HW6_MATH4322

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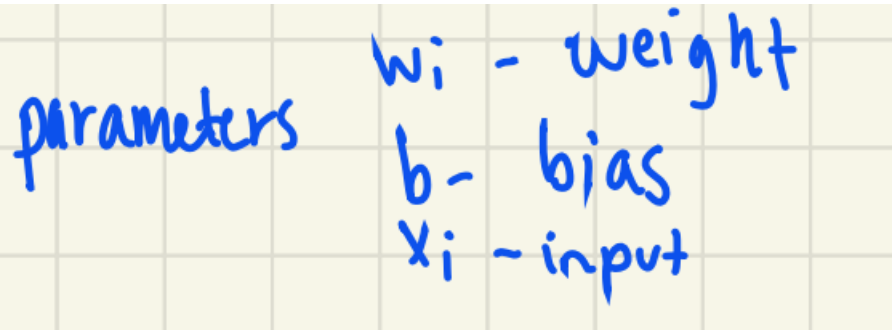
Question 1 (a):

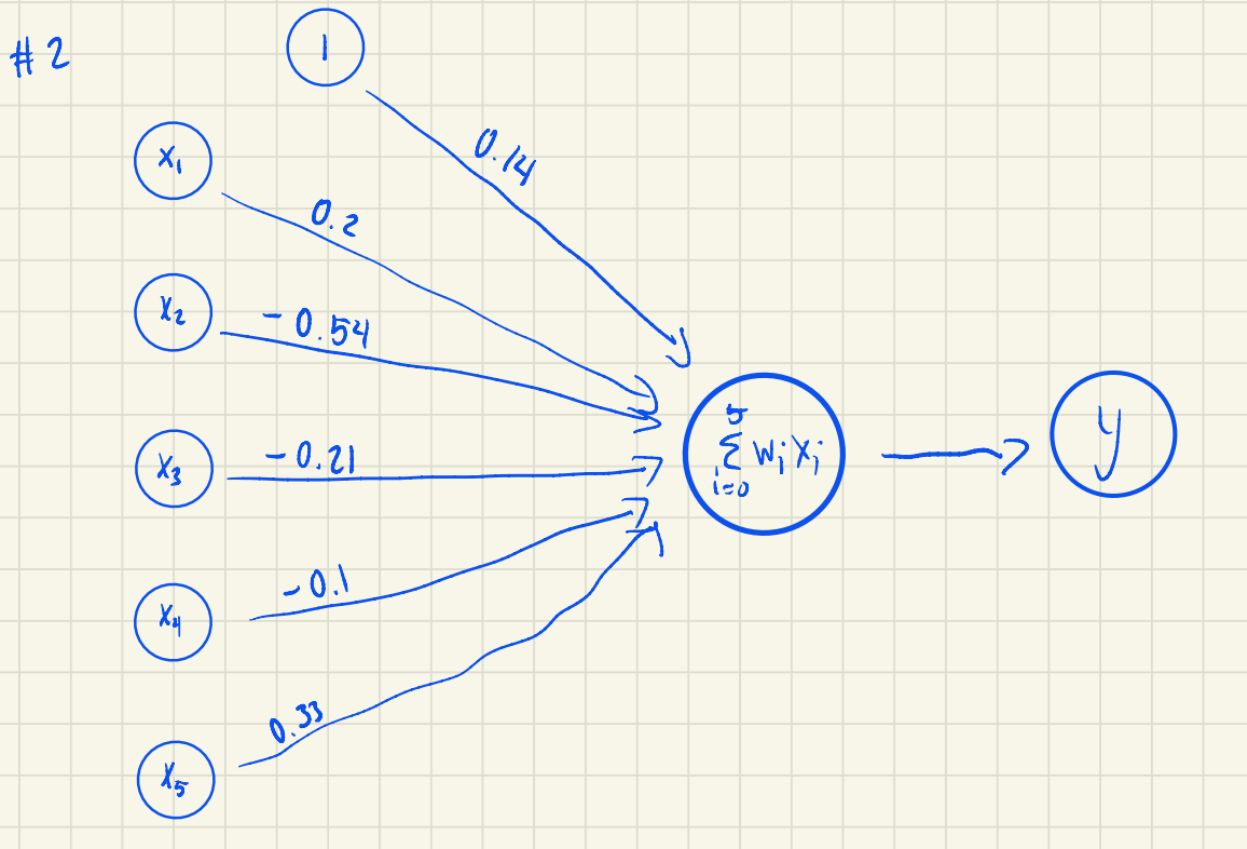
$$y = b + \sum_{i=1}^{b} w_i x_i$$



Question 1 (b):
