FINALPROJECT_jupyter

March 22, 2018

In [1]:
```
import scipy.io as sio
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
import pandas as pd
from sklearn import svm
from sklearn import tree
from sklearn.model_selection import GridSearchCV
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.datasets import make_classification
```

In [2]:
```
def convert_iris(label):
    """
    Function to convert the labels from string to numeric
    """
    if label == "Iris-virginica":
        return 1.0
    elif label == "Iris-setosa":
        return 0.0
    elif label == "Iris-versicolor":
        return 0.0
    else:
        return label

def convert_breast(label):
    """
    Function to convert the labels from string to numeric
    """
    if label == "M":
        return 1.0
    elif label == "B":
        return 0.0
    else:
        return label

def simple_cross_validation(X_train_val, Y_train_val, k, fold):
```

```python
    """
    A simple cross-validation function for k-NN.

    X_train_val: Features for train and val set.
                 Shape: (num of data points, num of features)
    Y_train_val: Labels for train and val set.
                 Shape: (num of data points,)
    k:           Parameter k for k-NN.
    fold:        The number of folds to do the cross-validation.

    Return the average accuracy on validation set.
    """
    val_acc_list = []
    train_acc_list = []
    for i in range(0,fold):
        size_split = int(X_train_val.shape[0]/fold)
        if i == 0:
            X_test_val_s = X_train_val[0:size_split,:]
            X_train_val_s = X_train_val[size_split:X_train_val.shape[0],:]

            Y_test_val_s = Y_train_val[0:size_split,]
            Y_train_val_s = Y_train_val[size_split:Y_train_val.shape[0],]

        else:
            X_test_val_s = X_train_val[i*size_split:i*size_split+size_split,:]
            train_beg_s = X_train_val[0:i*size_split,:]
            train_end_s = X_train_val[i*size_split+size_split:X_train_val.shape[0],:]
            X_train_val_s = np.concatenate((train_beg_s,train_end_s))

        classifier1 = KNeighborsClassifier(algorithm='brute', n_neighbors=k)
        classifier2 = KNeighborsClassifier(algorithm='brute', n_neighbors=k)

        classifier1.fit(X_test_val_s,Y_test_val_s.ravel())
        classifier2.fit(X_train_val_s,Y_train_val_s.ravel())

        val_acc_list.append(classifier1.score(X_test_val_s,Y_test_val_s))
        train_acc_list.append(classifier2.score(X_train_val_s,Y_train_val_s))

    return sum(val_acc_list) / len(val_acc_list), \
           sum(train_acc_list) / len(train_acc_list)

def simple_GridSearchCV_fit(X_train_val, Y_train_val, k_list, fold):
    """
    A simple grid search function for k with cross-validation in k-NN.

    X_train_val: Features for train and val set.
                 Shape: (num of data points, num of features)
    Y_train_val: Labels for train and val set.
```

```
                 Shape: (num of data points,)
    k_list:      The list of k values to try.
    fold:        The number of folds to do the cross-validation.

    Return the val and train accuracy matrix of cross-validation.
    All combinations of k are included in the array.
    Shape: (len(k_list), )
    """
    shape = len(k_list)
    val_acc_array = np.zeros(shape)
    train_acc_array = np.zeros(shape)
    for i in range(0,shape):
        val_acc_array[i], train_acc_array[i] = simple_cross_validation(
            X_train_val, Y_train_val, k_list[i], fold)
    return val_acc_array, train_acc_array

def draw_heatmap_knn(acc, acc_desc, k_list):
    """
    Draw heatmap for k-nearest neighbors hyper parameters
    """
    plt.figure(figsize = (2,4))
    ax = sns.heatmap(acc, annot=True, fmt='.3f', yticklabels=k_list, xticklabels=[])
    ax.collections[0].colorbar.set_label("accuracy")
    ax.set(ylabel='$k$')
    plt.title(acc_desc + ' w.r.t $k$')
    sns.set_style("whitegrid", {'axes.grid' : False})
    plt.show()

def draw_heatmap_linear(acc, acc_desc, depth_list):
    """
    Draw heatmap for linear classifier hyper parameters
    """
    plt.figure(figsize = (2,4))
    ax = sns.heatmap(acc, annot=True, fmt='.3f', yticklabels=depth_list, xticklabels=[
    ax.collections[0].colorbar.set_label("accuracy")
    ax.set(ylabel='depth')
    plt.title(acc_desc + ' w.r.t depth')
    sns.set_style("whitegrid", {'axes.grid' : False})
    plt.show()
```

1 Iris Dataset

```
In [3]: iris = pd.read_csv('http://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris
```

Clean and Split Dataset:

```
In [4]: iris['Iris-setosa'] = iris['Iris-setosa'].apply(convert_iris)
        iris_XY = iris.iloc[:,0:5].values
```

