Libraries

```
import os, glob
import random
from sklearn.model_selection import train_test_split
import cv2
import numpy as np
import pandas as pd
import multiprocessing
from copy import deepcopy
from sklearn.metrics import precision_recall_curve, auc
import keras
import keras.backend as K
from keras.optimizers import Adam
from keras.callbacks import Callback
from keras.applications.densenet import DenseNet201
from keras.layers import Dense, Flatten
from keras.models import Model, load_model
from keras.utils import Sequence
from albumentations import Compose, VerticalFlip, HorizontalFlip, Rotate,
GridDistortion
import matplotlib.pyplot as plt
from IPython.display import Image
from tqdm import tqdm_notebook as tqdm
from numpy.random import seed
seed(10)
from tensorflow import set_random_seed
set_random_seed(10)
import tensorflow -as tf
%matplotlib inline
```

- 사용할 모듈 import

```
test_imgs_folder = './drive/My Drive/Colab Notebooks/input/test_images/'
train_imgs_folder = './drive/My Drive/Colab Notebooks/input/train_images/'
num_cores = multiprocessing.cpu_count()
```

- test / train 이미지 폴더 지정

Data Generators

One-hot encoding classes

```
train_df = pd.read_csv('./drive/My Drive/Colab Notebooks/input/train.csv')
train_df.head()
```

```
    Image_Label         EncodedPixels
0   0011165.jpg_Fish    264918 937 266318 937 267718 937 269118 937 27...
1   0011165.jpg_Flower  1355565 1002 1356965 1002 1358365 1002 1359765...
2   0011165.jpg_Gravel  NaN
3   0011165.jpg_Sugar   NaN
4   002be4f.jpg_Fish    233813 878 235213 878 236613 878 238010 881 23...
```

- 훈련 데이터 로드

```
train_df = train_df[~train_df['EncodedPixels'].isnull()]
train_df['Image'] = train_df['Image_Label'].map(lambda x: x.split('_')[0])
train_df['Class'] = train_df['Image_Label'].map(lambda x: x.split('_')[1])
classes = train_df['Class'].unique()
train_df = train_df.groupby('Image')['Class'].agg(set).reset_index()
for class_name in classes:
    train_df[class_name] = train_df['Class'].map(lambda x: 1 if class_name in x
else 0)
train_df.head()
```

```
    Image       Class                  Fish    Flower  Sugar   Gravel
0   0011165.jpg {Flower, Fish}         1       1       0       0
1   002be4f.jpg {Flower, Sugar, Fish}  1       1       1       0
2   0031ae9.jpg {Flower, Sugar, Fish}  1       1       1       0
3   0035239.jpg {Gravel, Flower}       0       1       0       1
4   003994e.jpg {Gravel, Sugar, Fish}  1       0       1       1
```

```
# dictionary for fast access to ohe vectors
img_2_ohe_vector = {img:vec for img, vec in zip(train_df['Image'],
                                                train_df.iloc[:,
2:].values)}
```

- One-Hot encoding, 해당 이미지에 포함된 클래스 마스크 표시

Stratified split into train / val

```
train_imgs, val_imgs =
    train_test_split(train_df['Image'].values,
                     test_size=0.2,
                     stratify=train_df['Class'].map(lambda x:
str(sorted(list(x)))),
                    # sorting present classes in lexicographical order, just to
be sure
                     random_state=2019)
```

- 훈련 집합을 훈련집합/검증집합으로 나눔

Data Generator

```
class DataGenenerator(Sequence):
    def __init__(self, images_list=None, folder_imgs=train_imgs_folder,
                 batch_size=32, shuffle=True, augmentation=None,
                 resized_height=224, resized_width=224, num_channels=3):
        self.batch_size = batch_size
        self.shuffle = shuffle
        self.augmentation = augmentation
        if images_list is None:
            self.images_list = os.listdir(folder_imgs)
        else:
            self.images_list = deepcopy(images_list)
        self.folder_imgs = folder_imgs
        self.len = len(self.images_list) // self.batch_size
        self.resized_height = resized_height
```

```
        self.resized_width = resized_width
        self.num_channels = num_channels
        self.num_classes = 4
        self.is_test = not 'train' in folder_imgs
        if not shuffle and not self.is_test:
            self.labels = [img_2_ohe_vector[img] for img in
self.images_list[:self.len*self.batch_size]]

    def __len__(self):
        return self.len

    def on_epoch_start(self):
        if self.shuffle:
            random.shuffle(self.images_list)

    def __getitem__(self, idx):
        current_batch = self.images_list[idx * self.batch_size: (idx + 1) *
self.batch_size]
        X = np.empty((self.batch_size, self.resized_height, self.resized_width,
self.num_channels))
        y = np.empty((self.batch_size, self.num_classes))

        for i, image_name in enumerate(current_batch):
            path = os.path.join(self.folder_imgs, image_name)
            img = cv2.resize(cv2.imread(path), (self.resized_height,
self.resized_width)).astype(np.float32)
            if not self.augmentation is None:
                augmented = self.augmentation(image=img)
                img = augmented['image']
            X[i, :, :, :] = img/255.0
            if not self.is_test:
                y[i, :] = img_2_ohe_vector[image_name]
        return X, y

    def get_labels(self):
        if self.shuffle:
            images_current = self.images_list[:self.len*self.batch_size]
            labels = [img_2_ohe_vector[img] for img in images_current]
        else:
            labels = self.labels
        return np.array(labels)
```

- 데이터 전처리를 위한 `DataGenerator` 클래스 정의

```
albumentations_train = Compose([
    VerticalFlip(), HorizontalFlip(), Rotate(limit=20), GridDistortion()
], p=1)
```

- 사용할 Augmentation 정의

Generator Instances

```
data_generator_train = DataGenenerator(train_imgs,
augmentation=albumentations_train)
data_generator_train_eval = DataGenenerator(train_imgs, shuffle=False)
data_generator_val = DataGenenerator(val_imgs, shuffle=False)
```

- 학습에 사용할 데이터 생성

PR-AUC-based Callback

```
class PrAucCallback(Callback):
    def __init__(self, data_generator, num_workers=num_cores,
                 early_stopping_patience=5,
                 plateau_patience=3, reduction_rate=0.5,
                 stage='train', checkpoints_path='checkpoints/'):
        super(Callback, self).__init__()
        self.data_generator = data_generator
        self.num_workers = num_workers
        self.class_names = ['Fish', 'Flower', 'Sugar', 'Gravel']
        self.history = [[] for _ in range(len(self.class_names) + 1)] # to store
per each class and also mean PR AUC
        self.early_stopping_patience = early_stopping_patience
        self.plateau_patience = plateau_patience
        self.reduction_rate = reduction_rate
        self.stage = stage
        self.best_pr_auc = -float('inf')
        if not os.path.exists(checkpoints_path):
            os.makedirs(checkpoints_path)
        self.checkpoints_path = checkpoints_path

    def compute_pr_auc(self, y_true, y_pred):
        pr_auc_mean = 0
        print(f"\n{'#'*30}\n")
        for class_i in range(len(self.class_names)):
            precision, recall, _ = precision_recall_curve(y_true[:, class_i],
y_pred[:, class_i])
            pr_auc = auc(recall, precision)
            pr_auc_mean += pr_auc/len(self.class_names)
            print(f"PR AUC {self.class_names[class_i]}, {self.stage}:
{pr_auc:.3f}\n")
            self.history[class_i].append(pr_auc)
        print(f"\n{'#'*20}\n PR AUC mean, {self.stage}:
{pr_auc_mean:.3f}\n{'#'*20}\n")
        self.history[-1].append(pr_auc_mean)
        return pr_auc_mean

    def is_patience_lost(self, patience):
        if len(self.history[-1]) > patience:
            best_performance = max(self.history[-1][-(patience + 1):-1])
            return best_performance == self.history[-1][-(patience + 1)] and
best_performance >= self.history[-1][-1]

    def early_stopping_check(self, pr_auc_mean):
        if self.is_patience_lost(self.early_stopping_patience):
            self.model.stop_training = True

    def model_checkpoint(self, pr_auc_mean, epoch):
        if pr_auc_mean > self.best_pr_auc:
            # remove previous checkpoints to save space
            for checkpoint in glob.glob(os.path.join(self.checkpoints_path,
'classifier_densenet169_epoch_*')):
                os.remove(checkpoint)
            self.best_pr_auc = pr_auc_mean
```

```
            self.model.save(os.path.join(self.checkpoints_path,
f'classifier_densenet169_epoch_{epoch}_val_pr_auc_{pr_auc_mean}.h5'))

            print(f"\n{'#'*20}\nSaved new checkpoint\n{'#'*20}\n")

    def reduce_lr_on_plateau(self):
        if self.is_patience_lost(self.plateau_patience):
            new_lr = float(keras.backend.get_value(self.model.optimizer.lr)) *
self.reduction_rate
            keras.backend.set_value(self.model.optimizer.lr, new_lr)
            print(f"\n{'#'*20}\nReduced learning rate to {new_lr}.\n{'#'*20}\n")

    def on_epoch_end(self, epoch, logs={}):
        y_pred = self.model.predict_generator(self.data_generator,
workers=self.num_workers)
        y_true = self.data_generator.get_labels()
        # estimate AUC under precision recall curve for each class
        pr_auc_mean = self.compute_pr_auc(y_true, y_pred)

        if self.stage == 'val':
            # early stop after early_stopping_patience=4 epochs of no
improvement in mean PR AUC
            self.early_stopping_check(pr_auc_mean)

            # save a model with the best PR AUC in validation
            self.model_checkpoint(pr_auc_mean, epoch)

            # reduce learning rate on PR AUC plateau
            self.reduce_lr_on_plateau()

    def get_pr_auc_history(self):
        return self.history
```

