STAT 592: Project 3

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Contents

Background & Objective

Given that a city tax assessor is interested in predicting residential home sales prices in a midwestern city with various characteristics, we will be conducting a **multiple linear regression analysis (MLR)** from the Real Estate Sales (APPENC07) dataset from 2002. We aim to observe and predict the relationship using the given features, ***square feet***, the absence or presence of a ***swimming pool*** and ***air conditioning***, and our response variable as ***house sales price***.

```r
#Setting up our work environment
setwd("C:/Users/RUMIL/Desktop/APU/STAT 511 - Millie Mao (Applied Regression Analysis)/Project 2")
library(nortest)
library(olsrr)
library(car)
library(lmtest)
library(MASS)
library(tidyverse)
library(ggcorrplot)
library(knitr)
#Loading in the text data
raw_data = read.table(file = "APPENC07.txt", header = FALSE, sep = "")

#Converting into tibble data frame for easier data analysis
house_data <- as_tibble(raw_data)
```

```r
#Defining and renaming our Explanatory(X) and Response(Y) variables
house_data <- house_data %>% select(sales_price = V2,
                                    square_feet = V3,
                                    swimming_pool = V8,
                                    air_conditioning = V6)

#Setting explanatory and response variables
sales_price <-  house_data %>% select(sales_price) #Y
square_feet <- house_data %>% select(square_feet) #X1
swimming_pool <- house_data %>% select(swimming_pool) #X2
air_conditioning <- house_data %>% select(air_conditioning) #X3

knitr::kable(house_data) %>% head(5)
```

```
## [1] "| sales_price| square_feet| swimming_pool| air_conditioning|"
## [2] "|-----------:|-----------:|-------------:|----------------:|"
## [3] "|      360000|        3032|             0|                1|"
## [4] "|      340000|        2058|             0|                1|"
## [5] "|      250000|        1780|             0|                1|"
```

Part 1 - Regression using a Dummy Variable

1a. Estimated regression equation from regressing sales price on swimming pool only.

```r
#Regressing sales price only on swimming pool dummy variable
pool_lm <- lm(sales_price ~ swimming_pool, data = house_data)

#summarizing linear model
summary(pool_lm)
```

```
##
## Call:
```

```
## lm(formula = sales_price ~ swimming_pool, data = house_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -188396  -94396  -46896   52604  647604
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)     272396       6195   43.97  < 2e-16 ***
## swimming_pool    79724      23589    3.38  0.00078 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 136600 on 520 degrees of freedom
## Multiple R-squared:  0.02149,    Adjusted R-squared:  0.01961
## F-statistic: 11.42 on 1 and 520 DF,  p-value: 0.0007799
```

Estimated Regression model:

$\hat{Y} = 272396 + 79724X$

1b. Interpretation of estimated intercept and slope.

Intercept: B_0 = 272396

The estimated mean Y-value when X = 0 (reference/baseline group) is 272396. When put in context, the mean sales price of a house when the property **does not** contain a swimming pool is estimated to be $272,396.

Slope: B_1 = 79724

The slope of 79724 in our model indicates the change for the sales price of a property **containing** a swimming pool, **relative** to a property **without** a swimming pool to be $352,120.

The calculations of these coefficients can be represented in this table.

Table 1: Property Sales Price With & Without Swimming Pool

$\hat{Y} = B_0 + B_1X_1$	Swimming Pool = No	Swimming Pool = Yes
$\hat{Y} = 77.375 + 8.750X$	$\hat{Y} = 272396 + 79724(0)$	$\hat{Y} = 272396 + 79724(1)$
	= 272396	= 272396+ 79724
Estimated Mean Sales Price	**$272,396**	**$352,120**

1c. Hypothesis test on the significance of the slope coefficient.

Using a significance level of $\alpha = 0.05$.

Null Hypothesis: H_0: $\beta_j = 0$ (slopes are showing no change), X_j is not linearly associated with Y, therefore the partial slope is not significant.

Alternative Hypothesis: H_1: $\beta_j \neq 0$ (slopes are showing change), X_j is linearly associated with Y, therefore the partial slope is significant.

Testing the significance of a property **with** a swimming pool ($\hat{\beta}_1 = 79724$)

Conclusion and Decision Rule using p-value:

Because the **p-value** for having a swimming pool is [1] 0.00078 and is significantly smaller than $\alpha = 0.05$, we reject our NULL hypothesis and conclude that our partial slope, that a property **containing** a swimming pool in reference to one **without a swimming pool**, shows statistical significance in our model.