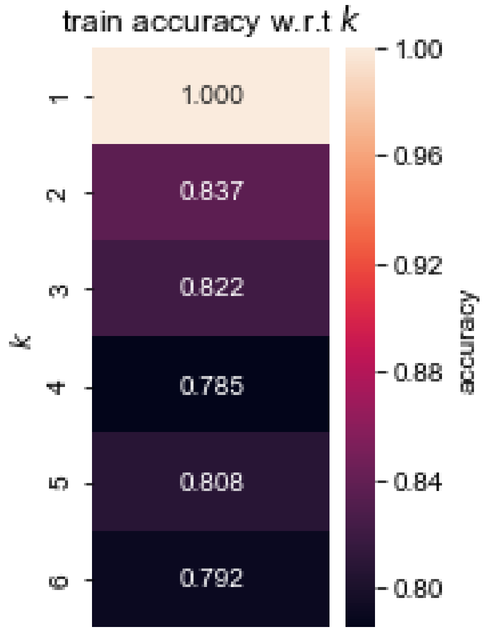
```
        np.random.shuffle(iris_XY)

        iris_X = iris_XY[:,0:4]
        iris_Y = iris_XY[:,4:5]

        num_training = int(0.8*iris_X.shape[0])
        num_testing = int(0.2*iris_X.shape[0])

        iris_X_train = iris_X[:num_training]
        iris_Y_train = iris_Y[:num_training]
        iris_X_test = iris_X[num_training:]
        iris_Y_test = iris_Y[num_training:]

        print(iris_X_train.shape)
        print(iris_Y_train.shape)
        print(iris_X_test.shape)
        print(iris_Y_test.shape)
```

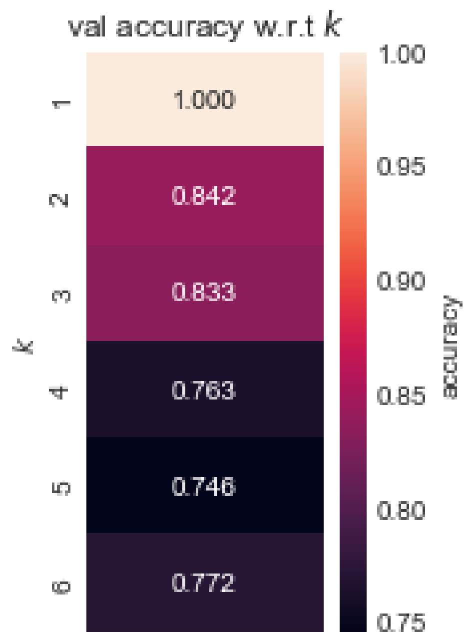
```
(119, 4)
(119, 1)
(30, 4)
(30, 1)
```

2 Performing KNN On Iris Data Set

```
In [5]: k_list = [1,2,3,4,5,6]
        val_acc_array, train_acc_array = \
            simple_GridSearchCV_fit(iris_X_train, iris_Y_train.ravel(), k_list, 6)
```

```
In [6]: draw_heatmap_knn(train_acc_array.reshape(-1,1), 'train accuracy', k_list)
        draw_heatmap_knn(val_acc_array.reshape(-1,1), 'val accuracy', k_list)
```





In [7]:
```
classifier = KNeighborsClassifier(6)
classifier.fit(iris_X_train, iris_Y_train.ravel())
preds = classifier.predict(iris_X_test)
```

```
asserted = []
for i in range(0,preds.shape[0]):
    if preds[i] == iris_Y_test[i]:
        asserted.append(preds[i])
test_accuracy = len(asserted)/preds.shape[0]
print("Test Accuracy: {0:f}".format(test_accuracy))
```

