Project1

October 12, 2022

[4]:
```
import numpy as np
import pandas as pd
from numpy.random import default_rng

from sklearn.datasets import make_classification, load_digits
from sklearn.linear_model import LogisticRegression, Ridge, Lasso
from sklearn.metrics import roc_curve, roc_auc_score, log_loss,␣
↪confusion_matrix, accuracy_score, r2_score
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn import svm
from sklearn.model_selection import GridSearchCV
from sklearn.svm import SVC

import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns

%matplotlib inline
np.set_printoptions(suppress=True, precision=3)

import warnings
warnings.filterwarnings('ignore')
```

[5]:
```
#importing files
x_train = np.loadtxt('x_train_p1.csv', delimiter=',', skiprows=1)
x_test = np.loadtxt('x_test_p1.csv', delimiter=',', skiprows=1)

y_train = np.loadtxt('y_train_p1.csv', delimiter=',', skiprows=1)
y_test = np.loadtxt('y_test_p1.csv', delimiter=',', skiprows=1)
```

[6]:
```
x_test
```

[6]:
```
array([[0., 0., 0., …, 0., 0., 0.],
       [0., 0., 1., …, 0., 0., 0.],
       [0., 0., 0., …, 0., 0., 1.],
       …,
       [0., 0., 0., …, 0., 0., 0.],
```

```
       [0., 0., 0., …, 0., 0., 0.],
       [0., 0., 0., …, 0., 0., 0.]])
```

[7]:
```python
y_test
```

[7]:
```
array([1., 1., 1., …, 1., 0., 1.])
```

https://towardsdatascience.com/logistic-regression-using-python-sklearn-numpy-mnist-handwriting-recognition-matplotlib-a6b31e2b166a

[8]:
```python
# load in model of logreg
logreg = LogisticRegression()
# Training the model on the data, storing the information learned from the data
logreg.fit(x_train, y_train)
```

[8]:
```
LogisticRegression()
```

[9]:
```python
# Making predictions on Testing Model
# Make predictions on entire test data
y_pred = logreg.predict(x_test)
```

[10]:
```python
# acc score for testing
scorelogreg = logreg.score(x_test, y_test)
print("Accuracy score test:" , round(scorelogreg *100,3),"%")
# acc score for training
score_logreg = logreg.score(x_train, y_train)
print("Accuracy score train:" , round(score_logreg *100,3),"%")
```

```
Accuracy score test: 95.814 %
Accuracy score train: 99.136 %
```

[11]:
```python
y_prob = logreg.predict_proba(x_train)
# log loss with y prob NOT y pred
log_loss(y_train, y_prob)
# (a) if we compare two models on the same data, lower numbers are better, and
# (b) if logistic loss is 0, we have the best possible result.
```

[11]:
```
0.031229596954079678
```

[12]:
```python
# weigths
coeff = logreg.coef_[0][0]
#sum((abs(coeff) > .5) == True)
```

1 PART 1: problem 1

[13]:
```
# iterating over model of logreg with maxiter changed
miter = list()
acc_mi_train = list()
acc_mi_test = list()
log_loss_mi = list()
for i in range(1, 41):
    logregmi = LogisticRegression(max_iter = i)
    logregmi.fit(x_train, y_train)
    y_predmi = logregmi.predict(x_test)
    acc_mi_test.append(logregmi.score(x_test, y_test))
    acc_mi_train.append(logregmi.score(x_train, y_train))
    y_probmi = logregmi.predict_proba(x_train)
    log_loss_mi.append(log_loss(y_train, y_probmi))
    miter.append(i)
```

[14]:
```
#turn into df inorder to better plot
d = {'Max_iter Number':miter ,'Accuracy Score train':acc_mi_train, 'Accuracy␣
↪Score test':acc_mi_test, 'Logistic Loss':log_loss_mi}
df_mi = pd.DataFrame(d)

df_mi = df_mi.sort_values(by=['Max_iter Number'])
df_mi
```

[14]:

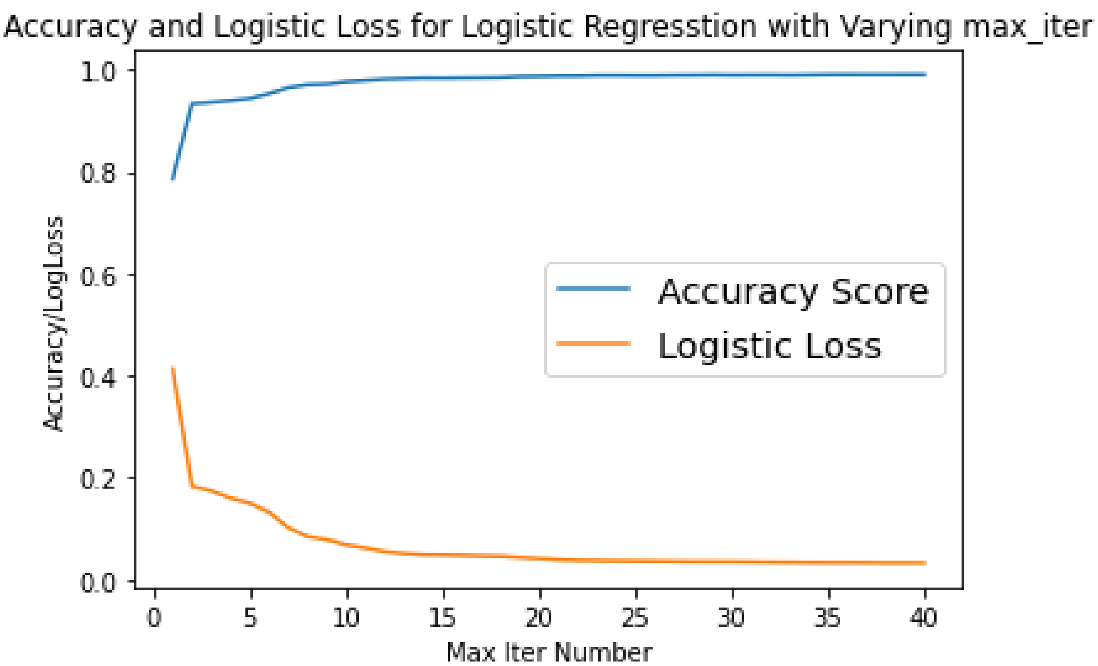
	Max_iter Number	Accuracy Score train	Accuracy Score test	Logistic Loss
0	1	0.786017	0.817448	0.413634
1	2	0.933305	0.935956	0.183294
2	3	0.935932	0.935451	0.174246
3	4	0.939492	0.942511	0.159756
4	5	0.943729	0.940494	0.149870
5	6	0.953220	0.949067	0.132453
6	7	0.965085	0.961170	0.101954
7	8	0.970763	0.963187	0.084304
8	9	0.971864	0.963691	0.078158
9	10	0.976441	0.968734	0.068061
10	11	0.979153	0.969743	0.061855
11	12	0.981525	0.969743	0.054767
12	13	0.982542	0.967726	0.051327
13	14	0.983729	0.965709	0.049050
14	15	0.983475	0.964700	0.048472
15	16	0.983814	0.964700	0.047719
16	17	0.984153	0.964700	0.046778
17	18	0.984661	0.964700	0.046030
18	19	0.986695	0.964700	0.043574
19	20	0.987034	0.963691	0.041479

20	21	0.987797	0.962179	0.039609
21	22	0.987797	0.959657	0.038094
22	23	0.988814	0.960666	0.037386
23	24	0.988814	0.961170	0.036930
24	25	0.988644	0.960161	0.036634
25	26	0.988644	0.958649	0.036186
26	27	0.989068	0.959153	0.035846
27	28	0.989322	0.958144	0.035615
28	29	0.989661	0.957136	0.035384
29	30	0.989407	0.957136	0.035270
30	31	0.989492	0.956631	0.034972
31	32	0.989661	0.955623	0.034434
32	33	0.989322	0.956127	0.034337
33	34	0.989746	0.955623	0.033846
34	35	0.990254	0.956127	0.033800
35	36	0.990339	0.955119	0.033711
36	37	0.990254	0.955119	0.033577
37	38	0.990254	0.956631	0.033268
38	39	0.990339	0.956631	0.033270
39	40	0.990254	0.956631	0.033080

[15]:
```
df_mi['Accuracy Score train'].idxmax() # 35
df_mi['Logistic Loss'].idxmin() #39
```

[15]: 39

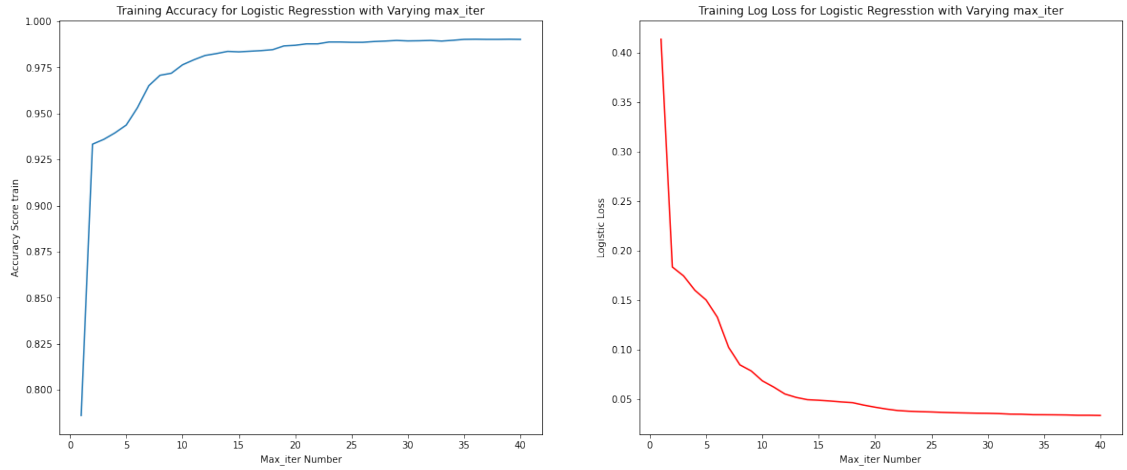
[16]:
```
# TODO make plot
plt.plot(miter, acc_mi_train)
plt.plot(miter, log_loss_mi)
# TODO add legend, titles, etc.
####plt.xscale('plt.xscale('log')')
plt.title('Accuracy and Logistic Loss for Logistic Regresstion with Varying␣
↪max_iter')
plt.legend(['Accuracy Score', 'Logistic Loss'], fontsize='x-large')
plt.xlabel('Max Iter Number');
plt.ylabel('Accuracy/LogLoss');
plt.show()
```



[17]:

```
# TODO make side by side plot
fig, (ax1, ax2) = plt.subplots(1,2, figsize=(20,8))

sns.lineplot(data=df_mi, x="Max_iter Number", y="Accuracy Score train", ax=ax1).
↪set(title='Training Accuracy for Logistic Regresstion with Varying max_iter')
sns.lineplot(data=df_mi, x="Max_iter Number", y="Logistic Loss", ax=ax2,␣
↪color='red').set(title='Training Log Loss for Logistic Regresstion with␣
↪Varying max_iter')
plt.show()
```



Explination here:

Log loss measure the performance of a classification model whose output is a probability between 0 and 1. The goal of an ML model is to minimize the log loss value. The value of log loss can be anything from zero to infinity. The lower the log loss the higher the predictive probability-power of your model.

The training accuracy score is found by calculating correct_predictions / total_predictions in the training dataset. We want to maximised the accuracy score our model produces with 1 being the best possible accuracy for our model.

We can see from the graphs above that as the Max_iter number increases the Logistic loss approaches zero and the Accuracy score approaches 1. The goal is to minimize the log loss while maximizing the accuracy so for this model we get this with the generally higher Max_iter number. By looking at the tabular data we can see the MAX for the training acc happens around Max_iter = 36 while the min for the log loss happens around Max_iter = 40. When chosing the Max iter that we want we will have to decide if we want to prioritise maximising the accuracy score or minimizing the log loss.

2 PART 1: problem 2

[18]:
```
# iterating over model of logreg with maxiter changed AND FINDING THE FIRST␣
↪COEF_ - weight
miter = list()
acc_mi_train = list()
acc_mi_test = list()
log_loss_mi = list()
first_weight = list()
for i in range(1, 41):
    logregmi = LogisticRegression(max_iter = i)
    logregmi.fit(x_train, y_train)
    y_predmi = logregmi.predict(x_test)
    acc_mi_test.append(logregmi.score(x_test, y_test))
    acc_mi_train.append(logregmi.score(x_train, y_train))
    y_probmi = logregmi.predict_proba(x_train)
    log_loss_mi.append(log_loss(y_train, y_probmi))
    first_weight.append(logregmi.coef_[0][0])
    miter.append(i)
```

[19]:
```
#turn into df inorder to better plot
dw = {'Max_iter Number':miter ,'First weights':first_weight}
df_w = pd.DataFrame(dw)

df_w = df_w.sort_values(by=['Max_iter Number'])
```

```python
df_w
```

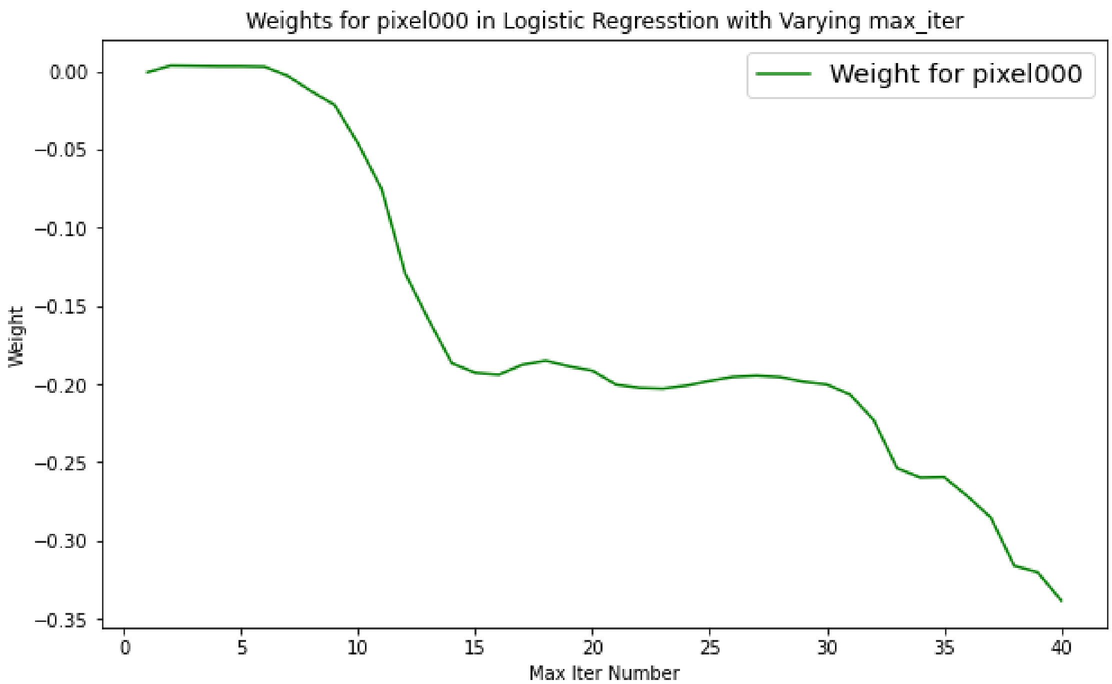
[19]:

