

## Machine Learning HW 5

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**Exercise 1** - Done, files included separately

**Exercise 2** -

- a) According to sklearn, alpha values must be greater than 0, and l1 ratio is valid from 0 to 1, so L1 and L2 weights with L1 = 0, and L1 > L2 were excluded.

Alphas were calculated to be L1 + L2, L1\_Ratio to be L1/alpha

b)

---Training Data---

Lambda1: 1e-06 Lambda2: 1e-06 MSE 339.90590946744516  
Lambda1: 1e-06 Lambda2: 1e-05 MSE 340.1233224738352  
Lambda1: 1e-06 Lambda2: 0.0001 MSE 343.4879299581253  
Lambda1: 1e-06 Lambda2: 0.001 MSE 356.12746426962144  
Lambda1: 1e-06 Lambda2: 0.01 MSE 370.93686275161025  
Lambda1: 1e-06 Lambda2: 0.1 MSE 382.9556949732654  
Lambda1: 1e-06 Lambda2: 1 MSE 396.36954517360397  
Lambda1: 1e-05 Lambda2: 1e-05 MSE 340.12587178852533  
Lambda1: 1e-05 Lambda2: 0.0001 MSE 343.4925540952204  
Lambda1: 1e-05 Lambda2: 0.001 MSE 356.13006088693203  
Lambda1: 1e-05 Lambda2: 0.01 MSE 370.9378818650156  
Lambda1: 1e-05 Lambda2: 0.1 MSE 382.9560812834793  
Lambda1: 1e-05 Lambda2: 1 MSE 396.3696715914269  
Lambda1: 0.0001 Lambda2: 0.0001 MSE 343.53910148248417  
Lambda1: 0.0001 Lambda2: 0.001 MSE 356.1561453117938  
Lambda1: 0.0001 Lambda2: 0.01 MSE 370.94807642421875  
Lambda1: 0.0001 Lambda2: 0.1 MSE 382.9599448487168  
Lambda1: 0.0001 Lambda2: 1 MSE 396.37093581869317  
Lambda1: 0.001 Lambda2: 0.001 MSE 356.4210630272975  
Lambda1: 0.001 Lambda2: 0.01 MSE 371.0505198158496  
Lambda1: 0.001 Lambda2: 0.1 MSE 382.99863096758645  
Lambda1: 0.001 Lambda2: 1 MSE 396.3835529946156  
Lambda1: 0.01 Lambda2: 0.01 MSE 372.0667951903921  
Lambda1: 0.01 Lambda2: 0.1 MSE 383.38945801173185  
Lambda1: 0.01 Lambda2: 1 MSE 396.50904403422277  
Lambda1: 0.1 Lambda2: 0.1 MSE 387.10068406119956  
Lambda1: 0.1 Lambda2: 1 MSE 397.6482132873825  
Lambda1: 1 Lambda2: 1 MSE 406.96508441603856

c)

---Validation Data---

Lambda1: 1e-06 Lambda2: 1e-06 MSE 371.4143620482267  
Lambda1: 1e-06 Lambda2: 1e-05 MSE 371.3763446961938

