Decision Boundaries

- #### The aim of this notebook is to understand or visualize the decision boundaries for the below tasks:
  - #### Comparing different classifiers
  - #### Evaluating classifier for overfitting or underfitting

In [1]:
```
import os
import sys
import shutil

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap

from itertools import product

from sklearn import datasets
from sklearn.datasets import load_iris
from sklearn.preprocessing import StandardScaler


from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from sklearn.ensemble import VotingClassifier

%matplotlib inline
```

In [2]:
```
# Loading some example data
iris = load_iris()
X = iris.data[:, [0, 2]]
y = iris.target
```

In [3]:
```
# Training classifiers
clf1 = DecisionTreeClassifier(max_depth=4)
clf2 = KNeighborsClassifier(n_neighbors=7)
clf3 = SVC(gamma=.1, kernel='rbf', probability=True)
eclf = VotingClassifier(estimators=[('dt', clf1), ('knn', clf2),
                                    ('svc', clf3)],
                        voting='soft', weights=[2, 1, 2])

clf1.fit(X, y)
clf2.fit(X, y)
clf3.fit(X, y)
eclf.fit(X, y)
```

Out[3]:
```
VotingClassifier(estimators=[('dt', DecisionTreeClassifier(max_depth=4)),
                             ('knn', KNeighborsClassifier(n_neighbors=7)),
                             ('svc', SVC(gamma=0.1, probability=True))],
                 voting='soft', weights=[2, 1, 2])
```

In [4]:
```
# grid cell size
h = .02

x_min, x_max = X[:, 0].min() - 1, X[:, 0].max() + 1
y_min, y_max = X[:, 1].min() - 1, X[:, 1].max() + 1
```

```
xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                     np.arange(y_min, y_max, h))
```

Q. How Numpy ravel works?

In [5]:
```
xx
```

Out[5]:
```
array([[3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88],
       [3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88],
       [3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88],
       ...,
       [3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88],
       [3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88],
       [3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88]])
```

In [6]:
```
xx.shape
```

Out[6]:
```
(395, 280)
```

In [7]:
```
pd.DataFrame(xx)
```

Out[7]:

	0	1	2	3	4	5	6	7	8	9	...	270	271	272	273	274	275	2
0	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
1	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
2	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
3	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
4	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
390	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
391	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
392	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
393	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8
394	3.3	3.32	3.34	3.36	3.38	3.4	3.42	3.44	3.46	3.48	...	8.7	8.72	8.74	8.76	8.78	8.8	8

395 rows × 280 columns

In [8]:
```
xx.ravel()
```

Out[8]:
```
array([3.3 , 3.32, 3.34, ..., 8.84, 8.86, 8.88])
```

In [9]:
```
xx.ravel().shape
```

Out[9]:
```
(110600,)
```

In [10]:
```
pd.DataFrame(xx.ravel())
```

Out[10]:

	0
0	3.30
1	3.32

	0
2	3.34
3	3.36
4	3.38
...	...
110595	8.80
110596	8.82
110597	8.84
110598	8.86
110599	8.88

110600 rows × 1 columns

Q. How np.c *and np.r* works?

In [11]:
```
x1 = np.array([[1,2],[3,5]])
x2 = np.array([[7,8],[9,2]])
print(x1.shape,x2.shape)
x1,x2
```

```
(2, 2) (2, 2)
```

Out[11]:
```
(array([[1, 2],
        [3, 5]]),
 array([[7, 8],
        [9, 2]]))
```

np.c_

- It concatenates the array-1 and array-2 column wise

In [12]:
```
print(np.c_[x1,x2].shape)
np.c_[x1,x2]
```

```
(2, 4)
```

Out[12]:
```
array([[1, 2, 7, 8],
       [3, 5, 9, 2]])
```

np.r_

- It concatenates the array-1 and array-2 row wise

In [13]:
```
print(np.r_[x1,x2].shape)
np.r_[x1,x2]
```

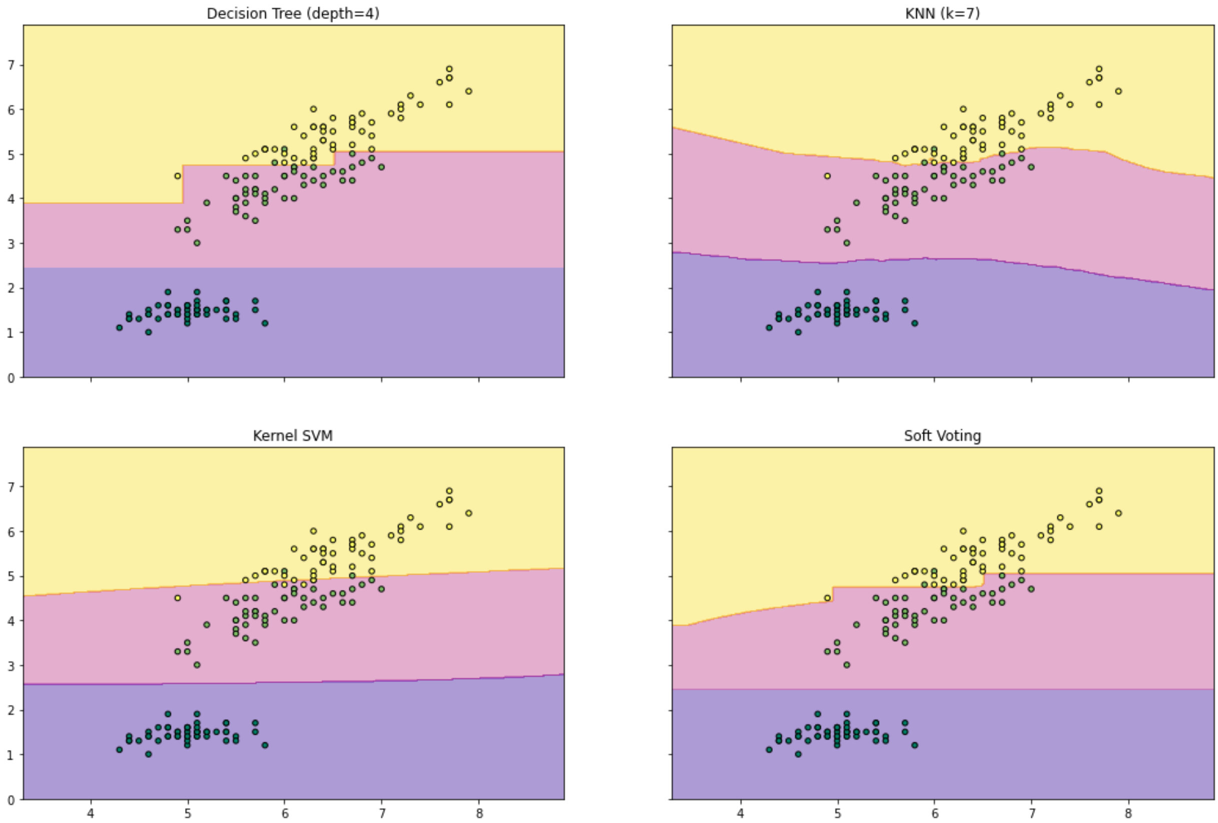
```
(4, 2)
```

Out[13]:
```
array([[1, 2],
       [3, 5],
       [7, 8],
       [9, 2]])
```

Different Classifiers Decision Boundaries

In [14]:
```
f, axarr = plt.subplots(2, 2, sharex='col', sharey='row', figsize=(18, 12)) ## 4 Sub

for idx, clf, tt in zip(product([0, 1], [0, 1]),  ## This gives the cartesian produc
                        [clf1, clf2, clf3, eclf], ## These are all the above 4 class
```

```
                    ['Decision Tree (depth=4)', 'KNN (k=7)', 'Kernel SVM', 'Soft

    Z = clf.predict(np.c_[xx.ravel(), yy.ravel()]) ## This first flattens the xx and
    Z = Z.reshape(xx.shape)

    axarr[idx[0], idx[1]].contourf(xx, yy, Z, alpha=0.4,cmap='plasma')
    axarr[idx[0], idx[1]].scatter(X[:, 0], X[:, 1], c=y, s=20, edgecolor='k',cmap='s
    axarr[idx[0], idx[1]].set_title(tt)

plt.show()
```



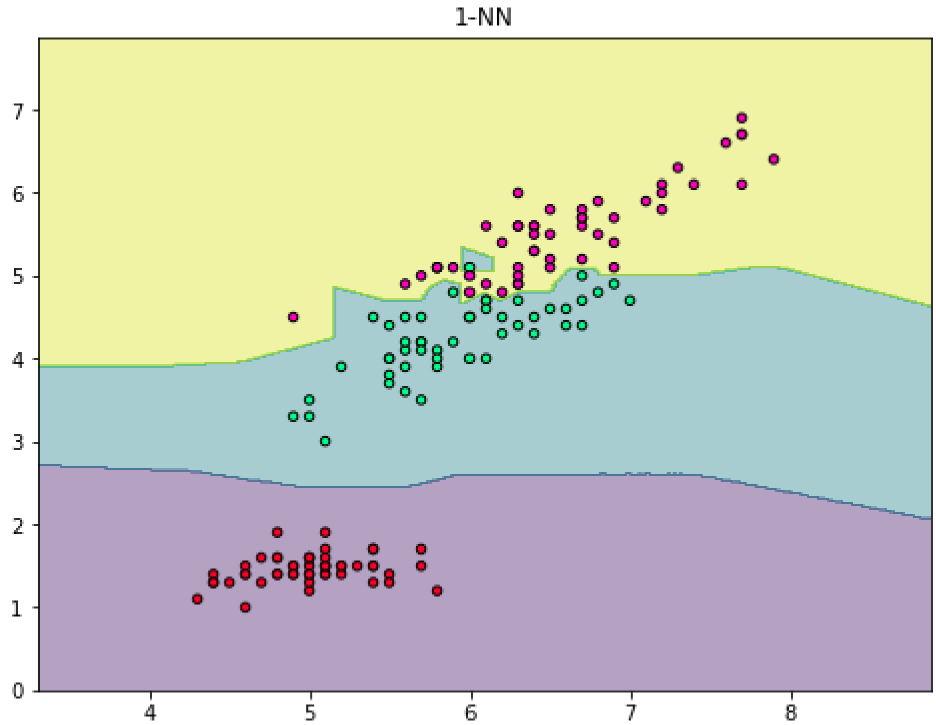
Decision Boundaries of K-Nearest Neighbors

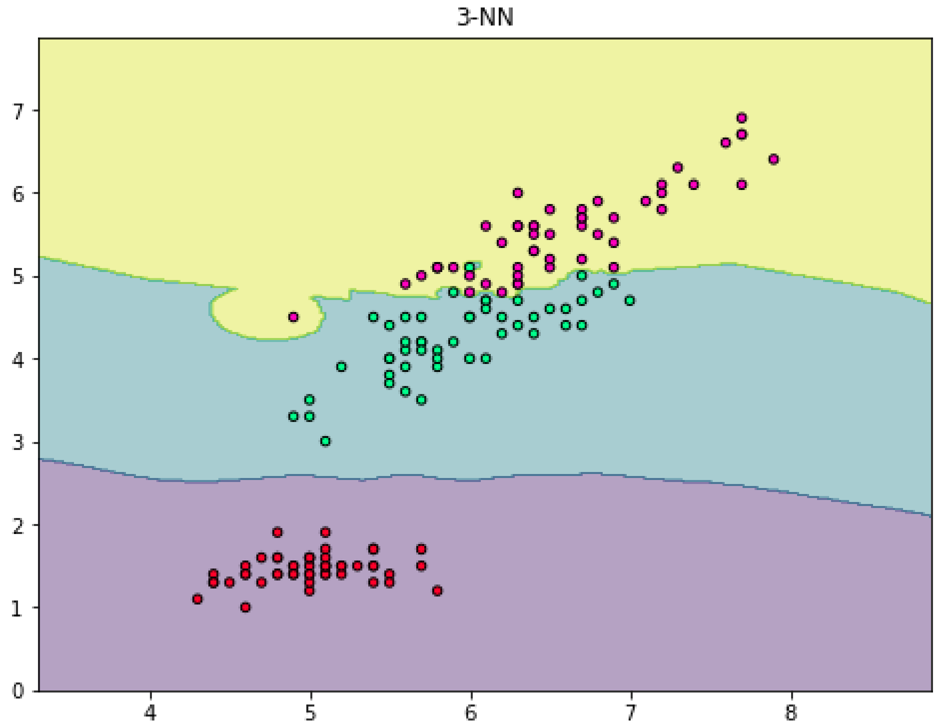
In [15]:

