Module 4

May 23, 2019

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*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.*

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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 featur
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
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_stat

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
```

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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
```

```
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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, ran

        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_subplo

        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()
```

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


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

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_subplo

        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)))
```

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

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

```
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, rar

        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_subplo

        X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_stat
        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()
```

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


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

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, ranc
         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()
```

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


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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_subpl

         X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_sta

         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 [ ]: 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_stat

        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 layer
```

```
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```

Regularization parameter: alpha

```
In [ ]: X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_stat

        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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```

The effect of different choices of activation function

```
In [ ]: X_train, X_test, y_train, y_test = train_test_split(X_D2, y_D2, random_stat

        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 [ ]: 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],

        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 [ ]: 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, ran
        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
```