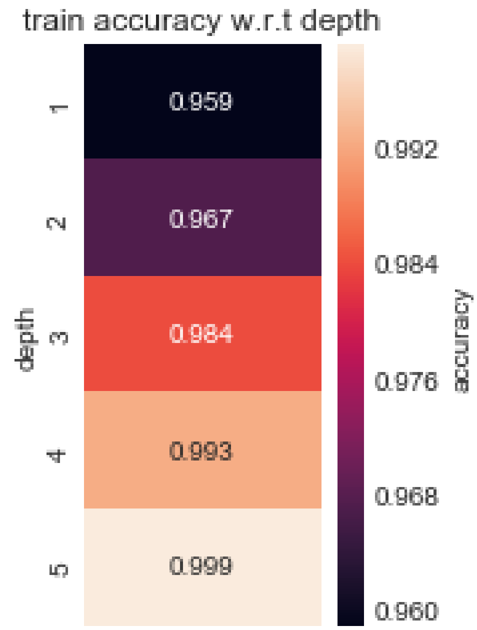
```
Test Accuracy: 1.000000
```

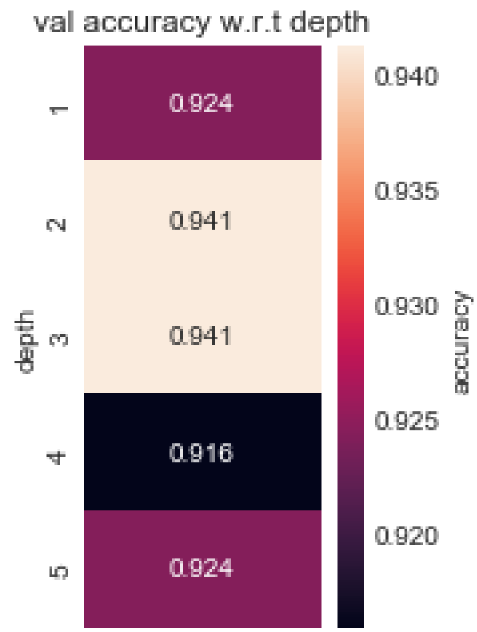
3 Performing Decision Trees On Iris Data Set

In [8]:
```
classifier = tree.DecisionTreeClassifier(
                    criterion='entropy')
depth_list = [1, 2, 3, 4, 5]
params = {"max_depth": depth_list}
grid_dt_iris = GridSearchCV(classifier, params,
                            return_train_score = True,
                            cv = 10)
grid_dt_iris.fit(iris_X_train, iris_Y_train)
```

Out[8]:
```
GridSearchCV(cv=10, error_score='raise',
       estimator=DecisionTreeClassifier(class_weight=None, criterion='entropy', max_dep
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=None,
            splitter='best'),
       fit_params=None, iid=True, n_jobs=1,
       param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
       refit=True, return_train_score=True, scoring=None, verbose=0)
```

In [9]:
```
train_acc = grid_dt_iris.cv_results_['mean_train_score'].reshape(-1,1)
draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

val_acc = grid_dt_iris.cv_results_['mean_test_score'].reshape(-1,1)
draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```






```
In [10]: pred = grid_dt_iris.predict(iris_X_test)
         asserted = []
         for i in range(0,pred.shape[0]):
             if pred[i] == iris_Y_test[i]:
```

```
                asserted.append(pred[i])
        test_accuracy = len(asserted)/pred.shape[0]
        print("Test Accuracy: {0:f}".format(test_accuracy))
        print(grid_dt_iris.best_params_)
```

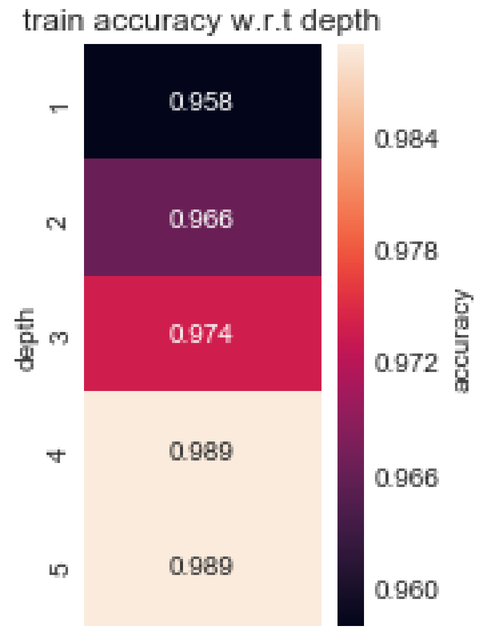
```
Test Accuracy: 0.933333
{'max_depth': 2}
```

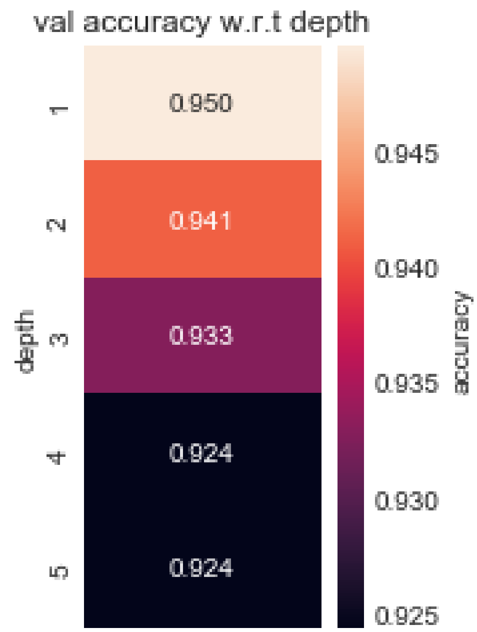
4 Performing Random Forests On Iris Data Set

```
In [11]: depth_list = [1, 2, 3, 4, 5]
         params = {"max_depth": depth_list}
         classifier = RandomForestClassifier(max_depth=5,
                                             random_state=0)
         grid_rf_iris = GridSearchCV(classifier, params,
                                     return_train_score = True, cv = 10)
         grid_rf_iris.fit(iris_X_train, iris_Y_train.ravel())
```

