In [1]:
```
#Import Libraries
import csv
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import math
import re
pd.options.display.max_columns=40

### Import Descision Tree Classifier
from sklearn.preprocessing import scale
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import roc_auc_score
# Basic imports
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import RandomizedSearchCV
import matplotlib.pyplot as plt
from sklearn.metrics import accuracy_score
```

In [2]:
```
### Load
path_hw7="C:\\Users\\fbaharkoush\\IE 598 Machine Learning\\Homework\\HW 7\\"
df_ts=pd.read_csv(path_hw7+"ccdefault.csv").drop("ID",axis=1)
### Missing Values
df_ts.isnull().sum().sum()==0
```

Out[2]:
```
True
```

In [3]:
```
## Values
X=df_ts.drop("DEFAULT",axis=1).values
y=df_ts["DEFAULT"].values

# ## Values scaled
# X=scale(df_ts.drop("DEFAULT",axis=1).values)
# y=df_ts["DEFAULT"].values
```

Part 1: Random forest estimators

Fit a random forest model, try several different values for N_estimators, report in-sample accuracies.

In [4]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y,test_size=0.1,random_state=39)
```

In [5]:
```
### Random Forest Parameters
prameters_for_rfc={'n_estimators': [100,200,300,400,500],
          'criterion':['gini','entropy']}
```

In [6]:
```
# ### Random Forest Parameters
# prameters_for_rfc={'n_estimators': [6000],
#           'criterion':['entropy']}
```

In [7]:
```
### Initiate Random Forest Model With Max Depth=2
random_forest_classsifier_model=RandomForestClassifier(random_state=32,max_depth=2)

### Initiate Random Forest Model with 10 Fold Cross Validation
random_forest_classsifier_model_gridcv=GridSearchCV(estimator=random_forest_classsifier_
                                                    cv=10,
                                                   scoring='roc_auc')

### Fit Random Forest Model with Cross Validation
random_forest_classsifier_model_gridcv.fit(X_train,y_train)

### Get the Best Score of the cross validate model
random_forest_classsifier_model_gridcv.best_score_
```

Out[7]:
```
0.7701609142583414
```

In [8]:
```
print("Best Random Forest Model is the one with the following Parameters",random_forest_
```

```
Best Random Forest Model is the one with the following Parameters {'criterion': 'gini',
'n_estimators': 100}
```

Selecting best model

In [9]:
```
random_forest_classsifier_model_with_best_param=random_forest_classsifier_model_gridcv.b
random_forest_classsifier_model_gridcv.best_estimator_
```

Out[9]:
```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=2, 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=100,
                       n_jobs=None, oob_score=False, random_state=32, verbose=0,
                       warm_start=False)
```

In Sample Accuracy (Train)

In [10]:
```
### Fit to the best Model
random_forest_classsifier_model_with_best_param.fit(X_train,y_train)
### Training set prediction
y_pred_train=random_forest_classsifier_model_with_best_param.predict(X_train)
### Training set ROC Score
print("ROC Sccore of the best model on Training Set",roc_auc_score(y_train,y_pred_train)
```

```
ROC Sccore of the best model on Training Set 0.5737034538150259
```

Out Sample Accuracy (Test)

In [11]:
```
y_pred_test=random_forest_classsifier_model_with_best_param.predict(X_test)
print("ROC AUC Sccore of the best model on Test Set",roc_auc_score(y_test,y_pred_test))
```

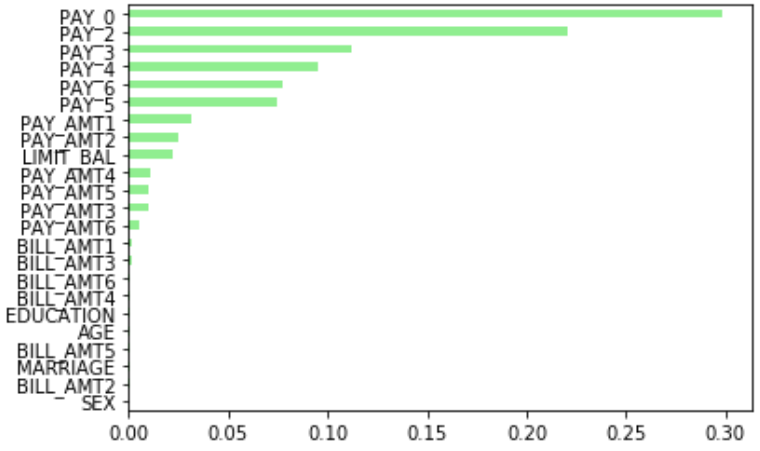
```
ROC AUC Sccore of the best model on Test Set 0.5730674218700879
```

In [12]:
```
random_forest_classsifier_model_with_best_param.feature_importances_
```

Out[12]:
```
array([2.17658478e-02, 0.00000000e+00, 8.27397065e-04, 1.21697370e-04,
       4.87271629e-04, 2.98648620e-01, 2.20600102e-01, 1.12023642e-01,
       9.51834027e-02, 7.44340767e-02, 7.71084016e-02, 1.90629388e-03,
       7.36088849e-05, 1.85650646e-03, 8.72047354e-04, 4.28428133e-04,
       8.99267984e-04, 3.14764629e-02, 2.49779561e-02, 9.83123807e-03,
       1.08490776e-02, 1.00608539e-02, 5.56780018e-03])
```

Part 2: Random forest feature importance

In [13]:
```
importances_rf=pd.Series(random_forest_classsifier_model_with_best_param.feature_importa
          index = df_ts.drop("DEFAULT",axis=1).columns)
# Sort importances_rf
sorted_importances_rf = importances_rf.sort_values()
# Make a horizontal bar plot
sorted_importances_rf.plot(kind='barh', color='lightgreen')
plt.show()
```



In [14]:
```
print("accuracy score on Test",accuracy_score(y_test,y_pred_test))
print("accuracy score on Train",accuracy_score(y_train,y_pred_train))
```

```
accuracy score on Test 0.8033333333333333
accuracy score on Train 0.8022222222222222
```

In [89]:
```
random_forest_classsifier_model_gridcv.
```

Out[89]:
```
0.9733967781066895
```

In [59]:
```
df_result_summary=pd.DataFrame(random_forest_classsifier_model_gridcv.cv_results_['param
df_result_summary["Mean Test Score %"]=(list(random_forest_classsifier_model_gridcv.cv_r
df_result_summary["Mean Test Score %"]=df_result_summary["Mean Test Score %"]*100
```

In [82]:
```
random_forest_classsifier_model_gridcv.cv_results_['params']
```

Out[82]:
```
[{'criterion': 'gini', 'n_estimators': 100},
 {'criterion': 'gini', 'n_estimators': 200},
 {'criterion': 'gini', 'n_estimators': 300},
 {'criterion': 'gini', 'n_estimators': 400},
 {'criterion': 'gini', 'n_estimators': 500},
 {'criterion': 'entropy', 'n_estimators': 100},
 {'criterion': 'entropy', 'n_estimators': 200},
 {'criterion': 'entropy', 'n_estimators': 300},
 {'criterion': 'entropy', 'n_estimators': 400},
 {'criterion': 'entropy', 'n_estimators': 500}]
```

In [80]:
```
df_result_summary
```

Out[80]:

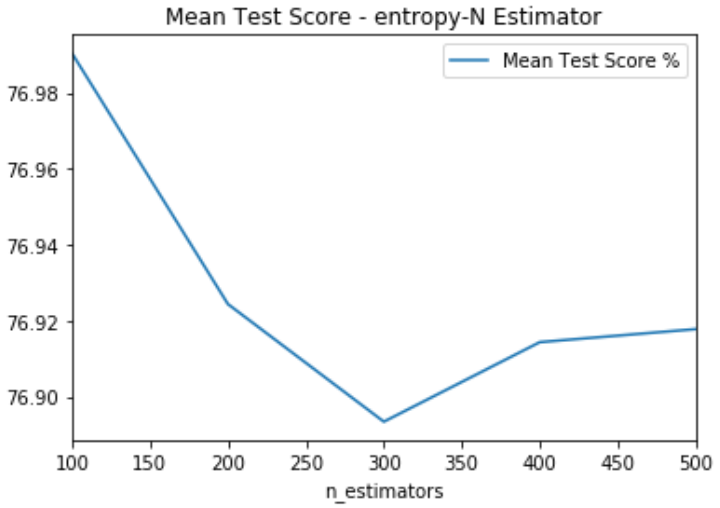
	criterion	n_estimators	Mean Test Score %
0	gini	100	77.016091
1	gini	200	76.946355
2	gini	300	76.914094
3	gini	400	76.938530
4	gini	500	76.958080
5	entropy	100	76.990509
6	entropy	200	76.924416
7	entropy	300	76.893430
8	entropy	400	76.914389
9	entropy	500	76.917823

In [79]:
```
df_result_summary.query("criterion=='gini'").plot(x="n_estimators",y="Mean Test Score %"
                                                  title="Mean Test Score - Gini-N Estima
```

Out[79]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1f1159830f0>
```

In [81]:
```
df_result_summary.query("criterion=='entropy'").plot(x="n_estimators",y="Mean Test Score
                                                     title="Mean Test Score - entropy-N Est
```

Out[81]: <matplotlib.axes._subplots.AxesSubplot at 0x1f1169ee7f0>



Final conclusion

Thea mean scores of all the models are very close to heach other.

1. As the number of tree grows, the compution gets loner and longer.
2. For this experiment 100 Tree is enough.
3. pay_0 is the most importnat feature.

4.according to https://towardsdatascience.com/the-mathematics-of-decision-trees-random-forest-and-feature-importance-in-scikit-learn-and-spark-f2861df67e3 (https://towardsdatascience.com/the-mathematics-of-decision-trees-random-forest-and-feature-importance-in-scikit-learn-and-spark-f2861df67e3)

The importance for each feature on a decision tree is then calculated as:

$$fi_i = \frac{\sum_{j:node\ j\ splits\ on\ feature\ i} ni_j}{\sum_{k \in all\ nodes} ni_k}$$

- fi sub(i) = the importance of feature i
- ni sub(j) = the importance of node j

These can then be normalized to a value between 0 and 1 by dividing by the sum of all feature importance values:

$$normfi_i = \frac{fi_i}{\sum_{j \in all\ features} fi_j}$$

The final feature importance, at the Random Forest level, is it's average over all the trees. The sum of the feature's importance value on each trees is calculated and divided by the total number of trees:

$$RFfi_i = \frac{\sum_{j \in all\ trees} normfi_{ij}}{T}$$

- RFfi sub(i) = the importance of feature i calculated from all trees in the Random Forest model
- normfi sub(ij) = the normalized feature importance for i in tree j
- T = total number of trees

In [90]:
```
print("My name is Farbod Baharkoush")
print("My NetID is: fbahar2")
print("I hereby certify that I have read the University policy on Academic Integrity and
```

```
My name is Farbod Baharkoush
My NetID is: fbahar2
I hereby certify that I have read the University policy on Academic Integrity and that
I am not in violation.
```

In [ ]:

In [ ]: