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# Programming Assignment 2: Report

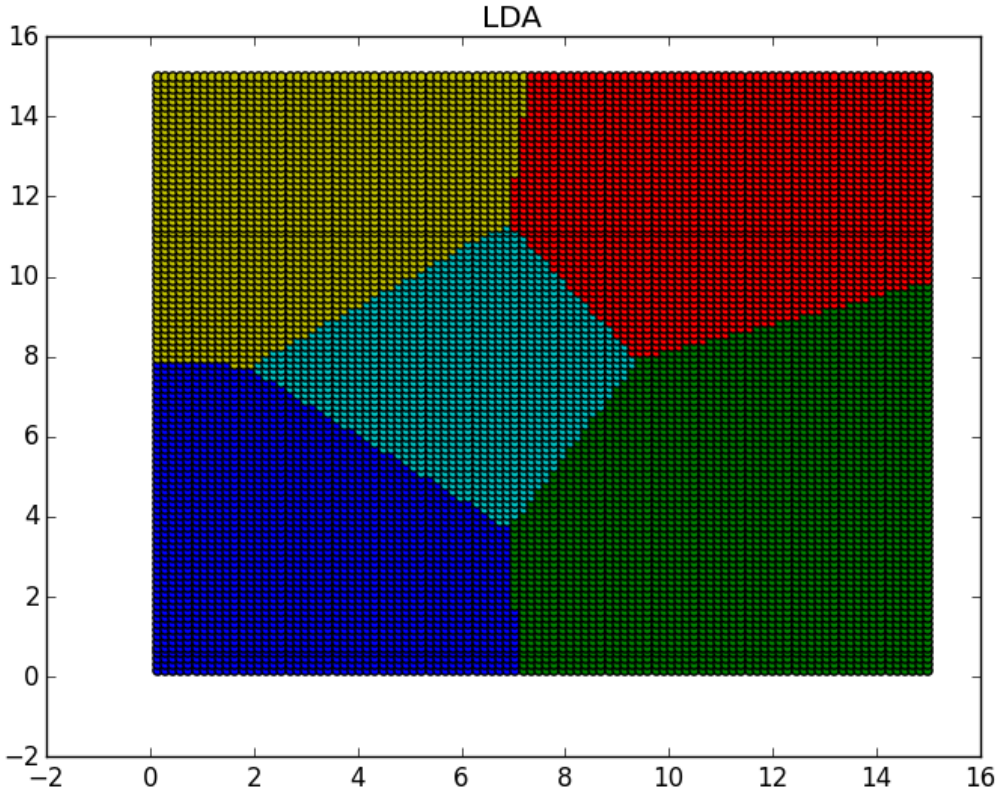
## Classification and Regression

## Problem 1. Experiment with Gaussian discriminators

Accuracy for LDA = **97%**

Accuracy for QDA = **96%**

The discriminating boundaries for LDA and QDA are plotted in the graphs shown below. The difference in the plot between LDA and QDA is due to the fact that LDA uses covariance of the data and QDA uses covariance of each class in generating the prediction.