	Max_iter Number	First weights
0	1	-0.000804
1	2	0.003549
2	3	0.003362
3	4	0.003116
4	5	0.003091
5	6	0.002831
6	7	-0.003135
7	8	-0.012893
8	9	-0.021696
9	10	-0.046496
10	11	-0.075487
11	12	-0.129157
12	13	-0.158916
13	14	-0.186746
14	15	-0.192944
15	16	-0.194142
16	17	-0.187716
17	18	-0.185095
18	19	-0.188747
19	20	-0.191585
20	21	-0.200421
21	22	-0.202549
22	23	-0.203063
23	24	-0.201075
24	25	-0.198092
25	26	-0.195519
26	27	-0.194713
27	28	-0.195631
28	29	-0.198592
29	30	-0.200344
30	31	-0.206918
31	32	-0.223068
32	33	-0.253901
33	34	-0.259978
34	35	-0.259592
35	36	-0.271786
36	37	-0.285442
37	38	-0.316305
38	39	-0.320494
39	40	-0.338431

[20]:
```python
df_w['First weights'].idxmax() # 1
df_w['First weights'].idxmin() #39
```

[20]: 39

[21]:
```
plt.figure(figsize=(10,6))
plt.plot(miter, first_weight, color='green')
plt.title('Weights for pixel000 in Logistic Regresstion with Varying max_iter')
plt.legend(['Weight for pixel000'], fontsize='x-large')
plt.xlabel('Max Iter Number');
plt.ylabel('Weight');
plt.show()
```



Explain: Here we can see the first coeficient values for each model with ith Max_iter value. The coef_ recorded here are non-intercept coeficients and thus tells you how important pixel000 being a 1 and not a 0 (zero being that pixel ic balck and 1 meaning that pixel is colored white) increases or decreases the odds of the outcome to be a number 9 or a n number 8. With zero reping an 8 and 1 reping a 9. A hiher absolute value of the coefficient means that this pixel has a larger effect on the odds of the outcome being a 0 or a 1 and a smaller absolute value means that this pixel doent have much effect on determening the outcome. We can see from the graph above that there is a general trend that as the Max_iter number increases the Weight decreases. By looking at the tabular data we can see the highest Weights score for pixel000 is at Max_iter = 2 while the lowest weights score for pixel000 is Max_iter = 40. Since the negative scores here are much greater greater in absolute value than the positive score for weights it is not necessary to plot the absolute value of the weights. However we do need the absolute values to see the smallest absolute value score which is at Max_iter = 6. This is where the pixel000 has the least effect on the resulting value.

3 PART 1: problem 3

ignore ridge and lasso it is incorect

[22]:
```
# Ridge Reg
C_grid = np.logspace(-9, 6, 31)

r_log_loss = list()
alpha_c = list()
for C in C_grid:
    ridge = Ridge(normalize = True)
    ridge.set_params(alpha = C)
    ridge.fit(x_train, y_train)
    y_prob_r = ridge.predict(x_test)
    r_log_loss.append(log_loss(y_test, y_prob_r))
    alpha_c.append(C)
```

[23]:
```
d = {'Alpha for Ridge':alpha_c , 'Logistic Loss':r_log_loss}
df_r = pd.DataFrame(d)

df_r = df_r.sort_values(by=['Alpha for Ridge'])
df_r
```

[23]:

	Alpha for Ridge	Logistic Loss
0	1.000000e-09	0.158295
1	3.162278e-09	0.158295
2	1.000000e-08	0.158295
3	3.162278e-08	0.158295
4	1.000000e-07	0.158295
5	3.162278e-07	0.158295
6	1.000000e-06	0.158295
7	3.162278e-06	0.158295
8	1.000000e-05	0.158294
9	3.162278e-05	0.158294
10	1.000000e-04	0.158294
11	3.162278e-04	0.158292
12	1.000000e-03	0.158285
13	3.162278e-03	0.158266
14	1.000000e-02	0.158214
15	3.162278e-02	0.158118
16	1.000000e-01	0.158259
17	3.162278e-01	0.160554
18	1.000000e+00	0.171391
19	3.162278e+00	0.204699
20	1.000000e+01	0.287171
21	3.162278e+01	0.429454
22	1.000000e+02	0.566659
23	3.162278e+02	0.645041

```
24     1.000000e+03       0.676812
25     3.162278e+03       0.687790
26     1.000000e+04       0.691365
27     3.162278e+04       0.692506
28     1.000000e+05       0.692868
29     3.162278e+05       0.692982
30     1.000000e+06       0.693018
```

[24]:
```
df_r['Logistic Loss'].idxmin() #15 ~ 0.158118
```

[24]:
```
15
```

[22]:
```
# Lasso Reg

C_grid = np.logspace(-9, 6, 31)

l_log_loss = list()
alpha_c = list()
lasso_acc = list()
for C in C_grid:
    lass = Lasso(normalize = True)
    lass.set_params(alpha = C)
    lass.fit(x_train, y_train)
    y_prob_l = lass.predict(x_test)
    l_log_loss.append(log_loss(y_test, y_prob_l))
    alpha_c.append(C)
    lasso_acc.append(r2_score(y_test, y_prob_l))
```

[23]:
```
d = {'Alpha for Lasso':alpha_c , 'Logistic Loss':l_log_loss, 'Lasso Acc R^2':
 ↪lasso_acc}
df_l = pd.DataFrame(d)

df_l = df_l.sort_values(by=['Alpha for Lasso'])
df_l
```

[23]:

	Alpha for Lasso	Logistic Loss	Lasso Acc R^2
0	1.000000e-09	0.158294	0.808211
1	3.162278e-09	0.158293	0.808213
2	1.000000e-08	0.158291	0.808220
3	3.162278e-08	0.158284	0.808242
4	1.000000e-07	0.158261	0.808311
5	3.162278e-07	0.158188	0.808528
6	1.000000e-06	0.157988	0.809180
7	3.162278e-06	0.157572	0.810857
8	1.000000e-05	0.157628	0.813717
9	3.162278e-05	0.161931	0.813373
10	1.000000e-04	0.184299	0.797211

11	3.162278e-04	0.244618	0.736806
12	1.000000e-03	0.415759	0.509668
13	3.162278e-03	0.693035	-0.000087
14	1.000000e-02	0.693035	-0.000087
15	3.162278e-02	0.693035	-0.000087
16	1.000000e-01	0.693035	-0.000087
17	3.162278e-01	0.693035	-0.000087
18	1.000000e+00	0.693035	-0.000087
19	3.162278e+00	0.693035	-0.000087
20	1.000000e+01	0.693035	-0.000087
21	3.162278e+01	0.693035	-0.000087
22	1.000000e+02	0.693035	-0.000087
23	3.162278e+02	0.693035	-0.000087
24	1.000000e+03	0.693035	-0.000087
25	3.162278e+03	0.693035	-0.000087
26	1.000000e+04	0.693035	-0.000087
27	3.162278e+04	0.693035	-0.000087
28	1.000000e+05	0.693035	-0.000087
29	3.162278e+05	0.693035	-0.000087
30	1.000000e+06	0.693035	-0.000087

[24]:
```
df_l['Alpha for Lasso log 10 scale'] = np.log10(df_l['Alpha for Lasso'])
df_l
```

[24]:

	Alpha for Lasso	Logistic Loss	Lasso Acc R^2	\
0	1.000000e-09	0.158294	0.808211	
1	3.162278e-09	0.158293	0.808213	
2	1.000000e-08	0.158291	0.808220	
3	3.162278e-08	0.158284	0.808242	
4	1.000000e-07	0.158261	0.808311	
5	3.162278e-07	0.158188	0.808528	
6	1.000000e-06	0.157988	0.809180	
7	3.162278e-06	0.157572	0.810857	
8	1.000000e-05	0.157628	0.813717	
9	3.162278e-05	0.161931	0.813373	
10	1.000000e-04	0.184299	0.797211	
11	3.162278e-04	0.244618	0.736806	
12	1.000000e-03	0.415759	0.509668	
13	3.162278e-03	0.693035	-0.000087	
14	1.000000e-02	0.693035	-0.000087	
15	3.162278e-02	0.693035	-0.000087	
16	1.000000e-01	0.693035	-0.000087	
17	3.162278e-01	0.693035	-0.000087	
18	1.000000e+00	0.693035	-0.000087	
19	3.162278e+00	0.693035	-0.000087	
20	1.000000e+01	0.693035	-0.000087	
21	3.162278e+01	0.693035	-0.000087	

```
22     1.000000e+02      0.693035      -0.000087
23     3.162278e+02      0.693035      -0.000087
24     1.000000e+03      0.693035      -0.000087
25     3.162278e+03      0.693035      -0.000087
26     1.000000e+04      0.693035      -0.000087
27     3.162278e+04      0.693035      -0.000087
28     1.000000e+05      0.693035      -0.000087
29     3.162278e+05      0.693035      -0.000087
30     1.000000e+06      0.693035      -0.000087

    Alpha for Lasso log 10 scale
0                           -9.0
1                           -8.5
2                           -8.0
3                           -7.5
4                           -7.0
5                           -6.5
6                           -6.0
7                           -5.5
8                           -5.0
9                           -4.5
10                          -4.0
11                          -3.5
12                          -3.0
13                          -2.5
14                          -2.0
15                          -1.5
16                          -1.0
17                          -0.5
18                           0.0
19                           0.5
20                           1.0
21                           1.5
22                           2.0
23                           2.5
24                           3.0
25                           3.5
26                           4.0
27                           4.5
28                           5.0
29                           5.5
30                           6.0
```

[25]:
```
df_l['Logistic Loss'].idxmin() #7 ~ 0.157572

# lasso model has a slightly lower Log loss so I will be going with that model␣
↪over ridge reg
```

[25]: 7

[37]:
```
## REAL C !!
C_grid = np.logspace(-9, 6, 31)



c_log_loss = list()
alpha_c = list()
c_acc = list()
for C in C_grid:
    lr = LogisticRegression(C=C)
    lr.fit(x_train_std, y_train)
    y_pred_c = lr.predict(x_test_std)
    y_prob_c = lr.predict_proba(x_test_std)
    log_loss_mi.append(log_loss(y_train, y_probmi))
    c_log_loss.append(log_loss(y_test, y_prob_c))
    alpha_c.append(C)
    c_acc.append(accuracy_score(y_test, y_pred_c))
```

[38]:
```
d = {'Regularization Penalty (C)':alpha_c , 'Logistic Loss':c_log_loss,␣
 ↪'Accuracy Score':c_acc, 'C log of 10':np.log10(alpha_c)}
df_c = pd.DataFrame(d)

df_c = df_c.sort_values(by=['Regularization Penalty (C)'])
df_c.head()
```

[38]:

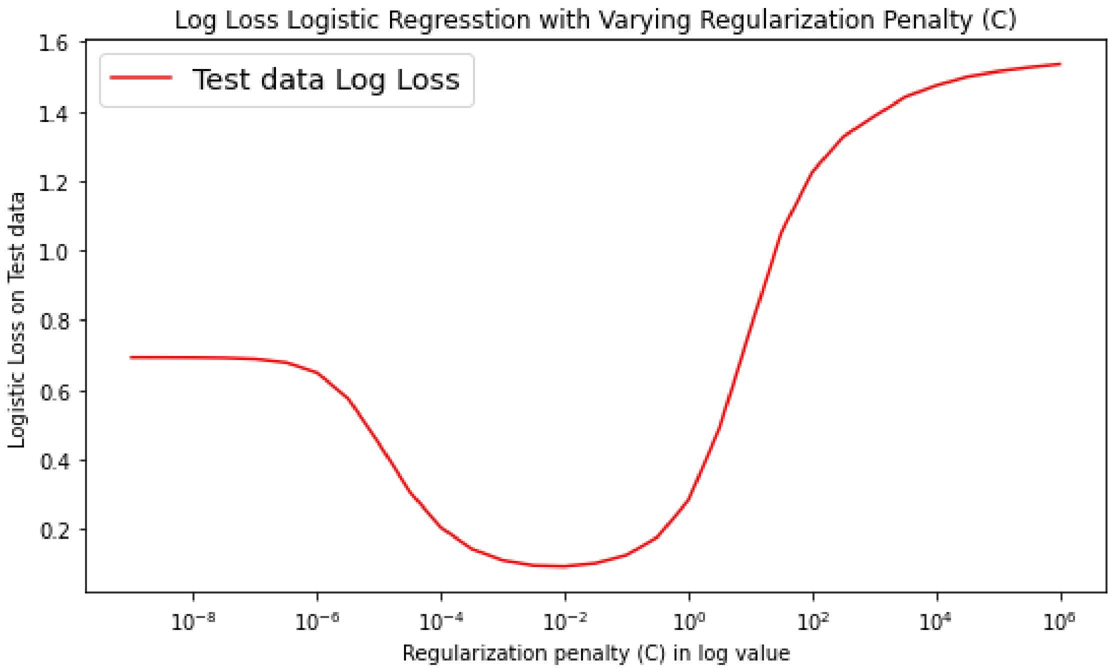
	Regularization Penalty (C)	Logistic Loss	Accuracy Score	C log of 10
0	1.000000e-09	0.692986	0.508825	-9.0
1	3.162278e-09	0.692879	0.508825	-8.5
2	1.000000e-08	0.692541	0.508825	-8.0
3	3.162278e-08	0.691476	0.508825	-7.5
4	1.000000e-07	0.688139	0.558245	-7.0

[39]:
```
df_c['Logistic Loss'].idxmin() #15
df_c['Accuracy Score'].idxmax() #16
```

