3.Logistic Regression - Multi Class

November 9, 2021

Multi-Class Classification using Logistic Regression

We will predict hand-written digits. The dataset is available here https://scikit-learn.org/stable/auto_examples/datasets/plot_digits_last_image.html

[1]:
```
# Import necessary package
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
```

0.0.1 Step 1: Load the dataset

[2]:
```
# Load the dataset into pandas dataframe
from sklearn.datasets import load_digits
digits = load_digits()
```

[3]:
```
# Dataset folder contains the following folders
dir(digits)
```

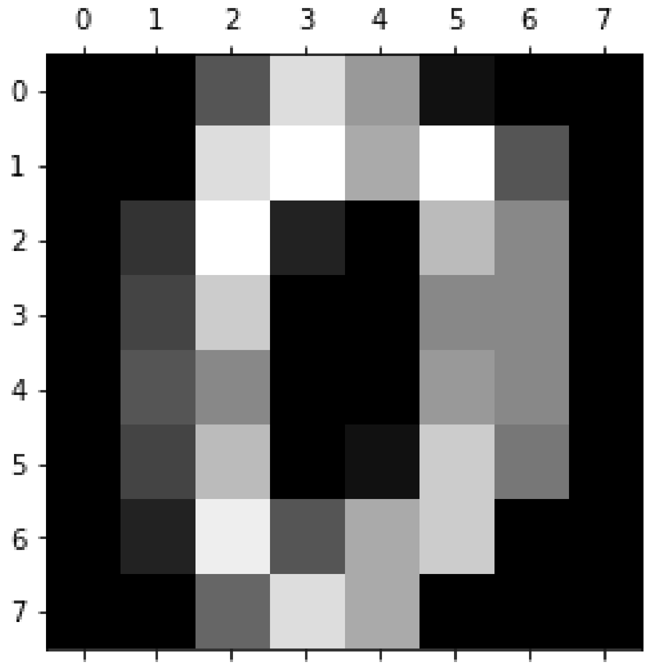
[3]:
```
['DESCR', 'data', 'feature_names', 'frame', 'images', 'target', 'target_names']
```

[4]:
```
digits.data[0]
# 64 values are used to represent an image (8x8 = 64 values as 1 D array) which␣
↪is availale in data folder
```

[4]:
```
array([ 0.,  0.,  5., 13.,  9.,  1.,  0.,  0.,  0.,  0., 13., 15., 10.,
       15.,  5.,  0.,  0.,  3., 15.,  2.,  0., 11.,  8.,  0.,  0.,  4.,
       12.,  0.,  0.,  8.,  8.,  0.,  0.,  5.,  8.,  0.,  0.,  9.,  8.,
        0.,  0.,  4., 11.,  0.,  1., 12.,  7.,  0.,  0.,  2., 14.,  5.,
       10., 12.,  0.,  0.,  0.,  0.,  6., 13., 10.,  0.,  0.,  0.])
```

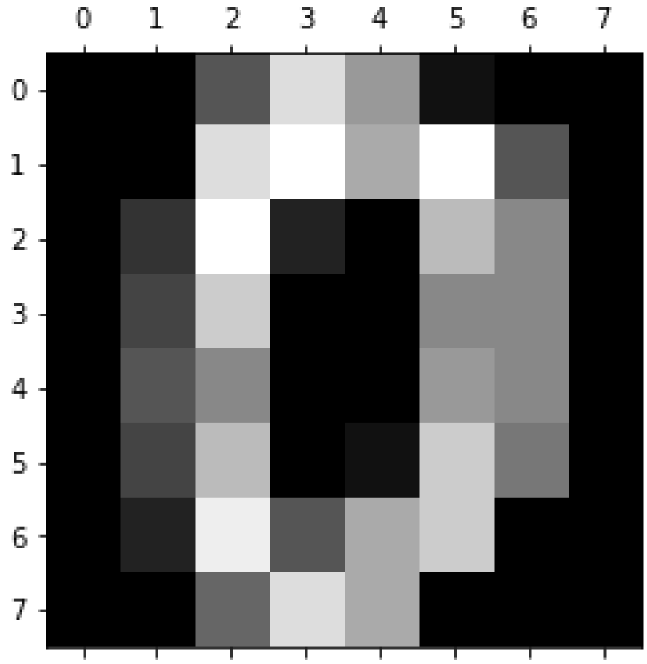
[5]:
```
# Display the image of respective input from images folder
plt.gray()
plt.matshow(digits.images[0])
plt.show()
```