**Discriminating Boundary for LDA**

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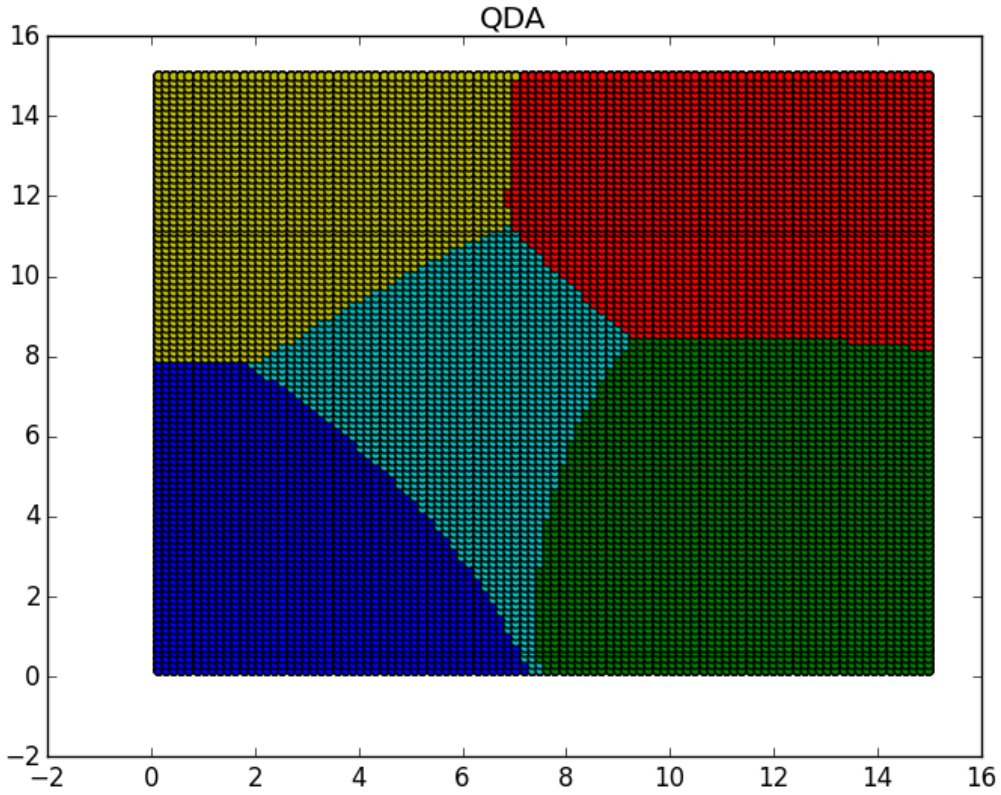


**Discriminating Boundary for QDA**

## Problem 2. Experiment with Linear Regression

### RMSE for Training Data

1. **without** intercept : 8.88388057
2. **with** intercept : 3.00630212

### RMSE for Test Data

1. **without** intercept : 23.10577434
2. **with** intercept : 4.30571724

The OLE with using intercept is better when compared with without using intercept since the smaller the RMSE, the better it is. It can be seen that the RMSE value with using intercept is lesser for both training and testing data.