[39]: 13

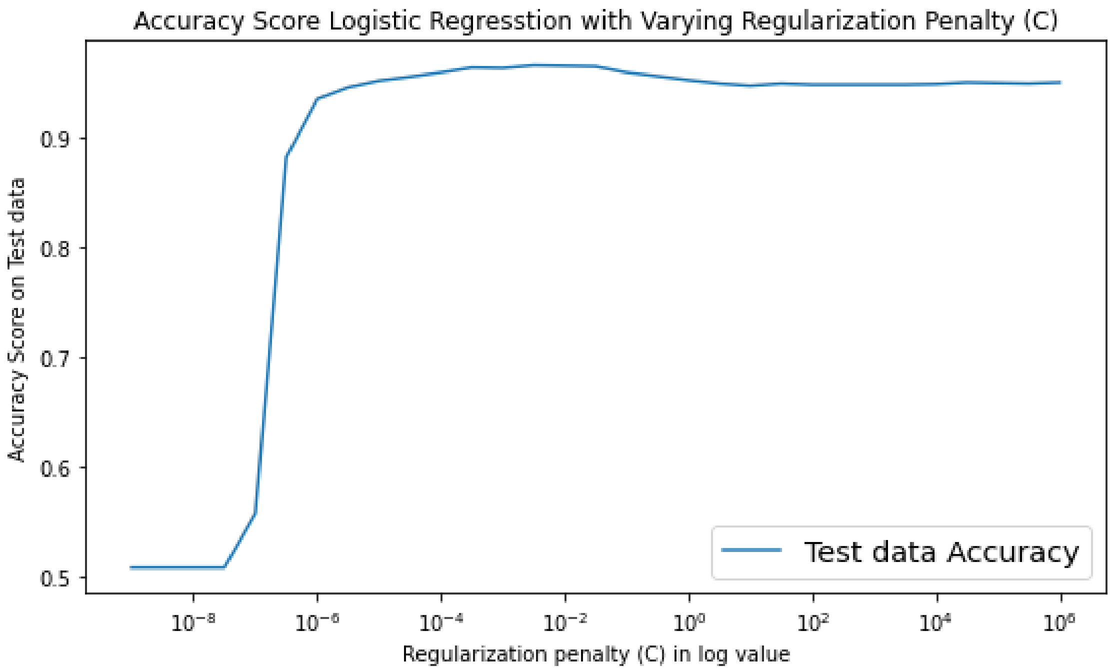
[30]:
```
#plot log loss for Ridge
plt.figure(figsize=(9,5))
plt.plot(alpha_c, c_log_loss, color='red')
plt.xscale('log')
plt.title('Log Loss Logistic Regresstion with Varying Regularization Penalty␣
 ↪(C)')
plt.xlabel('Regularization penalty (C) in log value')
```

```
plt.ylabel('Logistic Loss on Test data')
plt.legend(['Test data Log Loss'], fontsize='x-large')
plt.show()
```



[30]:

```
#plot log loss for Ridge
plt.figure(figsize=(9,5))
plt.plot(alpha_c, c_acc)
plt.xscale('log')
plt.title('Accuracy Score Logistic Regresstion with Varying Regularization␣
 ↪Penalty (C)')
plt.xlabel('Regularization penalty (C) in log value')
plt.ylabel('Accuracy Score on Test data')
plt.legend(['Test data Accuracy'], fontsize='x-large')
plt.show()
```

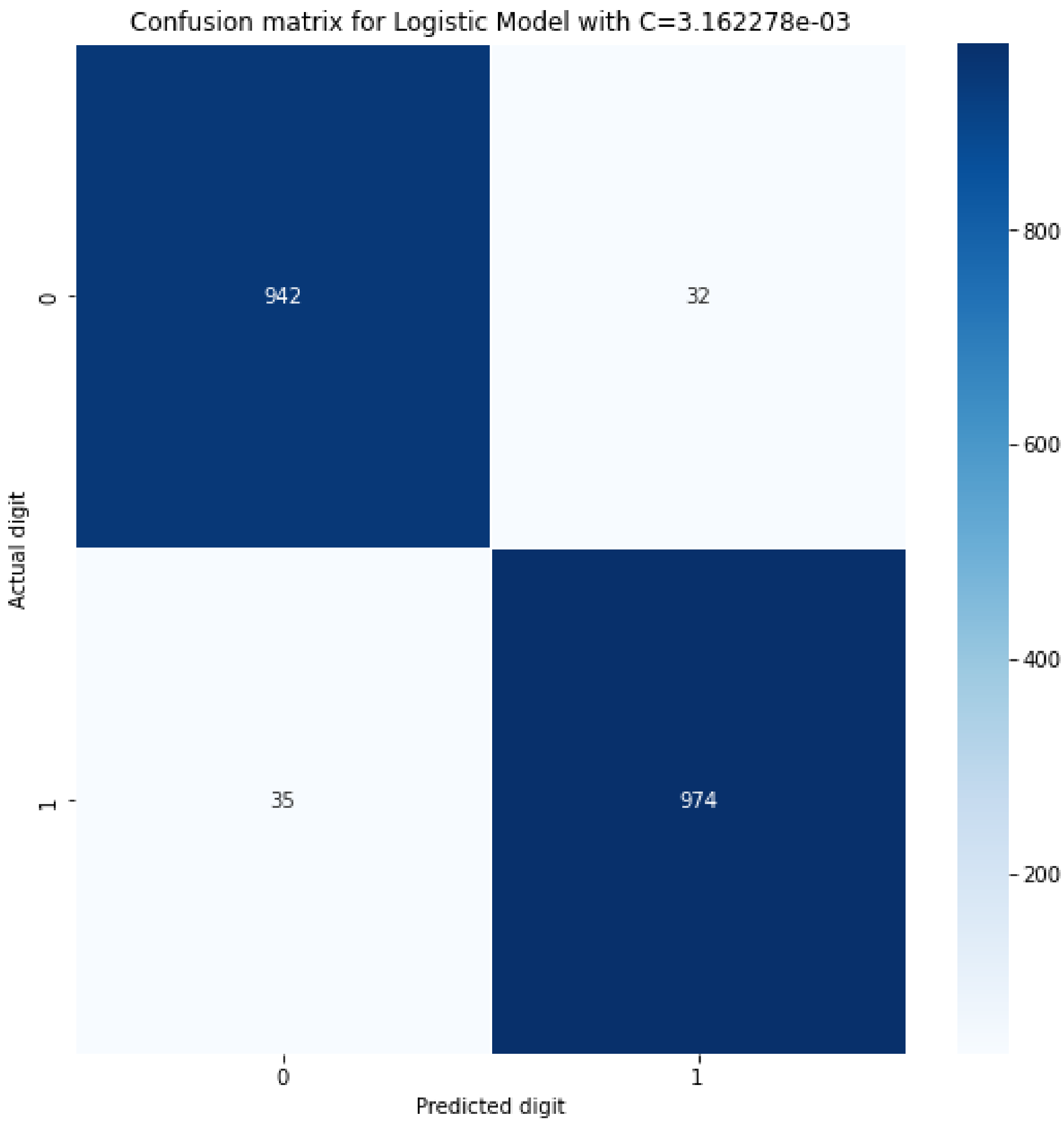


[31]:
```
lr = LogisticRegression(C=3.162278e-03)
lr.fit(x_train_std, y_train)
y_prob_c = lr.predict(x_test_std)
```

[32]:
```
conf_matrix = confusion_matrix(y_test, y_prob_c)
print(conf_matrix)
```

```
[[942  32]
 [ 35 974]]
```

[33]:
```
#prettier CM
plt.figure(figsize=(9, 9))
sns.heatmap(conf_matrix, annot=True, linewidths=0.5, cmap='Blues', fmt='g')
plt.ylabel('Actual digit')
plt.xlabel('Predicted digit')
plt.title('Confusion matrix for Logistic Model with C=3.162278e-03')
plt.show()
```



Explain: The smallest Log loss was found at the C = log 10 of -2.5 (C=3.162278e-03). This Logistic Regresion model iterated over many values for a regularization penalty by iterating over many C values. Smaller values of C specify stronger regularization. The lowest log loss was logloss=1.166981 with a corresponding accuracy score of acc=0.966213. The Confusion Matrix is shown above.

Analyze some of the mistakes that your best model makes: Taking a look at the confusion matrix for the model with a C= log 10 of -2.5 as regularization parameters to thus get the smallest Log loss and the highest possible accuracy score we can see that althought the accuracy score is at about 96% that there are severl error being made by this model. With 35 False Negatives (we predicted 0 but the output was actually 1). In terms of this data a False Negative means that we predicted the number in the image file to be an 8 but it was acctually a 9. We also have 32 False Positives in this data (we predicted 1 but the output was actually 0). In terms of this data a False

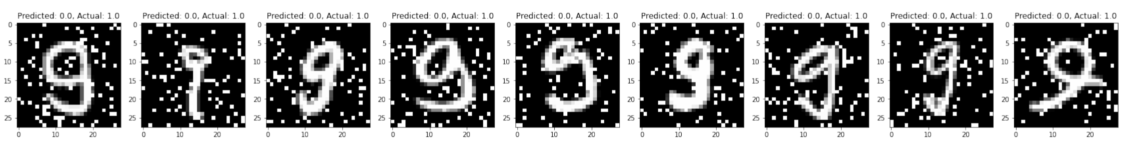
Positive means that we predicted the number in the image file to be an 9 but it was acctually an 8. This model tends to make slightly more FN errors than FP errors and thus is slightly more likly to falsely identify an image with a 9 on it as an 8.

4 PART 1: problem 4

[34]:
```
wrong_fn = np.nonzero(y_prob_c < y_test)[0]
wrong_fn.shape
```

[34]: (35,)

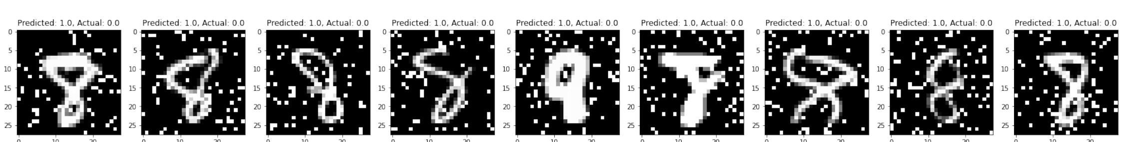
[35]:
```
plt.figure(figsize=(30, 3))
for plotIdx, wrongIdx in enumerate(wrong_fn[0:9]):
    plt.subplot(1, 9, plotIdx + 1)
    plt.imshow(np.reshape(x_test[wrongIdx], (28,28)), cmap=plt.cm.gray, vmin =
 ↪0.0, vmax = 1)
    plt.title('Predicted: {}, Actual: {}'.format(y_prob_c[wrongIdx],
              y_test[wrongIdx]))
```



[36]:
```
wrong_fp = np.nonzero(y_prob_c > y_test)[0]
wrong_fp
```

[36]:
```
array([  37,   69,  101,  156,  174,  290,  344,  352,  355,  401,  440,
        464,  580,  617,  712,  787,  809,  879,  896,  918,  926,  984,
        998, 1004, 1068, 1313, 1322, 1327, 1427, 1508, 1672, 1682])
```

[37]:
```
plt.figure(figsize=(30, 3))
for plotIdx, wrongIdx in enumerate(wrong_fp[0:9]):
    plt.subplot(1, 9, plotIdx + 1)
    plt.imshow(np.reshape(x_test[wrongIdx], (28,28)), cmap=plt.cm.gray, vmin =
 ↪0.0, vmax = 1)
    plt.title('Predicted: {}, Actual: {}'.format(y_prob_c[wrongIdx],
              y_test[wrongIdx]))
```



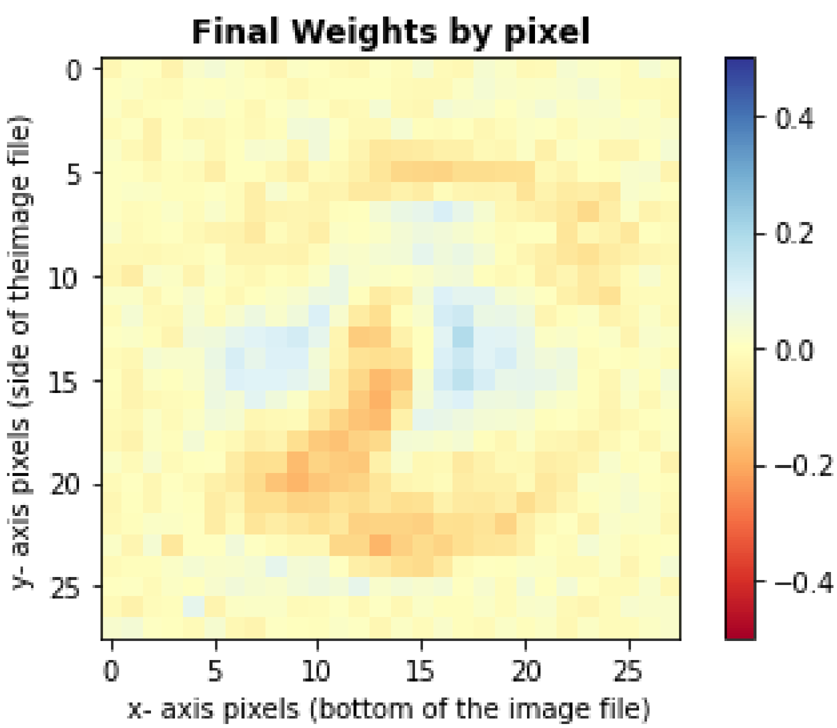
what mistakes: many of the mistakes seen in the false negatives can be seen to be written 9's that have a very loopy tail at the bottom that resembels but is not exactly the bottom half of an 8.

many of the false positive images seen above show 8's that have a bigger top loop than bottom loop almost resmbling a thick line on the bottom half of a 9.

5 PART 1: problem 5

[38]:
```
coef = lr.coef_[0]
```

[39]:
```
coef_fig = plt.imshow(np.reshape(coef, (28,28)), cmap='RdYlBu', vmin = -0.5,␣
 ↪vmax = 0.5)
plt.colorbar(coef_fig)
plt.title('Final Weights by pixel', fontweight ="bold")
plt.xlabel('x- axis pixels (bottom of the image file)')
plt.ylabel('y- axis pixels (side of theimage file)')
plt.show()
```



Explain: The figure above shows the weights associated with each pixel of the image inputs. We can see above the positive weights on blue and the negative weigths in red with the zero (or very small weights) a more yellow color. Thus, the yellow areas of the figure above indicate areas that the 8 or 9 tends to not appear in the image and thus these pixels have little to no effect on what the image is or what the prediction for what the image is. We can see a strong negative weight precence (and thus a good predictor of the image being of an 8) in the 5-15 range along the X axis and the 15-25 range along the y axis. This intuatively makes sense bc it is exactly the area where an 8 would be filled out but would be black space if a 9 was drawn. The image above also suggests that in this data set, 9's tend to be drawn with the top part starting lower than where the top part of the 8 is drawn. as we can see a blue downward curve right below a red one.