```
Out[11]: GridSearchCV(cv=10, error_score='raise',
                estimator=RandomForestClassifier(bootstrap=True, class_weight=None, criterion=
                     max_depth=5, max_features='auto', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
                     oob_score=False, random_state=0, verbose=0, warm_start=False),
                fit_params=None, iid=True, n_jobs=1,
                param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
                refit=True, return_train_score=True, scoring=None, verbose=0)
```

```
In [12]: train_acc = grid_rf_iris.cv_results_['mean_train_score'].reshape(-1,1)
         draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

         val_acc = grid_rf_iris.cv_results_['mean_test_score'].reshape(-1,1)
         draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```





In [13]:
```
pred = grid_rf_iris.predict(iris_X_test)
asserted = []
for i in range(0,pred.shape[0]):
    if pred[i] == iris_Y_test[i]:
```

```
                asserted.append(pred[i])
        test_accuracy = len(asserted)/pred.shape[0]
        print("Test Accuracy: {0:f}".format(test_accuracy))
        print(grid_rf_iris.get_params())
```

```
Test Accuracy: 0.966667
{'cv': 10, 'error_score': 'raise', 'estimator__bootstrap': True, 'estimator__class_weight': Nor
            max_depth=5, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
            oob_score=False, random_state=0, verbose=0, warm_start=False), 'fit_params': None,
```

5 Breast Cancer Dataset

```
In [14]: breast = pd.read_csv('http://archive.ics.uci.edu/ml/machine-learning-databases/breast-
```

Clean and Split Dataset:

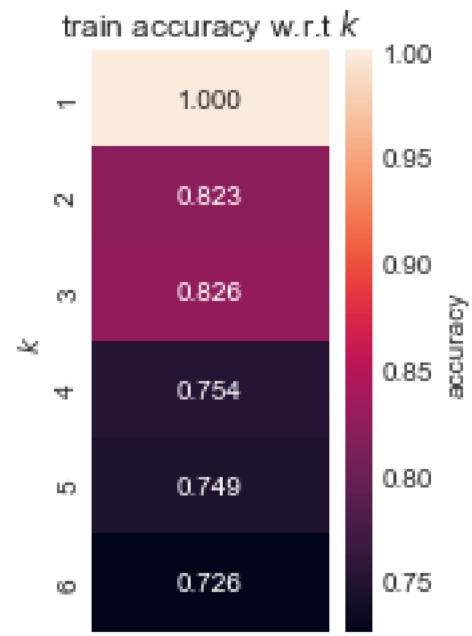
```
In [15]: breast.dropna(inplace = True)
         breast['M'] = breast['M'].apply(convert_breast)
         breast_XY = pd.concat([breast.iloc[:,0:1],breast.iloc[:,2:],
                                breast.iloc[:,1:2]],axis=1).values
         np.random.shuffle(breast_XY)

         breast_X = breast_XY[:,0:31]
         breast_Y = breast_XY[:,31:]

         num_training = int(0.8*breast_X.shape[0])
         num_testing = int(0.2*breast_X.shape[0])

         breast_X_train = breast_X[:num_training]
         breast_Y_train = breast_Y[:num_training]
         breast_X_test = breast_X[num_training:]
         breast_Y_test = breast_Y[num_training:]

         print(breast_X_train.shape)
         print(breast_Y_train.shape)
         print(breast_X_test.shape)
         print(breast_Y_test.shape)
```

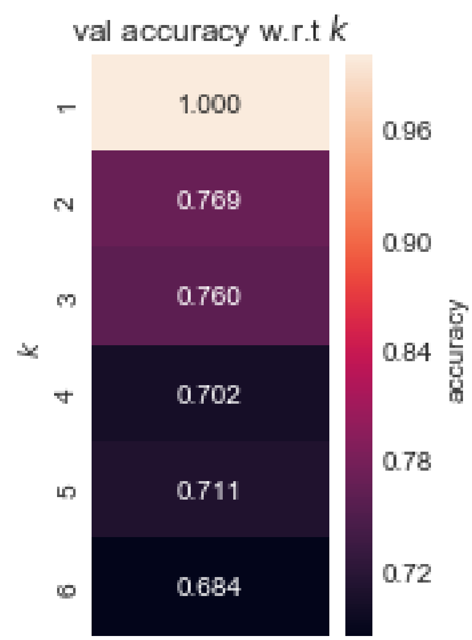
```
(454, 31)
(454, 1)
(114, 31)
(114, 1)
```

6 Performing KNN On Breast Cancer Data Set

```
In [16]: k_list = [1,2,3,4,5,6]
         val_acc_array, train_acc_array = \
             simple_GridSearchCV_fit(breast_X_train, breast_Y_train.ravel(), k_list, 6)
```

```
In [17]: draw_heatmap_knn(train_acc_array.reshape(-1,1), 'train accuracy', k_list)
         draw_heatmap_knn(val_acc_array.reshape(-1,1), 'val accuracy', k_list)
```

