

Module 4

June 1, 2020

*You are currently looking at **version 1.0** of this notebook. To download notebooks and datafiles, as well as get help on Jupyter notebooks in the Coursera platform, visit the [Jupyter Notebook FAQ](#) course resource.*

1 Applied Machine Learning: Module 4 (Supervised Learning, Part II)

1.1 Preamble and Datasets

```
In [1]: %matplotlib notebook
import numpy as np
import pandas as pd
import seaborn as sn
import matplotlib.pyplot as plt

from sklearn.model_selection import train_test_split
from sklearn.datasets import make_classification, make_blobs
from matplotlib.colors import ListedColormap
from sklearn.datasets import load_breast_cancer
from adspy_shared_utilities import load_crime_dataset

cmap_bold = ListedColormap(['#FFFF00', '#00FF00', '#0000FF', '#000000'])

# fruits dataset
fruits = pd.read_table('readonly/fruit_data_with_colors.txt')

feature_names_fruits = ['height', 'width', 'mass', 'color_score']
X_fruits = fruits[feature_names_fruits]
y_fruits = fruits['fruit_label']
target_names_fruits = ['apple', 'mandarin', 'orange', 'lemon']

X_fruits_2d = fruits[['height', 'width']]
y_fruits_2d = fruits['fruit_label']

# synthetic dataset for simple regression
```

```

from sklearn.datasets import make_regression
plt.figure()
plt.title('Sample regression problem with one input variable')
X_R1, y_R1 = make_regression(n_samples = 100, n_features=1,
                             n_informative=1, bias = 150.0,
                             noise = 30, random_state=0)

plt.scatter(X_R1, y_R1, marker= 'o', s=50)
plt.show()

# synthetic dataset for more complex regression
from sklearn.datasets import make_friedman1
plt.figure()
plt.title('Complex regression problem with one input variable')
X_F1, y_F1 = make_friedman1(n_samples = 100, n_features = 7,
                             random_state=0)

plt.scatter(X_F1[:, 2], y_F1, marker= 'o', s=50)
plt.show()

# synthetic dataset for classification (binary)
plt.figure()
plt.title('Sample binary classification problem with two informative features')
X_C2, y_C2 = make_classification(n_samples = 100, n_features=2,
                                 n_redundant=0, n_informative=2,
                                 n_clusters_per_class=1, flip_y = 0.1,
                                 class_sep = 0.5, random_state=0)

plt.scatter(X_C2[:, 0], X_C2[:, 1], marker= 'o',
            c=y_C2, s=50, cmap=cmap_bold)
plt.show()

# more difficult synthetic dataset for classification (binary)
# with classes that are not linearly separable
X_D2, y_D2 = make_blobs(n_samples = 100, n_features = 2,
                        centers = 8, cluster_std = 1.3,
                        random_state = 4)

y_D2 = y_D2 % 2
plt.figure()
plt.title('Sample binary classification problem with non-linearly separable classes')
plt.scatter(X_D2[:,0], X_D2[:,1], c=y_D2,
            marker= 'o', s=50, cmap=cmap_bold)
plt.show()

# Breast cancer dataset for classification
cancer = load_breast_cancer()
(X_cancer, y_cancer) = load_breast_cancer(return_X_y = True)

# Communities and Crime dataset
(X_crime, y_crime) = load_crime_dataset()

```

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1.2 Naive Bayes classifiers

```
In [2]: from sklearn.naive_bayes import GaussianNB
        from adspy_shared_utilities import plot_class_regions_for_classifier

        X_train, X_test, y_train, y_test = train_test_split(X_C2, y_C2, random_state=0)

        nbclf = GaussianNB().fit(X_train, y_train)
        plot_class_regions_for_classifier(nbclf, X_train, y_train, X_test, y_test,
                                         'Gaussian Naive Bayes classifier: Dataset C2')

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```

```
In [3]: X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2,
                                                            random_state=0)

        nbclf = GaussianNB().fit(X_train, y_train)
        plot_class_regions_for_classifier(nbclf, X_train, y_train, X_test, y_test,
                                         'Gaussian Naive Bayes classifier: Dataset D2')