- PR-AUC Callback를 다음과 같은 목적으로 정의
    - Precision-Recall 곡선을 기반으로 각 class의 AUC(Area Uncer Curve)를 계산
    - 5 세대 이상 PR-AUC의 향상이 없을 경우 학습을 조기에 멈춘다
    - 검증집합에서 가장 좋은 PR-AUC 값을 보인 모델을 저장
    - PR-AUC가 높은 곳에서는 학습률을 줄인다

Callback Instances

```
train_metric_callback = PrAucCallback(data_generator_train_eval)
val_callback = PrAucCallback(data_generator_val, stage='val')
```

Classifier

Defining a Model

```
from keras.losses import binary_crossentropy
def dice_coef(y_true, y_pred, smooth=1):
    y_true_f = K.flatten(y_true)
    y_pred_f = K.flatten(y_pred)
    intersection = K.sum(y_true_f * y_pred_f)
    return (2. * intersection + smooth) / (K.sum(y_true_f) + K.sum(y_pred_f) +
smooth)
```

```
def dice_loss(y_true, y_pred):
    smooth = 1.
    y_true_f = K.flatten(y_true)
    y_pred_f = K.flatten(y_pred)
    intersection = y_true_f * y_pred_f
    score = (2. * K.sum(intersection) + smooth) / (K.sum(y_true_f) +
K.sum(y_pred_f) + smooth)
    return 1. - score

def bce_dice_loss(y_true, y_pred):
    return binary_crossentropy(y_true, y_pred) + dice_loss(y_true, y_pred)
```

- competition의 평가방법인 dice coefficiency를 기반으로 손실함수 계산법 작성

```
!pip install -U git+https://github.com/qubvel/efficientnet
```

- base model로 사용할 모델 다운로드

```
import efficientnet.keras as efn
def get_model():
   with tf.device('/GPU:0'):
        K.clear_session()
        base_model =  efn.EfficientNetB2(weights='imagenet', include_top=False,
pooling='avg', input_shape=(224, 224, 3))
        x = base_model.output
        y_pred = Dense(4, activation='sigmoid')(x)
        return Model(inputs=base_model.input, outputs=y_pred)

model = get_model()
```

- 신경망 모델 정의

```
model.summary()
```

```
Model: "model_1"
_________________________________________________________________________________
__________________
Layer (type)                 Output Shape              Param #     Connected to

==================================================================================
==================
input_1 (InputLayer)         (None, 224, 224, 3)  0

_________________________________________________________________________________
__________________
stem_conv (Conv2D)           (None, 112, 112, 32) 864         input_1[0][0]

_________________________________________________________________________________
__________________
stem_bn (BatchNormalization)    (None, 112, 112, 32) 128         stem_conv[0][0]

_________________________________________________________________________________
__________________
```

```
stem_activation (Activation)    (None, 112, 112, 32) 0           stem_bn[0][0]


...
(중략)
...

_________
top_bn (BatchNormalization)     (None, 7, 7, 1408)   5632        top_conv[0][0]

__________________________________________________________________________________________
__________________
top_activation (Activation)     (None, 7, 7, 1408)   0           top_bn[0][0]

__________________________________________________________________________________________
__________________
avg_pool (GlobalAveragePooling2 (None, 1408)         0
top_activation[0][0]
__________________________________________________________________________________________
__________________
dense_1 (Dense)                 (None, 4)            5636        avg_pool[0][0]

==========================================================================================
==================
Total params: 7,774,198
Trainable params: 7,706,630
Non-trainable params: 67,568
__________________________________________________________________________________________
__________________
```