## Problem 3. Experiment with Ridge Regression

### RMSE using OLE with intercept

1. Training data: 3.00630212
2. Testing data: 4.30571724

### RMSE using Ridge Regression with intercept

1. Training data: 3.785409
2. Testing data: 3.226964

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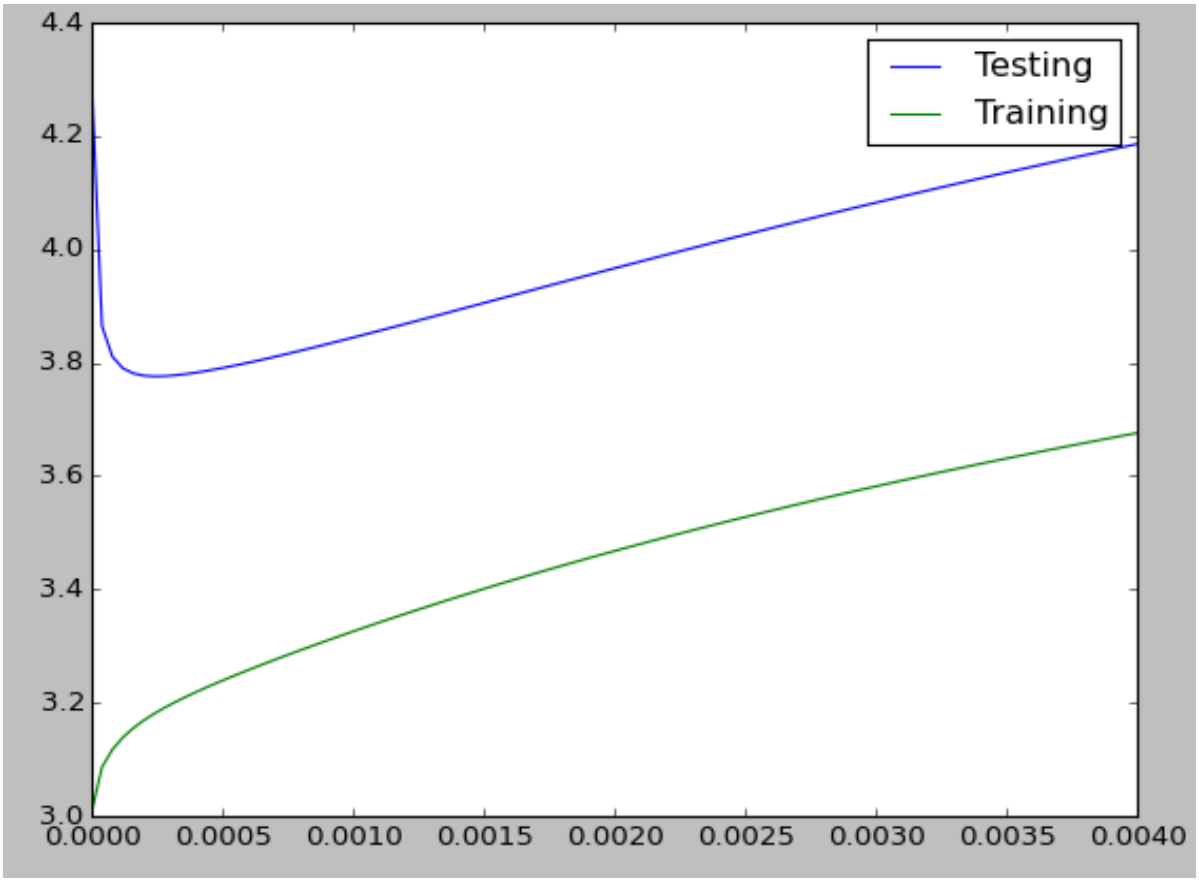
The Ridge regression is better when compared with OLE regression with using intercept since it can be seen that the RMSE value for testing data is lesser for ridge regression than the OLE regression.

The optimal value for lambda: **0.00024**. This value is chosen because the RMSE for the testing data starts to converge for at this position.

| Lambda | Testing Error | Training Error |
|---|---|---|
| 0 | 4.305717 | 3.006302 |
| 4.00E-05 | 3.864623 | 3.086167 |
| 8.00E-05 | 3.810497 | 3.117267 |
| 0.00012 | 3.790013 | 3.138688 |
| 0.00016 | 3.780952 | 3.155187 |
| 0.0002 | 3.777029 | 3.168816 |
| **0.00024** | **3.775823** | **3.180627** |
| 0.00028 | 3.77622 | 3.191217 |
| 0.00032 | 3.777644 | 3.200949 |
| 0.00036 | 3.779769 | 3.210056 |
| 0.0004 | 3.782399 | 3.218692 |
| 0.00044 | 3.785409 | 3.226964 |