need the analytical solution in order to minimize the error

Question 1 (c):
Gradient Descent

Question 2 (a):



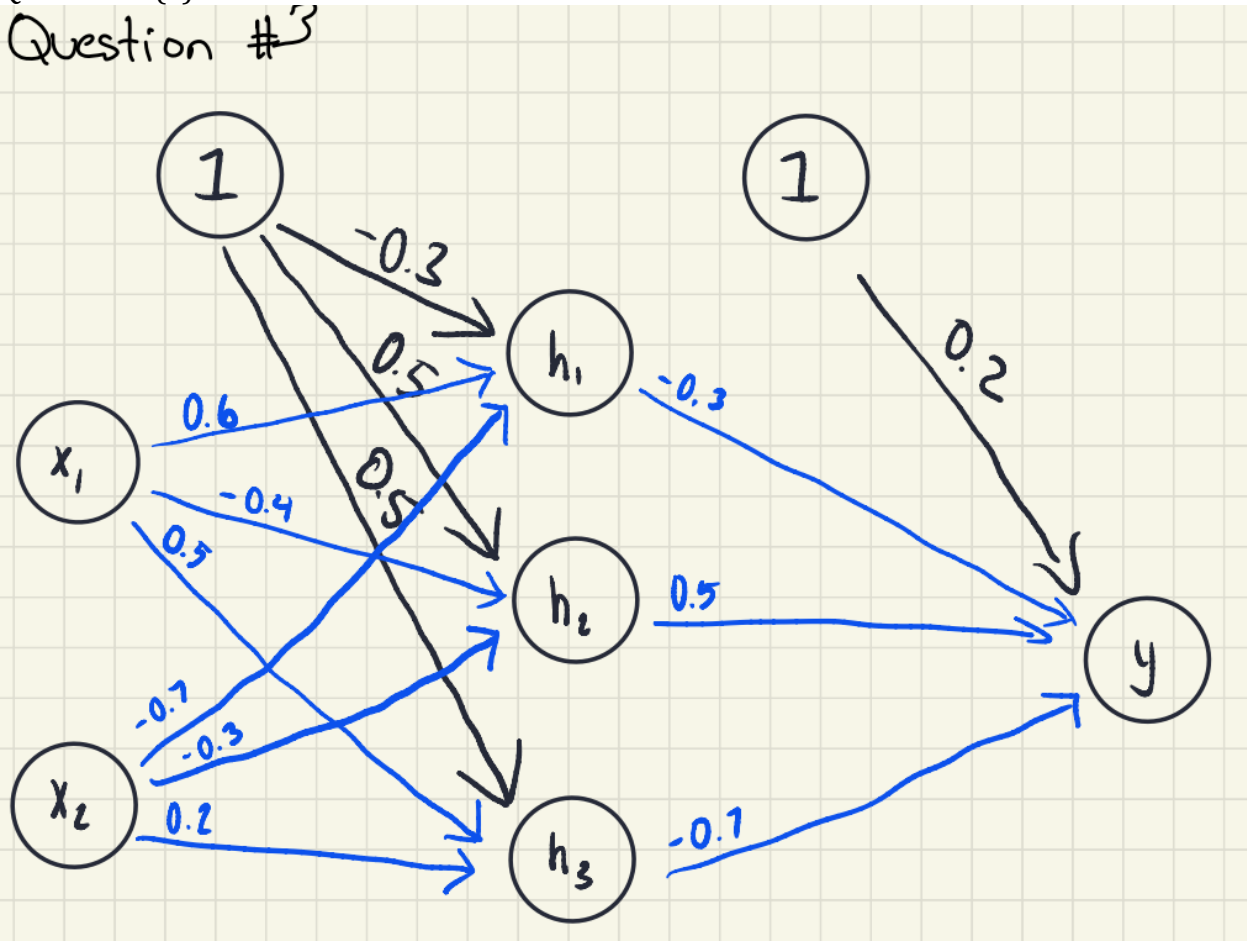
Question 2 (b):

```
y_hat <-0.14+0.2*4-0.54*-3-0.21*7-0.1*5+0.33*-1
```

