InceptionResNetV2

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```
import os
import shutil
import numpy as np
import pandas as pd
import tensorflow as tf
import matplotlib.pyplot as plt
import seaborn as sns
import cv2
import itertools
import sklearn
from sklearn.metrics import classification_report
from keras.applications import *
from keras.layers import *
from keras.models import Model, load_model
from keras.optimizers import Adam
from sklearn.utils import class_weight
from tqdm import tqdm
from keras.preprocessing.image import ImageDataGenerator
from keras.applications.resnet_v2 import preprocess_input as base_preprocess
from keras.callbacks import ReduceLROnPlateau, EarlyStopping, ModelCheckpoint
from sklearn.metrics import classification_report, confusion_matrix, roc_auc_score, roc_curve, RocCurveDisplay,
auc
from sklearn.utils.multiclass import unique_labels
from collections import Counter
from pathlib import Path
from sklearn.model_selection import train_test_split
from keras.utils import to_categorical
from PIL import Image
from sklearn.preprocessing import LabelEncoder
from sklearn.utils.class_weight import compute_class_weight
```

Load data

```
data = np.load('/content/drive/MyDrive/SC Lab/Dataset/data.npy',mmap_mode='r')
labels = np.load('/content/drive/MyDrive/SC Lab/Dataset/labels.npy',mmap_mode='r')
```

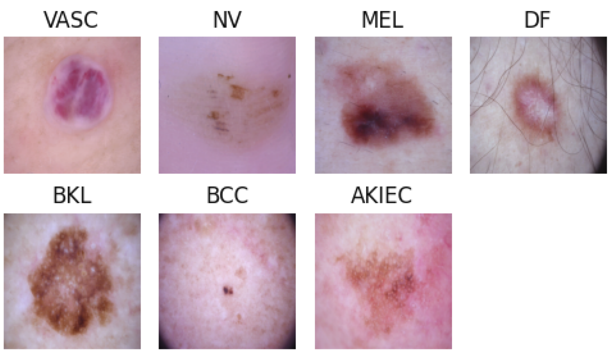
```
print("Data shape:", data.shape)
print("Labels shape:", labels.shape)
```

```
Data shape: (10015, 224, 224, 3)
Labels shape: (10015, 7)
```

Loading Images from the data

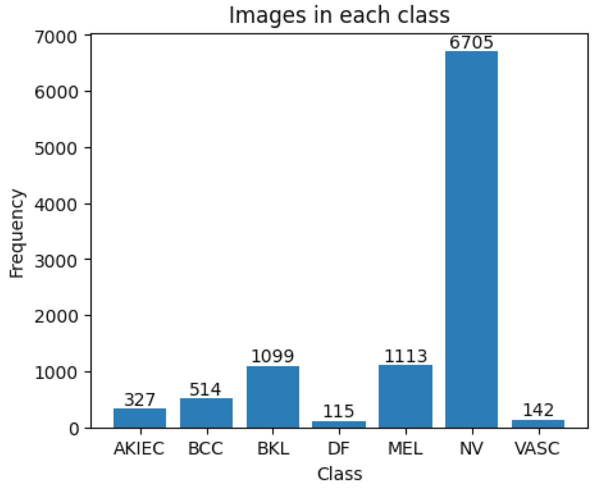
```
# Get unique class labels and their corresponding indices in the data array
unique_classes = np.unique(labels, axis=1)

# Create a dictionary to store one data sample from each class
```

```
class_samples = {}

# Map class indices to their corresponding names
class_names = {0: "AKIEC", 1: "BCC", 2: "BKL", 3: "DF", 4: "MEL", 5: "NV", 6: "VASC"}

# Select one data sample from each class
for class_label in unique_classes:
    class_indices = np.where(np.all(labels == class_label, axis=1))[0]
    class_samples[tuple(class_label)] = data[class_indices[0]]

# Plot the images in 2 rows
plt.figure(figsize=(5, 3))
for i, (class_label, image_data) in enumerate(class_samples.items()):
    class_index = np.argmax(class_label)  # Get the index of the class
    class_name = class_names[class_index]  # Get the corresponding class name
    plt.subplot(2, 4, i + 1)
    plt.imshow(image_data)
    plt.title(f'{class_name}')
    plt.axis('off')

plt.tight_layout()
plt.show()
```



Frequency of the data

```
# Sum the one-hot encoded labels along the rows to get the frequency of each class
class_counts = np.sum(labels, axis=0)

# Map class indices to their corresponding names
class_names = {0: "AKIEC", 1: "BCC", 2: "BKL", 3: "DF", 4: "MEL", 5: "NV", 6: "VASC"}

# Plot the class frequencies
plt.figure(figsize=(5, 4))
plt.bar([class_names[class_idx] for class_idx in range(len(class_names))], class_counts)
plt.xlabel('Class')
plt.ylabel('Frequency')
plt.title('Images in each class')

# Annotate the bars with the class frequencies (integer format)
for i, count in enumerate(class_counts):
    plt.text(i, count, str(int(count)), ha='center', va='bottom')

plt.show()
```



Split Data

```
# Split the data into train, test, and validation sets
train_data, test_data, train_labels, test_labels = train_test_split(data, labels, test_size=0.1,stratify=labels,
random_state=42)
train_data, val_data, train_labels, val_labels = train_test_split(train_data, train_labels,
test_size=0.1,stratify=train_labels, random_state=42)
```

Augmentation

```
# Create an ImageDataGenerator for data augmentation during training (optional)
datagen = ImageDataGenerator(
    rotation_range=20,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True
)
```

Callbacks

```
lr_reduce = ReduceLROnPlateau(monitor = 'val_accuracy', factor = 0.5, patience = 5,mode='max', min_lr = 1e-
4,verbose = 1)
#early_stop = EarlyStopping(monitor = "val_loss", patience = 5, verbose=1)
saved_model = '/content/drive/MyDrive/SC Lab/Saved Model/InceptionResNetV2.h5'
model_chkpt = ModelCheckpoint(saved_model ,save_best_only = True, monitor = 'val_accuracy',verbose = 1)

# callback_list = [early_stop, model_chkpt, lr_reduce]
callback_list = [model_chkpt, lr_reduce]
```

InceptionResNetV2 Model

```
base_model = InceptionResNetV2(weights='imagenet',
                        include_top=False,
                        input_shape=(224, 224, 3))
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/inception_resnet_v2/inception_resnet_v2_weights_tf_dim_ordering_tf_kernels_notop.h5
219055592/219055592 [==============================] - 10s 0us/step
```

```
# Add custom classification layers on top of InceptionResNetV2
x = base_model.output
x = GlobalAveragePooling2D()(x)
x = Dense(128, activation='relu')(x)
x = Dropout(0.5)(x)
predictions = Dense(7, activation='softmax')(x)

# Create the final model with custom classification layers
model = Model(inputs=base_model.input, outputs=predictions)




# Compile the model
model.compile(optimizer=Adam(learning_rate=0.001),
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

Model Training

```
epochs = 30
batch_size = 16
```

```
history = model.fit(datagen.flow(train_data, train_labels, batch_size=batch_size),
                    validation_data=(val_data, val_labels),
                    epochs=epochs,
                    callbacks=callback_list)
```

```
Epoch 1/30
507/507 [==============================] - ETA: 0s - loss: 0.9252 - accuracy: 0.6775
Epoch 1: val_accuracy improved from -inf to 0.62084, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 271s 471ms/step - loss: 0.9252 - accuracy: 0.6775 - val_loss: 0.9583
- val_accuracy: 0.6208 - lr: 0.0010
Epoch 2/30
507/507 [==============================] - ETA: 0s - loss: 0.8627 - accuracy: 0.6958
Epoch 2: val_accuracy improved from 0.62084 to 0.66851, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 234s 461ms/step - loss: 0.8627 - accuracy: 0.6958 - val_loss: 1.1028
- val_accuracy: 0.6685 - lr: 0.0010
Epoch 3/30
507/507 [==============================] - ETA: 0s - loss: 0.8543 - accuracy: 0.6999
Epoch 3: val_accuracy improved from 0.66851 to 0.73392, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 269s 530ms/step - loss: 0.8543 - accuracy: 0.6999 - val_loss: 0.8948
- val_accuracy: 0.7339 - lr: 0.0010
Epoch 4/30
507/507 [==============================] - ETA: 0s - loss: 0.7961 - accuracy: 0.7113
Epoch 4: val_accuracy improved from 0.73392 to 0.74390, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 372s 734ms/step - loss: 0.7961 - accuracy: 0.7113 - val_loss: 0.7181
- val_accuracy: 0.7439 - lr: 0.0010
Epoch 5/30
507/507 [==============================] - ETA: 0s - loss: 0.7459 - accuracy: 0.7281
Epoch 5: val_accuracy did not improve from 0.74390
```

```
507/507 [==============================] - 172s 339ms/step - loss: 0.7459 - accuracy: 0.7281 - val_loss: 0.7679
- val_accuracy: 0.7140 - lr: 0.0010
Epoch 6/30
507/507 [==============================] - ETA: 0s - loss: 0.7452 - accuracy: 0.7369
Epoch 6: val_accuracy improved from 0.74390 to 0.77051, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 486s 959ms/step - loss: 0.7452 - accuracy: 0.7369 - val_loss: 0.6412
- val_accuracy: 0.7705 - lr: 0.0010
Epoch 7/30
507/507 [==============================] - ETA: 0s - loss: 0.7440 - accuracy: 0.7305
Epoch 7: val_accuracy did not improve from 0.77051
507/507 [==============================] - 171s 337ms/step - loss: 0.7440 - accuracy: 0.7305 - val_loss: 0.8020
- val_accuracy: 0.7328 - lr: 0.0010
Epoch 8/30
507/507 [==============================] - ETA: 0s - loss: 0.7350 - accuracy: 0.7367
Epoch 8: val_accuracy did not improve from 0.77051
507/507 [==============================] - 170s 335ms/step - loss: 0.7350 - accuracy: 0.7367 - val_loss: 1.0050
- val_accuracy: 0.7118 - lr: 0.0010
Epoch 9/30
507/507 [==============================] - ETA: 0s - loss: 0.6796 - accuracy: 0.7531
Epoch 9: val_accuracy did not improve from 0.77051
507/507 [==============================] - 168s 332ms/step - loss: 0.6796 - accuracy: 0.7531 - val_loss: 0.9020
- val_accuracy: 0.7284 - lr: 0.0010
Epoch 10/30
507/507 [==============================] - ETA: 0s - loss: 0.6743 - accuracy: 0.7522
Epoch 10: val_accuracy improved from 0.77051 to 0.78160, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 639s 1s/step - loss: 0.6743 - accuracy: 0.7522 - val_loss: 0.6519 -
val_accuracy: 0.7816 - lr: 0.0010
Epoch 11/30
507/507 [==============================] - ETA: 0s - loss: 0.6500 - accuracy: 0.7651
Epoch 11: val_accuracy did not improve from 0.78160
507/507 [==============================] - 172s 338ms/step - loss: 0.6500 - accuracy: 0.7651 - val_loss: 0.8473
- val_accuracy: 0.7450 - lr: 0.0010
Epoch 12/30
507/507 [==============================] - ETA: 0s - loss: 0.6458 - accuracy: 0.7643
Epoch 12: val_accuracy did not improve from 0.78160
507/507 [==============================] - 172s 340ms/step - loss: 0.6458 - accuracy: 0.7643 - val_loss: 1.4048
- val_accuracy: 0.7095 - lr: 0.0010
Epoch 13/30
507/507 [==============================] - ETA: 0s - loss: 0.6381 - accuracy: 0.7667
Epoch 13: val_accuracy did not improve from 0.78160
507/507 [==============================] - 172s 339ms/step - loss: 0.6381 - accuracy: 0.7667 - val_loss: 0.6158
- val_accuracy: 0.7738 - lr: 0.0010
Epoch 14/30
507/507 [==============================] - ETA: 0s - loss: 0.6172 - accuracy: 0.7783
Epoch 14: val_accuracy improved from 0.78160 to 0.79601, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 754s 1s/step - loss: 0.6172 - accuracy: 0.7783 - val_loss: 0.5750 -
val_accuracy: 0.7960 - lr: 0.0010
Epoch 15/30
507/507 [==============================] - ETA: 0s - loss: 0.5962 - accuracy: 0.7824
```

```
Epoch 15: val_accuracy did not improve from 0.79601
507/507 [==============================] - 172s 339ms/step - loss: 0.5962 - accuracy: 0.7824 - val_loss: 0.6039
- val_accuracy: 0.7882 - lr: 0.0010
Epoch 16/30
507/507 [==============================] - ETA: 0s - loss: 0.5906 - accuracy: 0.7855
Epoch 16: val_accuracy did not improve from 0.79601
507/507 [==============================] - 173s 340ms/step - loss: 0.5906 - accuracy: 0.7855 - val_loss: 0.6329
- val_accuracy: 0.7517 - lr: 0.0010
Epoch 17/30
507/507 [==============================] - ETA: 0s - loss: 0.5812 - accuracy: 0.7903
Epoch 17: val_accuracy did not improve from 0.79601
507/507 [==============================] - 172s 338ms/step - loss: 0.5812 - accuracy: 0.7903 - val_loss: 0.6551
- val_accuracy: 0.7838 - lr: 0.0010
Epoch 18/30
507/507 [==============================] - ETA: 0s - loss: 0.5623 - accuracy: 0.7919
Epoch 18: val_accuracy improved from 0.79601 to 0.80044, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 604s 1s/step - loss: 0.5623 - accuracy: 0.7919 - val_loss: 0.5726 -
val_accuracy: 0.8004 - lr: 0.0010
Epoch 19/30
507/507 [==============================] - ETA: 0s - loss: 0.5775 - accuracy: 0.7908
Epoch 19: val_accuracy did not improve from 0.80044
507/507 [==============================] - 170s 334ms/step - loss: 0.5775 - accuracy: 0.7908 - val_loss: 0.7705
- val_accuracy: 0.7384 - lr: 0.0010
Epoch 20/30
507/507 [==============================] - ETA: 0s - loss: 0.5901 - accuracy: 0.7792
Epoch 20: val_accuracy did not improve from 0.80044
507/507 [==============================] - 169s 332ms/step - loss: 0.5901 - accuracy: 0.7792 - val_loss: 0.7370
- val_accuracy: 0.7572 - lr: 0.0010
Epoch 21/30
507/507 [==============================] - ETA: 0s - loss: 0.5599 - accuracy: 0.7993
Epoch 21: val_accuracy did not improve from 0.80044
507/507 [==============================] - 170s 334ms/step - loss: 0.5599 - accuracy: 0.7993 - val_loss: 0.5688
- val_accuracy: 0.7927 - lr: 0.0010
Epoch 22/30
507/507 [==============================] - ETA: 0s - loss: 0.5230 - accuracy: 0.8069
Epoch 22: val_accuracy improved from 0.80044 to 0.80377, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 645s 1s/step - loss: 0.5230 - accuracy: 0.8069 - val_loss: 0.5650 -
val_accuracy: 0.8038 - lr: 0.0010
Epoch 23/30
507/507 [==============================] - ETA: 0s - loss: 0.5223 - accuracy: 0.8110
Epoch 23: val_accuracy did not improve from 0.80377
507/507 [==============================] - 172s 338ms/step - loss: 0.5223 - accuracy: 0.8110 - val_loss: 0.5549
- val_accuracy: 0.8038 - lr: 0.0010
Epoch 24/30
507/507 [==============================] - ETA: 0s - loss: 0.5060 - accuracy: 0.8151
Epoch 24: val_accuracy improved from 0.80377 to 0.82927, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 690s 1s/step - loss: 0.5060 - accuracy: 0.8151 - val_loss: 0.5000 -
val_accuracy: 0.8293 - lr: 0.0010
Epoch 25/30
```

```
507/507 [==============================] - ETA: 0s - loss: 0.5118 - accuracy: 0.8101
Epoch 25: val_accuracy did not improve from 0.82927
507/507 [==============================] - 171s 336ms/step - loss: 0.5118 - accuracy: 0.8101 - val_loss: 0.5236
- val_accuracy: 0.8093 - lr: 0.0010
Epoch 26/30
507/507 [==============================] - ETA: 0s - loss: 0.4867 - accuracy: 0.8232
Epoch 26: val_accuracy did not improve from 0.82927
507/507 [==============================] - 172s 339ms/step - loss: 0.4867 - accuracy: 0.8232 - val_loss: 0.5240
- val_accuracy: 0.8160 - lr: 0.0010
Epoch 27/30
507/507 [==============================] - ETA: 0s - loss: 0.4796 - accuracy: 0.8204
Epoch 27: val_accuracy did not improve from 0.82927
507/507 [==============================] - 171s 337ms/step - loss: 0.4796 - accuracy: 0.8204 - val_loss: 0.6318
- val_accuracy: 0.7838 - lr: 0.0010
Epoch 28/30
507/507 [==============================] - ETA: 0s - loss: 0.4669 - accuracy: 0.8289
Epoch 28: val_accuracy improved from 0.82927 to 0.83259, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 733s 1s/step - loss: 0.4669 - accuracy: 0.8289 - val_loss: 0.4702 -
val_accuracy: 0.8326 - lr: 0.0010
Epoch 29/30
507/507 [==============================] - ETA: 0s - loss: 0.4517 - accuracy: 0.8385
Epoch 29: val_accuracy did not improve from 0.83259
507/507 [==============================] - 177s 348ms/step - loss: 0.4517 - accuracy: 0.8385 - val_loss: 0.5064
- val_accuracy: 0.8126 - lr: 0.0010
Epoch 30/30
507/507 [==============================] - ETA: 0s - loss: 0.4595 - accuracy: 0.8337
Epoch 30: val_accuracy did not improve from 0.83259
507/507 [==============================] - 173s 342ms/step - loss: 0.4595 - accuracy: 0.8337 - val_loss: 0.5816
- val_accuracy: 0.8060 - lr: 0.0010
```

```
model= load_model('/content/drive/MyDrive/SC Lab/Saved Model/irnv2.h5')
```

```
epochs = 20
batch_size = 16
```

```
history = model.fit(datagen.flow(train_data, train_labels, batch_size=batch_size),
                    validation_data=(val_data, val_labels),
                    epochs=epochs,
                    callbacks=callback_list)
```

```
Epoch 1/20
507/507 [==============================] - ETA: 0s - loss: 0.4504 - accuracy: 0.8364
Epoch 1: val_accuracy improved from -inf to 0.81264, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 230s 402ms/step - loss: 0.4504 - accuracy: 0.8364 - val_loss: 0.5414
- val_accuracy: 0.8126 - lr: 0.0010
Epoch 2/20
507/507 [==============================] - ETA: 0s - loss: 0.4483 - accuracy: 0.8366
Epoch 2: val_accuracy did not improve from 0.81264
507/507 [==============================] - 176s 347ms/step - loss: 0.4483 - accuracy: 0.8366 - val_loss: 0.5928
```

```
- val_accuracy: 0.8004 - lr: 0.0010
Epoch 3/20
507/507 [==============================] - ETA: 0s - loss: 0.4322 - accuracy: 0.8443
Epoch 3: val_accuracy did not improve from 0.81264
507/507 [==============================] - 174s 343ms/step - loss: 0.4322 - accuracy: 0.8443 - val_loss: 0.5310
- val_accuracy: 0.8038 - lr: 0.0010
Epoch 4/20
507/507 [==============================] - ETA: 0s - loss: 0.4242 - accuracy: 0.8456
Epoch 4: val_accuracy improved from 0.81264 to 0.82816, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 232s 458ms/step - loss: 0.4242 - accuracy: 0.8456 - val_loss: 0.4913
- val_accuracy: 0.8282 - lr: 0.0010
Epoch 5/20
507/507 [==============================] - ETA: 0s - loss: 0.4104 - accuracy: 0.8543
Epoch 5: val_accuracy did not improve from 0.82816
507/507 [==============================] - 172s 339ms/step - loss: 0.4104 - accuracy: 0.8543 - val_loss: 0.6853
- val_accuracy: 0.8027 - lr: 0.0010
Epoch 6/20
507/507 [==============================] - ETA: 0s - loss: 0.3928 - accuracy: 0.8516
Epoch 6: val_accuracy did not improve from 0.82816
507/507 [==============================] - 172s 339ms/step - loss: 0.3928 - accuracy: 0.8516 - val_loss: 0.6021
- val_accuracy: 0.8093 - lr: 0.0010