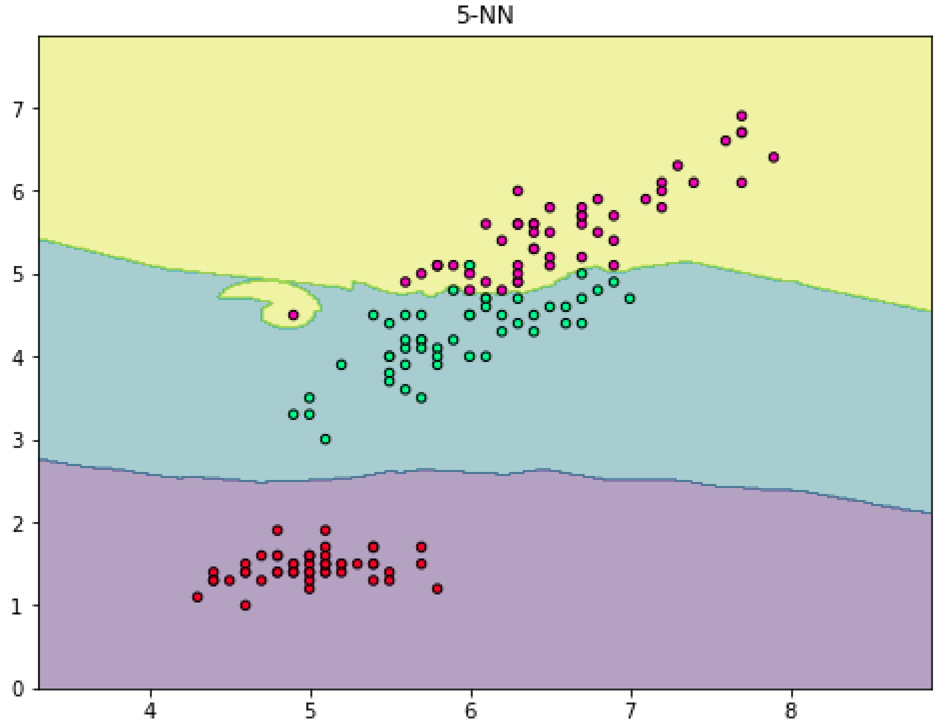
```
# Loading some example data
iris = load_iris()
X = iris.data[:, [0, 2]]
y = iris.target

# grid cell size
h = .02

x_min, x_max = X[:, 0].min() - 1, X[:, 0].max() + 1
y_min, y_max = X[:, 1].min() - 1, X[:, 1].max() + 1

xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                     np.arange(y_min, y_max, h))
```

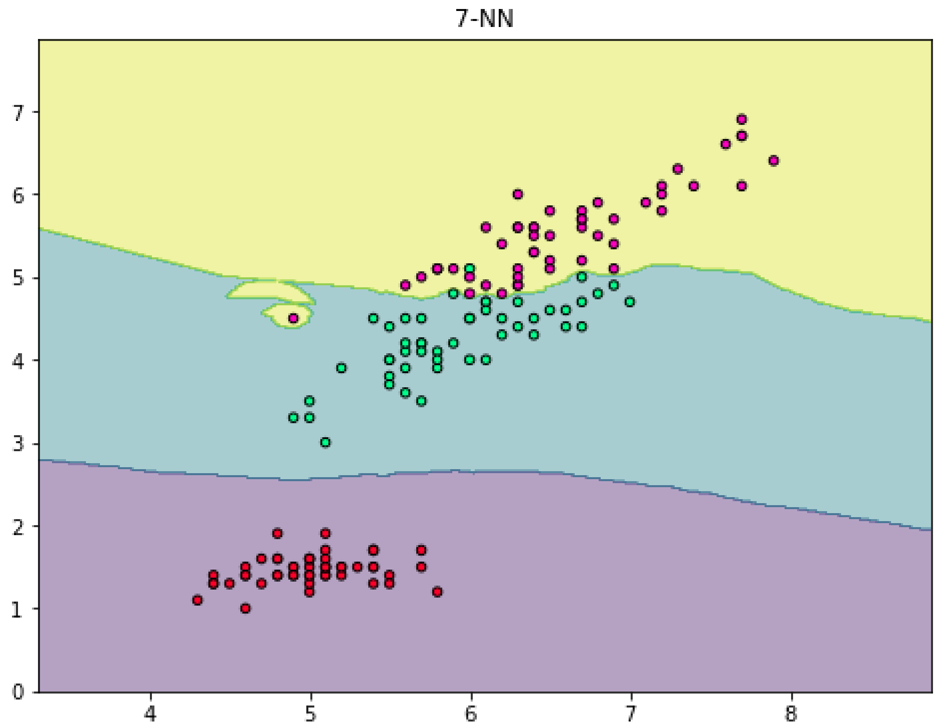
In [16]:

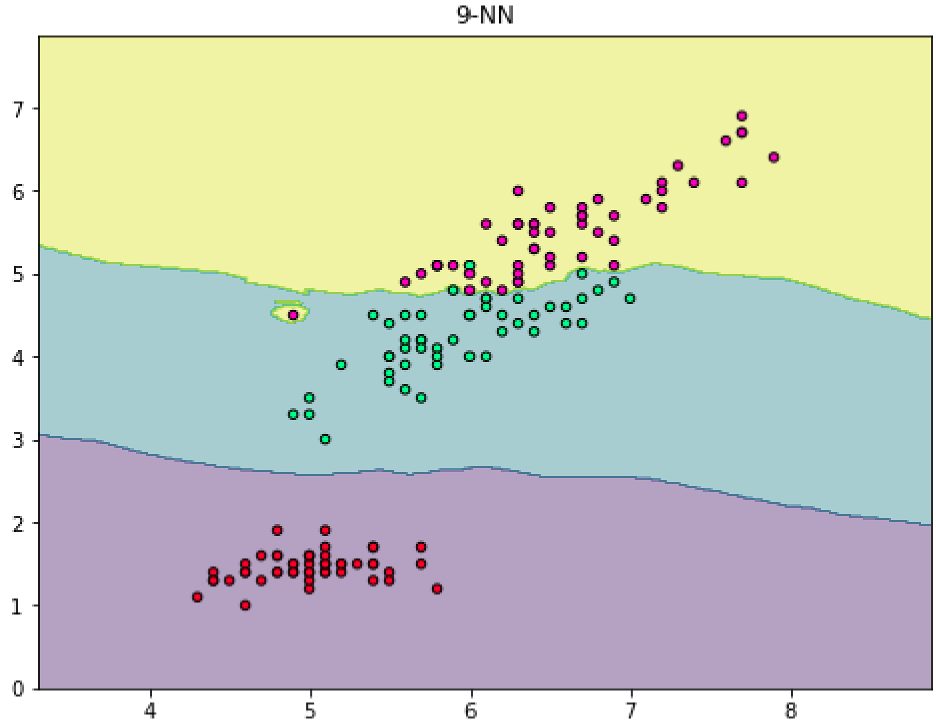
```
for k in range(1,12)[::2]:                    ## Generating an odd numbers list of NN
    f, axarr = plt.subplots(1,1, figsize=(8, 6))     ## Defining a subplot with 1 row
    clf11 = KNeighborsClassifier(n_neighbors=k,weights='distance',algorithm='kd_tree
    clf11.fit(X,y)
    Z = clf11.predict(np.c_[xx.ravel(), yy.ravel()])  ## This provide the flattened
    Z = Z.reshape(xx.shape)
    axarr.contourf(xx, yy, Z, alpha=0.4,cmap='viridis')  ## This plots the countour
    axarr.scatter(X[:, 0], X[:, 1], c=y,s=20, edgecolor='k',cmap='gist_rainbow')  ##
    axarr.set_title('{}-NN'.format(k))
    plt.show()
```