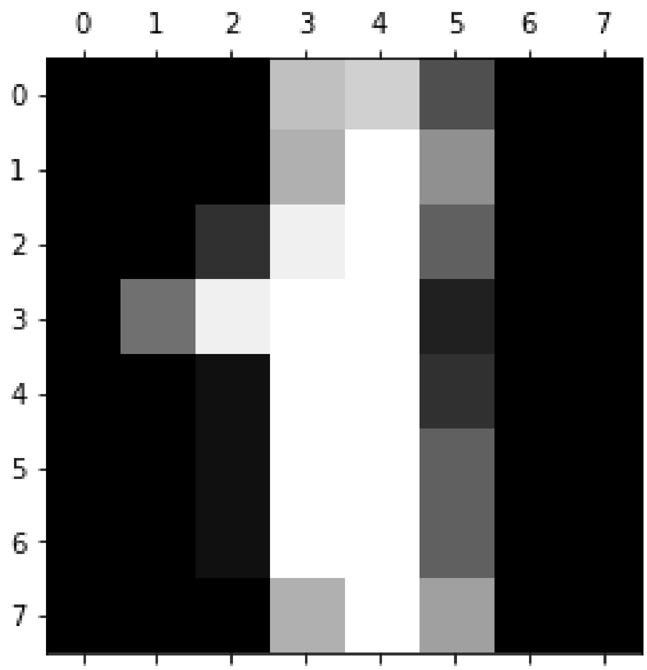
```
<Figure size 432x288 with 0 Axes>
```

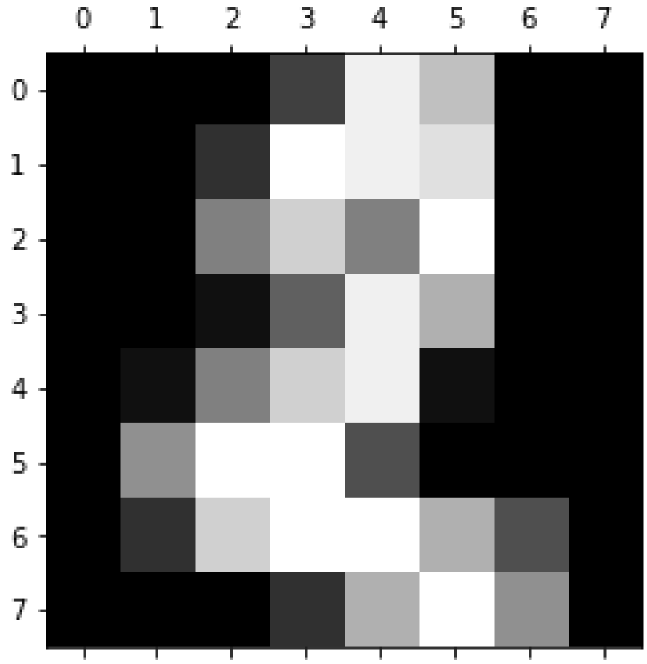


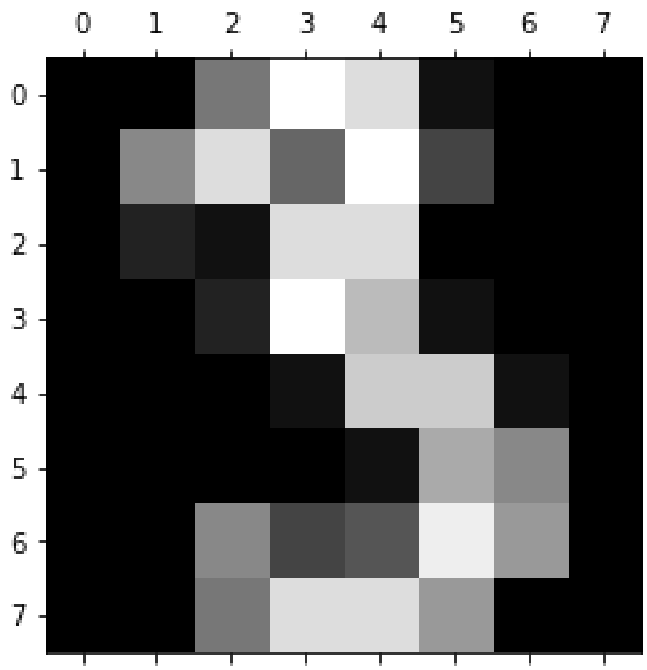
[6]:
```python
# Let us display 5 images
plt.gray()
for i in range(5):
    plt.matshow(digits.images[i])
    plt.show()
```

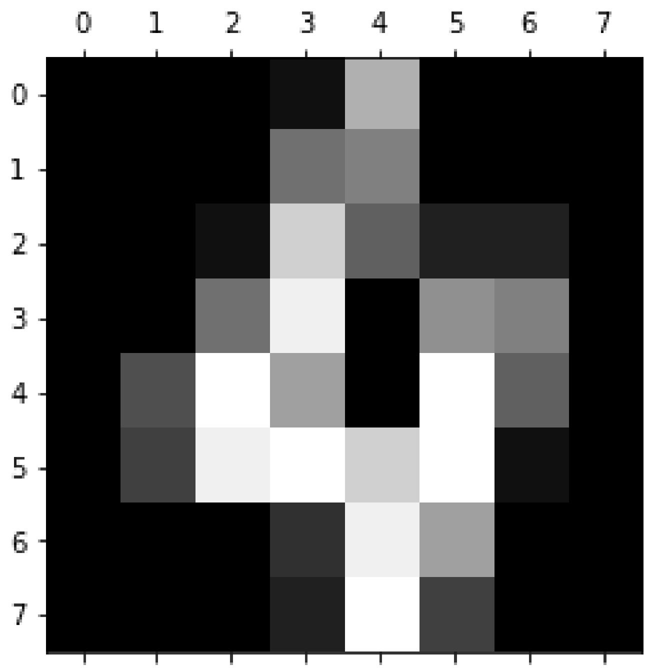
```
<Figure size 432x288 with 0 Axes>
```


0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7


0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7


0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7


0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7



[7]:
```
# Target label for each image
digits.target_names
```

[7]:
```
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

0.0.2 Step 2: Apply EDA

Any EDA techniques

0.0.3 Step 3. Pre-process and extract the features

It is already well loaded

0.0.4 Step 4. Split the data for training and testing

[8]:
```
# Splitting dataset into training and testing set
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(digits.data, digits.target,␣
↪test_size = 0.2)
```

0.0.5 Step 5. Training the model

Fitting the model

[9]:
```
from sklearn.linear_model import LogisticRegression
logistic_model = LogisticRegression()
logistic_model.fit(x_train, y_train)
```

```
C:\Users\Rathinaraja Jeyaraj\anaconda3\lib\site-
packages\sklearn\linear_model\_logistic.py:762: 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(
```

[9]:
```
LogisticRegression()
```

[10]:
```
y_train_pred = logistic_model.predict(x_train)
y_train_pred
```

[10]:
```
array([5, 3, 3, …, 9, 4, 8])
```

[11]:
```
train_predicted_prob = logistic_model.predict_proba(x_train)
train_predicted_prob
# each row contains probability for each digit
```

[11]:
```
array([[1.65343039e-06, 1.88862528e-13, 9.47297093e-10, …,
        4.21817324e-12, 1.78846051e-06, 6.06485540e-10],
       [8.65279130e-22, 2.78292795e-22, 1.56931565e-15, …,
        4.49431750e-19, 2.03211969e-12, 7.58522283e-11],
       [3.02423565e-13, 9.05636296e-14, 7.17503083e-07, …,
        1.43685765e-11, 3.02520639e-10, 8.97661248e-08],
       …,
       [3.30098358e-06, 4.36389257e-13, 2.40686173e-10, …,
        3.88021625e-08, 6.15172902e-08, 9.98643455e-01],
       [3.30213100e-12, 1.92304116e-11, 1.00558877e-20, …,
        3.10864231e-11, 1.50858926e-14, 1.23415495e-26],
       [8.98580572e-04, 4.23912326e-03, 2.21387617e-02, …,
        3.55708497e-05, 9.72201161e-01, 3.07963485e-06]])
```

Performance score for logistic regression

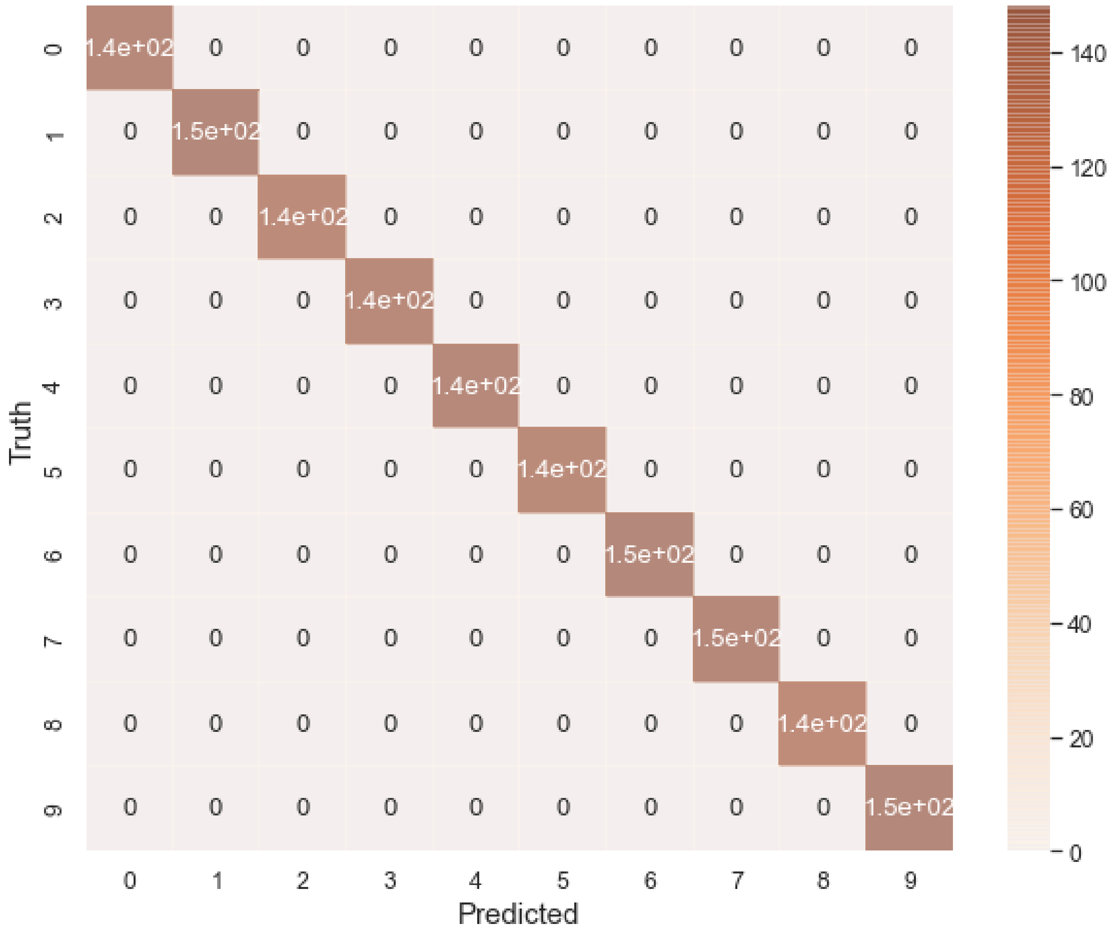
[12]:
```
out = logistic_model.score(x_train,y_train)
Logistic_Train_RS = np.round(out,2)*100
print("Performance score for training set :",Logistic_Train_RS,"%")
```

```
Performance score for training set : 100.0 %
```

Confusion matrix R2 score says the performance of logistic regression over simple probability that does not feature Age. We are interested to know how many has been correctly and wrongly classified.

[13]:
```
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_train,y_train_pred)

plt.figure(figsize = (10,8))
sns.set(font_scale=1.1)

axes = plt.gca()
axes.xaxis.label.set_size(15)
axes.yaxis.label.set_size(15)

sns.heatmap(cm, annot=True,cmap=plt.cm.Oranges, alpha=0.5)

plt.xlabel('Predicted')
plt.ylabel('Truth')
```

[13]:
```
Text(64.5, 0.5, 'Truth')
```



Precison, Recall, F1, Accuracy

[14]:
```python
# Total report
from sklearn import metrics
print(metrics.classification_report(y_train,y_train_pred))
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       144
           1       1.00      1.00      1.00       148
           2       1.00      1.00      1.00       139
           3       1.00      1.00      1.00       143
           4       1.00      1.00      1.00       145
           5       1.00      1.00      1.00       141
           6       1.00      1.00      1.00       147
           7       1.00      1.00      1.00       146
           8       1.00      1.00      1.00       137
           9       1.00      1.00      1.00       147
```

```
    accuracy                           1.00      1437
   macro avg       1.00      1.00      1.00      1437
weighted avg       1.00      1.00      1.00      1437
```

[15]:
```
# Accuracy score
temp = metrics.accuracy_score(y_train,y_train_pred)
Logistic_Train_Accuracy = np.round(temp,2)*100
print("Accuracy score : ",Logistic_Train_Accuracy,"%")
```

```
Accuracy score :  100.0 %
```

[16]:
```
# Precision score
temp = metrics.precision_score(y_train,y_train_pred,average="macro")
Logistic_Train_Precision = np.round(temp,2)*100
print("Precision score : ",Logistic_Train_Precision,"%")
```

```
Precision score :  100.0 %
```

[17]:
```
# Recall score
temp = metrics.recall_score(y_train,y_train_pred,average="macro")
Logistic_Train_Recall = np.round(temp,2)*100
print("Recall score : ",Logistic_Train_Recall,"%")
```

```
Recall score :  100.0 %
```

[18]:
```
# F1 score
temp = metrics.f1_score(y_train,y_train_pred,average="macro")
Logistic_Train_F1 = np.round(temp,2)*100
print("F1 score : ",Logistic_Train_F1,"%")
```

```
F1 score :  100.0 %
```

[19]:
```
# Cohen Kappa score
temp = metrics.cohen_kappa_score(y_train,y_train_pred)
Logistic_Train_CK = np.round(temp,2)*100
print("Cohen Kappa score : ",Logistic_Train_CK,"%")
```

```
Cohen Kappa score :  100.0 %
```

ROC It should be plotted

0.0.6 Step 6. Testing the model

[20]:
```
# Predicting values for test input set
y_test_pred = logistic_model.predict(x_test)
y_test_pred
```

[20]:
```
array([2, 7, 4, 7, 1, 9, 5, 1, 6, 4, 4, 0, 5, 4, 3, 4, 4, 6, 1, 4, 6, 2,
       3, 4, 9, 2, 3, 0, 5, 6, 2, 8, 7, 4, 2, 3, 2, 4, 0, 5, 9, 9, 7, 1,
       4, 1, 7, 0, 3, 5, 6, 3, 6, 1, 9, 7, 7, 7, 0, 2, 2, 4, 6, 3, 3, 3,
       7, 7, 3, 3, 9, 9, 1, 0, 8, 0, 3, 6, 8, 3, 9, 6, 0, 4, 8, 9, 5, 7,
       3, 7, 1, 8, 3, 3, 6, 6, 8, 2, 6, 6, 9, 6, 4, 9, 5, 8, 3, 8, 4, 5,
       1, 7, 5, 6, 0, 8, 8, 7, 2, 0, 2, 5, 2, 3, 5, 6, 6, 7, 0, 2, 8, 9,
       9, 2, 6, 9, 3, 2, 9, 0, 9, 4, 6, 8, 2, 3, 9, 4, 4, 0, 1, 5, 1, 0,
       7, 2, 7, 2, 8, 2, 9, 8, 9, 0, 8, 9, 1, 9, 9, 0, 6, 6, 3, 2, 8, 1,
       7, 2, 4, 9, 4, 9, 0, 3, 0, 1, 4, 4, 6, 5, 2, 3, 5, 3, 6, 0, 8, 2,
       5, 0, 3, 5, 5, 3, 1, 9, 4, 1, 1, 1, 8, 3, 5, 1, 9, 1, 2, 0, 2, 2,
       4, 9, 6, 8, 8, 5, 8, 1, 9, 8, 8, 8, 5, 8, 5, 8, 6, 6, 2, 1, 7, 8,
       4, 1, 3, 1, 3, 3, 5, 2, 4, 9, 8, 8, 4, 6, 6, 7, 8, 7, 7, 7, 1, 1,
       3, 5, 0, 0, 9, 7, 1, 0, 8, 4, 7, 8, 2, 2, 7, 1, 6, 7, 8, 9, 6, 3,
       3, 9, 0, 9, 5, 3, 8, 2, 0, 6, 2, 6, 1, 9, 0, 4, 8, 1, 7, 0, 8, 3,
       1, 0, 5, 7, 2, 2, 1, 5, 2, 0, 5, 9, 5, 1, 4, 4, 3, 7, 5, 4, 5, 8,
       9, 0, 3, 6, 7, 5, 6, 0, 7, 1, 5, 4, 8, 5, 6, 3, 2, 0, 1, 4, 5, 0,
       9, 5, 4, 2, 3, 1, 0, 5])
```

[21]:
```
test_predicted_prob = logistic_model.predict_proba(x_test)
test_predicted_prob
```

[21]:
```
array([[2.61582464e-17, 6.36102953e-14, 9.99981368e-01, …,
        6.32816723e-15, 8.43415735e-08, 2.54647447e-12],
       [1.12195460e-12, 3.38597251e-09, 1.84528603e-11, …,
        9.99999974e-01, 8.18932749e-11, 5.37784237e-13],
       [4.70747557e-09, 1.17521732e-02, 3.25445044e-15, …,
        2.42344059e-07, 2.83830434e-05, 9.41348585e-14],
       …,
       [2.41062240e-10, 9.99968965e-01, 4.12617874e-08, …,
        1.63297882e-09, 2.99847610e-06, 2.69792678e-06],
       [9.99917021e-01, 3.42658903e-17, 9.61063241e-09, …,
        3.61169708e-12, 8.27709068e-05, 9.43399890e-08],
       [1.50594596e-11, 6.48978633e-10, 1.04976291e-07, …,
        3.57640245e-10, 1.07855157e-07, 1.05188150e-08]])
```

Performance score for logistic regression

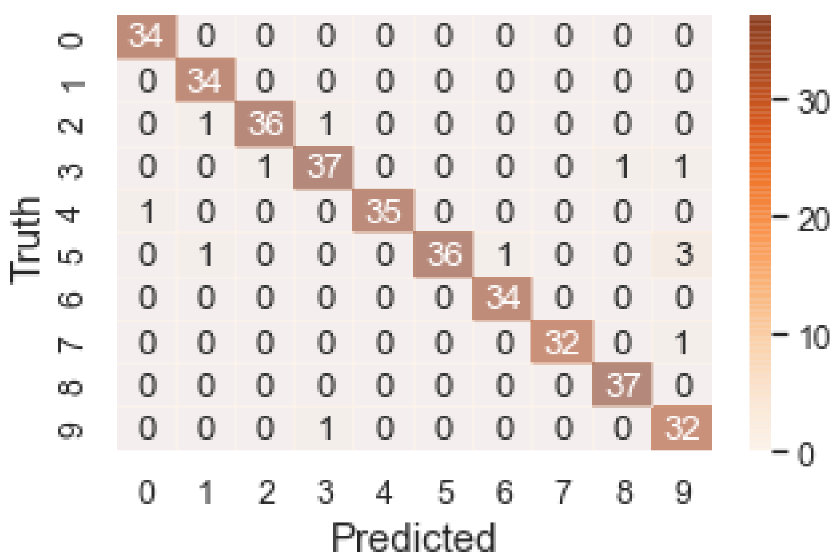
[22]:
```
out = logistic_model.score(x_test,y_test)
Logistic_Test_RS = np.round(out,2)*100
print("Performance score for training set :",Logistic_Test_RS,"%")
```

```
Performance score for training set : 96.0 %
```

Confusion matrix R2 score says the performance of logistic regression over simple probability that does not feature Age. We are interested to know how many has been correctly and wrongly classified.

[23]:
```python
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_test,y_test_pred)

plt.figure(figsize = (5,3))
sns.set(font_scale=1.1)

axes = plt.gca()
axes.xaxis.label.set_size(15)
axes.yaxis.label.set_size(15)

sns.heatmap(cm, annot=True,cmap=plt.cm.Oranges, alpha=0.5)

plt.xlabel('Predicted')
plt.ylabel('Truth')
```

[23]:
```
Text(19.5, 0.5, 'Truth')
```



Precison, Recall, F1, Accuracy

[24]:
```python
# Total report
from sklearn import metrics
print(metrics.classification_report(y_test,y_test_pred))
```

```
              precision    recall  f1-score   support

           0       0.97      1.00      0.99        34
           1       0.94      1.00      0.97        34
           2       0.97      0.95      0.96        38
           3       0.95      0.93      0.94        40
           4       1.00      0.97      0.99        36
           5       1.00      0.88      0.94        41
           6       0.97      1.00      0.99        34
           7       1.00      0.97      0.98        33
           8       0.97      1.00      0.99        37
           9       0.86      0.97      0.91        33

    accuracy                           0.96       360
   macro avg       0.96      0.97      0.96       360
weighted avg       0.97      0.96      0.96       360
```

[25]:

```
# Accuracy score
temp = metrics.accuracy_score(y_test,y_test_pred)
Logistic_Test_Accuracy = np.round(temp,2)*100
print("Accuracy score : ",Logistic_Test_Accuracy,"%")
```

```
Accuracy score :  96.0 %
```

[26]:

```
# Precision score
temp = metrics.precision_score(y_test,y_test_pred,average="macro")
Logistic_Test_Precision = np.round(temp,2)*100
print("Precision score : ",Logistic_Test_Precision,"%")
```

```
Precision score :  96.0 %
```

[27]:

```
# Recall score
temp = metrics.recall_score(y_test,y_test_pred,average="macro")
Logistic_Test_Recall = np.round(temp,2)*100
print("Recall score : ",Logistic_Test_Recall,"%")
```

```
Recall score :  97.0 %
```

[28]:

```
# F1 score
temp = metrics.f1_score(y_test,y_test_pred,average="macro")
Logistic_Test_F1 = np.round(temp,2)*100
print("F1 score : ",Logistic_Test_F1,"%")
```

```
F1 score :  96.0 %
```

[29]:

```
# Cohen Kappa score
temp = metrics.cohen_kappa_score(y_test,y_test_pred)
```

```
Logistic_Test_CK = np.round(temp,2)*100
print("Cohen Kappa score : ",Logistic_Test_CK,"%")
```

```
Cohen Kappa score :  96.0 %
```

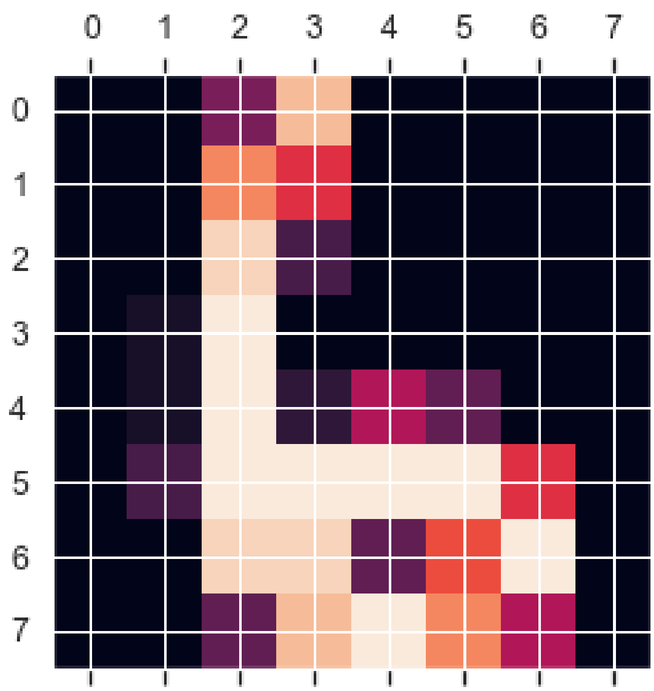
ROC It should be plotted

0.0.7 Step 7. Deploying model for prediction

Prediction by passing individual input

[30]:
```
plt.matshow(digits.images[67])
```

[30]: <matplotlib.image.AxesImage at 0x1f639ab8970>



[31]:
```
digits.target[67]
```

[31]: 6

[32]:
```
logistic_model.predict([digits.data[67]])
# giving the image index to the model, which will take the image as necessary␣
↪input
```

[32]: array([6])

[33]:
```
logistic_model.predict(digits.data[0:5])
```

[33]:
```
array([0, 1, 2, 3, 4])
```

0.0.8 Step 8. Summary

[34]:
```
print("             Logistic Regression      ")
print("====================================================")
print("\t\tTraining phase       Testing phase ")
print("====================================================")
print("RS\t\t   ",Logistic_Train_RS,"%\t\t", Logistic_Test_RS,"%")
print("Accuracy\t   ",Logistic_Train_Accuracy,"%\t\t",␣
↪Logistic_Test_Accuracy,"%")
print("Precision\t   ",Logistic_Train_Precision,"%\t\t",␣
↪Logistic_Test_Precision,"%")
print("Recall\t\t   ",Logistic_Train_Recall,"%\t\t", Logistic_Test_Recall,"%")
print("F1\t\t   ",Logistic_Train_F1,"%\t\t", Logistic_Test_F1,"%")
print("CK\t\t   ",Logistic_Train_CK,"%\t\t", Logistic_Test_CK,"%")
#print("AUC\t\t   ",Logistic_Train_AUC,"%\t\t", Logistic_Test_AUC,"%")
print("====================================================")
```

```
             Logistic Regression
====================================================
                Training phase       Testing phase
====================================================
RS                  100.0 %              96.0 %
Accuracy            100.0 %              96.0 %
Precision           100.0 %              96.0 %
Recall              100.0 %              97.0 %
F1                  100.0 %              96.0 %
CK                  100.0 %              96.0 %
====================================================
```