6 PART 2

[2]:
```
#importing files
x_trains = np.loadtxt('train_shirt_x.csv', delimiter=',', skiprows=1)
x_tests = np.loadtxt('test_shirt_x.csv', delimiter=',', skiprows=1)

y_trains = np.loadtxt('train_shirt_y.csv', delimiter=',', skiprows=1)
#y_tests = np.loadtxt('test_shirt_y.csv', delimiter=',', skiprows=1)
```

[3]:
```
#importing files
X_train = pd.read_csv('train_shirt_x.csv')
X_test = pd.read_csv('test_shirt_x.csv')

Y_train = pd.read_csv('train_shirt_y.csv')
```

[4]:
```
X_train
```

[4]:
```
       pixel000  pixel001  pixel002  pixel003  pixel004  pixel005  pixel006  \
0           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000
1           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0106
2           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000
3           0.0       0.0       0.0       0.0    0.0000    0.0043    0.0000
4           0.0       0.0       0.0       0.0    0.0051    0.0049    0.0000
…           …         …         …         …         …         …         …
11995       0.0       0.0       0.0       0.0    0.0000    0.0130    0.0000
11996       0.0       0.0       0.0       0.0    0.0000    0.0049    0.0053
11997       0.0       0.0       0.0       0.0    0.0000    0.0049    0.0000
11998       0.0       0.0       0.0       0.0    0.0000    0.0000    0.2434
11999       0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000

       pixel007  pixel008  pixel009  …  pixel774  pixel775  pixel776  \
0        0.0000    0.0041    0.0000  …    0.3480    0.3320    0.0000
1        0.0046    0.0000    0.0000  …    0.3098    0.3589    0.3577
2        0.0000    0.0000    0.0000  …    0.0000    0.0000    0.0000
3        0.0000    0.0041    0.0042  …    0.0080    0.0000    0.0000
4        0.0000    0.0000    0.0039  …    0.1569    0.1290    0.0285
…           …         …      …   …       …         …
11995    0.0000    0.0000    0.0546  …    0.0000    0.0000    0.0000
11996    0.0000    0.0000    0.0000  …    0.4667    0.3548    0.2561
11997    0.0000    0.0000    0.0000  …    0.4745    0.4194    0.2683
11998    0.3380    0.0000    0.0235  …    0.0471    0.0121    0.0163
```

```
11999    0.0000    0.0083    0.0000  ...    0.0000    0.0000    0.0706

       pixel777  pixel778  pixel779  pixel780  pixel781  pixel782  pixel783
0        0.0000     0.004    0.0000    0.0000    0.0000       0.0       0.0
1        0.0000     0.000    0.0000    0.0000    0.0000       0.0       0.0
2        0.0000     0.000    0.0000    0.0000    0.0000       0.0       0.0
3        0.0000     0.224    0.6392    0.5909    0.0000       0.0       0.0
4        0.0000     0.000    0.0045    0.0000    0.0000       0.0       0.0
...         ...       ...       ...       ...       ...       ...       ...
11995    0.0000     0.624    0.6902    0.3182    0.2202       0.0       0.0
11996    0.0000     0.000    0.0089    0.0000    0.0000       0.0       0.0
11997    0.0000     0.000    0.0000    0.0000    0.0000       0.0       0.0
11998    0.1373     0.000    0.0000    0.0000    0.0000       0.0       0.0
11999    0.6032     0.296    0.2118    0.0000    0.0000       0.0       0.0

[12000 rows x 784 columns]
```

[5]:
```python
shirts_df = pd.concat([X_train, Y_train], axis=1)
```

[6]:
```python
shirts_df
```

[6]:
```
       pixel000  pixel001  pixel002  pixel003  pixel004  pixel005  pixel006  \
0           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000
1           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0106
2           0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000
3           0.0       0.0       0.0       0.0    0.0000    0.0043    0.0000
4           0.0       0.0       0.0       0.0    0.0051    0.0049    0.0000
...         ...       ...       ...       ...       ...       ...       ...
11995       0.0       0.0       0.0       0.0    0.0000    0.0130    0.0000
11996       0.0       0.0       0.0       0.0    0.0000    0.0049    0.0053
11997       0.0       0.0       0.0       0.0    0.0000    0.0049    0.0000
11998       0.0       0.0       0.0       0.0    0.0000    0.0000    0.2434
11999       0.0       0.0       0.0       0.0    0.0000    0.0000    0.0000

       pixel007  pixel008  pixel009  ...  pixel775  pixel776  pixel777  \
0        0.0000    0.0041    0.0000  ...    0.3320    0.0000    0.0000
1        0.0046    0.0000    0.0000  ...    0.3589    0.3577    0.0000
2        0.0000    0.0000    0.0000  ...    0.0000    0.0000    0.0000
3        0.0000    0.0041    0.0042  ...    0.0000    0.0000    0.0000
4        0.0000    0.0000    0.0039  ...    0.1290    0.0285    0.0000
...         ...       ...       ...  ...       ...       ...       ...
11995    0.0000    0.0000    0.0546  ...    0.0000    0.0000    0.0000
11996    0.0000    0.0000    0.0000  ...    0.3548    0.2561    0.0000
11997    0.0000    0.0000    0.0000  ...    0.4194    0.2683    0.0000
11998    0.3380    0.0000    0.0235  ...    0.0121    0.0163    0.1373
11999    0.0000    0.0083    0.0000  ...    0.0000    0.0706    0.6032
```

```
       pixel778  pixel779  pixel780  pixel781  pixel782  pixel783  is_teeshirt
0         0.004    0.0000    0.0000    0.0000       0.0       0.0            0
1         0.000    0.0000    0.0000    0.0000       0.0       0.0            1
2         0.000    0.0000    0.0000    0.0000       0.0       0.0            1
3         0.224    0.6392    0.5909    0.0000       0.0       0.0            0
4         0.000    0.0045    0.0000    0.0000       0.0       0.0            1
…           …        …    …     …         …        …          …
11995     0.624    0.6902    0.3182    0.2202       0.0       0.0            0
11996     0.000    0.0089    0.0000    0.0000       0.0       0.0            1
11997     0.000    0.0000    0.0000    0.0000       0.0       0.0            1
11998     0.000    0.0000    0.0000    0.0000       0.0       0.0            1
11999     0.296    0.2118    0.0000    0.0000       0.0       0.0            0

[12000 rows x 785 columns]
```

[7]:
```
shirts_df.shape
```

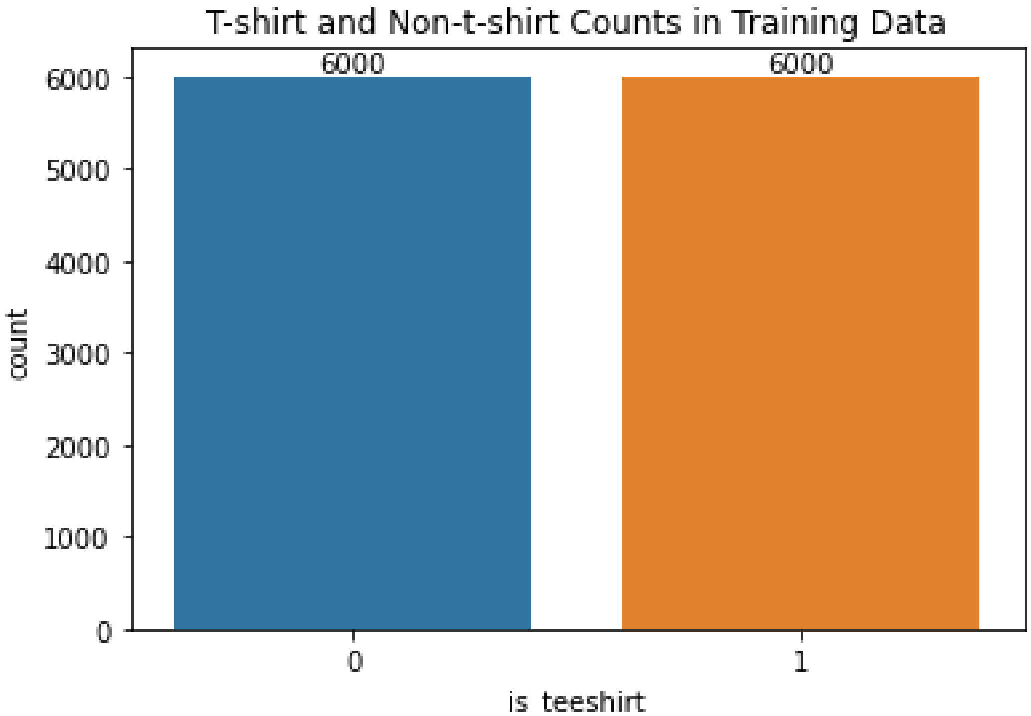
[7]:
```
(12000, 785)
```

[8]:
```
shirts_df.isnull().sum() # no nulls in dataset good
```

[8]:
```
pixel000       0
pixel001       0
pixel002       0
pixel003       0
pixel004       0
              ..
pixel780       0
pixel781       0
pixel782       0
pixel783       0
is_teeshirt    0
Length: 785, dtype: int64
```

[9]:
```
#exploring data outcomes
ax = sns.countplot(x='is_teeshirt', data=shirts_df)
shirts_df.is_teeshirt.value_counts()
ax.bar_label(ax.containers[0])
ax.set_title('T-shirt and Non-t-shirt Counts in Training Data')

plt.show()
```



From the bar graph above we can see the total amount of each outcome in the training data. The plot tells us that our training data has an equil amount of T-shits and Non-T-shits shits. This means that out model shold not suffer from bias towards FP or FN while obtaining a relatively high accuracy score because there is an even distribution of outcomes.

[10]:
```
shirts_df.columns
```

[10]:
```
Index(['pixel000', 'pixel001', 'pixel002', 'pixel003', 'pixel004', 'pixel005',
       'pixel006', 'pixel007', 'pixel008', 'pixel009',
       …
       'pixel775', 'pixel776', 'pixel777', 'pixel778', 'pixel779', 'pixel780',
       'pixel781', 'pixel782', 'pixel783', 'is_teeshirt'],
      dtype='object', length=785)
```

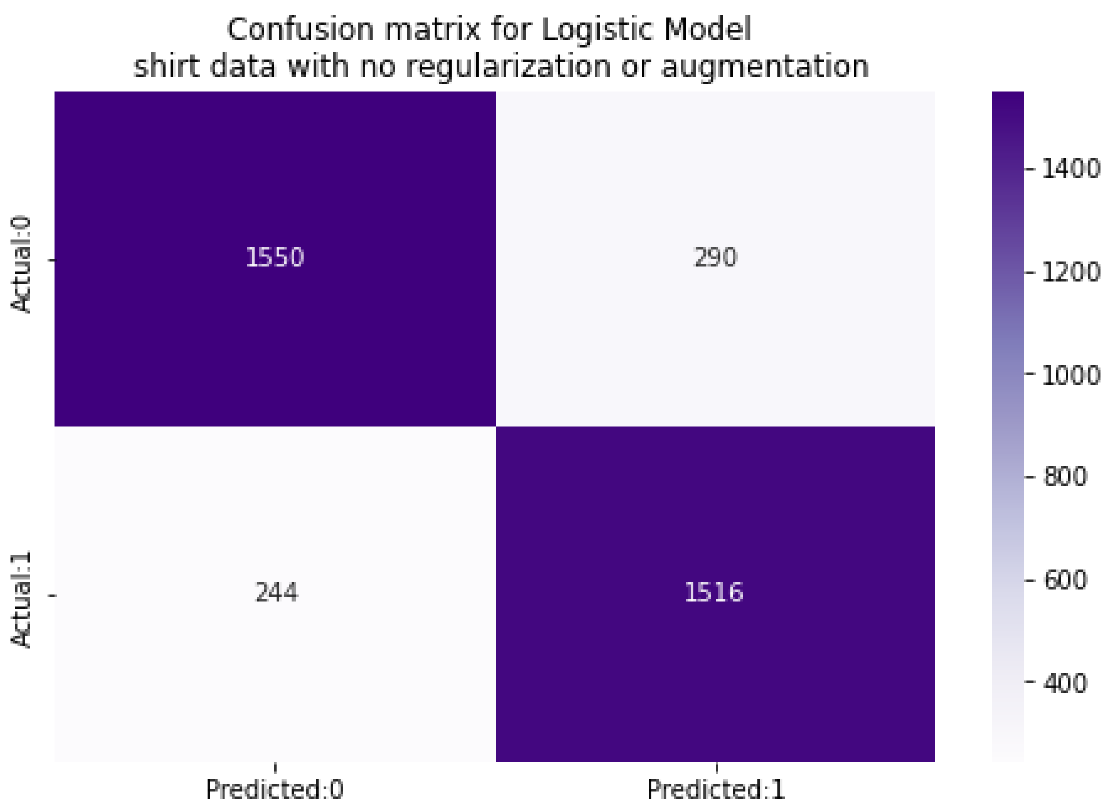
[11]:
```
X = shirts_df.drop('is_teeshirt', axis=1)
y = shirts_df.is_teeshirt
```

Model with no regs or augmentation

[22]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3,␣
 ↪random_state=0)
#Splitting the data into training and testing (70% Train and 30% Test)
```

[23]:
```
logreg = LogisticRegression() #Instantiating the LogisticRegression Object
logreg.fit(X_train, y_train) #Fitting the model on our training data using fit␣
↪method
y_pred = logreg.predict(X_test) #Making predictions on Testing Model
```

[24]:
```
#Creating Confusion Matrix to evaluate the model
cm = confusion_matrix(y_test,y_pred)
conf_matrix=pd.DataFrame(data=cm,columns=['Predicted:0','Predicted:
↪1'],index=['Actual:0','Actual:1'])
plt.figure(figsize = (8,5))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap="Purples")
plt.title('Confusion matrix for Logistic Model \n shirt data with no␣
↪regularization or augmentation')
plt.show()
```



[25]:
```
#True Negative, True Positive, False Negative, False Positive
TN=cm[0,0]
TP=cm[1,1]
FN=cm[1,0]
FP=cm[0,1]
```

```
#Accuracy
print('The acuracy of the model = TP+TN/(TP+TN+FP+FN) = ', round((TP+TN)/
 ↪float(TP+TN+FP+FN),3))
#Misclassification
print('The Missclassification = 1-Accuracy = ', round(1-((TP+TN)/
 ↪float(TP+TN+FP+FN)), 3))
#Sensitivity
print('Sensitivity or True Positive Rate = TP/(TP+FN) = ', round(TP/
 ↪float(TP+FN),3))
#Specificity
print('Specificity or True Negative Rate = TN/(TN+FP) = ', round(TN/
 ↪float(TN+FP),3))

#Classification Report
from sklearn.metrics import classification_report
print(classification_report(y_test, y_pred))
```

```
The acuracy of the model = TP+TN/(TP+TN+FP+FN) =  0.852
The Missclassification = 1-Accuracy =  0.148
Sensitivity or True Positive Rate = TP/(TP+FN) =  0.861
Specificity or True Negative Rate = TN/(TN+FP) =  0.842
              precision    recall  f1-score   support

           0       0.86      0.84      0.85      1840
           1       0.84      0.86      0.85      1760

    accuracy                           0.85      3600
   macro avg       0.85      0.85      0.85      3600
weighted avg       0.85      0.85      0.85      3600
```

https://machinelearningmastery.com/hyperparameters-for-classification-machine-learning-algorithms/

[39]:
```
## do the grid thing with logistic regressyion model

# example of grid searching key hyperparametres for logistic regression
from sklearn.datasets import make_blobs
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import LogisticRegression
# define models and parameters
model = LogisticRegression()
solvers = ['newton-cg', 'lbfgs', 'liblinear']
penalty = ['l1','l2']
c_values = [100, 10, 1.0, 0.1, 0.01]
# define grid search
grid = dict(solver=solvers,penalty=penalty,C=c_values)
```

```
cv = RepeatedStratifiedKFold(n_splits=5, n_repeats=3, random_state=1)
grid_search = GridSearchCV(estimator=model, param_grid=grid, n_jobs=-1, cv=cv,␣
↪scoring='accuracy',error_score=0)
grid_result = grid_search.fit(X, y)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
params = grid_result.cv_results_['params']
for mean, stdev, param in zip(means, stds, params):
    print("%f (%f) with: %r" % (mean, stdev, param))
```

```
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
```

```
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/Users/dalithendel/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:814: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

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```
Best: 0.965667 using {'C': 0.01, 'penalty': 'l1', 'solver': 'liblinear'}
0.000000 (0.000000) with: {'C': 100, 'penalty': 'l1', 'solver': 'newton-cg'}
0.000000 (0.000000) with: {'C': 100, 'penalty': 'l1', 'solver': 'lbfgs'}
0.953333 (0.016799) with: {'C': 100, 'penalty': 'l1', 'solver': 'liblinear'}
0.949667 (0.018025) with: {'C': 100, 'penalty': 'l2', 'solver': 'newton-cg'}
0.949333 (0.017404) with: {'C': 100, 'penalty': 'l2', 'solver': 'lbfgs'}
0.949667 (0.018117) with: {'C': 100, 'penalty': 'l2', 'solver': 'liblinear'}
0.000000 (0.000000) with: {'C': 10, 'penalty': 'l1', 'solver': 'newton-cg'}
0.000000 (0.000000) with: {'C': 10, 'penalty': 'l1', 'solver': 'lbfgs'}
0.952000 (0.017870) with: {'C': 10, 'penalty': 'l1', 'solver': 'liblinear'}
0.950667 (0.017689) with: {'C': 10, 'penalty': 'l2', 'solver': 'newton-cg'}
0.950000 (0.017981) with: {'C': 10, 'penalty': 'l2', 'solver': 'lbfgs'}
0.949667 (0.018117) with: {'C': 10, 'penalty': 'l2', 'solver': 'liblinear'}
0.000000 (0.000000) with: {'C': 1.0, 'penalty': 'l1', 'solver': 'newton-cg'}
0.000000 (0.000000) with: {'C': 1.0, 'penalty': 'l1', 'solver': 'lbfgs'}
0.952333 (0.016418) with: {'C': 1.0, 'penalty': 'l1', 'solver': 'liblinear'}
0.952333 (0.017211) with: {'C': 1.0, 'penalty': 'l2', 'solver': 'newton-cg'}
0.951333 (0.017839) with: {'C': 1.0, 'penalty': 'l2', 'solver': 'lbfgs'}
0.951667 (0.017095) with: {'C': 1.0, 'penalty': 'l2', 'solver': 'liblinear'}
0.000000 (0.000000) with: {'C': 0.1, 'penalty': 'l1', 'solver': 'newton-cg'}
```

```
0.000000 (0.000000) with: {'C': 0.1, 'penalty': 'l1', 'solver': 'lbfgs'}
0.958000 (0.017010) with: {'C': 0.1, 'penalty': 'l1', 'solver': 'liblinear'}
0.953667 (0.016479) with: {'C': 0.1, 'penalty': 'l2', 'solver': 'newton-cg'}
0.953667 (0.016479) with: {'C': 0.1, 'penalty': 'l2', 'solver': 'lbfgs'}
0.954333 (0.017404) with: {'C': 0.1, 'penalty': 'l2', 'solver': 'liblinear'}
0.000000 (0.000000) with: {'C': 0.01, 'penalty': 'l1', 'solver': 'newton-cg'}
0.000000 (0.000000) with: {'C': 0.01, 'penalty': 'l1', 'solver': 'lbfgs'}
0.965667 (0.012893) with: {'C': 0.01, 'penalty': 'l1', 'solver': 'liblinear'}
0.956000 (0.014399) with: {'C': 0.01, 'penalty': 'l2', 'solver': 'newton-cg'}
0.956000 (0.014399) with: {'C': 0.01, 'penalty': 'l2', 'solver': 'lbfgs'}
0.957000 (0.015362) with: {'C': 0.01, 'penalty': 'l2', 'solver': 'liblinear'}
```

[32]:
```
# example of grid searching key hyperparametres for ridge classifier
from sklearn.datasets import make_blobs
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import RidgeClassifier
# define models and parameters
model = RidgeClassifier()
alpha = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]
# define grid search
grid = dict(alpha=alpha)
cv = RepeatedStratifiedKFold(n_splits=5, n_repeats=3, random_state=1)
grid_search = GridSearchCV(estimator=model, param_grid=grid, n_jobs=-1, cv=cv,␣
↪scoring='accuracy',error_score=0)
grid_result = grid_search.fit(X, y)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
params = grid_result.cv_results_['params']
for mean, stdev, param in zip(means, stds, params):
    print("%f (%f) with: %r" % (mean, stdev, param))
```

```
Best: 0.967333 using {'alpha': 0.1}
0.967333 (0.013524) with: {'alpha': 0.1}
0.967333 (0.013524) with: {'alpha': 0.2}
0.967333 (0.013524) with: {'alpha': 0.3}
0.967333 (0.013524) with: {'alpha': 0.4}
0.967333 (0.013524) with: {'alpha': 0.5}
0.967333 (0.013524) with: {'alpha': 0.6}
0.967333 (0.013524) with: {'alpha': 0.7}
0.967333 (0.013524) with: {'alpha': 0.8}
0.967333 (0.013524) with: {'alpha': 0.9}
0.967333 (0.013524) with: {'alpha': 1.0}
```

[37]:
```
# example of grid searching key hyperparametres for ridge classifier
from sklearn.datasets import make_blobs
```

```python
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import Lasso
# define models and parameters
model = Lasso()
alpha = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]
# define grid search
grid = dict(alpha=alpha)
cv = RepeatedStratifiedKFold(n_splits=5, n_repeats=3, random_state=1)
grid_search = GridSearchCV(estimator=model, param_grid=grid, n_jobs=-1, cv=cv,␣
↪scoring='accuracy',error_score=0)
grid_result = grid_search.fit(X, y)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
params = grid_result.cv_results_['params']
for mean, stdev, param in zip(means, stds, params):
    print("%f (%f) with: %r" % (mean, stdev, param))
```

```
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ValueError: Classification metrics can't handle a mix of binary and continuous
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Best: 0.000000 using {'alpha': 0.1}
0.000000 (0.000000) with: {'alpha': 0.1}
0.000000 (0.000000) with: {'alpha': 0.2}
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0.000000 (0.000000) with: {'alpha': 0.3}
0.000000 (0.000000) with: {'alpha': 0.4}
0.000000 (0.000000) with: {'alpha': 0.5}
0.000000 (0.000000) with: {'alpha': 0.6}
0.000000 (0.000000) with: {'alpha': 0.7}
0.000000 (0.000000) with: {'alpha': 0.8}
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KNN

[33]:
```python
# example of grid searching key hyperparametres for KNeighborsClassifier
from sklearn.datasets import make_blobs
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import GridSearchCV
from sklearn.neighbors import KNeighborsClassifier
# define models and parameters
model = KNeighborsClassifier()
n_neighbors = range(1, 21, 2)
weights = ['uniform', 'distance']
metric = ['euclidean', 'manhattan', 'minkowski']
# define grid search
grid = dict(n_neighbors=n_neighbors,weights=weights,metric=metric)
```

```python
cv = RepeatedStratifiedKFold(n_splits=5, n_repeats=3, random_state=1)
grid_search = GridSearchCV(estimator=model, param_grid=grid, n_jobs=-1, cv=cv,␣
↪scoring='accuracy',error_score=0)
grid_result = grid_search.fit(X, y)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
params = grid_result.cv_results_['params']
for mean, stdev, param in zip(means, stds, params):
    print("%f (%f) with: %r" % (mean, stdev, param))
```

```
Best: 0.958000 using {'metric': 'euclidean', 'n_neighbors': 19, 'weights':
'uniform'}
0.862333 (0.024958) with: {'metric': 'euclidean', 'n_neighbors': 1, 'weights':
'uniform'}
0.862333 (0.024958) with: {'metric': 'euclidean', 'n_neighbors': 1, 'weights':
'distance'}
0.907333 (0.013646) with: {'metric': 'euclidean', 'n_neighbors': 3, 'weights':
'uniform'}
0.907333 (0.013646) with: {'metric': 'euclidean', 'n_neighbors': 3, 'weights':
'distance'}
0.928333 (0.010750) with: {'metric': 'euclidean', 'n_neighbors': 5, 'weights':
'uniform'}
0.928333 (0.010750) with: {'metric': 'euclidean', 'n_neighbors': 5, 'weights':
'distance'}
0.936333 (0.013098) with: {'metric': 'euclidean', 'n_neighbors': 7, 'weights':
'uniform'}
0.936333 (0.013098) with: {'metric': 'euclidean', 'n_neighbors': 7, 'weights':
'distance'}
0.946000 (0.012275) with: {'metric': 'euclidean', 'n_neighbors': 9, 'weights':
'uniform'}
0.946000 (0.012275) with: {'metric': 'euclidean', 'n_neighbors': 9, 'weights':
'distance'}
0.950667 (0.013888) with: {'metric': 'euclidean', 'n_neighbors': 11, 'weights':
'uniform'}
0.950667 (0.013888) with: {'metric': 'euclidean', 'n_neighbors': 11, 'weights':
'distance'}
0.952333 (0.013646) with: {'metric': 'euclidean', 'n_neighbors': 13, 'weights':
'uniform'}
0.952333 (0.013646) with: {'metric': 'euclidean', 'n_neighbors': 13, 'weights':
'distance'}
0.956000 (0.014629) with: {'metric': 'euclidean', 'n_neighbors': 15, 'weights':
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0.956000 (0.014629) with: {'metric': 'euclidean', 'n_neighbors': 15, 'weights':
'distance'}
0.957333 (0.013888) with: {'metric': 'euclidean', 'n_neighbors': 17, 'weights':
'uniform'}
```

```
0.957333 (0.013888) with: {'metric': 'euclidean', 'n_neighbors': 17, 'weights':
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0.853333 (0.019206) with: {'metric': 'manhattan', 'n_neighbors': 1, 'weights':
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0.897667 (0.017594) with: {'metric': 'manhattan', 'n_neighbors': 3, 'weights':
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0.915667 (0.013646) with: {'metric': 'manhattan', 'n_neighbors': 5, 'weights':
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0.915667 (0.013646) with: {'metric': 'manhattan', 'n_neighbors': 5, 'weights':
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0.948667 (0.016173) with: {'metric': 'manhattan', 'n_neighbors': 19, 'weights':
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0.862333 (0.024958) with: {'metric': 'minkowski', 'n_neighbors': 1, 'weights':
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```

```
0.862333 (0.024958) with: {'metric': 'minkowski', 'n_neighbors': 1, 'weights':
'distance'}
0.907333 (0.013646) with: {'metric': 'minkowski', 'n_neighbors': 3, 'weights':
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0.952333 (0.013646) with: {'metric': 'minkowski', 'n_neighbors': 13, 'weights':
'distance'}
0.956000 (0.014629) with: {'metric': 'minkowski', 'n_neighbors': 15, 'weights':
'uniform'}
0.956000 (0.014629) with: {'metric': 'minkowski', 'n_neighbors': 15, 'weights':
'distance'}
0.957333 (0.013888) with: {'metric': 'minkowski', 'n_neighbors': 17, 'weights':
'uniform'}
0.957333 (0.013888) with: {'metric': 'minkowski', 'n_neighbors': 17, 'weights':
'distance'}
0.958000 (0.013515) with: {'metric': 'minkowski', 'n_neighbors': 19, 'weights':
'uniform'}
0.958000 (0.013515) with: {'metric': 'minkowski', 'n_neighbors': 19, 'weights':
'distance'}
```

[35]:
```
# example of grid searching key hyperparametres for SVC
from sklearn.datasets import make_blobs
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import GridSearchCV
from sklearn.svm import SVC
# define model and parameters
model = SVC()
kernel = ['poly', 'rbf', 'sigmoid']
```

```
C = [50, 10, 1.0, 0.1, 0.01]
gamma = ['scale']
# define grid search
grid = dict(kernel=kernel,C=C,gamma=gamma)
cv = RepeatedStratifiedKFold(n_splits=5, n_repeats=3, random_state=1)
grid_search = GridSearchCV(estimator=model, param_grid=grid, n_jobs=-1, cv=cv,␣
↪scoring='accuracy',error_score=0)
grid_result = grid_search.fit(X, y)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
params = grid_result.cv_results_['params']
for mean, stdev, param in zip(means, stds, params):
    print("%f (%f) with: %r" % (mean, stdev, param))
```

```
Best: 0.979667 using {'C': 0.1, 'gamma': 'scale', 'kernel': 'sigmoid'}
0.970333 (0.010719) with: {'C': 50, 'gamma': 'scale', 'kernel': 'poly'}
0.972667 (0.014126) with: {'C': 50, 'gamma': 'scale', 'kernel': 'rbf'}
0.953000 (0.017493) with: {'C': 50, 'gamma': 'scale', 'kernel': 'sigmoid'}
0.970333 (0.010719) with: {'C': 10, 'gamma': 'scale', 'kernel': 'poly'}
0.972667 (0.014126) with: {'C': 10, 'gamma': 'scale', 'kernel': 'rbf'}
0.956667 (0.016600) with: {'C': 10, 'gamma': 'scale', 'kernel': 'sigmoid'}
0.970333 (0.013098) with: {'C': 1.0, 'gamma': 'scale', 'kernel': 'poly'}
0.973333 (0.013250) with: {'C': 1.0, 'gamma': 'scale', 'kernel': 'rbf'}
0.969000 (0.011284) with: {'C': 1.0, 'gamma': 'scale', 'kernel': 'sigmoid'}
0.670333 (0.139266) with: {'C': 0.1, 'gamma': 'scale', 'kernel': 'poly'}
0.979333 (0.007930) with: {'C': 0.1, 'gamma': 'scale', 'kernel': 'rbf'}
0.979667 (0.010242) with: {'C': 0.1, 'gamma': 'scale', 'kernel': 'sigmoid'}
0.670333 (0.139266) with: {'C': 0.01, 'gamma': 'scale', 'kernel': 'poly'}
0.977333 (0.009978) with: {'C': 0.01, 'gamma': 'scale', 'kernel': 'rbf'}
0.971000 (0.010198) with: {'C': 0.01, 'gamma': 'scale', 'kernel': 'sigmoid'}
```

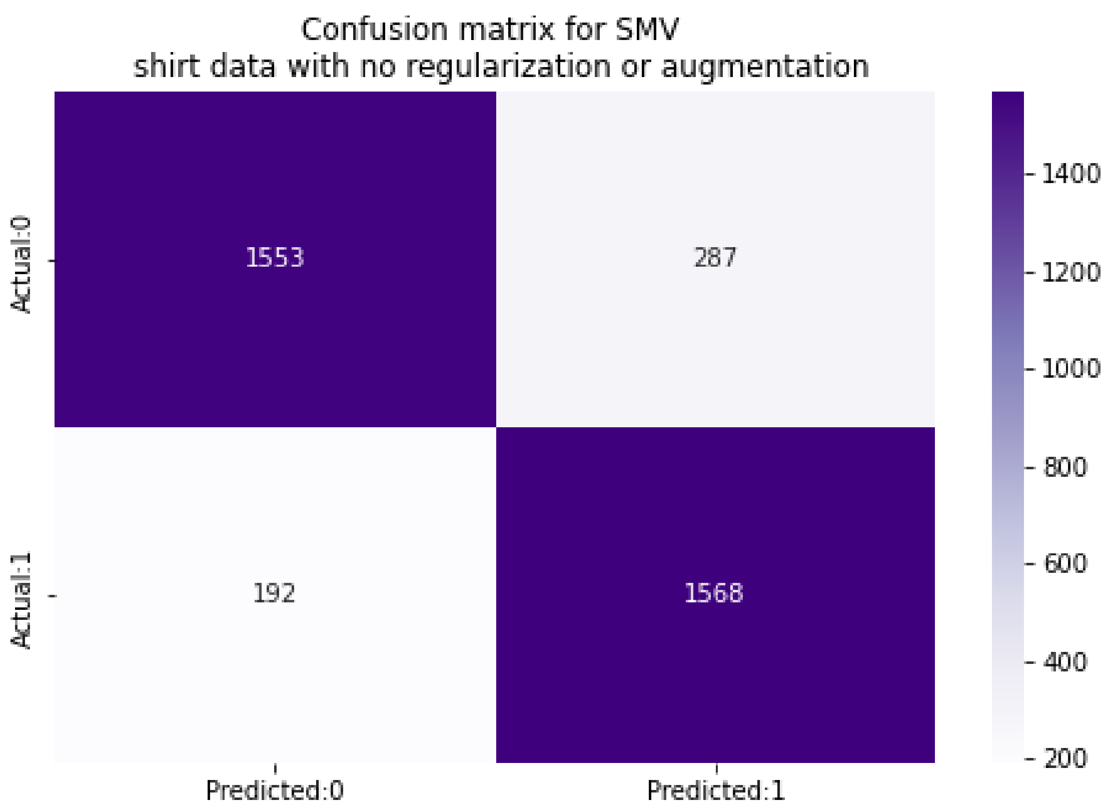
trying same with svm

[17]:
```
#Loading the SVM model
clf = svm.SVC()
#Fitting the SVM model on our training data
clf.fit(X_train, y_train)
#Making predictions on our testing data
y_pred = clf.predict(X_test)
#Evaluating our model

print(confusion_matrix(y_test,y_pred))
print(classification_report(y_test,y_pred))
```