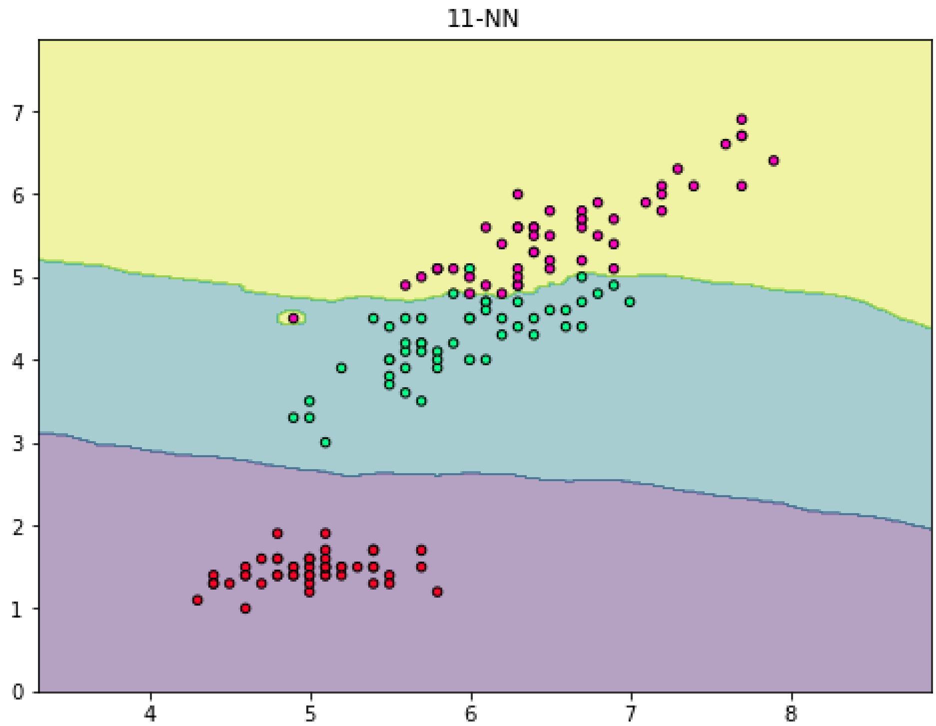

1-NN
0
1
2
3
4
5
6
7
4
5
6
7
8


3-NN
0
1
2
3
4
5
6
7
4
5
6
7
8


5-NN
0
1
2
3
4
5
6
7
4
5
6
7
8


7-NN
0
1
2
3
4
5
6
7
4
5
6
7
8





Work with some random shaped datasets

In [17]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap
import seaborn as sns

%matplotlib inline

# Import statements required for Plotly
import plotly.offline as py
py.init_notebook_mode(connected=True)
import plotly.graph_objs as go
from plotly import tools
from plotly import subplots
```

```python
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVC
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.datasets import make_moons, make_circles, make_classification, make_blo
from sklearn.neighbors import KNeighborsClassifier
from sklearn.cluster import KMeans
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import (RandomForestClassifier, AdaBoostClassifier,
                              ExtraTreesClassifier, GradientBoostingClassifier, Bagg
from sklearn.naive_bayes import GaussianNB
from sklearn.linear_model import LogisticRegression
```

Decision boundaries on some random shaped toy datasets

In [18]:

```python
random_shaped_toy_datasets = [make_moons(noise=0.25, random_state=41,n_samples=500),
                              make_circles(noise=0.2, factor=0.5, random_state=23,n_
                              make_blobs(random_state=44,n_samples=500)]

classifier_names = ["Decision Tree","Random Forest", "ExtraTrees", "KNN"]