$$\hat{y} = 0.14 + 0.2 X_1 - 0.54 X_2 - 0.21 X_3 - 0.1 X_4 + 0.33 X_5$$

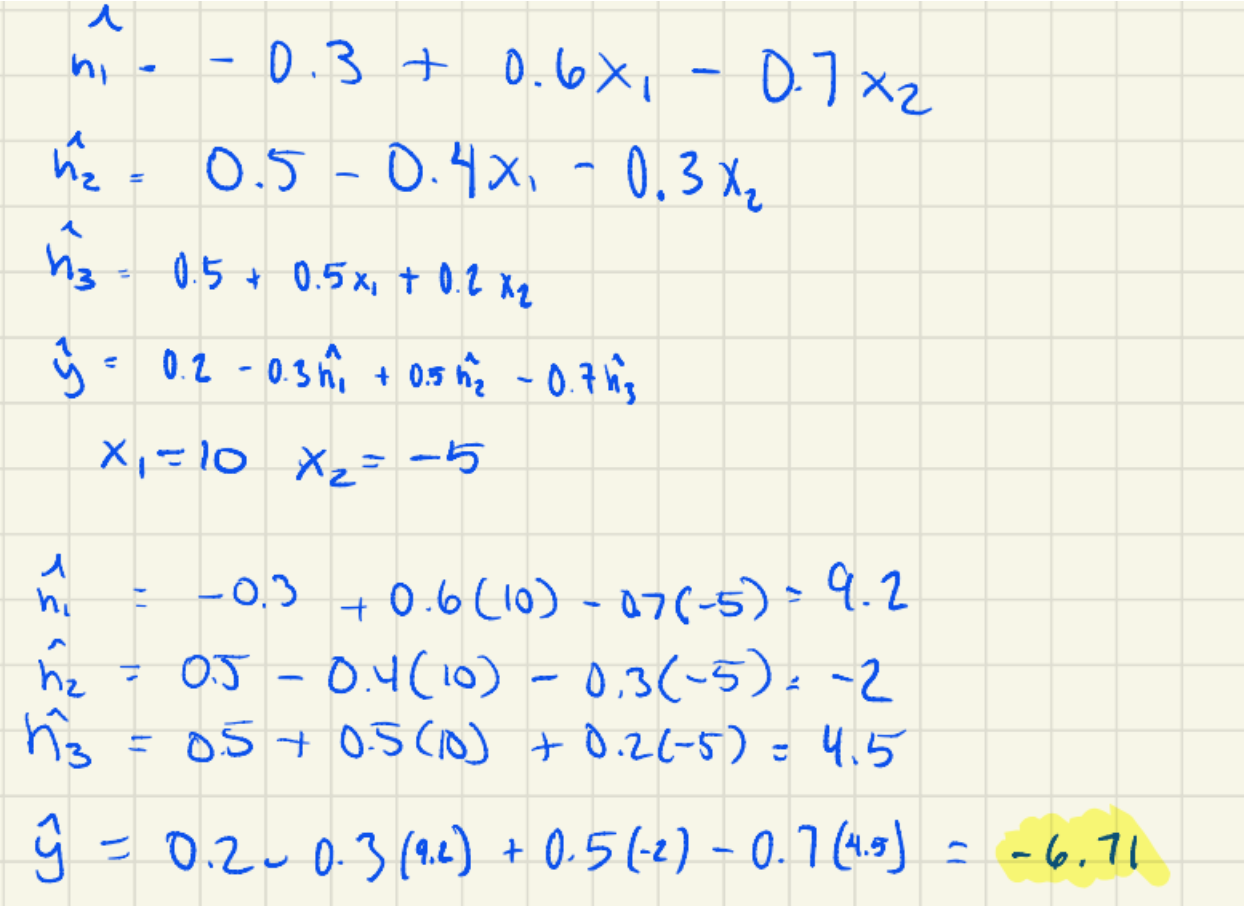
$$\hat{y} = 0.14 + 0.2(4) - 0.54(-3) - 0.21(7) - 0.1(5) + 0.33(-1) = .26$$