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```

1.2.1 Application to a real-world dataset

```
In [4]: X_train, X_test, y_train, y_test = train_test_split(X_cancer, y_cancer, random_state=0)

nbclf = GaussianNB().fit(X_train, y_train)
print('Breast cancer dataset')
print('Accuracy of GaussianNB classifier on training set: {:.2f}'
      .format(nbclf.score(X_train, y_train)))
print('Accuracy of GaussianNB classifier on test set: {:.2f}'
      .format(nbclf.score(X_test, y_test)))
```

Breast cancer dataset

Accuracy of GaussianNB classifier on training set: 0.95

Accuracy of GaussianNB classifier on test set: 0.94

1.3 Ensembles of Decision Trees

1.3.1 Random forests

```
In [5]: from sklearn.ensemble import RandomForestClassifier
        from sklearn.model_selection import train_test_split
        from adspy_shared_utilities import plot_class_regions_for_classifier_subplot

X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2,
                                                    random_state=0)

fig, subaxes = plt.subplots(1, 1, figsize=(6, 6))

clf = RandomForestClassifier().fit(X_train, y_train)
title = 'Random Forest Classifier, complex binary dataset, default settings'
plot_class_regions_for_classifier_subplot(clf, X_train, y_train, X_test,
                                         y_test, title, subaxes)

plt.show()
```

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1.3.2 Random forest: Fruit dataset

```
In [6]: from sklearn.ensemble import RandomForestClassifier
        from sklearn.model_selection import train_test_split
        from adspy_shared_utilities import plot_class_regions_for_classifier_subplot

X_train, X_test, y_train, y_test = train_test_split(X_fruits.as_matrix(),
                                                    y_fruits.as_matrix(),
```

```

random_state = 0)

fig, subaxes = plt.subplots(6, 1, figsize=(6, 32))

title = 'Random Forest, fruits dataset, default settings'
pair_list = [[0,1], [0,2], [0,3], [1,2], [1,3], [2,3]]

for pair, axis in zip(pair_list, subaxes):
    X = X_train[:, pair]
    y = y_train

    clf = RandomForestClassifier().fit(X, y)
    plot_class_regions_for_classifier_subplot(clf, X, y, None,
                                             None, title, axis,
                                             target_names_fruits)

    axis.set_xlabel(feature_names_fruits[pair[0]])
    axis.set_ylabel(feature_names_fruits[pair[1]])

plt.tight_layout()
plt.show()

clf = RandomForestClassifier(n_estimators = 10,
                            random_state=0).fit(X_train, y_train)

print('Random Forest, Fruit dataset, default settings')
print('Accuracy of RF classifier on training set: {:.2f}'
      .format(clf.score(X_train, y_train)))
print('Accuracy of RF classifier on test set: {:.2f}'
      .format(clf.score(X_test, y_test)))

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```

```

Random Forest, Fruit dataset, default settings
Accuracy of RF classifier on training set: 1.00
Accuracy of RF classifier on test set: 0.80

```

Random Forests on a real-world dataset

```
In [7]: from sklearn.ensemble import RandomForestClassifier
```

```
X_train, X_test, y_train, y_test = train_test_split(X_cancer, y_cancer, ran
```

```
clf = RandomForestClassifier(max_features = 8, random_state = 0)
```

```

clf.fit(X_train, y_train)

print('Breast cancer dataset')
print('Accuracy of RF classifier on training set: {:.2f}'
      .format(clf.score(X_train, y_train)))
print('Accuracy of RF classifier on test set: {:.2f}'
      .format(clf.score(X_test, y_test)))

```

Breast cancer dataset

Accuracy of RF classifier on training set: 1.00

Accuracy of RF classifier on test set: 0.99

1.3.3 Gradient-boosted decision trees

```

In [8]: from sklearn.ensemble import GradientBoostingClassifier
        from sklearn.model_selection import train_test_split
        from adspy_shared_utilities import plot_class_regions_for_classifier_subplot

X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_state=0)
fig, subaxes = plt.subplots(1, 1, figsize=(6, 6))

clf = GradientBoostingClassifier().fit(X_train, y_train)
title = 'GBDT, complex binary dataset, default settings'
plot_class_regions_for_classifier_subplot(clf, X_train, y_train, X_test,
                                         y_test, title, subaxes)

plt.show()

```

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Gradient boosted decision trees on the fruit dataset