```
[[1553  287]
 [ 192 1568]]
              precision    recall  f1-score   support
```

```
           0       0.89      0.84      0.87      1840
           1       0.85      0.89      0.87      1760

    accuracy                           0.87      3600
   macro avg       0.87      0.87      0.87      3600
weighted avg       0.87      0.87      0.87      3600
```

[18]:
```
#Creating Confusion Matrix to evaluate the model
cm = confusion_matrix(y_test,y_pred)
conf_matrix=pd.DataFrame(data=cm,columns=['Predicted:0','Predicted:
 ↪1'],index=['Actual:0','Actual:1'])
plt.figure(figsize = (8,5))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap="Purples")
plt.title('Confusion matrix for SMV \n shirt data with no regularization or␣
 ↪augmentation')
plt.show()
```



SMV MODEL IS PERFORMING BETTER now svm with C regularization

[35]:

```
# param grif for RBF
from sklearn.model_selection import GridSearchCV
from sklearn.svm import SVC
# train the model on train set

model = SVC()
model.fit(X_train, y_train)
# print prediction results
predictions = model.predict(X_test)
print(classification_report(y_test, predictions))
# defining parameter range
param_grid = {'C': [0.1, 1, 10, 100, 1000],
              'gamma': [0.1, 0.01, 0.001, 0.0001], # removing gamma = 1 bc they␣
↪were around 50% score
              'kernel': ['rbf']} #sigmoid (low),  'linear', 'poly'

grid = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3)

# fitting the model for grid search
grid.fit(X_train, y_train)
```

```
              precision    recall  f1-score   support

           0       0.89      0.84      0.87      1840
           1       0.85      0.89      0.87      1760

    accuracy                           0.87      3600
   macro avg       0.87      0.87      0.87      3600
weighted avg       0.87      0.87      0.87      3600

Fitting 5 folds for each of 20 candidates, totalling 100 fits
[CV 1/5] END …C=0.1, gamma=0.1, kernel=rbf;, score=0.812 total time=  18.2s
[CV 2/5] END …C=0.1, gamma=0.1, kernel=rbf;, score=0.811 total time=  19.2s
[CV 3/5] END …C=0.1, gamma=0.1, kernel=rbf;, score=0.815 total time=  19.0s
[CV 4/5] END …C=0.1, gamma=0.1, kernel=rbf;, score=0.813 total time=  18.9s
[CV 5/5] END …C=0.1, gamma=0.1, kernel=rbf;, score=0.798 total time=  19.4s
[CV 1/5] END …C=0.1, gamma=0.01, kernel=rbf;, score=0.827 total time=  11.9s
[CV 2/5] END …C=0.1, gamma=0.01, kernel=rbf;, score=0.839 total time=  12.0s
[CV 3/5] END …C=0.1, gamma=0.01, kernel=rbf;, score=0.840 total time=  12.0s
[CV 4/5] END …C=0.1, gamma=0.01, kernel=rbf;, score=0.816 total time=  12.2s
[CV 5/5] END …C=0.1, gamma=0.01, kernel=rbf;, score=0.825 total time=  12.2s
[CV 1/5] END …C=0.1, gamma=0.001, kernel=rbf;, score=0.817 total time=  15.1s
[CV 2/5] END …C=0.1, gamma=0.001, kernel=rbf;, score=0.820 total time=  15.4s
[CV 3/5] END …C=0.1, gamma=0.001, kernel=rbf;, score=0.825 total time=  15.3s
[CV 4/5] END …C=0.1, gamma=0.001, kernel=rbf;, score=0.809 total time=  15.5s
[CV 5/5] END …C=0.1, gamma=0.001, kernel=rbf;, score=0.812 total time=  15.5s
[CV 1/5] END …C=0.1, gamma=0.0001, kernel=rbf;, score=0.814 total time=  25.2s
[CV 2/5] END …C=0.1, gamma=0.0001, kernel=rbf;, score=0.810 total time=  25.2s
```

```
[CV 3/5] END …C=0.1, gamma=0.0001, kernel=rbf;, score=0.813 total time=  24.6s
[CV 4/5] END …C=0.1, gamma=0.0001, kernel=rbf;, score=0.810 total time=  24.8s
[CV 5/5] END …C=0.1, gamma=0.0001, kernel=rbf;, score=0.801 total time=  24.7s
[CV 1/5] END …C=1, gamma=0.1, kernel=rbf;, score=0.860 total time=  16.3s
[CV 2/5] END …C=1, gamma=0.1, kernel=rbf;, score=0.864 total time=  16.1s
[CV 3/5] END …C=1, gamma=0.1, kernel=rbf;, score=0.863 total time=  16.2s
[CV 4/5] END …C=1, gamma=0.1, kernel=rbf;, score=0.870 total time=  16.2s
[CV 5/5] END …C=1, gamma=0.1, kernel=rbf;, score=0.855 total time=  16.0s
[CV 1/5] END …C=1, gamma=0.01, kernel=rbf;, score=0.861 total time=   9.8s
[CV 2/5] END …C=1, gamma=0.01, kernel=rbf;, score=0.875 total time=   9.9s
[CV 3/5] END …C=1, gamma=0.01, kernel=rbf;, score=0.873 total time=   9.8s
[CV 4/5] END …C=1, gamma=0.01, kernel=rbf;, score=0.868 total time=   9.9s
[CV 5/5] END …C=1, gamma=0.01, kernel=rbf;, score=0.868 total time=  10.0s
[CV 1/5] END …C=1, gamma=0.001, kernel=rbf;, score=0.832 total time=  11.4s
[CV 2/5] END …C=1, gamma=0.001, kernel=rbf;, score=0.843 total time=  11.6s
[CV 3/5] END …C=1, gamma=0.001, kernel=rbf;, score=0.841 total time=  11.3s
[CV 4/5] END …C=1, gamma=0.001, kernel=rbf;, score=0.824 total time=  11.3s
[CV 5/5] END …C=1, gamma=0.001, kernel=rbf;, score=0.832 total time=  10.8s
[CV 1/5] END …C=1, gamma=0.0001, kernel=rbf;, score=0.817 total time=  15.0s
[CV 2/5] END …C=1, gamma=0.0001, kernel=rbf;, score=0.822 total time=  15.1s
[CV 3/5] END …C=1, gamma=0.0001, kernel=rbf;, score=0.824 total time=  15.0s
[CV 4/5] END …C=1, gamma=0.0001, kernel=rbf;, score=0.807 total time=  15.1s
[CV 5/5] END …C=1, gamma=0.0001, kernel=rbf;, score=0.812 total time=  15.5s
[CV 1/5] END …C=10, gamma=0.1, kernel=rbf;, score=0.860 total time=  20.2s
[CV 2/5] END …C=10, gamma=0.1, kernel=rbf;, score=0.873 total time=  20.1s
[CV 3/5] END …C=10, gamma=0.1, kernel=rbf;, score=0.870 total time=  20.6s
[CV 4/5] END …C=10, gamma=0.1, kernel=rbf;, score=0.869 total time=  20.3s
[CV 5/5] END …C=10, gamma=0.1, kernel=rbf;, score=0.859 total time=  20.4s
[CV 1/5] END …C=10, gamma=0.01, kernel=rbf;, score=0.865 total time=   9.5s
[CV 2/5] END …C=10, gamma=0.01, kernel=rbf;, score=0.881 total time=   9.7s
[CV 3/5] END …C=10, gamma=0.01, kernel=rbf;, score=0.877 total time=   9.5s
[CV 4/5] END …C=10, gamma=0.01, kernel=rbf;, score=0.885 total time=   9.7s
[CV 5/5] END …C=10, gamma=0.01, kernel=rbf;, score=0.876 total time=   9.8s
[CV 1/5] END …C=10, gamma=0.001, kernel=rbf;, score=0.857 total time=   9.7s
[CV 2/5] END …C=10, gamma=0.001, kernel=rbf;, score=0.869 total time=   9.7s
[CV 3/5] END …C=10, gamma=0.001, kernel=rbf;, score=0.868 total time=   9.7s
[CV 4/5] END …C=10, gamma=0.001, kernel=rbf;, score=0.863 total time=   9.7s
[CV 5/5] END …C=10, gamma=0.001, kernel=rbf;, score=0.860 total time=   9.7s
[CV 1/5] END …C=10, gamma=0.0001, kernel=rbf;, score=0.832 total time=  11.4s
[CV 2/5] END …C=10, gamma=0.0001, kernel=rbf;, score=0.843 total time=  11.3s
[CV 3/5] END …C=10, gamma=0.0001, kernel=rbf;, score=0.842 total time=  11.4s
[CV 4/5] END …C=10, gamma=0.0001, kernel=rbf;, score=0.826 total time=  11.2s
[CV 5/5] END …C=10, gamma=0.0001, kernel=rbf;, score=0.832 total time=  11.4s
[CV 1/5] END …C=100, gamma=0.1, kernel=rbf;, score=0.860 total time=  20.2s
[CV 2/5] END …C=100, gamma=0.1, kernel=rbf;, score=0.873 total time=  20.3s
[CV 3/5] END …C=100, gamma=0.1, kernel=rbf;, score=0.870 total time=  20.2s
[CV 4/5] END …C=100, gamma=0.1, kernel=rbf;, score=0.869 total time=  20.4s
[CV 5/5] END …C=100, gamma=0.1, kernel=rbf;, score=0.859 total time=  20.3s
```

```
[CV 1/5] END …C=100, gamma=0.01, kernel=rbf;, score=0.866 total time=   9.5s
[CV 2/5] END …C=100, gamma=0.01, kernel=rbf;, score=0.870 total time=   9.8s
[CV 3/5] END …C=100, gamma=0.01, kernel=rbf;, score=0.868 total time=   9.7s
[CV 4/5] END …C=100, gamma=0.01, kernel=rbf;, score=0.876 total time=   9.9s
[CV 5/5] END …C=100, gamma=0.01, kernel=rbf;, score=0.863 total time=   9.5s
[CV 1/5] END …C=100, gamma=0.001, kernel=rbf;, score=0.859 total time=   9.6s
[CV 2/5] END …C=100, gamma=0.001, kernel=rbf;, score=0.872 total time=   9.2s
[CV 3/5] END …C=100, gamma=0.001, kernel=rbf;, score=0.863 total time=   9.1s
[CV 4/5] END …C=100, gamma=0.001, kernel=rbf;, score=0.868 total time=   9.4s
[CV 5/5] END …C=100, gamma=0.001, kernel=rbf;, score=0.860 total time=   9.3s
[CV 1/5] END …C=100, gamma=0.0001, kernel=rbf;, score=0.854 total time=   9.9s
[CV 2/5] END …C=100, gamma=0.0001, kernel=rbf;, score=0.864 total time=  10.0s
[CV 3/5] END …C=100, gamma=0.0001, kernel=rbf;, score=0.864 total time=  10.0s
[CV 4/5] END …C=100, gamma=0.0001, kernel=rbf;, score=0.854 total time=  10.0s
[CV 5/5] END …C=100, gamma=0.0001, kernel=rbf;, score=0.857 total time=   9.8s
[CV 1/5] END …C=1000, gamma=0.1, kernel=rbf;, score=0.860 total time=  20.4s
[CV 2/5] END …C=1000, gamma=0.1, kernel=rbf;, score=0.873 total time=  20.4s
[CV 3/5] END …C=1000, gamma=0.1, kernel=rbf;, score=0.870 total time=  20.3s
[CV 4/5] END …C=1000, gamma=0.1, kernel=rbf;, score=0.869 total time=  21.0s
[CV 5/5] END …C=1000, gamma=0.1, kernel=rbf;, score=0.859 total time=  20.7s
[CV 1/5] END …C=1000, gamma=0.01, kernel=rbf;, score=0.867 total time=   9.5s
[CV 2/5] END …C=1000, gamma=0.01, kernel=rbf;, score=0.865 total time=   9.8s
[CV 3/5] END …C=1000, gamma=0.01, kernel=rbf;, score=0.873 total time=   9.7s
[CV 4/5] END …C=1000, gamma=0.01, kernel=rbf;, score=0.873 total time=   9.8s
[CV 5/5] END …C=1000, gamma=0.01, kernel=rbf;, score=0.864 total time=   9.4s
[CV 1/5] END …C=1000, gamma=0.001, kernel=rbf;, score=0.853 total time=  10.7s
[CV 2/5] END …C=1000, gamma=0.001, kernel=rbf;, score=0.860 total time=  11.0s
[CV 3/5] END …C=1000, gamma=0.001, kernel=rbf;, score=0.864 total time=  10.8s
[CV 4/5] END …C=1000, gamma=0.001, kernel=rbf;, score=0.868 total time=  11.6s
[CV 5/5] END …C=1000, gamma=0.001, kernel=rbf;, score=0.852 total time=  11.1s
[CV 1/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.857 total time=   9.6s
[CV 2/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.867 total time=   9.8s
[CV 3/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.861 total time=   9.5s
[CV 4/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.855 total time=   9.8s
[CV 5/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.852 total time=   9.6s
```

[35]:
```
GridSearchCV(estimator=SVC(),
             param_grid={'C': [0.1, 1, 10, 100, 1000],
                         'gamma': [0.1, 0.01, 0.001, 0.0001],
                         'kernel': ['rbf']},
             verbose=3)
```

[36]:
```python
# print best parameter after tuning
print(grid.best_params_)

