Healthcare Analytics Project Implementation

April 11, 2023

[1]:
```
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```

[61]:
```
import numpy as np
import pandas as pd
import os
import cv2 as cv
import matplotlib.pyplot as plt
import seaborn as sns
```

# Load and Check Data

[62]:
```
all_0 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_0/
 ↪all"
all_1 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_1/
 ↪all"
all_2 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_2/
 ↪all"

hem_0 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_0/
 ↪hem"
hem_1 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_1/
 ↪hem"
hem_2 = "../input/leukemia-classification/C-NMC_Leukemia/training_data/fold_2/
 ↪hem"
```

[63]:
```
def get_path_image(folder):
    image_paths = []
    image_fnames = os.listdir(folder)
    for img_id in range(len(image_fnames)):
        img = os.path.join(folder,image_fnames[img_id])
        image_paths.append(img)

    return image_paths
```

[64]:
```
img_data = []
```

```
for i in [all_0,all_1,all_2,hem_0,hem_1,hem_2]:
    paths = get_path_image(i)
    img_data.extend(paths)
print(len(img_data))
```

```
10661
```

[65]:

```
data = {"img_data":img_data,
        "labels":[np.nan for x in range(len(img_data))]}

data = pd.DataFrame(data)
```

[66]:

```
data["labels"][0:7272] = 1 # ALL
data["labels"][7272:10661] = 0 # HEM
```

```
/opt/conda/lib/python3.7/site-packages/ipykernel_launcher.py:1:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  """Entry point for launching an IPython kernel.
/opt/conda/lib/python3.7/site-packages/ipykernel_launcher.py:2:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

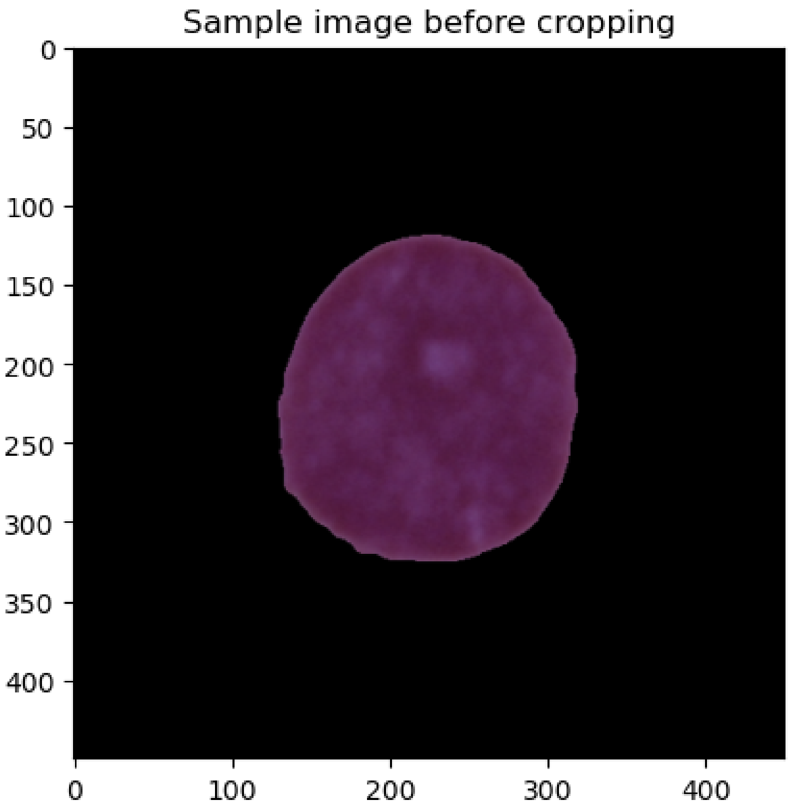
[67]:

```
data["labels"] = data["labels"].astype("int64")
```