```

In [9]: X_train, X_test, y_train, y_test = train_test_split(X_fruits.as_matrix(),
                                                            y_fruits.as_matrix(),
                                                            random_state = 0)

fig, subaxes = plt.subplots(6, 1, figsize=(6, 32))

pair_list = [[0,1], [0,2], [0,3], [1,2], [1,3], [2,3]]

for pair, axis in zip(pair_list, subaxes):
    X = X_train[:, pair]
    y = y_train

    clf = GradientBoostingClassifier().fit(X, y)

```

```

        plot_class_regions_for_classifier_subplot(clf, X, y, None,
                                                None, title, axis,
                                                target_names_fruits)

        axis.set_xlabel(feature_names_fruits[pair[0]])
        axis.set_ylabel(feature_names_fruits[pair[1]])

plt.tight_layout()
plt.show()
clf = GradientBoostingClassifier().fit(X_train, y_train)

print('GBDT, Fruit dataset, default settings')
print('Accuracy of GBDT classifier on training set: {:.2f}'
      .format(clf.score(X_train, y_train)))
print('Accuracy of GBDT classifier on test set: {:.2f}'
      .format(clf.score(X_test, y_test)))

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```

```

GBDT, Fruit dataset, default settings
Accuracy of GBDT classifier on training set: 1.00
Accuracy of GBDT classifier on test set: 0.80

```

Gradient-boosted decision trees on a real-world dataset

```

In [10]: from sklearn.ensemble import GradientBoostingClassifier

X_train, X_test, y_train, y_test = train_test_split(X_cancer, y_cancer, ra

clf = GradientBoostingClassifier(random_state = 0)
clf.fit(X_train, y_train)

print('Breast cancer dataset (learning_rate=0.1, max_depth=3)')
print('Accuracy of GBDT classifier on training set: {:.2f}'
      .format(clf.score(X_train, y_train)))
print('Accuracy of GBDT classifier on test set: {:.2f}\n'
      .format(clf.score(X_test, y_test)))

clf = GradientBoostingClassifier(learning_rate = 0.01, max_depth = 2, rand
clf.fit(X_train, y_train)

print('Breast cancer dataset (learning_rate=0.01, max_depth=2)')
print('Accuracy of GBDT classifier on training set: {:.2f}'

```

```

        .format(clf.score(X_train, y_train)))
print('Accuracy of GBDT classifier on test set: {:.2f}'
      .format(clf.score(X_test, y_test)))

```

Breast cancer dataset (learning_rate=0.1, max_depth=3)
 Accuracy of GBDT classifier on training set: 1.00
 Accuracy of GBDT classifier on test set: 0.96

Breast cancer dataset (learning_rate=0.01, max_depth=2)
 Accuracy of GBDT classifier on training set: 0.97
 Accuracy of GBDT classifier on test set: 0.97

1.4 Neural networks

Activation functions

```

In [11]: xrange = np.linspace(-2, 2, 200)

plt.figure(figsize=(7,6))

plt.plot(xrange, np.maximum(xrange, 0), label = 'relu')
plt.plot(xrange, np.tanh(xrange), label = 'tanh')
plt.plot(xrange, 1 / (1 + np.exp(-xrange)), label = 'logistic')
plt.legend()
plt.title('Neural network activation functions')
plt.xlabel('Input value (x)')
plt.ylabel('Activation function output')

plt.show()

```

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1.4.1 Neural networks: Classification

Synthetic dataset 1: single hidden layer

```

In [12]: from sklearn.neural_network import MLPClassifier
         from adspy_shared_utilities import plot_class_regions_for_classifier_subplot

X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_state=0)

fig, subaxes = plt.subplots(3, 1, figsize=(6,18))

for units, axis in zip([1, 10, 100], subaxes):

```



```

nnclf = MLPClassifier(hidden_layer_sizes = [units], solver='lbfgs',
                      random_state = 0).fit(X_train, y_train)

title = 'Dataset 1: Neural net classifier, 1 layer, {} units'.format(u

plot_class_regions_for_classifier_subplot(nnclf, X_train, y_train,
                                         X_test, y_test, title, axis)

plt.tight_layout()

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```

Synthetic dataset 1: two hidden layers