# print how our model looks after hyper-parameter tuning
print(grid.best_estimator_)
```

```
## {'C': 10, 'gamma': 0.01, 'kernel': 'rbf'}
## SVC(C=10, gamma=0.01)
```

```
{'C': 10, 'gamma': 0.01, 'kernel': 'rbf'}
SVC(C=10, gamma=0.01)
```

[37]:

```
grid_predictions = grid.predict(X_test)

# print classification report
print(classification_report(y_test, grid_predictions))

## acc 89
```

```
              precision    recall  f1-score   support

           0       0.90      0.88      0.89      1840
           1       0.87      0.90      0.88      1760

    accuracy                           0.89      3600
   macro avg       0.89      0.89      0.89      3600
weighted avg       0.89      0.89      0.89      3600
```

[19]:

```
# param grid for LINEAR
model = SVC()
model.fit(X_train, y_train)
# print prediction results
predictions = model.predict(X_test)
print(classification_report(y_test, predictions))
# defining parameter range
param_grid = {'C': [0.1, 1, 10], #maybe remove 100 and 1000, taking too long
              'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
              'kernel': ['linear']}

grid = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3)

# fitting the model for grid search
grid.fit(X_train, y_train)
```

```
              precision    recall  f1-score   support

           0       0.89      0.84      0.87      1840
           1       0.85      0.89      0.87      1760

    accuracy                           0.87      3600
   macro avg       0.87      0.87      0.87      3600
weighted avg       0.87      0.87      0.87      3600
```

```
Fitting 5 folds for each of 15 candidates, totalling 75 fits
[CV 1/5] END …C=0.1, gamma=1, kernel=linear;, score=0.848 total time=   8.0s
[CV 2/5] END …C=0.1, gamma=1, kernel=linear;, score=0.862 total time=   8.4s
[CV 3/5] END …C=0.1, gamma=1, kernel=linear;, score=0.863 total time=   8.2s
[CV 4/5] END …C=0.1, gamma=1, kernel=linear;, score=0.854 total time=   8.3s
[CV 5/5] END …C=0.1, gamma=1, kernel=linear;, score=0.845 total time=   8.3s
[CV 1/5] END …C=0.1, gamma=0.1, kernel=linear;, score=0.848 total time=   8.2s
[CV 2/5] END …C=0.1, gamma=0.1, kernel=linear;, score=0.862 total time=   8.4s
[CV 3/5] END …C=0.1, gamma=0.1, kernel=linear;, score=0.863 total time=   8.3s
[CV 4/5] END …C=0.1, gamma=0.1, kernel=linear;, score=0.854 total time=   8.4s
[CV 5/5] END …C=0.1, gamma=0.1, kernel=linear;, score=0.845 total time=   8.5s
[CV 1/5] END ..C=0.1, gamma=0.01, kernel=linear;, score=0.848 total time=   8.2s
[CV 2/5] END ..C=0.1, gamma=0.01, kernel=linear;, score=0.862 total time=   8.3s
[CV 3/5] END ..C=0.1, gamma=0.01, kernel=linear;, score=0.863 total time=   8.3s
[CV 4/5] END ..C=0.1, gamma=0.01, kernel=linear;, score=0.854 total time=   8.3s
[CV 5/5] END ..C=0.1, gamma=0.01, kernel=linear;, score=0.845 total time=   8.4s
[CV 1/5] END .C=0.1, gamma=0.001, kernel=linear;, score=0.848 total time=   8.2s
[CV 2/5] END .C=0.1, gamma=0.001, kernel=linear;, score=0.862 total time=   8.4s
[CV 3/5] END .C=0.1, gamma=0.001, kernel=linear;, score=0.863 total time=   8.2s
[CV 4/5] END .C=0.1, gamma=0.001, kernel=linear;, score=0.854 total time=   8.2s
[CV 5/5] END .C=0.1, gamma=0.001, kernel=linear;, score=0.845 total time=   8.4s
[CV 1/5] END C=0.1, gamma=0.0001, kernel=linear;, score=0.848 total time=   8.2s
[CV 2/5] END C=0.1, gamma=0.0001, kernel=linear;, score=0.862 total time=   8.3s
[CV 3/5] END C=0.1, gamma=0.0001, kernel=linear;, score=0.863 total time=   8.2s
[CV 4/5] END C=0.1, gamma=0.0001, kernel=linear;, score=0.854 total time=   8.3s
[CV 5/5] END C=0.1, gamma=0.0001, kernel=linear;, score=0.845 total time=   8.3s
[CV 1/5] END …C=1, gamma=1, kernel=linear;, score=0.846 total time=  10.6s
[CV 2/5] END …C=1, gamma=1, kernel=linear;, score=0.858 total time=  11.7s
[CV 3/5] END …C=1, gamma=1, kernel=linear;, score=0.854 total time=  11.6s
[CV 4/5] END …C=1, gamma=1, kernel=linear;, score=0.851 total time=  12.2s
[CV 5/5] END …C=1, gamma=1, kernel=linear;, score=0.845 total time=  11.1s
[CV 1/5] END …C=1, gamma=0.1, kernel=linear;, score=0.846 total time=  10.3s
[CV 2/5] END …C=1, gamma=0.1, kernel=linear;, score=0.858 total time=  10.9s
[CV 3/5] END …C=1, gamma=0.1, kernel=linear;, score=0.854 total time=  11.4s
[CV 4/5] END …C=1, gamma=0.1, kernel=linear;, score=0.851 total time=  10.8s
[CV 5/5] END …C=1, gamma=0.1, kernel=linear;, score=0.845 total time=  11.4s
[CV 1/5] END …C=1, gamma=0.01, kernel=linear;, score=0.846 total time=  10.7s
[CV 2/5] END …C=1, gamma=0.01, kernel=linear;, score=0.858 total time=  11.2s
[CV 3/5] END …C=1, gamma=0.01, kernel=linear;, score=0.854 total time=  11.0s
[CV 4/5] END …C=1, gamma=0.01, kernel=linear;, score=0.851 total time=  11.5s
[CV 5/5] END …C=1, gamma=0.01, kernel=linear;, score=0.845 total time=  12.4s
[CV 1/5] END …C=1, gamma=0.001, kernel=linear;, score=0.846 total time=  10.7s
[CV 2/5] END …C=1, gamma=0.001, kernel=linear;, score=0.858 total time=  11.2s
[CV 3/5] END …C=1, gamma=0.001, kernel=linear;, score=0.854 total time=  10.7s
[CV 4/5] END …C=1, gamma=0.001, kernel=linear;, score=0.851 total time=  10.6s
[CV 5/5] END …C=1, gamma=0.001, kernel=linear;, score=0.845 total time=  10.9s
[CV 1/5] END ..C=1, gamma=0.0001, kernel=linear;, score=0.846 total time=  11.2s
[CV 2/5] END ..C=1, gamma=0.0001, kernel=linear;, score=0.858 total time=  12.3s
```

```
[CV 3/5] END ..C=1, gamma=0.0001, kernel=linear;, score=0.854 total time=  11.6s
[CV 4/5] END ..C=1, gamma=0.0001, kernel=linear;, score=0.851 total time=  11.0s
[CV 5/5] END ..C=1, gamma=0.0001, kernel=linear;, score=0.845 total time=  11.0s
[CV 1/5] END …C=10, gamma=1, kernel=linear;, score=0.845 total time=  39.1s
[CV 2/5] END …C=10, gamma=1, kernel=linear;, score=0.855 total time=  42.8s
[CV 3/5] END …C=10, gamma=1, kernel=linear;, score=0.839 total time=  36.8s
[CV 4/5] END …C=10, gamma=1, kernel=linear;, score=0.836 total time=  35.7s
[CV 5/5] END …C=10, gamma=1, kernel=linear;, score=0.834 total time=  39.8s
[CV 1/5] END …C=10, gamma=0.1, kernel=linear;, score=0.845 total time=  40.2s
[CV 2/5] END …C=10, gamma=0.1, kernel=linear;, score=0.855 total time=  41.0s
[CV 3/5] END …C=10, gamma=0.1, kernel=linear;, score=0.839 total time=  37.5s
[CV 4/5] END …C=10, gamma=0.1, kernel=linear;, score=0.836 total time=  36.6s
[CV 5/5] END …C=10, gamma=0.1, kernel=linear;, score=0.834 total time=  41.8s
[CV 1/5] END …C=10, gamma=0.01, kernel=linear;, score=0.845 total time=  41.4s
[CV 2/5] END …C=10, gamma=0.01, kernel=linear;, score=0.855 total time=  43.7s
[CV 3/5] END …C=10, gamma=0.01, kernel=linear;, score=0.839 total time=  37.8s
[CV 4/5] END …C=10, gamma=0.01, kernel=linear;, score=0.836 total time=  37.4s
[CV 5/5] END …C=10, gamma=0.01, kernel=linear;, score=0.834 total time=  40.0s
[CV 1/5] END ..C=10, gamma=0.001, kernel=linear;, score=0.845 total time=  39.9s
[CV 2/5] END ..C=10, gamma=0.001, kernel=linear;, score=0.855 total time=  41.3s
[CV 3/5] END ..C=10, gamma=0.001, kernel=linear;, score=0.839 total time=  36.6s
[CV 4/5] END ..C=10, gamma=0.001, kernel=linear;, score=0.836 total time=  36.9s
[CV 5/5] END ..C=10, gamma=0.001, kernel=linear;, score=0.834 total time=  39.6s
[CV 1/5] END .C=10, gamma=0.0001, kernel=linear;, score=0.845 total time=  39.6s
[CV 2/5] END .C=10, gamma=0.0001, kernel=linear;, score=0.855 total time=  41.1s
[CV 3/5] END .C=10, gamma=0.0001, kernel=linear;, score=0.839 total time=  37.3s
[CV 4/5] END .C=10, gamma=0.0001, kernel=linear;, score=0.836 total time=  35.1s
[CV 5/5] END .C=10, gamma=0.0001, kernel=linear;, score=0.834 total time=  40.3s
```

[19]:
```
GridSearchCV(estimator=SVC(),
             param_grid={'C': [0.1, 1, 10],
                         'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
                         'kernel': ['linear']},
             verbose=3)
```

[20]:
```python
# print best parameter after tuning
print(grid.best_params_)

# print how our model looks after hyper-parameter tuning
print(grid.best_estimator_)

grid_predictions = grid.predict(X_test)

# print classification report
print(classification_report(y_test, grid_predictions))

## {'C': 0.1, 'gamma': 1, 'kernel': 'linear'}
```

```
## SVC(C=0.1, gamma=1, kernel='linear')

## 0.86
```

```
{'C': 0.1, 'gamma': 1, 'kernel': 'linear'}
SVC(C=0.1, gamma=1, kernel='linear')
              precision    recall  f1-score   support

           0       0.87      0.84      0.86      1840
           1       0.84      0.87      0.86      1760

    accuracy                           0.86      3600
   macro avg       0.86      0.86      0.86      3600
weighted avg       0.86      0.86      0.86      3600
```

[21]:

```
# param grid for LINEAR
model = SVC()
model.fit(X_train, y_train)
# print prediction results
predictions = model.predict(X_test)
print(classification_report(y_test, predictions))
# defining parameter range
param_grid = {'C': [0.1, 1, 10, 100, 1000],
              'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
              'degrees': [0, 1, 2, 3, 4, 5, 6],
              'kernel': ['poly']}

grid = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3)

# fitting the model for grid search
grid.fit(X_train, y_train)

# print best parameter after tuning
print(grid.best_params_)

# print how our model looks after hyper-parameter tuning
print(grid.best_estimator_)

grid_predictions = grid.predict(X_test)

# print classification report
print(classification_report(y_test, grid_predictions))
```

```
              precision    recall  f1-score   support

           0       0.89      0.84      0.87      1840
           1       0.85      0.89      0.87      1760
```

```
    accuracy                           0.87      3600
   macro avg       0.87      0.87      0.87      3600
weighted avg       0.87      0.87      0.87      3600
```

```
Fitting 5 folds for each of 175 candidates, totalling 875 fits
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Input In [21], in <cell line: 16>()
     13 grid = GridSearchCV(SVC(), param_grid, refit = True, verbose = 3)
     15 # fitting the model for grid search
---> 16 grid.fit(X_train, y_train)
     18 # print best parameter after tuning
     19 print(grid.best_params_)

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
 ↪model_selection/_search.py:891, in BaseSearchCV.fit(self, X, y, groups,␣
 ↪**fit_params)
    885     results = self._format_results(
    886         all_candidate_params, n_splits, all_out, all_more_results
    887     )
    889     return results
--> 891 self._run_search(evaluate_candidates)
    893 # multimetric is determined here because in the case of a callable
    894 # self.scoring the return type is only known after calling
    895 first_test_score = all_out[0]["test_scores"]

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
 ↪model_selection/_search.py:1392, in GridSearchCV._run_search(self,␣
 ↪evaluate_candidates)
   1390 def _run_search(self, evaluate_candidates):
   1391     """Search all candidates in param_grid"""
-> 1392     evaluate_candidates(ParameterGrid(self.param_grid))

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
 ↪model_selection/_search.py:838, in BaseSearchCV.fit.<locals>.
 ↪evaluate_candidates(candidate_params, cv, more_results)
    830 if self.verbose > 0:
    831     print(
    832         "Fitting {0} folds for each of {1} candidates,"
    833         " totalling {2} fits".format(
    834             n_splits, n_candidates, n_candidates * n_splits
    835         )
    836     )
--> 838 out = parallel(
    839     delayed(_fit_and_score)(
    840         clone(base_estimator),
```

```
 841             X,
 842             y,
 843             train=train,
 844             test=test,
 845             parameters=parameters,
 846             split_progress=(split_idx, n_splits),
 847             candidate_progress=(cand_idx, n_candidates),
 848             **fit_and_score_kwargs,
 849         )
 850         for (cand_idx, parameters), (split_idx, (train, test)) in product(
 851             enumerate(candidate_params), enumerate(cv.split(X, y, groups))
 852         )
 853 )
 855 if len(out) < 1:
 856     raise ValueError(
 857         "No fits were performed. "
 858         "Was the CV iterator empty? "
 859         "Were there no candidates?"
 860     )

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
↪parallel.py:1043, in Parallel.__call__(self, iterable)
   1034 try:
   1035     # Only set self._iterating to True if at least a batch
   1036     # was dispatched. In particular this covers the edge
   (…)
   1040     # was very quick and its callback already dispatched all the
   1041     # remaining jobs.
   1042     self._iterating = False
-> 1043     if self.dispatch_one_batch(iterator):
   1044         self._iterating = self._original_iterator is not None
   1046     while self.dispatch_one_batch(iterator):