# Crop Black Edges In Image

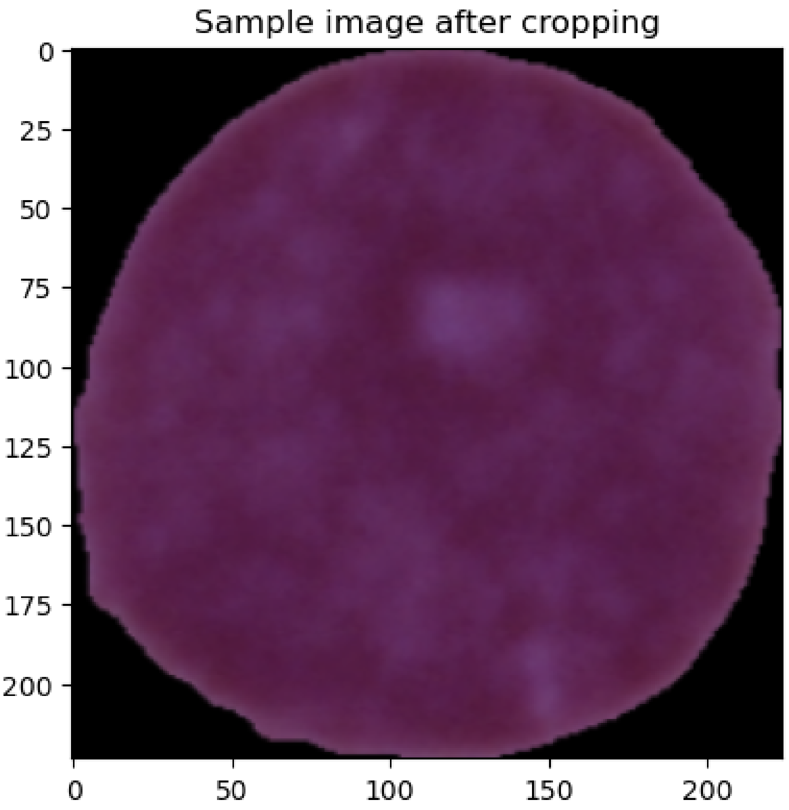
[68]:

```
image = cv.imread(data["img_data"][1000])
plt.imshow(image)
plt.title("Sample image before cropping")
plt.show()
```



[69]:
```
img_list = []
for i in range(len(img_data)):
    image = cv.imread(data["img_data"][i])
    gray = cv.cvtColor(image, cv.COLOR_BGR2GRAY)
    thresh = cv.threshold(gray, 0, 255, cv.THRESH_BINARY_INV + cv.
 ↪THRESH_OTSU)[1]

    result = cv.bitwise_and(image, image, mask=thresh)
    result[thresh==0] = [255,255,255]
    (x, y, z_) = np.where(result > 0)
    mnx = (np.min(x))
    mxx = (np.max(x))
    mny = (np.min(y))
    mxy = (np.max(y))
    crop_img = image[mnx:mxx,mny:mxy,:]
    crop_img_r = cv.resize(crop_img, (224,224))
    img_list.append(crop_img_r)
```

[70]:
```
plt.imshow(img_list[1000])
plt.title("Sample image after cropping")
plt.show()
```



# Feature Extraction with ResNet50

[71]:

```
from tensorflow.keras.applications import ResNet50, ResNet101
from keras.applications.vgg19 import VGG19
from tensorflow.keras.preprocessing import image
from tensorflow.keras.models import Model
from tensorflow.keras.applications.resnet50 import preprocess_input
```

[72]:

```
def feature_extract(model):
    if model == "VGG19": model = VGG19(weights='imagenet',include_top=False,␣
 ↪pooling="avg")
    elif model == "ResNet50": model =␣
 ↪ResNet50(weights='imagenet',include_top=False,pooling="avg")
    elif model == "ResNet101": model =␣
 ↪ResNet101(weights='imagenet',include_top=False,pooling="avg")
    return model
```

[73]:

```
model = feature_extract("ResNet50")
```

[74]:

```
features_list = []
for i in range(len(img_list)):
    image = img_list[i].reshape(-1, 224, 224, 3)
    image = preprocess_input(image)
    features = model.predict(image).reshape(2048, )
    features_list.append(features)
```

```
1/1 [==============================] - 1s 1s/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 143ms/step
1/1 [==============================] - 0s 148ms/step
1/1 [==============================] - 0s 126ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 126ms/step
1/1 [==============================] - 0s 153ms/step
1/1 [==============================] - 0s 135ms/step
1/1 [==============================] - 0s 143ms/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 132ms/step
1/1 [==============================] - 0s 141ms/step
1/1 [==============================] - 0s 126ms/step
1/1 [==============================] - 0s 137ms/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 139ms/step
1/1 [==============================] - 0s 128ms/step
1/1 [==============================] - 0s 127ms/step
1/1 [==============================] - 0s 141ms/step
1/1 [==============================] - 0s 144ms/step
1/1 [==============================] - 0s 137ms/step
1/1 [==============================] - 0s 135ms/step
1/1 [==============================] - 0s 147ms/step
1/1 [==============================] - 0s 129ms/step
1/1 [==============================] - 0s 138ms/step
1/1 [==============================] - 0s 137ms/step
1/1 [==============================] - 0s 135ms/step
1/1 [==============================] - 0s 146ms/step
1/1 [==============================] - 0s 144ms/step
1/1 [==============================] - 0s 133ms/step
1/1 [==============================] - 0s 133ms/step
1/1 [==============================] - 0s 130ms/step
1/1 [==============================] - 0s 133ms/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 134ms/step
1/1 [==============================] - 0s 135ms/step
1/1 [==============================] - 0s 133ms/step
1/1 [==============================] - 0s 143ms/step
```

```
1/1 [==============================] - 0s 155ms/step
1/1 [==============================] - 0s 140ms/step
1/1 [==============================] - 0s 128ms/step
1/1 [==============================] - 0s 128ms/step
1/1 [==============================] - 0s 132ms/step
1/1 [==============================] - 0s 144ms/step
1/1 [==============================] - 0s 140ms/step
1/1 [==============================] - 0s 131ms/step
1/1 [==============================] - 0s 130ms/step
1/1 [==============================] - 0s 130ms/step
1/1 [==============================] - 0s 136ms/step
1/1 [==============================] - 0s 127ms/step
```

```
[75]: features = model.predict(image).reshape(2048, )
      features_list.append(features)
```

```
[76]: features_df = pd.DataFrame(features_list)
```

```
[77]: features_df["labels"] = data["labels"]
```

```
[78]: x = features_df.drop(['labels'], axis = 1)
      y = features_df.loc[:,"labels"].values
```

```
[79]: x
```

```
[79]:            0         1         2         3         4         5         6     \
      0      3.888965  0.003357  0.000000  0.080566  0.002496  0.003217  0.178870
      1      6.105568  0.000000  0.008155  0.063793  0.005606  0.047762  0.079004
      2      4.191666  0.000000  0.000000  0.073727  0.007410  0.040819  0.126976
      3      4.969837  0.190751  0.000000  0.060903  0.012210  0.034155  0.038725
      4      7.409759  0.000000  0.000000  0.223266  0.000000  0.013826  0.060581
      …         …       …       …       …       …       …       …
      10656  4.650623  0.000000  0.000000  0.003782  0.000000  0.000000  0.079633
      10657  5.075249  0.000000  0.000000  0.073403  0.000000  0.050068  0.109488
      10658  5.491919  0.000000  0.000000  0.062658  0.087209  0.227873  0.310514
      10659  4.076108  0.017551  0.000000  0.118688  0.000000  0.000000  0.148364
      10660  8.373823  0.000000  0.038963  0.043950  0.000000  0.000000  0.222565

                 7         8         9     …      2038      2039      2040  \
      0      0.054217  0.015593  0.044378  …  1.161147  0.046141  0.090094
      1      0.000000  0.002628  0.012909  …  0.067440  0.000000  0.000000
      2      0.026118  0.000000  0.000000  …  0.646453  0.000000  0.218996
      3      0.035803  0.183820  0.000000  …  0.090973  0.018727  0.066534
      4      0.000000  0.044893  0.025707  …  0.179018  0.005104  0.000000
      …         …       …       …  …       …       …       …
      10656  0.035964  0.052119  0.277229  …  1.089402  0.014226  0.000000
      10657  0.000000  0.127485  0.027882  …  0.697676  0.000000  0.084635
```

```
10658  0.037401  0.000000  0.043395  …  0.154101  0.003430  0.000000
10659  0.000000  0.000000  0.000000  …  0.407699  0.026058  0.270066
10660  0.000000  0.000000  0.057938  …  0.648262  0.004149  0.000000

           2041      2042      2043      2044      2045      2046      2047
0      0.396494  0.005847  0.000000  0.605872  0.689851  0.192494  1.315786
1      0.291204  0.000000  0.000000  0.194592  0.897486  0.181279  0.888027
2      0.082670  0.000000  0.000000  0.033167  0.255844  0.011669  1.841871
3      0.355468  0.086318  0.053395  0.031325  0.539635  0.013693  1.445034
4      0.408164  0.000000  0.000000  0.100929  0.117949  0.972514  0.484715
…           …         …         …         …         …         …         …
10656  1.019124  0.584857  0.000000  0.643598  0.648637  0.098623  0.295180
10657  0.057695  0.176103  0.000000  0.666509  0.455349  1.335689  0.615851
10658  0.094444  0.133244  0.000000  0.083235  0.834814  0.120172  2.136771
10659  0.208164  0.037543  0.000000  0.560540  0.330985  0.199827  1.003238
10660  0.978938  0.364705  0.000000  0.245678  0.166369  0.471063  0.754563

[10661 rows x 2048 columns]
```

[80]:
```python
print(f"Number of features before feature selection: {x.shape[1]}")
```

```
Number of features before feature selection: 2048
```

[81]:
```python
y
```

[81]:
```
array([1, 1, 1, …, 0, 0, 0])
```

# Data Scaling

[82]:
```python
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler()
scaler.fit(x)
x_ = scaler.transform(x)
```

[83]:
```python
x_ = pd.DataFrame(x_)
```

# Feature Selection Methods

## ANOVA

[84]:
```python
from sklearn.feature_selection import SelectKBest
from sklearn.feature_selection import f_classif

def anova_fs():

    selector = SelectKBest(f_classif, k=500) # k is number of features
    selector.fit(x_, y)

    cols = selector.get_support(indices=True)
    anova_x = x_[cols]
    return anova_x
```

## Recursive Feature Elimination (RFE)

[85]:

```
from sklearn.feature_selection import RFE
from sklearn.ensemble import RandomForestClassifier

def RFE_fs():
    rfe_selector = RFE(estimator=RandomForestClassifier())
    rfe_selector.fit(x_, y)

    rfe_support = rfe_selector.get_support()
    rfe_feature = x_.loc[:,rfe_support].columns.tolist()

    rfe_x = x_[rfe_feature]
    return rfe_x
```

## Random Forest

[86]:

```
from sklearn.feature_selection import SelectFromModel
from sklearn.ensemble import RandomForestClassifier

def rf_fs():
    embeded_rf_selector =␣
  ↪SelectFromModel(RandomForestClassifier(n_estimators=200, random_state=5),␣
  ↪threshold='1.25*median')
    embeded_rf_selector.fit(x, y)

    embeded_rf_support = embeded_rf_selector.get_support()
    embeded_rf_feature = x.loc[:,embeded_rf_support].columns.tolist()

    rf_x = x[embeded_rf_feature]
    return rf_x
```

[87]:

```
fs_x = rf_fs()
```

[88]:

```
print(f"Number of features after feature selection: {fs_x.shape[1]}")
```

```
Number of features after feature selection: 590
```

# Train Test Split

[89]:

```
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(fs_x, y, test_size = 0.2,␣
  ↪random_state = 42)
```

# Classification with ML Algorithms

[90]:

```
from sklearn.model_selection import cross_val_score,cross_val_predict
from sklearn.ensemble import RandomForestClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.neighbors import KNeighborsClassifier
from sklearn import svm
from sklearn.metrics import confusion_matrix
from sklearn.metrics import f1_score,precision_score,recall_score,accuracy_score
from sklearn.model_selection import GridSearchCV
```