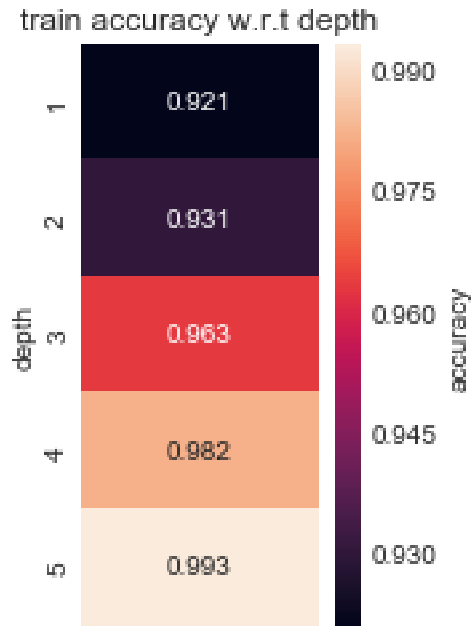


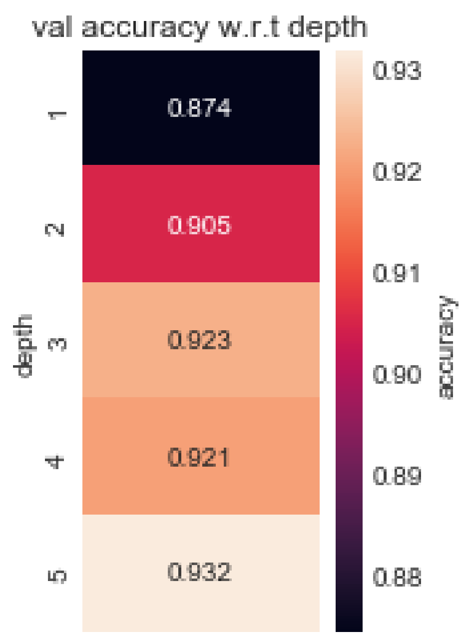


```
In [18]: classifier = KNeighborsClassifier(6)
         classifier.fit(breast_X_train, breast_Y_train.ravel())
         preds = classifier.predict(breast_X_test)
         asserted = []
         for i in range(0,preds.shape[0]):
             if preds[i] == breast_Y_test[i]:
                 asserted.append(preds[i])
         test_accuracy = len(asserted)/preds.shape[0]
         print("Test Accuracy: {0:f}".format(test_accuracy))

Test Accuracy: 0.736842
```

7 Performing Decision Trees On Breast Cancer Data Set

```
In [19]: classifier = tree.DecisionTreeClassifier(criterion='entropy')
         depth_list = [1, 2, 3, 4, 5]
         params = {"max_depth": depth_list}
         grid_dt_breast = GridSearchCV(classifier, params, return_train_score = True, cv = 10)
         grid_dt_breast.fit(breast_X_train, breast_Y_train)

Out[19]: GridSearchCV(cv=10, error_score='raise',
                estimator=DecisionTreeClassifier(class_weight=None, criterion='entropy', max_de
                     max_features=None, max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, presort=False, random_state=None,
                     splitter='best'),
                fit_params=None, iid=True, n_jobs=1,
                param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
                refit=True, return_train_score=True, scoring=None, verbose=0)

In [20]: train_acc = grid_dt_breast.cv_results_['mean_train_score'].reshape(-1,1)
         draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

         val_acc = grid_dt_breast.cv_results_['mean_test_score'].reshape(-1,1)
         draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```






```
In [21]: pred = grid_dt_breast.predict(breast_X_test)
         asserted = []
         for i in range(0,pred.shape[0]):
             if pred[i] == breast_Y_test[i]:
```