- 모델의 summary

```
from keras_radam import RAdam
```

- optimizer로 사용할 RAdam import

Initial tuning of the added fully-connected layer

```
for base_layer in model.layers[:-3]:
    base_layer.trainable = True

model.compile(optimizer=RAdam(warmup_proportion=0.1, min_lr=1e-5),
 loss='categorical_crossentropy', metrics=['accuracy'])
history_1 = model.fit_generator(generator=data_generator_train,
                                validation_data=data_generator_val,
                                epochs=20,
                                callbacks=[train_metric_callback, val_callback],
                                workers=num_cores,
                                verbose=1,
                                initial_epoch=1
                               )
```

```
Epoch 2/20
138/138 [==============================] - 335s 2s/step - loss: 2.8027 - acc:
0.3707 - val_loss: 2.7250 - val_acc: 0.4026
```

```
##############################

PR AUC Fish, train: 0.735

PR AUC Flower, train: 0.866

PR AUC Sugar, train: 0.839

PR AUC Gravel, train: 0.774


####################
 PR AUC mean, train: 0.803
####################


##############################

PR AUC Fish, val: 0.686

PR AUC Flower, val: 0.831

PR AUC Sugar, val: 0.815

PR AUC Gravel, val: 0.772


####################
 PR AUC mean, val: 0.776
####################


####################
Saved new checkpoint
####################

...
(중략)
...

Epoch 17/20
138/138 [==============================] - 278s 2s/step - loss: 2.1722 - acc:
0.5111 - val_loss: 3.1151 - val_acc: 0.4706

##############################

PR AUC Fish, train: 0.947

PR AUC Flower, train: 0.966

PR AUC Sugar, train: 0.953

PR AUC Gravel, train: 0.950


####################
 PR AUC mean, train: 0.954
####################
```

```
############################

PR AUC Fish, val: 0.761

PR AUC Flower, val: 0.882

PR AUC Sugar, val: 0.886

PR AUC Gravel, val: 0.799


####################
 PR AUC mean, val: 0.832
####################
```

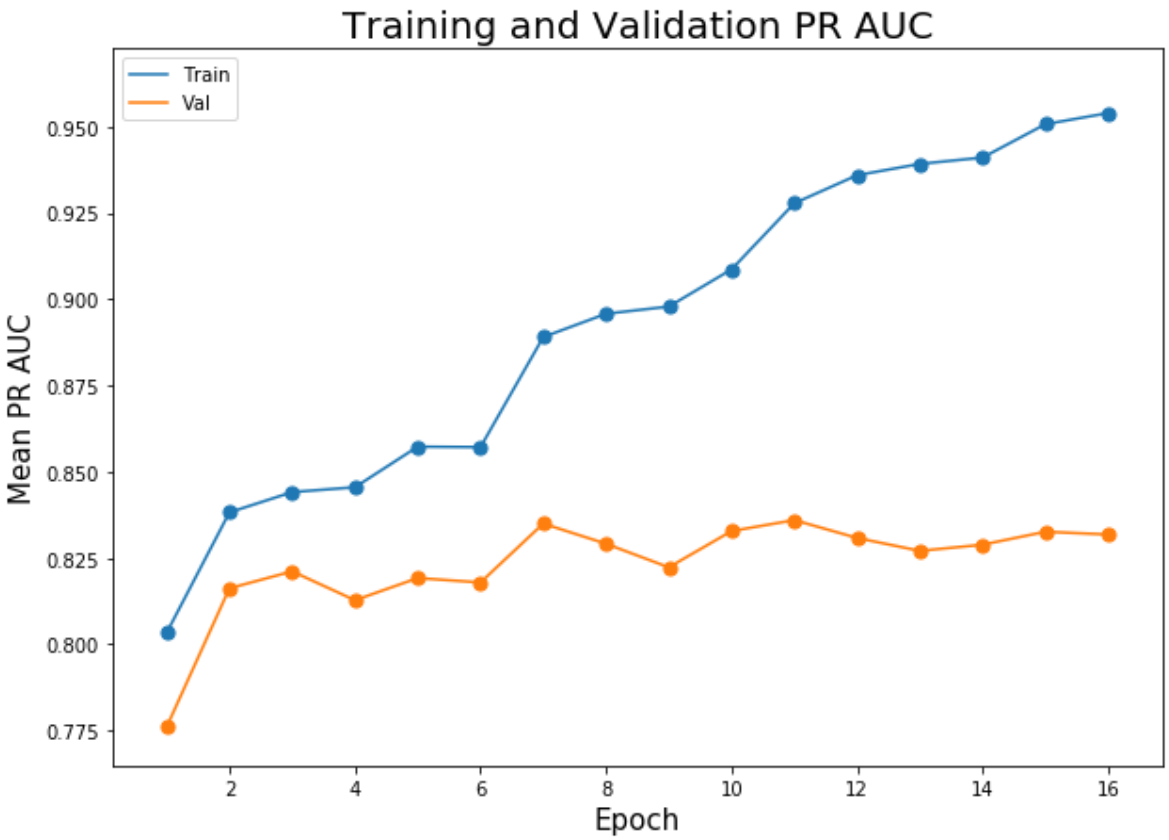
- 훈련집합으로 최대 20세대까지 먼저 훈련(위 결과에서는 17번째 세대에서 early stop)