```

In [13]: from adspy_shared_utilities import plot_class_regions_for_classifier

X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_state=0)

nnclf = MLPClassifier(hidden_layer_sizes = [10, 10], solver='lbfgs',
                      random_state = 0).fit(X_train, y_train)

plot_class_regions_for_classifier(nnclf, X_train, y_train, X_test, y_test,
                                'Dataset 1: Neural net classifier, 2 layers')

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```

Regularization parameter: alpha

```

In [14]: X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_state=0)

fig, subaxes = plt.subplots(4, 1, figsize=(6, 23))

for this_alpha, axis in zip([0.01, 0.1, 1.0, 5.0], subaxes):
    nnclf = MLPClassifier(solver='lbfgs', activation = 'tanh',
                          alpha = this_alpha,
                          hidden_layer_sizes = [100, 100],
                          random_state = 0).fit(X_train, y_train)

    title = 'Dataset 2: NN classifier, alpha = {:.3f} '.format(this_alpha)

    plot_class_regions_for_classifier_subplot(nnclf, X_train, y_train,
                                             X_test, y_test, title, axis)

```

```
plt.tight_layout()
```

```
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```

```
<IPython.core.display.HTML object>
```

The effect of different choices of activation function

```
In [15]: X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_state=0)
```

```
fig, subaxes = plt.subplots(3, 1, figsize=(6,18))
```

```
for this_activation, axis in zip(['logistic', 'tanh', 'relu'], subaxes):  
    nnclf = MLPClassifier(solver='lbfgs', activation = this_activation,  
                          alpha = 0.1, hidden_layer_sizes = [10, 10],  
                          random_state = 0).fit(X_train, y_train)
```

```
    title = 'Dataset 2: NN classifier, 2 layers 10/10, {} \\  
activation function'.format(this_activation)
```

```
    plot_class_regions_for_classifier_subplot(nnclf, X_train, y_train,  
                                             X_test, y_test, title, axis)  
plt.tight_layout()
```

```
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```

1.4.2 Neural networks: Regression

```
In [16]: from sklearn.neural_network import MLPRegressor
```

```
fig, subaxes = plt.subplots(2, 3, figsize=(11,8), dpi=70)
```

```
X_predict_input = np.linspace(-3, 3, 50).reshape(-1,1)
```

```
X_train, X_test, y_train, y_test = train_test_split(X_R1[0::5], y_R1[0::5], random_state=0)
```

```
for thisaxisrow, thisactivation in zip(subaxes, ['tanh', 'relu']):  
    for thisalpha, thisaxis in zip([0.0001, 1.0, 100], thisaxisrow):  
        mlpreg = MLPRegressor(hidden_layer_sizes = [100,100],  
                               activation = thisactivation,  
                               alpha = thisalpha,  
                               solver = 'lbfgs').fit(X_train, y_train)
```

```

y_predict_output = mlpreg.predict(X_predict_input)
thisaxis.set_xlim([-2.5, 0.75])
thisaxis.plot(X_predict_input, y_predict_output,
              '^', markersize = 10)
thisaxis.plot(X_train, y_train, 'o')
thisaxis.set_xlabel('Input feature')
thisaxis.set_ylabel('Target value')
thisaxis.set_title('MLP regression\nalpha={}, activation={})'
                    .format(thisalpha, thisactivation))
plt.tight_layout()

```

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Application to real-world dataset for classification

```

In [17]: from sklearn.neural_network import MLPClassifier
         from sklearn.preprocessing import MinMaxScaler

```

```

scaler = MinMaxScaler()

```

```

X_train, X_test, y_train, y_test = train_test_split(X_cancer, y_cancer, ra
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

```

```

clf = MLPClassifier(hidden_layer_sizes = [100, 100], alpha = 5.0,
                    random_state = 0, solver='lbfgs').fit(X_train_scaled, y

```

```

print('Breast cancer dataset')
print('Accuracy of NN classifier on training set: {:.2f}'
      .format(clf.score(X_train_scaled, y_train)))
print('Accuracy of NN classifier on test set: {:.2f}'
      .format(clf.score(X_test_scaled, y_test)))

```

Breast cancer dataset

Accuracy of NN classifier on training set: 0.98

Accuracy of NN classifier on test set: 0.97