Lambda1: 1e-06 Lambda2: 0.0001 MSE 373.3194797559115  
Lambda1: 1e-06 Lambda2: 0.001 MSE 380.2057516795013  
Lambda1: 1e-06 Lambda2: 0.01 MSE 389.6773298174837  
Lambda1: 1e-06 Lambda2: 0.1 MSE 399.7673241123965  
Lambda1: 1e-06 Lambda2: 1 MSE 412.87606086846137  
Lambda1: 1e-05 Lambda2: 1e-05 MSE 371.37752953766096  
Lambda1: 1e-05 Lambda2: 0.0001 MSE 373.32397912045417  
Lambda1: 1e-05 Lambda2: 0.001 MSE 380.2077743209786  
Lambda1: 1e-05 Lambda2: 0.01 MSE 389.6783783213214  
Lambda1: 1e-05 Lambda2: 0.1 MSE 399.7677239408512  
Lambda1: 1e-05 Lambda2: 1 MSE 412.87620280029876  
Lambda1: 0.0001 Lambda2: 0.0001 MSE 373.36934331174126  
Lambda1: 0.0001 Lambda2: 0.001 MSE 380.2280417051086  
Lambda1: 0.0001 Lambda2: 0.01 MSE 389.688867677143  
Lambda1: 0.0001 Lambda2: 0.1 MSE 399.7717227178177  
Lambda1: 0.0001 Lambda2: 1 MSE 412.87762214050736  
Lambda1: 0.001 Lambda2: 0.001 MSE 380.4347516718024  
Lambda1: 0.001 Lambda2: 0.01 MSE 389.79418600702786  
Lambda1: 0.001 Lambda2: 0.1 MSE 399.8117595697313  
Lambda1: 0.001 Lambda2: 1 MSE 412.89181691630665  
Lambda1: 0.01 Lambda2: 0.01 MSE 390.87501985923177  
Lambda1: 0.01 Lambda2: 0.1 MSE 400.216629954475  
Lambda1: 0.01 Lambda2: 1 MSE 413.03419421234844  
Lambda1: 0.1 Lambda2: 0.1 MSE 403.6795417152145  
Lambda1: 0.1 Lambda2: 1 MSE 414.4135823533389  
Lambda1: 1 Lambda2: 1 MSE 424.0946332039565

**d)**

---Best MSE---

Training Data:

Best - Lambda1: 1e-06 Lambda2: 1e-06 MSE: 339.90590946744516

Validation Data:

Best - Lambda1: 1e-06 Lambda2: 1e-05 MSE: 371.3763446961938

**e)**

---Testing Data---

MSE: 362.0125529209285

### Exercise 3

a)-c) Excel sheets submitted separately

d)

a) Same as Ex. 2

b)

---Training Data---

Lambda1: 1e-06 Lambda2: 1e-06 MSE 0.14825342813704354  
Lambda1: 1e-06 Lambda2: 1e-05 MSE 0.14825342893672327  
Lambda1: 1e-06 Lambda2: 0.0001 MSE 0.14825348521439785  
Lambda1: 1e-06 Lambda2: 0.001 MSE 0.14825874918416096  
Lambda1: 1e-06 Lambda2: 0.01 MSE 0.14867628606629163  
Lambda1: 1e-06 Lambda2: 0.1 MSE 0.15818215845625513  
Lambda1: 1e-06 Lambda2: 1 MSE 0.17516443196471324  
Lambda1: 1e-05 Lambda2: 1e-05 MSE 0.14825343703128965  
Lambda1: 1e-05 Lambda2: 0.0001 MSE 0.1482535167375668  
Lambda1: 1e-05 Lambda2: 0.001 MSE 0.1482590089732004  
Lambda1: 1e-05 Lambda2: 0.01 MSE 0.14867832837895745  
Lambda1: 1e-05 Lambda2: 0.1 MSE 0.15818706151105325  
Lambda1: 1e-05 Lambda2: 1 MSE 0.17516607649470853  
Lambda1: 0.0001 Lambda2: 0.0001 MSE 0.14825428284434658  
Lambda1: 0.0001 Lambda2: 0.001 MSE 0.14826206484147464  
Lambda1: 0.0001 Lambda2: 0.01 MSE 0.14869917862917464  
Lambda1: 0.0001 Lambda2: 0.1 MSE 0.15823622131823367  
Lambda1: 0.0001 Lambda2: 1 MSE 0.17518292486346165  
Lambda1: 0.001 Lambda2: 0.001 MSE 0.1483339428646282  
Lambda1: 0.001 Lambda2: 0.01 MSE 0.14894311902738222  
Lambda1: 0.001 Lambda2: 0.1 MSE 0.15873961451466345  
Lambda1: 0.001 Lambda2: 1 MSE 0.175348380621257  
Lambda1: 0.01 Lambda2: 0.01 MSE 0.15413876034106297  
Lambda1: 0.01 Lambda2: 0.1 MSE 0.16440362836964567  
Lambda1: 0.01 Lambda2: 1 MSE 0.17700034680427554  
Lambda1: 0.1 Lambda2: 0.1 MSE 0.18412684527123094  
Lambda1: 0.1 Lambda2: 1 MSE 0.18675524722392434  
Lambda1: 1 Lambda2: 1 MSE 0.22986637149098427

c)