Fine-tuning the whole model

- 조금 더 낮은 학습률로 다시 학습(최대 100세대)

Visualizing train and val PR AUC

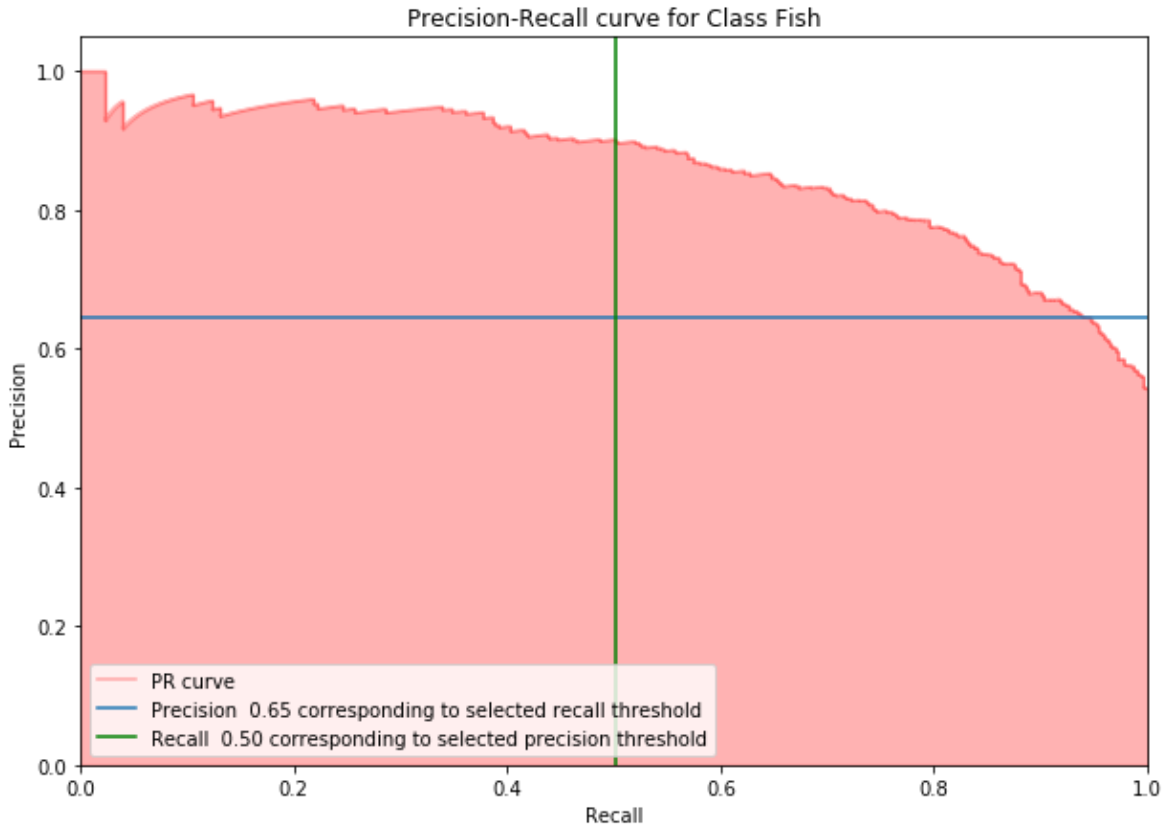
```
def plot_with_dots(ax, np_array):
   ax.scatter(list(range(1, len(np_array) + 1)), np_array, s=50)
   ax.plot(list(range(1, len(np_array) + 1)), np_array)

pr_auc_history_train = train_metric_callback.get_pr_auc_history()
pr_auc_history_val = val_callback.get_pr_auc_history()

plt.figure(figsize=(10, 7))
plot_with_dots(plt, pr_auc_history_train[-1])
plot_with_dots(plt, pr_auc_history_val[-1])

plt.xlabel('Epoch', fontsize=15)
plt.ylabel('Mean PR AUC', fontsize=15)
plt.legend(['Train', 'Val'])
plt.title('Training and Validation PR AUC', fontsize=20)
plt.savefig('pr_auc_hist.png')
```