Question 3 (a):



Question 3 (b):

```
h1 <- -0.3+0.6*10-0.7*-5
h2 <- 0.5-0.4*10-0.3*-5
h3 <- 0.5+0.5*10+0.2*-5
y <- 0.2-0.3*9.2+0.5*-2-0.7*4.5
```



Question 4 (a):

```
library(neuralnet)
library(MASS)

data <- Boston
summary(data)
```

```
##       crim                zn              indus            chas        
##  Min.   : 0.00632   Min.   :  0.00   Min.   : 0.46   Min.   :0.00000  
##  1st Qu.: 0.08205   1st Qu.:  0.00   1st Qu.: 5.19   1st Qu.:0.00000  
##  Median : 0.25651   Median :  0.00   Median : 9.69   Median :0.00000  
##  Mean   : 3.61352   Mean   : 11.36   Mean   :11.14   Mean   :0.06917  
##  3rd Qu.: 3.67708   3rd Qu.: 12.50   3rd Qu.:18.10   3rd Qu.:0.00000  
##  Max.   :88.97620   Max.   :100.00   Max.   :27.74   Max.   :1.00000  
##       nox                rm              age              dis        
##  Min.   :0.3850   Min.   :3.561   Min.   :  2.90   Min.   : 1.130  
##  1st Qu.:0.4490   1st Qu.:5.886   1st Qu.: 45.02   1st Qu.: 2.100  
##  Median :0.5380   Median :6.208   Median : 77.50   Median : 3.207  
##  Mean   :0.5547   Mean   :6.285   Mean   : 68.57   Mean   : 3.795  
##  3rd Qu.:0.6240   3rd Qu.:6.623   3rd Qu.: 94.08   3rd Qu.: 5.188  
##  Max.   :0.8710   Max.   :8.780   Max.   :100.00   Max.   :12.127
```

```
##       rad              tax           ptratio          black       
##  Min.   : 1.000   Min.   :187.0   Min.   :12.60   Min.   :  0.32  
##  1st Qu.: 4.000   1st Qu.:279.0   1st Qu.:17.40   1st Qu.:375.38  
##  Median : 5.000   Median :330.0   Median :19.05   Median :391.44  
##  Mean   : 9.549   Mean   :408.2   Mean   :18.46   Mean   :356.67  
##  3rd Qu.:24.000   3rd Qu.:666.0   3rd Qu.:20.20   3rd Qu.:396.23  
##  Max.   :24.000   Max.   :711.0   Max.   :22.00   Max.   :396.90  
##      lstat            medv      
##  Min.   : 1.73   Min.   : 5.00  
##  1st Qu.: 6.95   1st Qu.:17.02  
##  Median :11.36   Median :21.20  
##  Mean   :12.65   Mean   :22.53  
##  3rd Qu.:16.95   3rd Qu.:25.00  
##  Max.   :37.97   Max.   :50.00
```

mean of variable age is 68.57
mean of variable ptratio is 18.46
Question 4 (b):

```
max_data = apply(data,2,max)
min_data = apply(data,2,min)
data_scaled <- scale(data, center = min_data,
                     scale = max_data-min_data)
head(data_scaled)
```

```
##           crim   zn      indus chas       nox        rm       age
dis
## 1 0.0000000000 0.18 0.06781525    0 0.3148148 0.5775053 0.6416066
0.2692031
## 2 0.0002359225 0.00 0.24230205    0 0.1728395 0.5479977 0.7826982
0.3489620
## 3 0.0002356977 0.00 0.24230205    0 0.1728395 0.6943859 0.5993821
0.3489620
## 4 0.0002927957 0.00 0.06304985    0 0.1502058 0.6585553 0.4418126
0.4485446
## 5 0.0007050701 0.00 0.06304985    0 0.1502058 0.6871048 0.5283213
0.4485446
## 6 0.0002644715 0.00 0.06304985    0 0.1502058 0.5497222 0.5746653
0.4485446
##          rad        tax   ptratio     black      lstat      medv
## 1 0.00000000 0.20801527 0.2872340 1.0000000 0.08967991 0.4222222
## 2 0.04347826 0.10496183 0.5531915 1.0000000 0.20447020 0.3688889
## 3 0.04347826 0.10496183 0.5531915 0.9897373 0.06346578 0.6600000
## 4 0.08695652 0.06679389 0.6489362 0.9942761 0.03338852 0.6311111
## 5 0.08695652 0.06679389 0.6489362 1.0000000 0.09933775 0.6933333
## 6 0.08695652 0.06679389 0.6489362 0.9929901 0.09602649 0.5266667
```

obs#1 medv = 0.4222222

Question 4 (c):

```
set.seed(10)
index <- sample(1:nrow(data), round(0.7*nrow(data)))
train_data <- as.data.frame(data_scaled[index,])
test_data <- as.data.frame(data_scaled[-index,])
dim(train_data)
```

```
## [1] 354  14
```

```
dim(test_data)
```

```
## [1] 152  14
```

training set has 354 observations

Question 4 (d):

```
set.seed(1)
net_data <- neuralnet(medv~.,
                      data = train_data,
                      hidden = 10,
                      linear.output = TRUE)
plot(net_data)

predict_net <- predict(net_data,test_data)
predict_net_start <- predict_net*(max(data$medv) - min(data$medv)) +
min(data$medv)
test_data_start <- test_data$medv*(max(data$medv) - min(data$medv)) +
min(data$medv)
#test MSE
sum((predict_net_start - test_data_start)^2)/nrow(test_data)
```

```
## [1] 15.37819
```

Question 4 (e):

```
lm.boston <- lm(medv~.,
                data = data,
                subset = index)
summary(lm.boston)
```

```
##
## Call:
## lm(formula = medv ~ ., data = data, subset = index)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
```

```
## -13.981  -3.029  -0.529   1.882  25.349
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.073e+01  6.167e+00   6.606 1.53e-10 ***
## crim        -9.253e-02  5.445e-02  -1.700 0.090140 .
## zn           4.810e-02  1.737e-02   2.769 0.005936 **
## indus       -6.504e-04  8.068e-02  -0.008 0.993573
## chas         2.910e+00  1.124e+00   2.589 0.010045 *
## nox         -1.948e+01  4.636e+00  -4.202 3.39e-05 ***
## rm           3.203e+00  5.057e-01   6.333 7.60e-10 ***
## age          1.022e-02  1.627e-02   0.628 0.530150
## dis         -1.481e+00  2.454e-01  -6.033 4.20e-09 ***
## rad          2.948e-01  8.303e-02   3.551 0.000439 ***
## tax         -1.227e-02  4.786e-03  -2.564 0.010775 *
## ptratio     -9.461e-01  1.678e-01  -5.638 3.61e-08 ***
## black        9.767e-03  3.464e-03   2.819 0.005094 **
## lstat       -5.385e-01  6.229e-02  -8.646  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.989 on 340 degrees of freedom
## Multiple R-squared:  0.7062, Adjusted R-squared:  0.6949
## F-statistic: 62.85 on 13 and 340 DF,  p-value: < 2.2e-16

train <- data[index,]
test <- data[-index,]
predict_lm <- predict(lm.boston,test)
predict_lm_train <- predict(lm.boston,train)
#test MSE
sum((predict_lm - test$medv)^2)/nrow(test)

## [1] 17.77379

#train MSE
sum((predict_lm_train - train$medv)^2)/nrow(train)

## [1] 23.91002
```