## kNN

[91]:

```
neig = np.arange(1, 25)
train_accuracy = []
test_accuracy = []

for i, k in enumerate(neig):

    knn = KNeighborsClassifier(n_neighbors=k)
    knn.fit(x_train,y_train)
    prediction_ = knn.predict(x_test)
    train_accuracy.append(knn.score(x_train, y_train))
    test_accuracy.append(knn.score(x_test, y_test))

print("Best accuracy is {} with K = {}".format(np.
  ↪max(test_accuracy),1+test_accuracy.index(np.max(test_accuracy))))
```

```
Best accuracy is 0.8326300984528833 with K = 15
```

[92]:

```
knn = KNeighborsClassifier(n_neighbors=17)
knn.fit(x_train,y_train)
predicted = knn.predict(x_test)
score = knn.score(x_test, y_test)
knn_score_ = np.mean(score)

print('Accuracy : %.3f' % (knn_score_))
```

```
Accuracy : 0.832
```

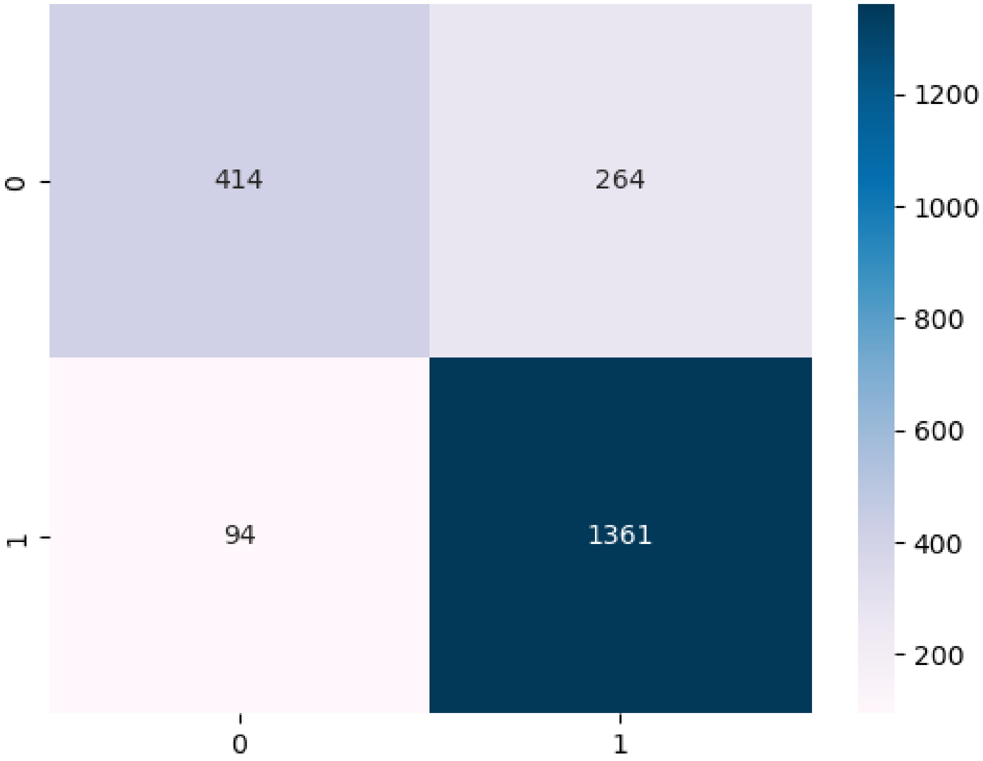
[93]:

```
p=precision_score(y_test, predicted)
print('Precision : %.3f' % (p))

r=recall_score(y_test, predicted)
print('Recall : %.3f' % (r))

f1=f1_score(y_test, predicted)
print('F1-score: %.3f' % (f1))

f1_w=f1_score(y_test, predicted, average='weighted')
```

```
print('Weighted f1-score: %.3f' % (f1_w))
```

```
Precision : 0.838
Recall : 0.935
F1-score: 0.884
Weighted f1-score: 0.825
```

[94]:
```
cf_matrix = confusion_matrix(y_test, predicted)
sns.heatmap(cf_matrix, cmap="PuBu", annot=True, fmt='.0f')
plt.show()
```