**Errors on Training and Test Data Vs Lambda**



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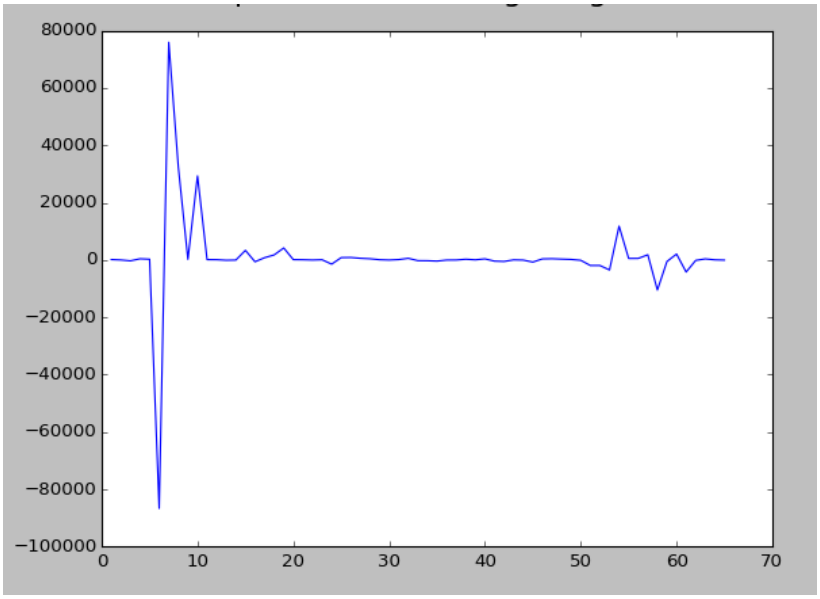
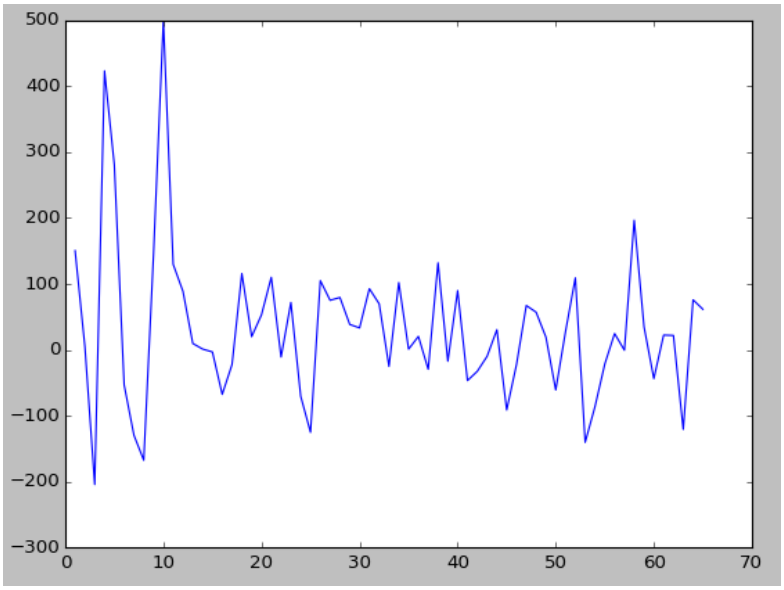
It can be observed from the mean weight of OLE and Ridge regression for the lambda value 0.00024 that Ridge regression is better since it has lesser mean weight.

## Comparison of Relative weights learnt using OLE and Ridge regression:

| | Weights using OLE | Weights using ridge regression |
|---|---|---|
| **Mean** | **882.81** | **32.19** |




