 1$ ? Why?
- (c) What is our KNN prediction with  $K = 3$ ? Why?
- (d) If the Bayes (optimal) decision boundary in this problem is highly non-linear, then would we expect the best value for  $K$  to be large or small? Why?
- (e) Use Python's `scikit-learn` library to estimate the KNN classifier of the test point  $X_1 = X_2 = X_3 = 1$  with  $K = 2$ .

3. **Multivariable logistic (logit) regression (3 points).** In this problem, you will use the [Auto.csv](#) dataset from Exercise 1. We will study the factors that make miles per gallon high or low. Create a binary variable `mpg_high` that equals 1 if `mpg_high`  $\geq$  `median(mpg_high)` and equals 0 if `mpg_high`  $<$  `median(mpg_high)`.

- (a) Use `statsmodel.api` to estimate the logistic regression of `mpg_high` on the regressors from Exercise 1: number of cylinders (`cyl`), engine displacement (`dspl`), horsepower (`hpwr`), vehicle weight (`wgt`), acceleration (`accl`), vehicle year (`yr`), vehicle origin (`orgn`). Make sure to include a constant term. Report all the regressors that have coefficients that are statistically significant at the 5% level ( $p < 0.05$ ).

$$Pr(mpg\_high = 1 | \mathbf{X}\boldsymbol{\beta}) = \frac{e^{\mathbf{X}\boldsymbol{\beta}}}{1 + e^{\mathbf{X}\boldsymbol{\beta}}}$$

$$\text{where } \mathbf{X}\boldsymbol{\beta} = \beta_0 + \beta_1 cyl_i + \beta_2 dspl_i + \beta_3 hpwr_i + \beta_4 wgt_i + \beta_5 accl_i + \beta_6 yr_i + \beta_7 orgn_i$$

- (b) Divide the data into a training set of half of the data randomly selected and a test set of the remaining half of the data using the `.train_test_split` module of the `scikit-learn.cross_validation` package. Set the `test_size = 0.5` and set the `random_state=10`. Use the format listed below

```
X_train, X_test, y_train, y_test = \
    train_test_split(X, y, test_size = 0.5, random_state=10)
```

- (c) Use `scikit-learn` to estimate a logistic regression model on the training data. Report your estimated intercept  $\beta_0$  and coefficients  $(\beta_1, \beta_2, \dots, \beta_7)$ . [Note. These estimates will be different from the estimates in part (a) because you are only using half the data.]
- (d) Create predicted values of `mpg_high` for the test set and calculate the `confusion matrix` and `classification report` for the Logit model on the test data. Does this model predict low mpg (`mpg_high=0`) or high mpg (`mpg_high=1`) better?

## References

James, Gareth, Daniela Witten, Trevor Hastie, and Robert Tibshirani, *An Introduction to Statistical Learning with Applications in R* Springer Texts in Statistics, Springer, 2017.