## SVM

[95]:
```
param_grid_svm = {'C': [0.1, 1, 10, 100, 1000],
              'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
              'kernel': ['rbf', 'poly']}

SVM_grid = GridSearchCV(svm.SVC(), param_grid_svm, cv=5)
SVM_grid.fit(x_train, y_train)
```

[95]:
```
GridSearchCV(cv=5, estimator=SVC(),
             param_grid={'C': [0.1, 1, 10, 100, 1000],
                                    'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
                                    'kernel': ['rbf', 'poly']})
```

[96]:

```
print(SVM_grid.best_params_)

print(SVM_grid.best_estimator_)
```

```
{'C': 10, 'gamma': 0.01, 'kernel': 'rbf'}
SVC(C=10, gamma=0.01)
```

[97]:

```
svm_clf = svm.SVC(C=100, gamma=0.01, kernel='rbf')
svm_clf.fit(x_train,y_train)
predicted = svm_clf.predict(x_test)
score = svm_clf.score(x_test, y_test)
svm_score_ = np.mean(score)

print('Accuracy : %.3f' % (svm_score_))
```

```
Accuracy : 0.899
```

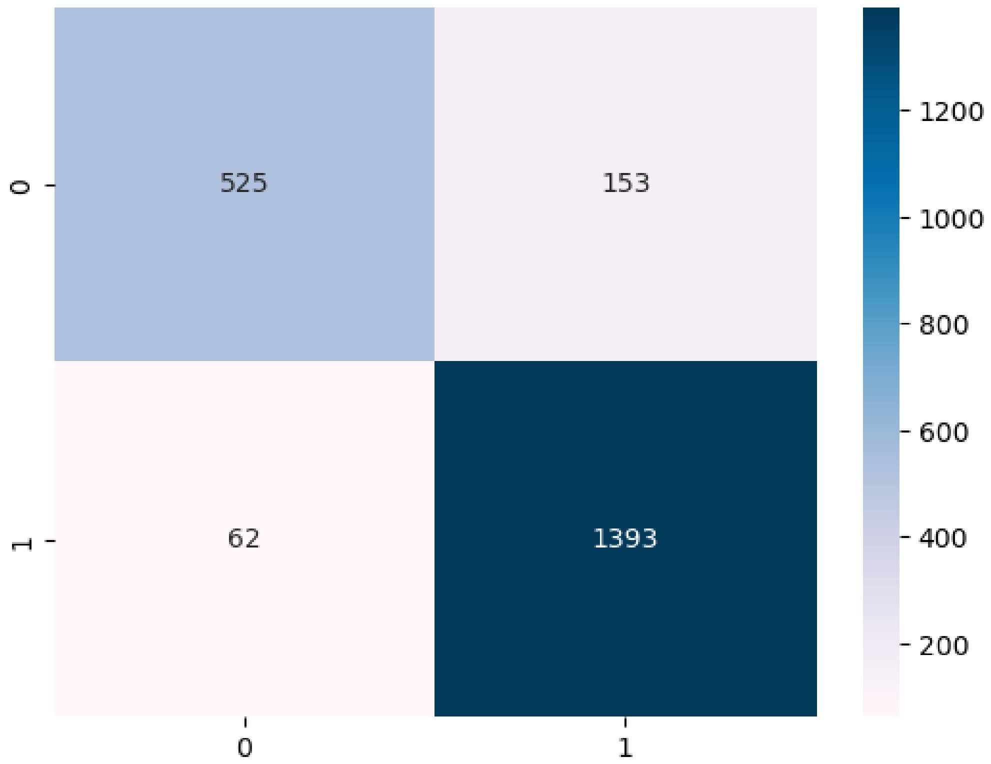
[98]:

```
p=precision_score(y_test, predicted)
print('precision : %.3f' % (p))

r=recall_score(y_test, predicted)
print('recall : %.3f' % (r))

f1=f1_score(y_test, predicted)
print('f1-score: %.3f' % (f1))

f1_w=f1_score(y_test, predicted, average='weighted')
print('weighted f1-score: %.3f' % (f1_w))
```

```
precision : 0.901
recall : 0.957
f1-score: 0.928
weighted f1-score: 0.897
```

[99]:

```
cf_matrix = confusion_matrix(y_test, predicted)
sns.heatmap(cf_matrix, cmap="PuBu", annot=True, fmt='.0f')
plt.show()
```



## Random Forest

[100]:
```
param_grid_rf = {
    'n_estimators': [200, 500],
    'max_depth' : [4,5,6,7,8]}

RF_grid = GridSearchCV(estimator=RandomForestClassifier(),␣
 ↪param_grid=param_grid_rf, cv= 5)
RF_grid.fit(x_train, y_train)
```

[100]:
```
GridSearchCV(cv=5, estimator=RandomForestClassifier(),
             param_grid={'max_depth': [4, 5, 6, 7, 8],
                         'n_estimators': [200, 500]})
```

[101]:
```
print(RF_grid.best_params_)
```

```
{'max_depth': 8, 'n_estimators': 500}
```

[102]:
```
r_forest = RandomForestClassifier(500,max_depth=8, random_state=5)
r_forest.fit(x_train,y_train)
predicted = r_forest.predict(x_test)
score = r_forest.score(x_test, y_test)
```

```
rf_score_ = np.mean(score)

print('Accuracy : %.3f' % (rf_score_))
```

```
Accuracy : 0.826
```

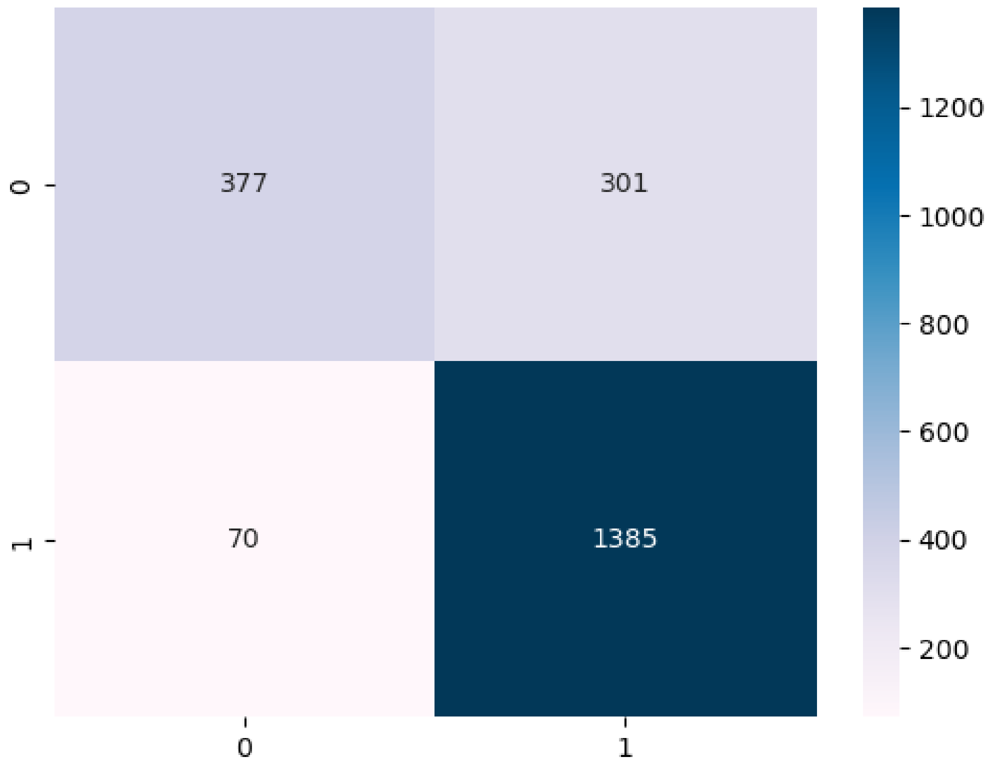
[103]:

```
p=precision_score(y_test, predicted)
print('precision : %.3f' % (p))

r=recall_score(y_test, predicted)
print('recall : %.3f' % (r))

f1=f1_score(y_test, predicted)
print('f1-score: %.3f' % (f1))

f1_w=f1_score(y_test, predicted, average='weighted')
print('weighted f1-score: %.3f' % (f1_w))
```

```
precision : 0.821
recall : 0.952
f1-score: 0.882
weighted f1-score: 0.815
```

[104]:

```
cf_matrix = confusion_matrix(y_test, predicted)
sns.heatmap(cf_matrix, cmap="PuBu", annot=True, fmt='.0f')
plt.show()
```



## Naive Bayes

[105]:
```
nb_model = GaussianNB()
nb_model.fit(x_train,y_train)
predicted = nb_model.predict(x_test)
score = nb_model.score(x_test, y_test)
nb_score_ = np.mean(score)

print('Accuracy : %.3f' % (nb_score_))
```

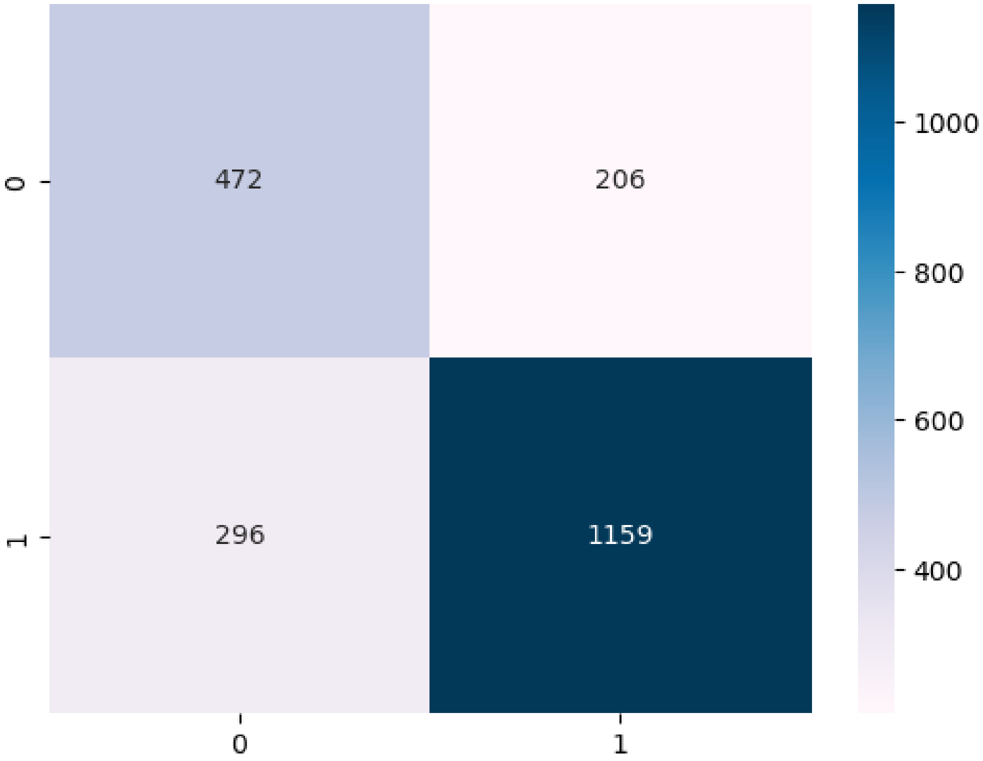
```
Accuracy : 0.765
```

[106]:
```
p=precision_score(y_test, predicted)
print('precision : %.3f' % (p))

r=recall_score(y_test, predicted)
print('recall : %.3f' % (r))

f1=f1_score(y_test, predicted)
print('f1-score: %.3f' % (f1))

f1_w=f1_score(y_test, predicted, average='weighted')
```

```
print('weighted f1-score: %.3f' % (f1_w))
```

```
precision : 0.849
recall : 0.797
f1-score: 0.822
weighted f1-score: 0.768
```

[107]:
```
cf_matrix = confusion_matrix(y_test, predicted)
sns.heatmap(cf_matrix, cmap="PuBu", annot=True, fmt='.0f')
plt.show()
```


472
206
296
1159
0
1
0
1
1000
800
600
400