**Weights learnt using OLE Regression for data with intercept**




**Weights learnt using Ridge Regression for data with intercept**

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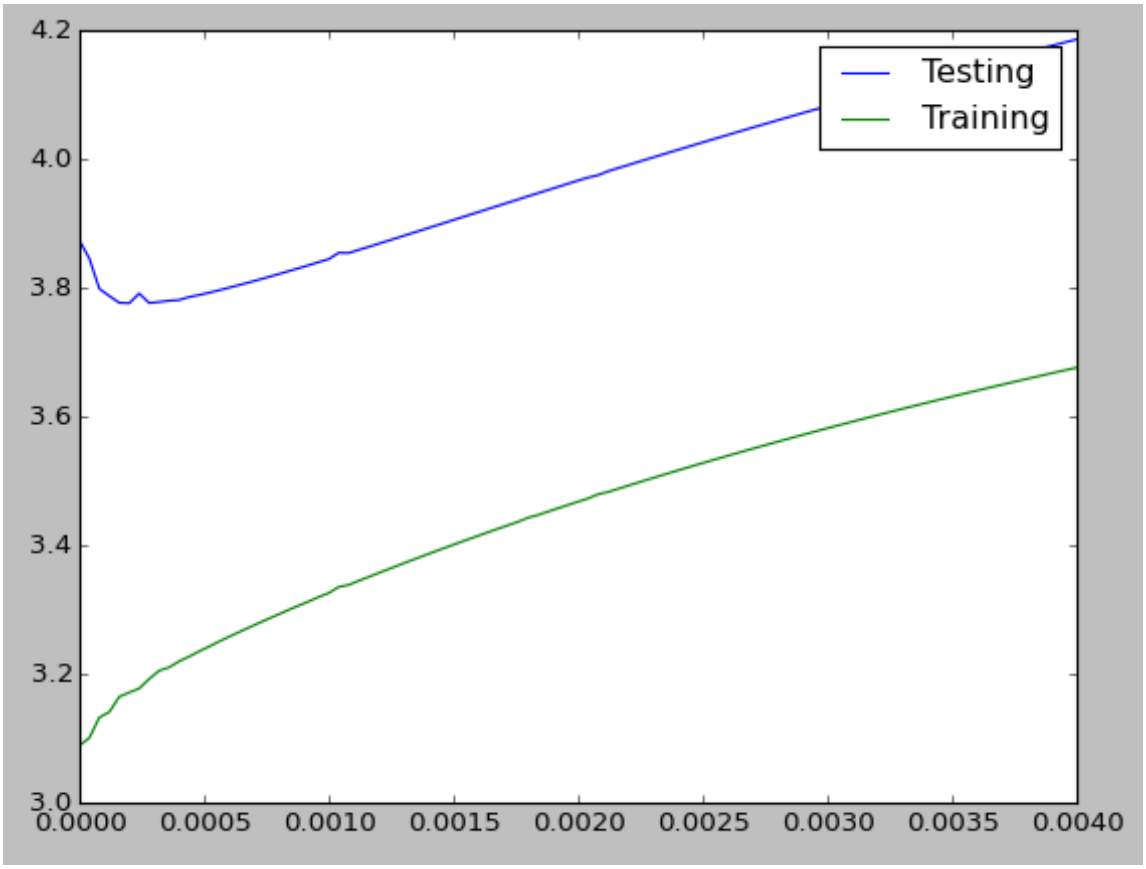
## Problem 4. Ridge Regression using Gradient Descent

From the graphs plotted for the training and testing set for Ridge Regression and Gradient descent based Ridge regression it can be observed that the RMSE doesn't vary too much. Similarly it can be observed that there is not much deviation among optimal lambda values for both.