```
                asserted.append(pred[i])
        test_accuracy = len(asserted)/pred.shape[0]
        print(test_accuracy)
        print(grid_dt_breast.best_params_)
```

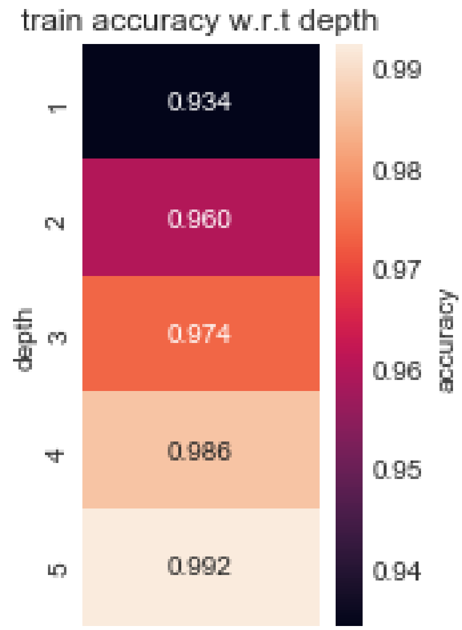
```
0.9385964912280702
{'max_depth': 5}
```

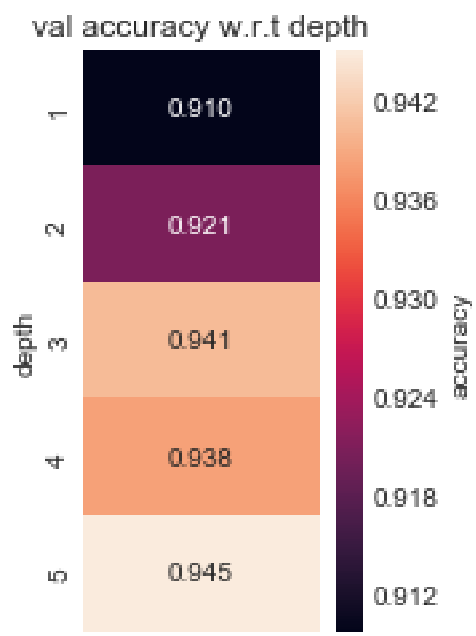
8 Performing Random Forests On Breast Cancer Data Set

```
In [22]: depth_list = [1, 2, 3, 4, 5]
         params = {"max_depth": depth_list}
         classifier = RandomForestClassifier(max_depth=5, random_state=0)
         grid_rf_breast = GridSearchCV(classifier, params, return_train_score = True, cv = 10)
         grid_rf_breast.fit(breast_X_train, breast_Y_train.ravel())
```

```
Out[22]: GridSearchCV(cv=10, error_score='raise',
                estimator=RandomForestClassifier(bootstrap=True, class_weight=None, criterion=
                     max_depth=5, max_features='auto', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
                     oob_score=False, random_state=0, verbose=0, warm_start=False),
                fit_params=None, iid=True, n_jobs=1,
                param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
                refit=True, return_train_score=True, scoring=None, verbose=0)
```

```
In [23]: train_acc = grid_rf_breast.cv_results_['mean_train_score'].reshape(-1,1)
         draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

         val_acc = grid_rf_breast.cv_results_['mean_test_score'].reshape(-1,1)
         draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```






```
In [24]: pred = grid_rf_breast.predict(breast_X_test)
         asserted = []
         for i in range(0,pred.shape[0]):
             if pred[i] == breast_Y_test[i]:
```

```
                asserted.append(pred[i])
        test_accuracy = len(asserted)/pred.shape[0]
        print("Test Accuracy: {0:f}".format(test_accuracy))
        print(grid_rf_breast.get_params())
```

```
Test Accuracy: 0.964912
{'cv': 10, 'error_score': 'raise', 'estimator__bootstrap': True, 'estimator__class_weight': Nor
            max_depth=5, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
            oob_score=False, random_state=0, verbose=0, warm_start=False), 'fit_params': None,
```

9 Mammographic Masses Dataset

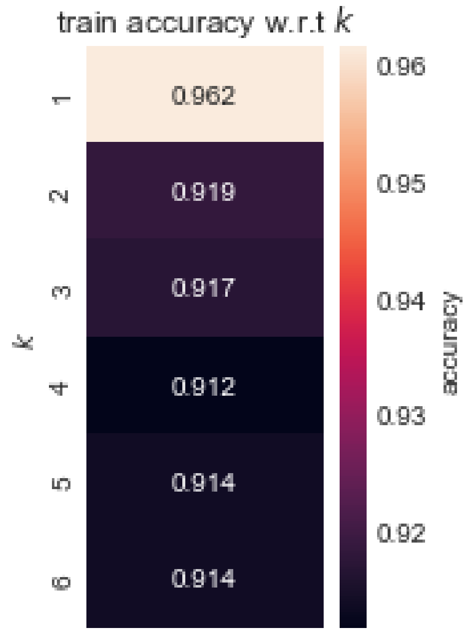
```
In [25]: mammograph = pd.read_csv('http://archive.ics.uci.edu/ml/machine-learning-databases/mam
         mammograph = mammograph.replace({'?':np.nan}).dropna()
         mammograph_XY = mammograph.iloc[:,0:5].values
         np.random.shuffle(mammograph_XY)

         mammograph_X = mammograph_XY[:,0:4]
         mammograph_Y = mammograph_XY[:,4:5]

         num_training = int(0.8*mammograph_X.shape[0])
         num_testing = int(0.2*mammograph_X.shape[0])

         mam_X_train = mammograph_X[:num_training]
         mam_Y_train = mammograph_Y[:num_training]
         mam_X_test = mammograph_X[num_training:]
         mam_Y_test = mammograph_Y[num_training:]

         print(mam_X_train.shape)
         print(mam_Y_train.shape)
         print(mam_X_test.shape)
         print(mam_Y_test.shape)
```