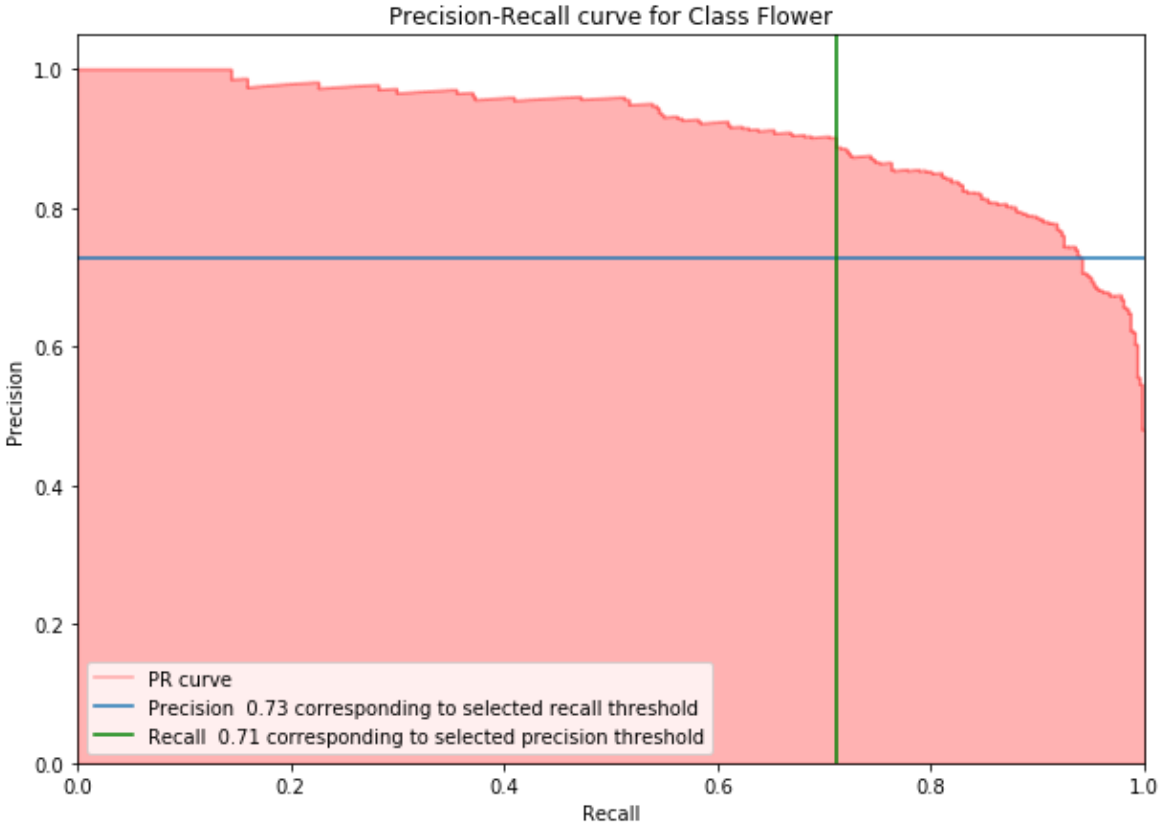


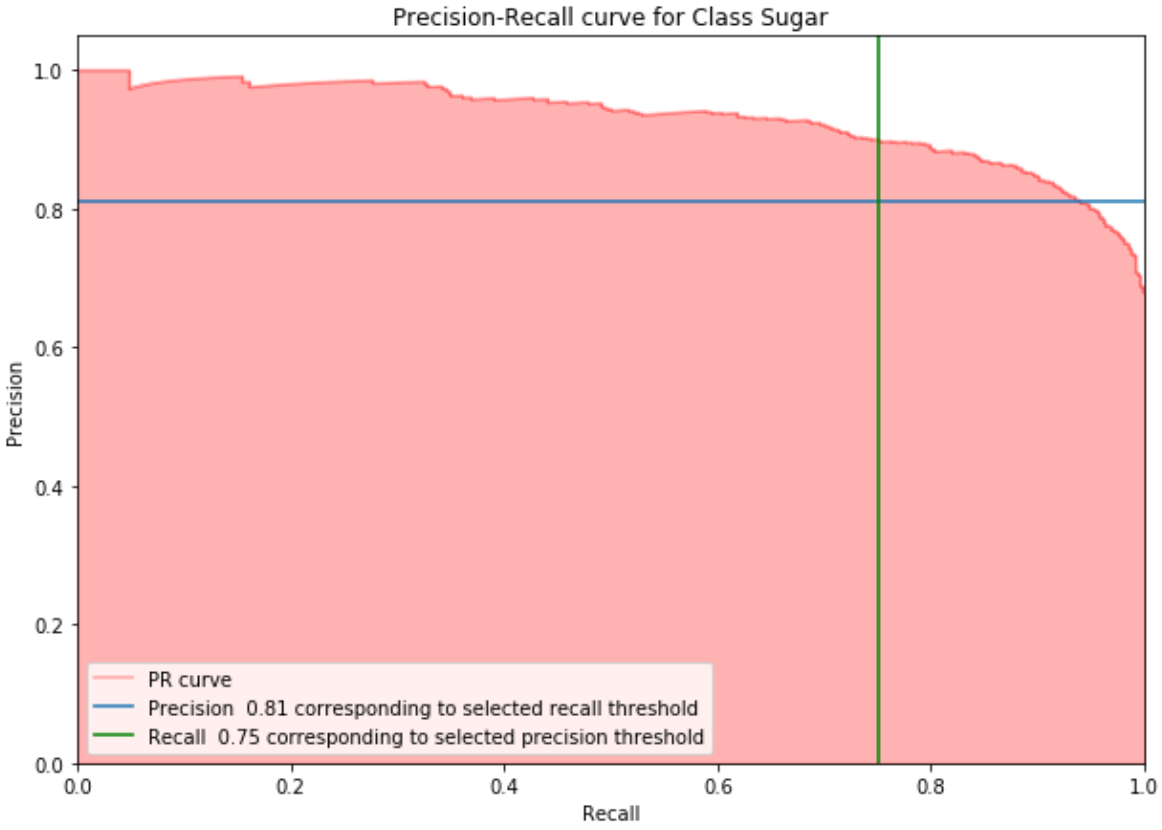
Selecting Postprocessing Thresholds

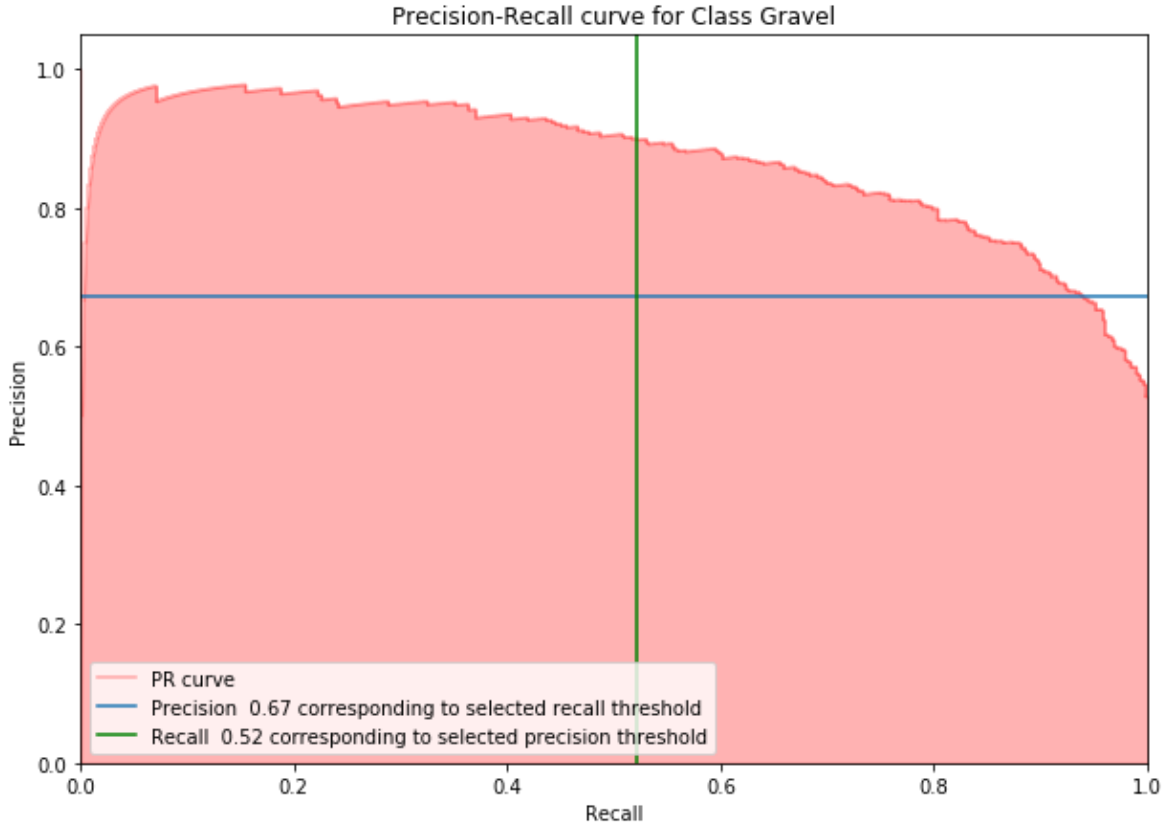
```
class_names = ['Fish', 'Flower', 'Sugar', 'Gravel']
def get_threshold_for_recall(y_true, y_pred, class_i, recall_threshold=0.94,
precision_threshold=0.90, plot=False):
    precision, recall, thresholds = precision_recall_curve(y_true[:, class_i],
y_pred[:, class_i])
    i = len(thresholds) - 1
    best_recall_threshold = None
    while best_recall_threshold is None:
        next_threshold = thresholds[i]
        next_recall = recall[i]
        if next_recall >= recall_threshold:
            best_recall_threshold = next_threshold
        i -= 1

    # consice, even though unnecessary passing through all the values
    best_precision_threshold = [thres for prec, thres in zip(precision,
thresholds) if prec >= precision_threshold][0]

    if plot:
        plt.figure(figsize=(10, 7))
        plt.step(recall, precision, color='r', alpha=0.3, where='post')
        plt.fill_between(recall, precision, alpha=0.3, color='r')
        plt.axhline(y=precision[i + 1])
        recall_for_prec_thres = [rec for rec, thres in zip(recall, thresholds)
                                 if thres == best_precision_threshold][0]
        plt.axvline(x=recall_for_prec_thres, color='g')
        plt.xlabel('Recall')
        plt.ylabel('Precision')
        plt.ylim([0.0, 1.05])
        plt.xlim([0.0, 1.0])
        plt.legend(['PR curve',
```

```
                    f'Precision {precision[i + 1]: .2f} corresponding to
selected recall threshold',
                    f'Recall {recall_for_prec_thres: .2f} corresponding to
selected precision threshold'])
        plt.title(f'Precision-Recall curve for Class {class_names[class_i]}')
    return best_recall_threshold, best_precision_threshold

y_pred = model.predict_generator(data_generator_val, workers=num_cores)
y_true = data_generator_val.get_labels()
recall_thresholds = dict()
precision_thresholds = dict()
for i, class_name in tqdm(enumerate(class_names)):
    recall_thresholds[class_name], precision_thresholds[class_name] =
get_threshold_for_recall(y_true, y_pred, i, plot=True)
```