---Validation Data---

Lambda1: 1e-06 Lambda2: 1e-06 MSE 0.14016520590097192  
Lambda1: 1e-06 Lambda2: 1e-05 MSE 0.140165206825425  
Lambda1: 1e-06 Lambda2: 0.0001 MSE 0.14016527260000375  
Lambda1: 1e-06 Lambda2: 0.001 MSE 0.1401714357140736  
Lambda1: 1e-06 Lambda2: 0.01 MSE 0.1406610571589251  
Lambda1: 1e-06 Lambda2: 0.1 MSE 0.15188758342050424  
Lambda1: 1e-06 Lambda2: 1 MSE 0.17212327571600797  
Lambda1: 1e-05 Lambda2: 1e-05 MSE 0.1401652154553455

Lambda1: 1e-05 Lambda2: 0.0001 MSE 0.14016530767439808  
Lambda1: 1e-05 Lambda2: 0.001 MSE 0.1401717284627447  
Lambda1: 1e-05 Lambda2: 0.01 MSE 0.1406633640702923  
Lambda1: 1e-05 Lambda2: 0.1 MSE 0.15189315063902256  
Lambda1: 1e-05 Lambda2: 1 MSE 0.17212514890870134  
Lambda1: 0.0001 Lambda2: 0.0001 MSE 0.1401661693411689  
Lambda1: 0.0001 Lambda2: 0.001 MSE 0.1401751564905921  
Lambda1: 0.0001 Lambda2: 0.01 MSE 0.14068684730863534  
Lambda1: 0.0001 Lambda2: 0.1 MSE 0.15194896066204536  
Lambda1: 0.0001 Lambda2: 1 MSE 0.1721436071923778  
Lambda1: 0.001 Lambda2: 0.001 MSE 0.14025947605176362  
Lambda1: 0.001 Lambda2: 0.01 MSE 0.14096332879012796  
Lambda1: 0.001 Lambda2: 0.1 MSE 0.15252074621161293  
Lambda1: 0.001 Lambda2: 1 MSE 0.17233218202596942  
Lambda1: 0.01 Lambda2: 0.01 MSE 0.1465940048059349  
Lambda1: 0.01 Lambda2: 0.1 MSE 0.1588182319569801  
Lambda1: 0.01 Lambda2: 1 MSE 0.1741876315435103  
Lambda1: 0.1 Lambda2: 0.1 MSE 0.1819092376195592  
Lambda1: 0.1 Lambda2: 1 MSE 0.1847102376885835  
Lambda1: 1 Lambda2: 1 MSE 0.23235980171175677

**d)**

---Best MSE---

Training Data:

Best - Lambda1: 1e-06 Lambda2: 1e-06 MSE: 0.14825342813704354

Validation Data:

Best - Lambda1: 1e-06 Lambda2: 1e-06 MSE: 0.14016520590097192

**e)**

---Testing Data---

MSE: 0.15098271118825493

#### Exercise 4

a) Done

b)

---Validation Data Logistic Regression---

L2 regularization model empirical risk: 0.8074037018509255

No regularization model empirical risk: 0.8084042021010506

---Confusion Matrix---

L2 Regularization Model Confusion Matrix

True Negative: 1128

False Positive: 137

False Negative: 248

True Positive: 486

No Regularization Model Confusion Matrix

True Negative: 1129

False Positive: 136

False Negative: 247

True Positive: 487

c)

---Best performance---

L2 Regularized model is better with risk of :  $0.8074037018509255 < 0.8084042021010506$

---Training Data Logistic Regression using L2 Regularized Model---

L2 regularization model empirical risk: 0.7955340776537244

L2 Regularization Model Confusion Matrix

True Negative: 3342

False Positive: 510

False Negative: 717

True Positive: 1432