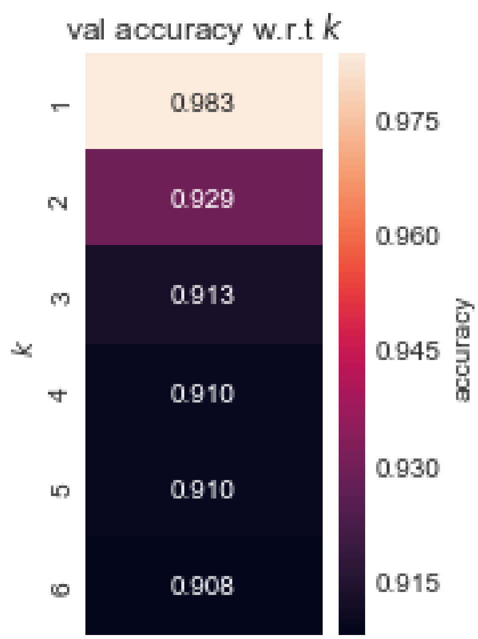
```
(663, 4)
(663, 1)
(166, 4)
(166, 1)
```

10 Performing KNN On Mammograph Data Set

```
In [26]: k_list = [1,2,3,4,5,6]
         val_acc_array, train_acc_array = \
             simple_GridSearchCV_fit(mam_X_train, mam_Y_train.ravel(), k_list, 3)
```

```
In [27]: draw_heatmap_knn(train_acc_array.reshape(-1,1), 'train accuracy', k_list)
         draw_heatmap_knn(val_acc_array.reshape(-1,1), 'val accuracy', k_list)
```





```
In [28]: classifier = KNeighborsClassifier()
         classifier.fit(mam_X_train, mam_Y_train.ravel())
         preds = classifier.predict(mam_X_test)
         asserted = []
         for i in range(0,preds.shape[0]):
             if preds[i] == mam_Y_test[i]:
                 asserted.append(preds[i])
         test_accuracy = len(asserted)/preds.shape[0]
         print("Test Accuracy: {0:f}".format(test_accuracy))
```

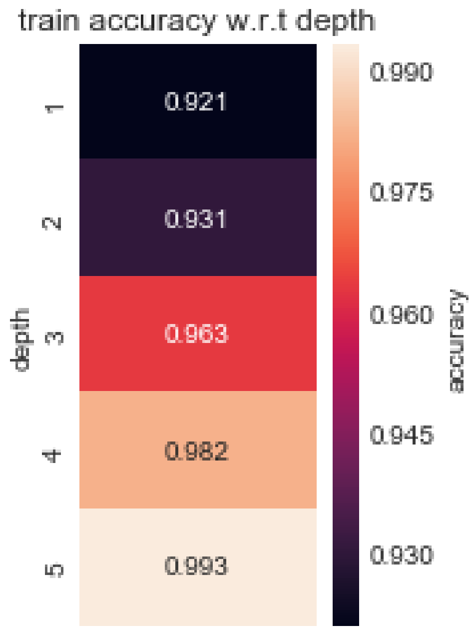
```
Test Accuracy: 0.891566
```

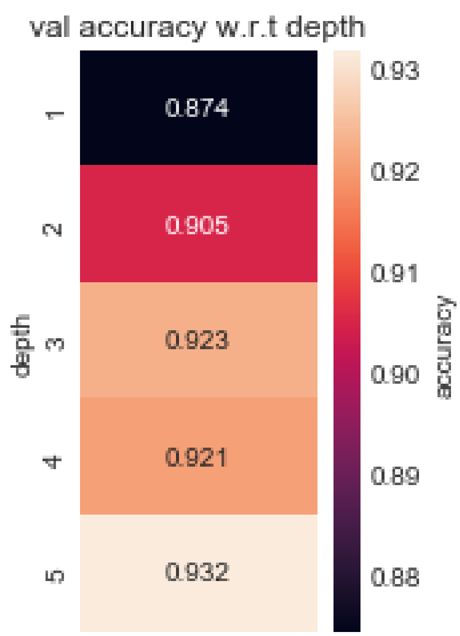
11 Performing Decision Trees On Mammograph Data Set

```
In [29]: classifier = tree.DecisionTreeClassifier(criterion='entropy')
         depth_list = [1, 2, 3, 4, 5]
         params = {"max_depth": depth_list}
         grid_dt_mam = GridSearchCV(classifier, params, return_train_score = True, cv = 5)
         grid_dt_mam.fit(mam_X_train, mam_Y_train)
```

```
Out[29]: GridSearchCV(cv=5, error_score='raise',
                estimator=DecisionTreeClassifier(class_weight=None, criterion='entropy', max_de
                     max_features=None, max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, presort=False, random_state=None,
                     splitter='best'),
                fit_params=None, iid=True, n_jobs=1,
                param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
                refit=True, return_train_score=True, scoring=None, verbose=0)
```

```
In [30]: train_acc = grid_dt_breast.cv_results_['mean_train_score'].reshape(-1,1)
         draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

         val_acc = grid_dt_breast.cv_results_['mean_test_score'].reshape(-1,1)
         draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```





In [31]:
```
pred = grid_dt_mam.predict(mam_X_test)
asserted = []
for i in range(0,pred.shape[0]):
    if pred[i] == mam_Y_test[i]:
```