Precision-Recall curve for Class Flower
Precision
Recall
PR curve
Precision 0.73 corresponding to selected recall threshold
Recall 0.71 corresponding to selected precision threshold
0.0
0.2
0.4
0.6
0.8
1.0


Precision-Recall curve for Class Sugar
Precision
Recall
PR curve
Precision 0.81 corresponding to selected recall threshold
Recall 0.75 corresponding to selected precision threshold
0.0
0.2
0.4
0.6
0.8
1.0



- PR Curve를 기반으로 각 Class의 최적 Threshold 도출

Post-processing segmentation submisssion

```
model = load_model('./drive/My
Drive/4classifier_densenet169_epoch_21_val_pr_auc_0.8365921057512743.h5')
```

- submission에서는 pre-trained 모델을 사용

```
data_generator_test = DataGenenerator(folder_imgs=test_imgs_folder,
shuffle=False)
y_pred_test = model.predict_generator(data_generator_test, workers=num_cores)
```

- test image 전처리

```
image_labels_empty = set()
for i, (img, predictions) in enumerate(zip(os.listdir(test_imgs_folder),
y_pred_test)):
    for class_i, class_name in enumerate(class_names):
        if predictions[class_i] < recall_thresholds[class_name]:
            image_labels_empty.add(f'{img}_{class_name}')
```

- 각각 Image_Label들 정리해서 추가

```
recall_thresholds
```

```
{'Fish': 0.2712186,
 'Flower': 0.22801664,
 'Gravel': 0.2691737,
 'Sugar': 0.45162806}
```

- 위에서 도출한 class 별 최적 threshold

```
submission = pd.read_csv('./drive/My Drive/Colab
Notebooks/input/submission_segmentation_and_classifier.csv')
```

- Threshold 안했던 submission 파일 불러오기

```
predictions_nonempty = set(submission.loc[
                           ~submission['EncodedPixels'].isnull(),
'Image_Label'].values)
```

```
#removing masks
submission.loc[submission['Image_Label'].isin(image_labels_empty),
'EncodedPixels'] = np.nan
submission.to_csv('new3.csv', index=None)
```

- class 별 threshold값에 따라 해당하는 image_label의 세그멘테이션 데이터를 제거하고, csv 파일로 재생성