# Creating a list with 4 classifiers
diff_classifiers = [
    DecisionTreeClassifier(max_depth=5),
    RandomForestClassifier(max_depth=5, n_estimators=20, max_features=1),
    ExtraTreesClassifier(),
    KNeighborsClassifier(n_neighbors=9,weights='distance',algorithm='kd_tree',leaf_s
```

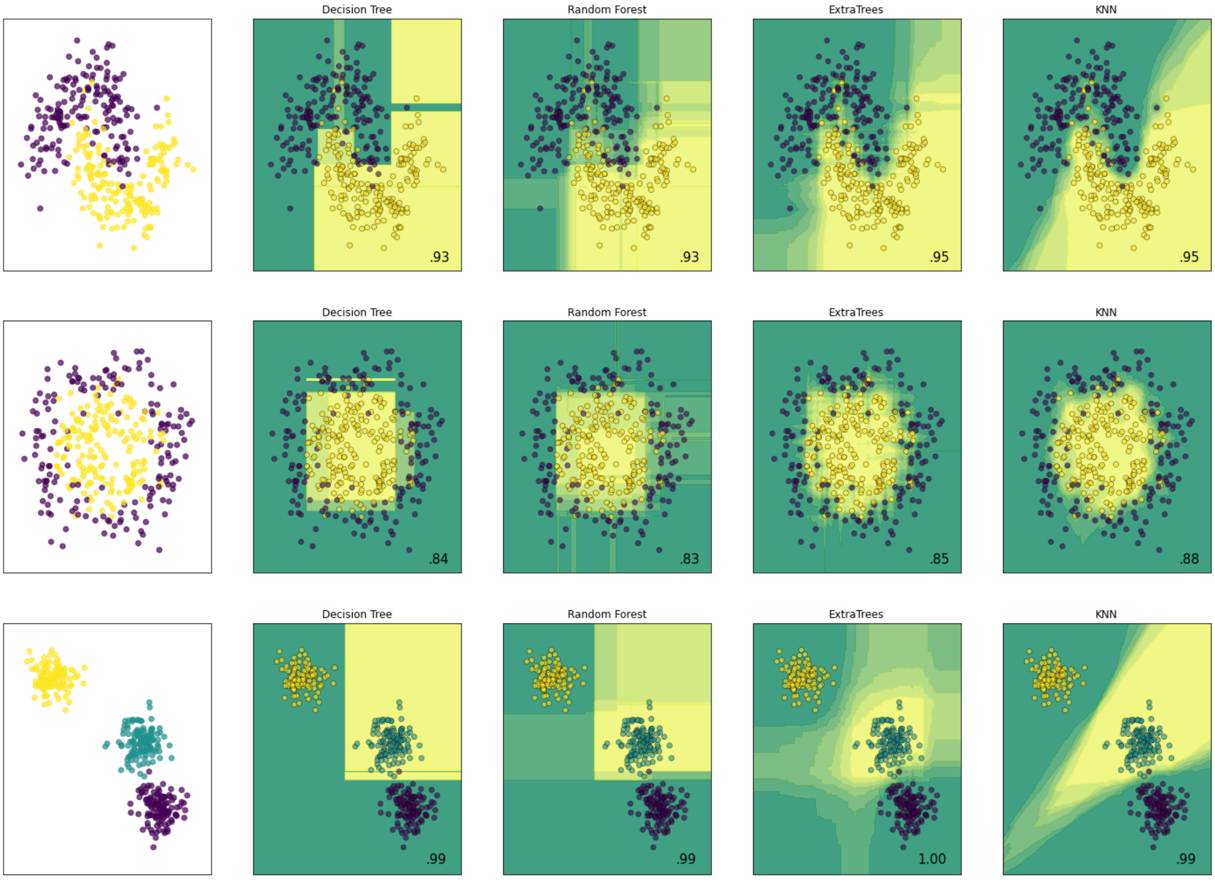
In [19]:

```python
def plot_decision_boundaries(datasets,clf_names,classifiers,test_label=False):
    """
    Description : This function is created for generating the decision boundaries of

    Inputs : It accepts the below parameters:
        1. datasets --> list
            This is the list which contains the pandas dataframe object
        2. clf_names --> list
            List containing names of classifiers
        3. classifiers --> list
            List containing actual classifier objects
        4. test_label --> boolean
            Flag that handles whether test data points to be generated

    Return : None
    """
    figure = plt.figure(figsize=(20, 18))     # Defining figure size
    h = 0.02     # Defining the cell size of a grid
    i = 1        # Counter for iterating over datasets
    for ds in datasets:
        # Scaling dataset, split into training and test part
        X, y = ds
        X = StandardScaler().fit_transform(X)
        X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=.3)

        # Creating the data point grid
        x_min, x_max = X[:, 0].min() -.5, X[:, 0].max() + .5
        y_min, y_max = X[:, 1].min() -.5, X[:, 1].max() + .5
        xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                             np.arange(y_min, y_max, h))
```

```
        # First, only plotting the dataset
        ax = plt.subplot(len(datasets), len(classifiers) + 1, i) # i means index sta
        # Plot the training points
        ax.scatter(X_train[:, 0], X_train[:, 1], c=y_train, cmap='viridis', alpha=0.
        # Plot the testing points
        if test_label:
            ax.scatter(X_test[:, 0], X_test[:, 1], c=y_test, cmap='gist_rainbow', al

        ax.set_xlim(xx.min(), xx.max())
        ax.set_ylim(yy.min(), yy.max())
        ax.set_xticks(())
        ax.set_yticks(())
        i += 1

        # Iterate over classifiers
        for name, clf in zip(clf_names, classifiers):
            ax = plt.subplot(len(datasets), len(classifiers) + 1, i)
            clf.fit(X_train, y_train)
            score = clf.score(X_test, y_test)  # Calculating the accuracy