```
                asserted.append(pred[i])
        test_accuracy = len(asserted)/pred.shape[0]
        print("Test Accuracy: {0:f}".format(test_accuracy))
        print(grid_dt_mam.best_params_)
```

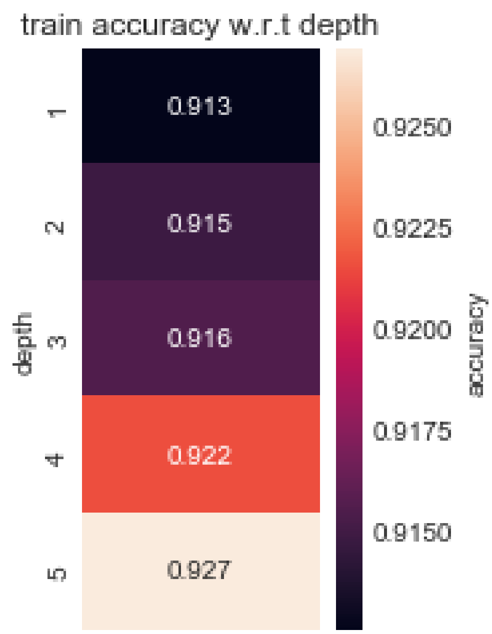
```
Test Accuracy: 0.897590
{'max_depth': 1}
```

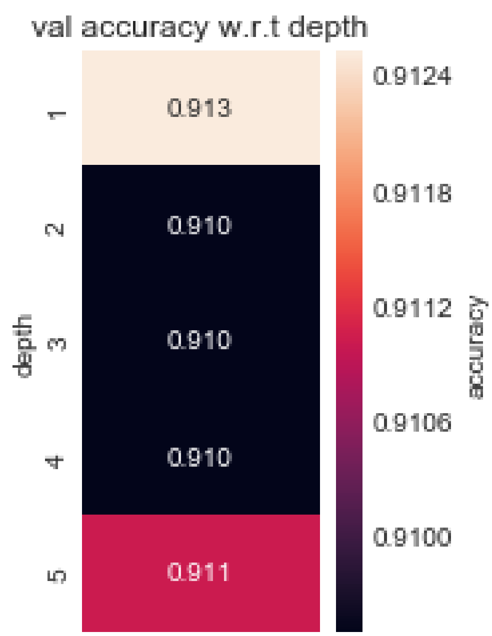
12 Performing Random Forests On Mammograph Data Set

```
In [32]: depth_list = [1, 2, 3, 4, 5]
         params = {"max_depth": depth_list}
         classifier = RandomForestClassifier(max_depth=5, random_state=0)
         grid_rf_mam = GridSearchCV(classifier, params, return_train_score = True)
         grid_rf_mam.fit(mam_X_train, mam_Y_train.ravel())
```

```
Out[32]: GridSearchCV(cv=None, error_score='raise',
                estimator=RandomForestClassifier(bootstrap=True, class_weight=None, criterion=
                     max_depth=5, max_features='auto', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
                     oob_score=False, random_state=0, verbose=0, warm_start=False),
                fit_params=None, iid=True, n_jobs=1,
                param_grid={'max_depth': [1, 2, 3, 4, 5]}, pre_dispatch='2*n_jobs',
                refit=True, return_train_score=True, scoring=None, verbose=0)
```

```
In [33]: train_acc = grid_rf_mam.cv_results_['mean_train_score'].reshape(-1,1)
         draw_heatmap_linear(train_acc, 'train accuracy', depth_list)

         val_acc = grid_rf_mam.cv_results_['mean_test_score'].reshape(-1,1)
         draw_heatmap_linear(val_acc, 'val accuracy', depth_list)
```





In [34]:
```
pred = grid_rf_mam.predict(mam_X_test)
asserted = []
for i in range(0,pred.shape[0]):
    if pred[i] == mam_Y_test[i]:
```

```
            asserted.append(pred[i])
    test_accuracy = len(asserted)/pred.shape[0]
    print("Test Accuracy: {0:f}".format(test_accuracy))
    print(grid_rf_mam.get_params())
```

```
Test Accuracy: 0.897590
{'cv': None, 'error_score': 'raise', 'estimator__bootstrap': True, 'estimator__class_weight': N
            max_depth=5, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=1,
            oob_score=False, random_state=0, verbose=0, warm_start=False), 'fit_params': None,
```