Part 2 - Fitting a MLR model with the Interaction Term of a Dummy and Continuous Variable

2a. Regressing sales price on the (1)swimming pool dummy variable, (2)area of residence, and the (3)interaction between these two variables.

```
pool_sqft_lm <- lm(sales_price ~ swimming_pool +
                                     square_feet +
                                     swimming_pool * square_feet,
                                     data = house_data)
summary(pool_sqft_lm)
```

```
##
## Call:
## lm(formula = sales_price ~ swimming_pool + square_feet + swimming_pool *
##     square_feet, data = house_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -247193  -40579   -7542   24476  384051
##
## Coefficients:
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)               -88538.996  12063.237  -7.340 8.34e-13 ***
## swimming_pool             105909.972  47262.735   2.241   0.0255 *
## square_feet                  161.910      5.168  31.331  < 2e-16 ***
## swimming_pool:square_feet    -37.213     17.102  -2.176   0.0300 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 78890 on 518 degrees of freedom
## Multiple R-squared:  0.6747, Adjusted R-squared:  0.6728
## F-statistic: 358.1 on 3 and 518 DF,  p-value: < 2.2e-16
```

Estimated regression equation for each kind of property:

$\hat{Y} = -88538.996 + 105909.972X + 161.910Y - 37.213(X * Y)$

note variables:

X = Swimming pool

Y = Square feet

X * Y = Interaction of swimming pool and square feet

Table 2: Calculating Estimated Regression Equations for Properties With and Without Pools

$\hat{Y} = B_0 + B_1X + B_2Y + B_3(X*Y)$	Swimming Pool = No	Swimming Pool = Yes
$\hat{Y} = -88538.996 + 105909.972X + 161.910Y - 37.213(X*Y)$	$\hat{Y} = -88538.996 + 105909.972(0) + 161.910Y - 37.213(0*Y)$ $= -88538.996 + 161.910Y$	$\hat{Y} = -88538.996 + 105909.972(1) + 161.910Y - 37.213(1*Y)$ $= -88538.996 + 105909.972 + 161.910Y - 37.213(Y)$ $= 17370.976 + 124.697Y$
Estimated Regression Equations	$= -88538.996 + 161.910Y$	$= 17370.976 + 124.697Y$

2b. Plotting Fitted regression lines

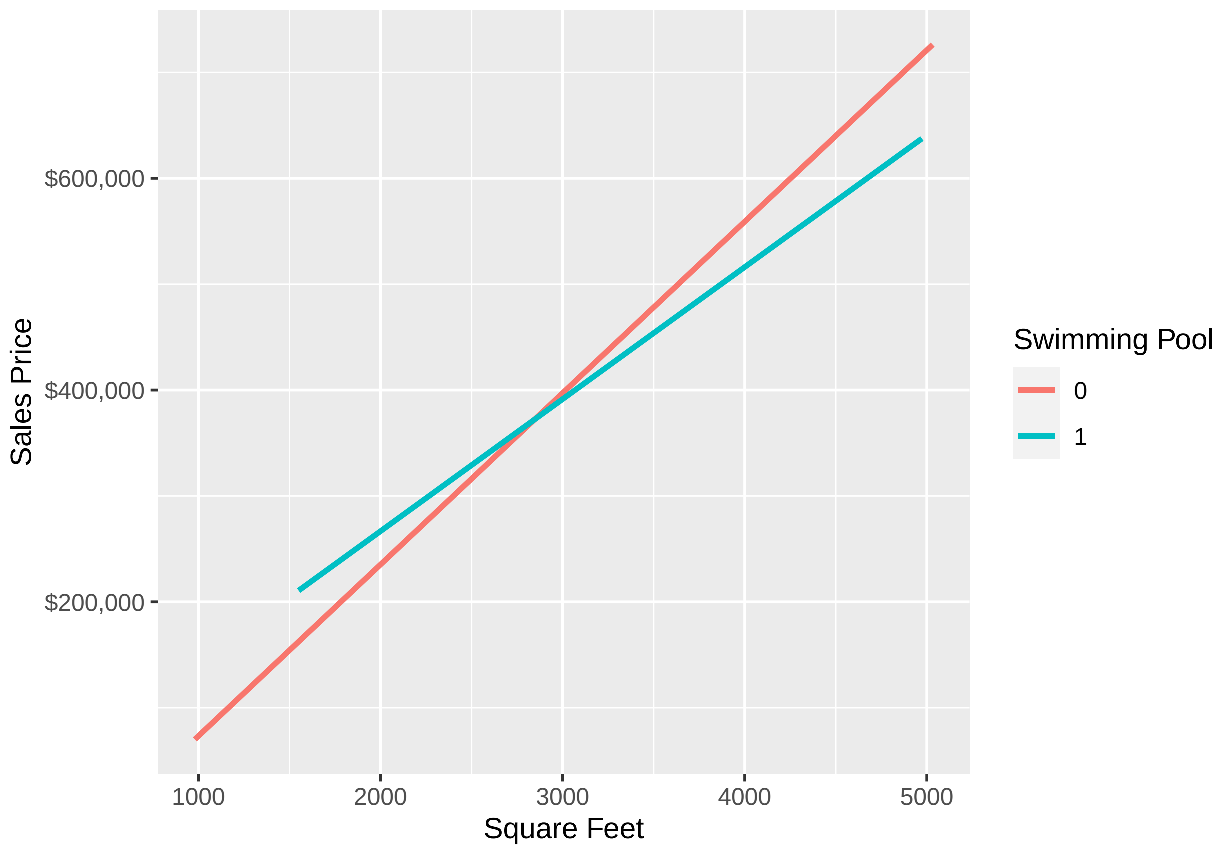
```
#no_pool <- house_data %>%
           #select(swimming_pool == 0)
# Code to plot regression equations model:
plot_coef <- house_data %>%

  ggplot(aes(x = square_feet, y = sales_price, color = as.factor(swimming_pool))) +

  geom_smooth(method = "lm", se = FALSE) +
  labs(x = "Square Feet", y = "Sales Price", color = "Swimming Pool")+
  scale_y_continuous(labels = scales::dollar)


plot_coef
```

```
## `geom_smooth()` using formula 'y ~ x'
```



To find the value at which these two lines intersect algebraically by can setting equal to one another, solving for one variable then plugging that back into the equation to get the other variable to obtain the coordinates.