            # Inplace of below if else statement we can also use the classifier pred
            # Decision function tells on which side of the hyperplane(generated by t
            # Mathematically we can say that it is the result of dot product it +ve
            if hasattr(clf, "decision_function"):
                Z = clf.decision_function(np.c_[xx.ravel(), yy.ravel()])
            else:
                Z = clf.predict_proba(np.c_[xx.ravel(), yy.ravel()])[:, 1]

            Z = Z.reshape(xx.shape)  # The height values over which the contour is d
            # Put the result into a color plot
            ax.contourf(xx, yy, Z, cmap='summer', alpha=.8)
            # Plot the training points
            ax.scatter(X_train[:, 0], X_train[:, 1], c=y_train, cmap='viridis', alph
            # Plot the testing points
            if test_label:
                ax.scatter(X_test[:, 0], X_test[:, 1], c=y_test, cmap='gist_rainbow'

            ax.set_xlim(xx.min(), xx.max())
            ax.set_ylim(yy.min(), yy.max())
            ax.set_xticks(())
            ax.set_yticks(())
            ax.set_title(name)
            ax.text(xx.max() - .3, yy.min() + .2, ('%.2f' % score).lstrip('0'), size
            i += 1

    figure.subplots_adjust(left=.02, right=.98)
    plt.show()
```

In [20]:

```
plot_decision_boundaries(datasets=random_shaped_toy_datasets,
                         clf_names=classifier_names,
                         classifiers=diff_classifiers)
```



In [ ]:

In [27]:
```
iris = load_iris()
X = iris.data[:, [0, 2]]
y = iris.target
h = .02  # step size in the mesh

X = StandardScaler().fit_transform(X)


# Train two Random Forests. One with normal reasonable parameters and the other with
rf_trees = RandomForestClassifier(max_depth=4,
                                  n_estimators=20,
                                  random_state=42)
rf_trees.fit(X, y)

rf_trees_overfit = RandomForestClassifier(max_depth=128,
                                          n_estimators=5,
                                          random_state=42)
rf_trees_overfit.fit(X, y)

x_min, x_max = X[:, 0].min() - 1, X[:, 0].max() + 1
y_min, y_max = X[:, 1].min() - 1, X[:, 1].max() + 1

xx, yy = np.meshgrid(np.arange(x_min, x_max, h)
                     , np.arange(y_min, y_max, h))
y_ = np.arange(y_min, y_max, h)

Z = rf_trees.predict(np.c_[xx.ravel(), yy.ravel()])
Z = Z.reshape(xx.shape)


fig = subplots.make_subplots(rows=1, cols=2,
                          subplot_titles=("Random Forest (Depth = 4)",
                                          "Random Forest (Depth = 200)")
                         )
```

```python
trace1 = go.Heatmap(x=xx[0], y=y_, z=Z,
                  colorscale='Viridis',
                  showscale=False)

trace2 = go.Scatter(x=X[:, 0], y=X[:, 1],
                    mode='markers',
                    showlegend=False,
                    marker=dict(size=10,
                                color=y,
                                colorscale='Viridis',
                                line=dict(color='black', width=1))
                    )

fig.append_trace(trace1, 1, 1)
fig.append_trace(trace2, 1, 1)

# transform grid using ExtraTreesClassifier
# y_grid_pred = trees.predict_proba(np.c_[xx.ravel(), yy.ravel()])[:, 1]

Z = rf_trees_overfit.predict(np.c_[xx.ravel(), yy.ravel()])
Z = Z.reshape(xx.shape)


trace3 = go.Heatmap(x=xx[0], y=y_,
                    z=Z,
                    colorscale='Viridis',
                    showscale=True)

trace4 = go.Scatter(x=X[:, 0], y=X[:, 1],
                    mode='markers',
                    showlegend=False,
                    marker=dict(size=10,
                                color=y,
                                colorscale='Viridis',
                                line=dict(color='black', width=1))
                   )
fig.append_trace(trace3, 1, 2)
fig.append_trace(trace4, 1, 2)

for i in map(str, range(1, 3)):
    x = 'xaxis' + i
    y = 'yaxis' + i
    fig['layout'][x].update(showgrid=False,
                            zeroline=False,
                            showticklabels=False,
                            ticks='',
                            autorange=True)
    fig['layout'][y].update(showgrid=False,
                            zeroline=False,
                            showticklabels=False,
                            ticks='',
                            autorange=True)

py.iplot(fig)
```

In [ ]:

In [ ]: