Data 557 HW4

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2/13/2022

Data: ‘Sales.csv’

The data consist of sales prices for a sample of homes from a US city and some features of the houses.

Variables:

LAST\_SALE\_PRICE: the sale price of the home SQFT: area of the house (sq. ft.) LOT\_SIZE: area of the lot (sq. ft.) BEDS: number of bedrooms BATHS: number of bathrooms

sales = read.csv('Sales.csv')  
colnames(sales)

## [1] "LAST\_SALE\_PRICE" "SQFT" "LOT\_SIZE" "BEDS"   
## [5] "BATHS"

summary(sales)

## LAST\_SALE\_PRICE SQFT LOT\_SIZE BEDS   
## Min. : 20100 Min. : 400 Min. : 446 Min. : 0.000   
## 1st Qu.: 462000 1st Qu.: 1550 1st Qu.: 4000 1st Qu.: 3.000   
## Median : 622050 Median : 2040 Median : 5500 Median : 3.000   
## Mean : 728308 Mean : 2189 Mean : 6572 Mean : 3.358   
## 3rd Qu.: 830000 3rd Qu.: 2660 3rd Qu.: 7610 3rd Qu.: 4.000   
## Max. :5750000 Max. :12280 Max. :120542 Max. :11.000   
## NA's :97 NA's :24 NA's :506 NA's :8   
## BATHS   
## Min. :0.500   
## 1st Qu.:1.500   
## Median :2.000   
## Mean :2.051   
## 3rd Qu.:2.500   
## Max. :7.750   
## NA's :22

sales\_new = na.omit(sales)  
summary(sales\_new)

## LAST\_SALE\_PRICE SQFT LOT\_SIZE BEDS   
## Min. : 79950 Min. : 446 Min. : 446 Min. : 0.000   
## 1st Qu.: 476950 1st Qu.: 1620 1st Qu.: 4000 1st Qu.: 3.000   
## Median : 631268 Median : 2110 Median : 5500 Median : 3.000   
## Mean : 742552 Mean : 2252 Mean : 6522 Mean : 3.408   
## 3rd Qu.: 849950 3rd Qu.: 2710 3rd Qu.: 7609 3rd Qu.: 4.000   
## Max. :5750000 Max. :12280 Max. :94089 Max. :11.000   
## BATHS   
## Min. :0.500   
## 1st Qu.:1.500   
## Median :2.000   
## Mean :2.122   
## 3rd Qu.:2.500   
## Max. :7.750

nrow(sales\_new)

## [1] 4065

**1. Calculate all pairwise correlations between all five variables.**

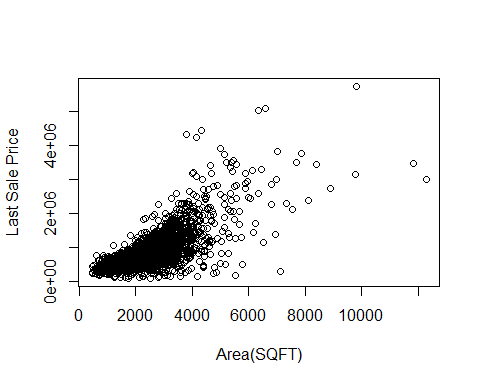
cor(sales\_new)

## LAST\_SALE\_PRICE SQFT LOT\_SIZE BEDS BATHS  
## LAST\_SALE\_PRICE 1.0000000 0.7408940 0.1349629 0.3785385 0.5980328  
## SQFT 0.7408940 1.0000000 0.2369659 0.6360399 0.7455693  
## LOT\_SIZE 0.1349629 0.2369659 1.0000000 0.1770005 0.1353978  
## BEDS 0.3785385 0.6360399 0.1770005 1.0000000 0.6163141  
## BATHS 0.5980328 0.7455693 0.1353978 0.6163141 1.0000000

The correlations between the five variables are as follows:  
1. LAST\_SALE\_PRICE, SQFT = **0.7408940**  
2. LAST\_SALE\_PRICE, LOT\_SIZE = **0.1349629**  
3. LAST\_SALE\_PRICE, BEDS = **0.3785385**  
4. LAST\_SALE\_PRICE, BATHS = **0.5980328**  
5. SQFT, LOT\_SIZE = **0.2369659**  
6. SQFT, BEDS = **0.6360399**  
7. SQFT, BATHS = **0.7455693**  
8. LOT\_SIZE, BEDS = **0.1770005**  
9. LOT\_SIZE, BATHS = **0.1353978**  
10. BEDS, BATHS = **0.6163141**

**2. Make a scatterplot of the sale price versus the area of the house. Describe the association between these two variables.**

plot(sales\_new$LAST\_SALE\_PRICE ~ sales\_new$SQFT, data=sales\_new,xlab = "Area(SQFT)", ylab = "Last Sale Price")

  
From the above displayed scatterplot, it can be inferred that there is a strong linear correlation between the two variables Sale Price and Area (SQFT)

**3. Fit a simple linear regression model (Model 1) with sale price as response variable and area of the house (SQFT) as predictor variable. State the estimated value of the intercept and the estimated coefficient for the area variable.**

lm(LAST\_SALE\_PRICE ~ SQFT, data=sales\_new)

##   
## Call:  
## lm(formula = LAST\_SALE\_PRICE ~ SQFT, data = sales\_new)  
##   
## Coefficients:  
## (Intercept) SQFT   
## -47566.5 350.9

The estimated value of the intercerpt is **-47566.5**. The estimated coefficient for the area variable is **350.9**.

**4. Write the equation that describes the relationship between the mean sale price and SQFT.**

is the *intercept* = -47566.5

is the *regression coefficient* for = 350.9

The equation of the fitted line is

**5. State the interpretation in words of the estimated intercept.**

The interpretation of is the mean of given , i.e., . This is the point where the regression line crosses the -axis.

For a given data set, the fitted regression model is written as , where is the point where the fitted regression line crosses the y-axis and is the slope of the fitted regression line.

is the estimated mean sale price if the area is set to 0.

**6. State the interpretation in words of the estimated coefficient for the area variable.**

The interpretation of is the average *difference* in the mean of per unit *difference* in .

Sometimes this is expressed as the average difference in corresponding to a 1-unit difference in , i.e.,

For a given data set, the fitted regression model is written as , where is the point where the fitted regression line crosses the y-axis and is the slope of the fitted regression line.

is the estimated average difference in sale price per unit difference in area.

**7. Add the LOT\_SIZE variable to the linear regression model (Model 2). How did the estimated coefficient for the SQFT variable change?**

summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT, data = sales\_new))$coef

## Estimate Std. Error t value Pr(>|t|)  
## (Intercept) -47566.522 12241.465236 -3.885689 0.000103666  
## SQFT 350.909 4.990453 70.316074 0.000000000

summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new))$coef

## Estimate Std. Error t value Pr(>|t|)  
## (Intercept) -32579.055135 1.278808e+04 -2.547612 1.088285e-02  
## SQFT 355.737262 5.127433e+00 69.379206 0.000000e+00  
## LOT\_SIZE -3.965089 9.978163e-01 -3.973766 7.197273e-05

The estimate of the coefficient of SQFT variable is different in the two models: The estimated value in the second model is higher.

First model: The coefficient of `SQFT’ is > 0 and statistically significant

Second model: The coefficient of `SQFT’ is > 0 and statistically significant

**8. State the interpretation of the coefficient of SQFT in Model 2.**

In the first model the coefficient of SQFT is the average difference in sales price comparing different area sizes (in sqft).

In the second model the coefficient of SQFT is interpreted as the average difference in sales price comparing different area sizes(in sqft) **having the same lot size(in sqft)**.

Due to the addition of the lot size, there is a certain amount if change in the coefficient of the Area variable however, this addition does not have a significant impact on the estimated coefficient of area i.e. the Lot size variable does not have a confounding effect.

**9. Report the R-squared values from the two models. Explain why they are different.**

summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT, data = sales\_new))

##   
## Call:  
## lm(formula = LAST\_SALE\_PRICE ~ SQFT, data = sales\_new)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -2166915 -147629 -9306 124458 3046130   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -47566.52 12241.47 -3.886 0.000104 \*\*\*  
## SQFT 350.91 4.99 70.316 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 309700 on 4063 degrees of freedom  
## Multiple R-squared: 0.5489, Adjusted R-squared: 0.5488   
## F-statistic: 4944 on 1 and 4063 DF, p-value: < 2.2e-16

summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new))

##   
## Call:  
## lm(formula = LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -2162244 -146163 -11297 119938 3333236   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -3.258e+04 1.279e+04 -2.548 0.0109 \*   
## SQFT 3.557e+02 5.127e+00 69.379 < 2e-16 \*\*\*  
## LOT\_SIZE -3.965e+00 9.978e-01 -3.974 7.2e-05 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 309100 on 4062 degrees of freedom  
## Multiple R-squared: 0.5507, Adjusted R-squared: 0.5504   
## F-statistic: 2489 on 2 and 4062 DF, p-value: < 2.2e-16

The value from the first model:.  
The value from the second model:.

For simple linear regression models, the R-squared is just the square of the Pearson correlation coefficient. For models with more than 1 predictor R-squared has an interpretation in terms of correlation between observed and fitted values and also as a percentage of variance explained by the model. The R squared values are different for the two models as one is a simple linear regression model with one variable and the other is a model having two predictors.

**10. Report the estimates of the error variances from the two models. Explain why they are different.**

The error variance is the variance of the errors , is calculated using the sum of squares of residuals:

(summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT, data = sales\_new))$sigma)\*\*2

## [1] 95895947932

(summary(lm(formula = LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new))$sigma)\*\*2

## [1] 95548117507

The estimated error variance of Model 1 is **95895947932**. The estimated error variance of Model 2 is **95548117507**.

The estimated variance basically tells you about the variance of the standard errors. The estimated variance of the first model tells us about the variance of the standard errors when we take only one predictor into consideration. The estimated variance of the second model tells us about the variance of the standard error when we take take 2 predictors ( SQFT and LOT\_SIZE) into consideration which is the reason why that the standard error variance differ for the two models.

**11. State the interpretation of the estimated error variance for Model 2.**

Estimated variance essentially tells us about the variance of the residuals. In the case of model two, there are multiple predictors. In such a case, the standard errors do not depend on just the sums of squares of the standard error but also on the sums of cross-products of the different predictor variables.

The standard error of the regression coefficient can change when a variable is added to the modeled and whether or not it changes depends on the the sum of the squares of cross - products of predictors as well as whether the estimated of error variance changes. In model two, we can see that the estimated error variance has changes, which indicates that the standard error of the regression model has also changed.

**12. Test the null hypothesis that the coefficient of the SQFT variable in Model 2 is equal to 0. (Assume that the assumptions required for the test are met.)**

The full model is

Testing that the coefficient of the SQFT variable is 0 in the model, the null hypothesis is

The reduced model is

The F-test for full model is

options(scipen = 999)  
anova(lm(LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new))#["Residuals","Sum Sq"]

## Analysis of Variance Table  
##   
## Response: LAST\_SALE\_PRICE  
## Df Sum Sq Mean Sq F value Pr(>F)  
## SQFT 1 474143156081999 474143156081999 4962.350 < 0.00000000000000022  
## LOT\_SIZE 1 1508783132972 1508783132972 15.791 0.00007197  
## Residuals 4062 388116453312974 95548117507   
##   
## SQFT \*\*\*  
## LOT\_SIZE \*\*\*  
## Residuals   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

The F-test for reduced models

anova(lm(LAST\_SALE\_PRICE ~ LOT\_SIZE, data = sales\_new))

## Analysis of Variance Table  
##   
## Response: LAST\_SALE\_PRICE  
## Df Sum Sq Mean Sq F value Pr(>F)   
## LOT\_SIZE 1 15733534826184 15733534826184 75.381 < 0.00000000000000022 \*\*\*  
## Residuals 4063 848034857701759 208721353114   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

The F-statistic is defined as:

The F-test for comparing full and reduced models

((848034857701759-388116453312974)/(4063-4062))/(388116453312974/4062)

## [1] 4813.474

The p-value obtained for the tail probability for the value **4813.474 in the F-distribution with 1 numerator df and 4062 denominator df** is:

1-pf(4813.474,1,4062)

## [1] 0

We **reject the null hypothesis** as the p value is less than the level of significance which mean that the SQFT variable is statistically significant and there is evidence for association between the SQFT and Last Sale Price.

**13. Test the null hypothesis that the coefficients of both the SQFT and LOT\_SIZE variables are equal to 0. Report the test statistic.**

The full model is

Testing that the coefficient of the SQFT and LOT\_SIZE variable is 0 in the model, the null hypothesis is

The reduced model is

The F-test for full model is

anova(lm(LAST\_SALE\_PRICE ~ SQFT + LOT\_SIZE, data = sales\_new))

## Analysis of Variance Table  
##   
## Response: LAST\_SALE\_PRICE  
## Df Sum Sq Mean Sq F value Pr(>F)  
## SQFT 1 474143156081999 474143156081999 4962.350 < 0.00000000000000022  
## LOT\_SIZE 1 1508783132972 1508783132972 15.791 0.00007197  
## Residuals 4062 388116453312974 95548117507   
##   
## SQFT \*\*\*  
## LOT\_SIZE \*\*\*  
## Residuals   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

The F-test for reduced model is

anova(lm(LAST\_SALE\_PRICE ~ 1, data = sales\_new))

## Analysis of Variance Table  
##   
## Response: LAST\_SALE\_PRICE  
## Df Sum Sq Mean Sq F value Pr(>F)  
## Residuals 4064 863768392527944 212541435169

The F-test for comparing full and reduced models

((863768392527944-388116453312974)/(4064-4062))/(388116453312974/4062)

## [1] 2489.07

The F-statistic is **2489.07 with 2 numerator df and 4062 denominator df**.

**14. What is the distribution of the test statistic under the null hypothesis (assuming model assumptions are met)?**

The F-statistic is referred to the distribution for calculation of the p-value : . This means that assuming that the model assumptions are met, we need to find the p value for the tail probability for the value 2489.07 in the F-distribution with 2 numerator df and 4062 denominator df.

**15. Report the p-value for the test in Q13.**

The p-value obtained for the tail probability for the value 2489.07 in the F-distribution with 2 numerator df and 4062 denominator df is:

1-pf(2489.07,2,4062)

## [1] 0

The p value is 0.

We **reject the null hypothesis** as the p value is less than the level of significance which mean that the SQFT and LOT\_SIZE variables are statistically significant and there is evidence for association between the SQFT, LOT\_SIZE and Last Sale Price.