The point of intersection of these two lines are when the values of: **Square feet is 2846.04 and sales price = 372264.58**.

2c. Testing if the two regression lines are parallel.

***Nested F-test?

Using a significance level of $\alpha = 0.05$.

Null Hypothesis: H_0: $\beta_c = 0$ The coefficient of the interaction term is 0.

Alternative Hypothesis: H_1: $\beta_c \neq 0$ The coefficient of the interaction term is nonzero.

Testing the significance of a property **with** a swimming pool ($\hat{\beta}_1 = 79724$)

Conclusion and Decision Rule using p-value:

Looking at our model summary, we see that the p-value of our interaction term is [1]0.0300 which means we **reject** NULL hypothesis and ***conclude with our alternative hypothesis and that our regression lines are not parallel and a relationship exists between the two lines (because the interaction coefficient is not 0)

Part 3 - MLR Only with the Interaction of Dummy Variables

3a. Fitting a MLR on both Swimming Pool and AC dummy variables and the estimated regression equation.

```
#Regressing house sales price on both dummy variables: swimming pool and AC, plus their interaction


pool_ac_lm <- lm(sales_price ~ swimming_pool +
                              (air_conditioning) +
                               swimming_pool * air_conditioning,
                               data = house_data)

summary(pool_ac_lm)
```

```
##
## Call:
## lm(formula = sales_price ~ swimming_pool + (air_conditioning) +
##     swimming_pool * air_conditioning, data = house_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -181752  -92704  -35504   44546  629546
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    189578.2    14087.8  13.457  < 2e-16 ***
## swimming_pool                     421.8   132154.9   0.003    0.997
## air_conditioning               100875.8    15548.0   6.488 2.03e-10 ***
## swimming_pool:air_conditioning  65876.5   134169.7   0.491    0.624
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 131400 on 518 degrees of freedom
## Multiple R-squared:  0.09756,    Adjusted R-squared:  0.09233
## F-statistic: 18.67 on 3 and 518 DF,  p-value: 1.642e-11
```

```
#testing to see why interaction term is insignificant
count_with_pools <- house_data %>% select(swimming_pool) %>%
               filter(swimming_pool == 1) %>%
                count()
count_with_pools
```

```
## # A tibble: 1 x 1
##       n
##   <int>
## 1    36
```

```
count_no_pools <- house_data %>% select(swimming_pool) %>%
               filter(swimming_pool == 0 ) %>%
                count()

count_no_pools
```

```
## # A tibble: 1 x 1
##       n
##   <int>
## 1   486
```

Estimated regression equation for each kind of property:

$\hat{Y} = 189578.2 + 421.8X + 100875.8Z - 65876.5(X * Z)$

note variables:

X = Swimming pool

Z = Air conditioning

X * Z = Interaction of swimming pool and air conditioning

3c. Calculating estimated mean sales prices for 4 types of properties:

-1. No swimming pool and no AC

```r
#Coding in our variables based on its absence or presence
x = 0
z = 0

#Running our regression formula with our coded variables
reg_eq_1 <- 189578.2 + 421.8*x + 100875.8*z - 65876.5*x*z

#printing
reg_eq_1
```

```
## [1] 189578.2
```

The estimated mean sales price of a property without a swimming pool and AC is $189,578.2.

-2. No swimming pool and has AC

```r
#Coding in our variables based on its absence or presence
x = 0
z = 1

#Running our regression formula with our coded variables
reg_eq_2 <- 189578.2 + 421.8*x + 100875.8*z - 65876.5*x*z

#printing
reg_eq_2
```

```
## [1] 290454
```

The estimated mean sales price of a property without a swimming pool but has AC is $290,454.

-3. Has swimming pool and no AC

```r
#Coding in our variables based on its absence or presence
x = 1
z = 0

#Running our regression formula with our coded variables
reg_eq_3 <- 189578.2 + 421.8*x + 100875.8*z - 65876.5*x*z

#printing
reg_eq_3
```

```
## [1] 190000
```

The estimated mean sales price of a property with a swimming pool and no AC is $190,000.

-4. Has swimming pool and has AC

```r
#Coding in our variables based on its absence or presence
x = 1
z = 1

#Running our regression formula with our coded variables
reg_eq_4 <- 189578.2 + 421.8*x + 100875.8*z - 65876.5*x*z

#printing
reg_eq_4
```

```
## [1] 224999.3
```

The estimated mean sales price of a property with a swimming pool and AC is $224,999.3.