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
↪parallel.py:861, in Parallel.dispatch_one_batch(self, iterator)
    859     return False
    860 else:
--> 861     self._dispatch(tasks)
    862     return True

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
↪parallel.py:779, in Parallel._dispatch(self, batch)
    777 with self._lock:
    778     job_idx = len(self._jobs)
--> 779     job = self._backend.apply_async(batch, callback=cb)
    780     # A job can complete so quickly than its callback is
    781     # called before we get here, causing self._jobs to
    782     # grow. To ensure correct results ordering, .insert is
```

```
    783     # used (rather than .append) in the following line
    784     self._jobs.insert(job_idx, job)

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
 ↪_parallel_backends.py:208, in SequentialBackend.apply_async(self, func,␣
 ↪callback)
    206 def apply_async(self, func, callback=None):
    207     """Schedule a func to be run"""
--> 208     result = ImmediateResult(func)
    209     if callback:
    210         callback(result)

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
 ↪_parallel_backends.py:572, in ImmediateResult.__init__(self, batch)
    569 def __init__(self, batch):
    570     # Don't delay the application, to avoid keeping the input
    571     # arguments in memory
--> 572     self.results = batch()

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
 ↪parallel.py:262, in BatchedCalls.__call__(self)
    258 def __call__(self):
    259     # Set the default nested backend to self._backend but do not set th
    260     # change the default number of processes to -1
    261     with parallel_backend(self._backend, n_jobs=self._n_jobs):
--> 262         return [func(*args, **kwargs)
    263                 for func, args, kwargs in self.items]

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/joblib/
 ↪parallel.py:262, in <listcomp>(.0)
    258 def __call__(self):
    259     # Set the default nested backend to self._backend but do not set th
    260     # change the default number of processes to -1
    261     with parallel_backend(self._backend, n_jobs=self._n_jobs):
--> 262         return [func(*args, **kwargs)
    263                 for func, args, kwargs in self.items]

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
 ↪utils/fixes.py:216, in _FuncWrapper.__call__(self, *args, **kwargs)
    214 def __call__(self, *args, **kwargs):
    215     with config_context(**self.config):
--> 216         return self.function(*args, **kwargs)

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
 ↪model_selection/_validation.py:668, in _fit_and_score(estimator, X, y, scorer ␣
 ↪train, test, verbose, parameters, fit_params, return_train_score,␣
 ↪return_parameters, return_n_test_samples, return_times, return_estimator,␣
 ↪split_progress, candidate_progress, error_score)
    665     for k, v in parameters.items():
```

```
    666         cloned_parameters[k] = clone(v, safe=False)
--> 668     estimator = estimator.set_params(**cloned_parameters)
    670 start_time = time.time()
    672 X_train, y_train = _safe_split(estimator, X, y, train)

File ~/opt/anaconda3/envs/ml135_env_su22/lib/python3.9/site-packages/sklearn/
↪base.py:245, in BaseEstimator.set_params(self, **params)
    243 key, delim, sub_key = key.partition("__")
    244 if key not in valid_params:
--> 245     raise ValueError(
    246         "Invalid parameter %s for estimator %s. "
    247         "Check the list of available parameters "
    248         "with `estimator.get_params().keys()`." % (key, self)
    249     )
    251 if delim:
    252     nested_params[key][sub_key] = value

ValueError: Invalid parameter degrees for estimator SVC(C=0.1). Check the list␣
↪of available parameters with `estimator.get_params().keys()`.
```

visualizing the images

[679]:
```
X_train
```

[679]:
```
       pixel000  pixel001  pixel002  pixel003  pixel004  pixel005  pixel006  \
10228       0.0       0.0       0.0    0.0000    0.1287    0.2565    0.2234
2939        0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
3827        0.0       0.0       0.0    0.0076    0.0000    0.0049    0.0159
312         0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
4088        0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
…           …         …         …         …         …         …         …
4859        0.0       0.0       0.0    0.0000    0.0051    0.0000    0.0000
3264        0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
9845        0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
10799       0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000
2732        0.0       0.0       0.0    0.0000    0.0000    0.0000    0.0000

       pixel007  pixel008  pixel009  …  pixel774  pixel775  pixel776  \
10228    0.2009    0.1446    0.1513  …    0.1800    0.1943    0.1647
2939     0.0091    0.0083    0.0000  …    0.0000    0.0000    0.0000
3827     0.0139    0.0000    0.0000  …    0.5137    0.4879    0.3984
312      0.0000    0.0000    0.0000  …    0.0000    0.0000    0.0000
4088     0.0000    0.0041    0.0000  …    0.4200    0.0405    0.0000
…           …         …         …    …     …         …
4859     0.1806    0.1732    0.4510  …    0.3882    0.4315    0.3821
3264     0.0000    0.0000    0.0000  …    0.0800    0.0000    0.0000
9845     0.0000    0.0000    0.0000  …    0.1440    0.0445    0.0000
```

10799	0.1644	0.4959	0.9370	…	0.0000	0.4939	0.8863
2732	0.0000	0.0000	0.0000	…	0.1640	0.1336	0.0902

	pixel777	pixel778	pixel779	pixel780	pixel781	pixel782	pixel783
10228	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.0
2939	0.3603	0.5960	0.5137	0.2686	0.0000	0.0	0.0
3827	0.0000	0.0000	0.0089	0.0000	0.0000	0.0	0.0
312	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.0
4088	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.0
…	…	…	…	…	…	…	…
4859	0.3333	0.3426	0.0804	0.0000	0.0192	0.0	0.0
3264	0.0000	0.2920	0.3098	0.2149	0.1284	0.0	0.0
9845	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.0
10799	0.2308	0.0000	0.0118	0.0000	0.0000	0.0	0.0
2732	0.0810	0.0000	0.0000	0.0041	0.0046	0.0	0.0

[8400 rows x 784 columns]

[680]:
```
X_train.shape, X_test.shape, y_train.shape, y_test.shape
```

[680]:
```
((8400, 784), (3600, 784), (8400,), (3600,))
```

[681]:
```
# needed to use array not df in imshow()
xt = X_train[0:5].to_numpy()
xt.ndim
```

[681]:
```
2
```

[682]:
```
# visualizing the image data
plt.figure(figsize=(15,4))
for index, (image,label) in enumerate(zip(xt[0:5], y_train[0:5])):
    plt.subplot(1,5,index+1)
    plt.imshow(np.reshape(image,(28,28)), cmap=plt.cm.gray, vmin = 0.0, vmax = 1)
    plt.title('Shirst training %d' % label, fontsize=10)
```

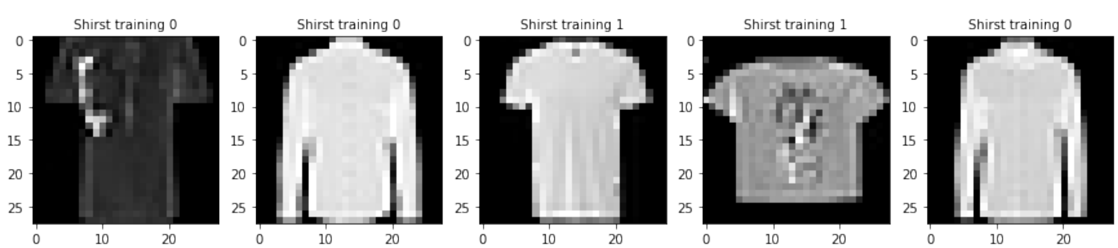
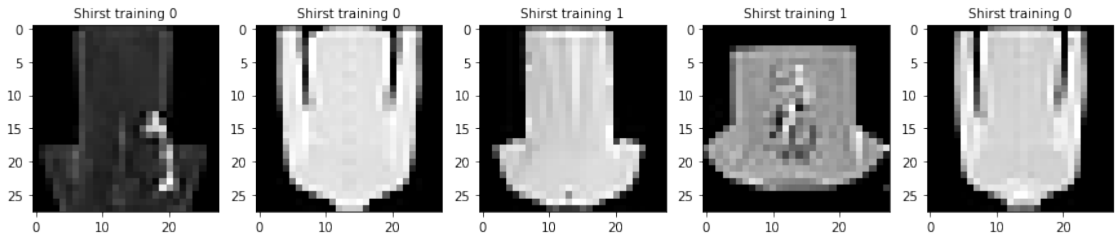


image augmentation

[683]:
```
#check images to see if flipping technique works
tx = xt[:,::-1]
tx
plt.figure(figsize=(15,4))
for index, (image,label) in enumerate(zip(tx[0:5], y_train[0:5])):
    plt.subplot(1,5,index+1)
    plt.imshow(np.reshape(image,(28,28)), cmap=plt.cm.gray, vmin = 0.0, vmax =␣
 ↪1)
    plt.title('Shirst training %d' % label, fontsize=10)
```



[684]:
```
# X to array not df
Xt = X.to_numpy()
#do flipping technique on data and combine them flipped and non flipped
XT = Xt[:,::-1]
YT = y

#combining the flipped and non flipped data
X_t = np.concatenate((Xt, XT), axis=0)
y_t = np.concatenate((YT, YT), axis=0)

X_t.shape, y_t.shape # same length good working
```

[684]: ((24000, 784), (24000,))

[685]:
```
# train test split w
X_train, X_test, y_train, y_test = train_test_split(X_t, y_t, test_size=0.3,␣
 ↪random_state=0)
```

[ ]:
```

```

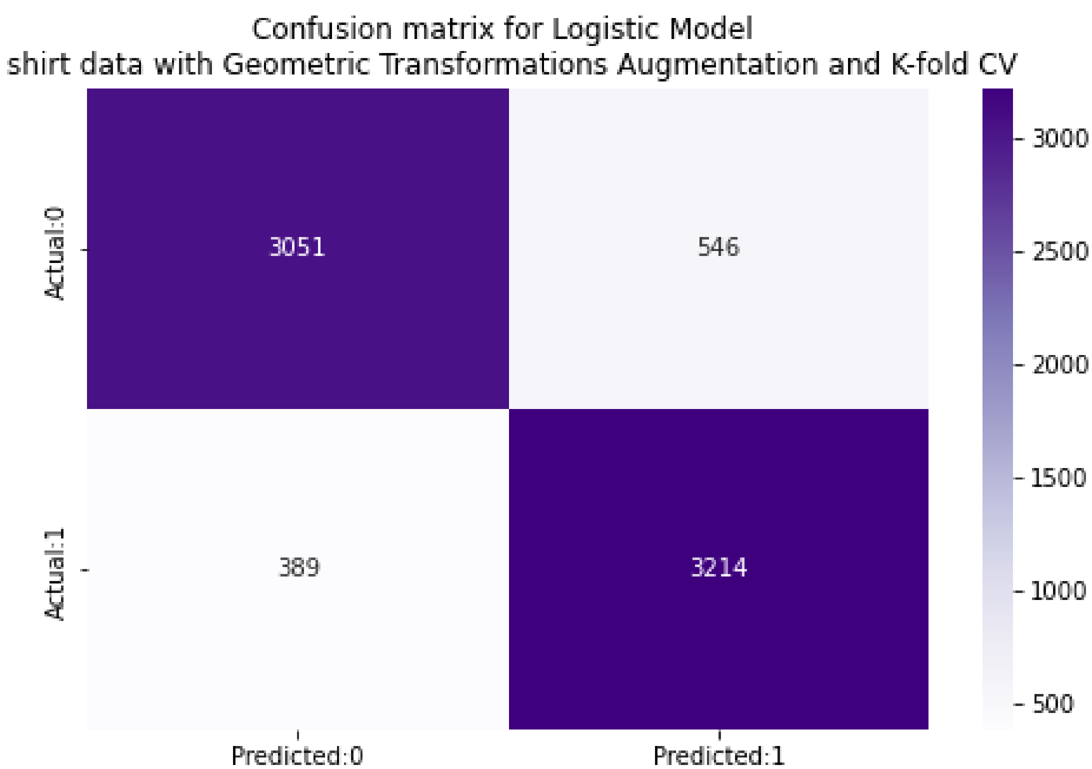
[ ]:
```

```

[ ]:
```
df_smv['Logistic Loss'].idxmin() #
df_smv['Accuracy Score'].idxmax() #
```

[ ]:
```
#evaluating the model
print(confusion_matrix(y_test,y_pred))
```

```
print(classification_report(y_test,y_pred))
```

[687]:
```
#Creating Confusion Matrix to evaluate the model
cm = confusion_matrix(y_test,y_pred)
conf_matrix=pd.DataFrame(data=cm,columns=['Predicted:0','Predicted:
↪1'],index=['Actual:0','Actual:1'])
plt.figure(figsize = (8,5))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap="Purples")
plt.title('Confusion matrix for Logistic Model \n shirt data with Geometric␣
↪Transformations Augmentation and K-fold CV')
plt.show()
```



[688]:
```
#True Negative, True Positive, False Negative, False Positive
TN=cm[0,0]
TP=cm[1,1]
FN=cm[1,0]
FP=cm[0,1]

#Accuracy
print('The acuracy of the model = TP+TN/(TP+TN+FP+FN) = ', round((TP+TN)/
↪float(TP+TN+FP+FN),3))
#Misclassification
```

```
print('The Missclassification = 1-Accuracy = ', round(1-((TP+TN)/
↪float(TP+TN+FP+FN)), 3))
#Sensitivity
print('Sensitivity or True Positive Rate = TP/(TP+FN) = ', round(TP/
↪float(TP+FN),3))
#Specificity
print('Specificity or True Negative Rate = TN/(TN+FP) = ', round(TN/
↪float(TN+FP),3))

#Classification Report
from sklearn.metrics import classification_report
print(classification_report(y_test, y_pred))
```

```
The acuracy of the model = TP+TN/(TP+TN+FP+FN) =  0.87
The Missclassification = 1-Accuracy =  0.13
Sensitivity or True Positive Rate = TP/(TP+FN) =  0.892
Specificity or True Negative Rate = TN/(TN+FP) =  0.848
              precision    recall  f1-score   support

           0       0.89      0.85      0.87      3597
           1       0.85      0.89      0.87      3603

    accuracy                           0.87      7200
   macro avg       0.87      0.87      0.87      7200
weighted avg       0.87      0.87      0.87      7200
```

In this case data augmentation did not increase the accuracy without other tweeks. Adding other tweeks to model. starting with K fold CV

[3]:
```
list(np.logspace(-9, 6, 31) )
```

[3]:
```
[1e-09,
 3.1622776601683795e-09,
 1e-08,
 3.162277660168379e-08,
 1e-07,
 3.162277660168379e-07,
 1e-06,
 3.162277660168379e-06,
 1e-05,
 3.1622776601683795e-05,
 0.0001,
 0.00031622776601683794,
 0.001,
 0.0031622776601683794,
 0.01,
 0.03162277660168379,
```

```
0.1,
0.31622776601683794,
1.0,
3.1622776601683795,
10.0,
31.622776601683793,
100.0,
316.22776601683796,
1000.0,
3162.2776601683795,
10000.0,
31622.776601683792,
100000.0,
316227.7660168379,
1000000.0]
```

```
[ ]:
```