**Comparison of lambda vs training and testing error**

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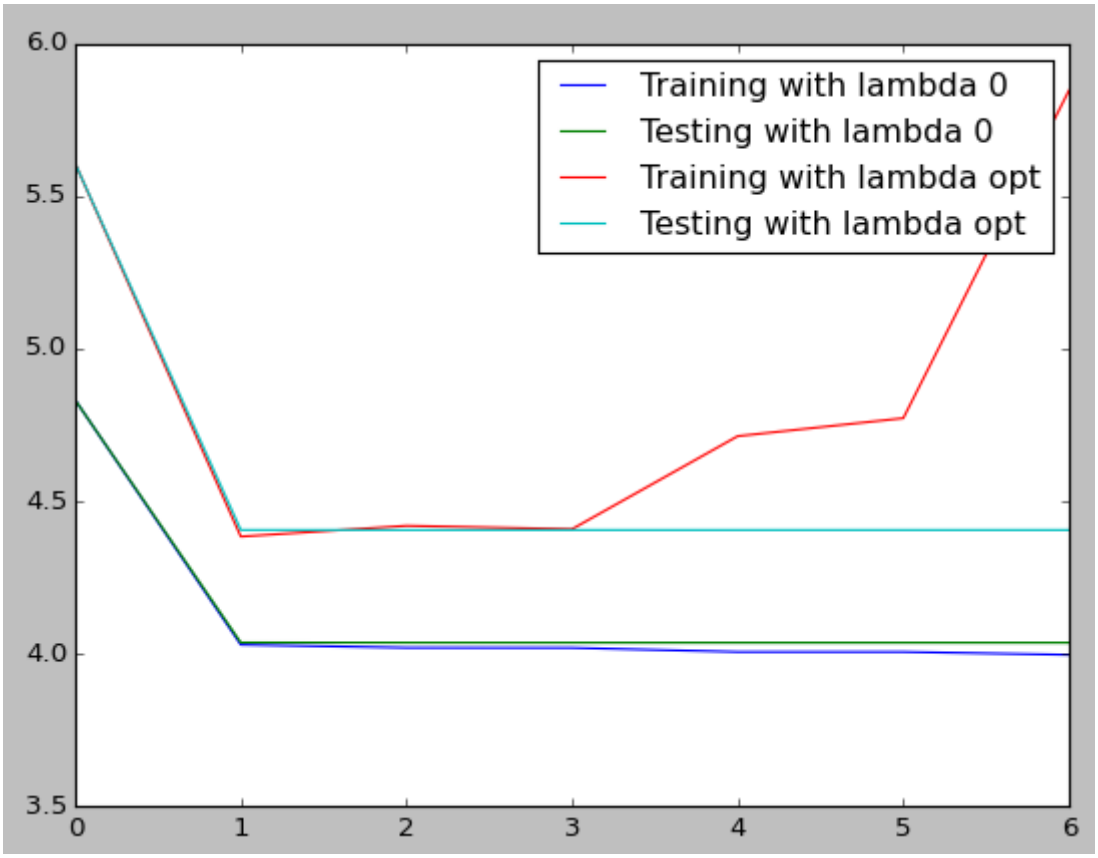
## Problem 5. Non-Linear Regression




**Comparison of p values against training and testing error with lambda value 0 and optimal value (0.00024)**

| p | Train Errors with zero lambda | Test Error zero lambda | p | Train Errors with optimal lambda | Test Error optimal lambda |
|---|---|---|---|---|---|
| 0 | 4.83218828 | 4.83218866 | 0 | 5.60642702 | 5.60659858 |
| 1 | 4.03031662 | 4.03759718 | 1 | 4.38465206 | 4.40623928 |
| 2 | 4.02052568 | 4.03690644 | 2 | 4.41991408 | 4.40616766 |
| 3 | 4.02019112 | 4.03690408 | 3 | 4.40906767 | 4.40616843 |
| 4 | 4.00695319 | 4.03690397 | 4 | 4.71345303 | 4.40616843 |
| 5 | 4.0069192 | 4.03690396 | 5 | 4.77222714 | 4.40616843 |
| 6 | 3.99735628 | 4.03690396 | 6 | 5.84527978 | 4.40616843 |

It can be observed from the graph and table that the test data optimal **p is 5** when lambda=0 and **p is 3** when lambda = 0.00024 (optimal value).

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## Problem 6. Interpreting Results

**OLE Regression:**

**RMSE for Training data without** intercept: 8.88388057

**RMSE for Training data with** intercept: 3.00630212

**RMSE for Test data without** intercept: 23.10577434

**RMSE for Test data with** intercept: 4.30571724

**Ridge Regression (lambda=0.00024)**

Training error: 3.180627

Testing Error: 3.775823

**Non-Linear**

| | **Training error** | **Testing Error** |
|---|---|---|
| (p=3) | 4.40906767 | 4.40616843 |
| (p=5) | 4.0069192 | 4.03690396 |

## Conclusion:

Based on RMSE (error) values for training and testing data in various methods, it can be seen that OLE regression with intercept is better for training data and Ridge Regression is better for testing data. By computing average error for training and testing for the above methods, it can be seen that the ridge regression or ridge regression with gradient descent is the best approach in terms of training and testing error.