Epoch 7/20
507/507 [==============================] - ETA: 0s - loss: 0.3959 - accuracy: 0.8533
Epoch 7: val_accuracy improved from 0.82816 to 0.82927, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 330s 651ms/step - loss: 0.3959 - accuracy: 0.8533 - val_loss: 0.5819
- val_accuracy: 0.8293 - lr: 0.0010
Epoch 8/20
507/507 [==============================] - ETA: 0s - loss: 0.3927 - accuracy: 0.8555
Epoch 8: val_accuracy did not improve from 0.82927
507/507 [==============================] - 173s 341ms/step - loss: 0.3927 - accuracy: 0.8555 - val_loss: 0.6252
- val_accuracy: 0.8049 - lr: 0.0010
Epoch 9/20
507/507 [==============================] - ETA: 0s - loss: 0.4073 - accuracy: 0.8572
Epoch 9: val_accuracy improved from 0.82927 to 0.83370, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 401s 792ms/step - loss: 0.4073 - accuracy: 0.8572 - val_loss: 0.4890
- val_accuracy: 0.8337 - lr: 0.0010
Epoch 10/20
507/507 [==============================] - ETA: 0s - loss: 0.3724 - accuracy: 0.8645
Epoch 10: val_accuracy improved from 0.83370 to 0.84257, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 433s 854ms/step - loss: 0.3724 - accuracy: 0.8645 - val_loss: 0.5298
- val_accuracy: 0.8426 - lr: 0.0010
Epoch 11/20
507/507 [==============================] - ETA: 0s - loss: 0.3504 - accuracy: 0.8720
Epoch 11: val_accuracy did not improve from 0.84257
507/507 [==============================] - 175s 346ms/step - loss: 0.3504 - accuracy: 0.8720 - val_loss: 0.6008
- val_accuracy: 0.8237 - lr: 0.0010
Epoch 12/20
507/507 [==============================] - ETA: 0s - loss: 0.3531 - accuracy: 0.8726
```

```
Epoch 12: val_accuracy did not improve from 0.84257
507/507 [==============================] - 172s 339ms/step - loss: 0.3531 - accuracy: 0.8726 - val_loss: 0.5454
- val_accuracy: 0.8182 - lr: 0.0010
Epoch 13/20
507/507 [==============================] - ETA: 0s - loss: 0.3669 - accuracy: 0.8709
Epoch 13: val_accuracy did not improve from 0.84257
507/507 [==============================] - 174s 343ms/step - loss: 0.3669 - accuracy: 0.8709 - val_loss: 0.5729
- val_accuracy: 0.8126 - lr: 0.0010
Epoch 14/20
507/507 [==============================] - ETA: 0s - loss: 0.3305 - accuracy: 0.8802
Epoch 14: val_accuracy did not improve from 0.84257
507/507 [==============================] - 175s 344ms/step - loss: 0.3305 - accuracy: 0.8802 - val_loss: 0.6240
- val_accuracy: 0.8160 - lr: 0.0010
Epoch 15/20
507/507 [==============================] - ETA: 0s - loss: 0.3342 - accuracy: 0.8788
Epoch 15: val_accuracy did not improve from 0.84257

Epoch 15: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.
507/507 [==============================] - 175s 344ms/step - loss: 0.3342 - accuracy: 0.8788 - val_loss: 0.4771
- val_accuracy: 0.8404 - lr: 0.0010
Epoch 16/20
507/507 [==============================] - ETA: 0s - loss: 0.2606 - accuracy: 0.9093
Epoch 16: val_accuracy improved from 0.84257 to 0.86475, saving model to /content/drive/MyDrive/SC Lab/Saved
Model/irnv2.h5
507/507 [==============================] - 454s 897ms/step - loss: 0.2606 - accuracy: 0.9093 - val_loss: 0.4470
- val_accuracy: 0.8647 - lr: 5.0000e-04
Epoch 17/20
507/507 [==============================] - ETA: 0s - loss: 0.2465 - accuracy: 0.9107
Epoch 17: val_accuracy did not improve from 0.86475
507/507 [==============================] - 177s 349ms/step - loss: 0.2465 - accuracy: 0.9107 - val_loss: 0.5806
- val_accuracy: 0.8348 - lr: 5.0000e-04
Epoch 18/20
507/507 [==============================] - ETA: 0s - loss: 0.2278 - accuracy: 0.9192
Epoch 18: val_accuracy did not improve from 0.86475
507/507 [==============================] - 172s 338ms/step - loss: 0.2278 - accuracy: 0.9192 - val_loss: 0.5385
- val_accuracy: 0.8514 - lr: 5.0000e-04
Epoch 19/20
507/507 [==============================] - ETA: 0s - loss: 0.2212 - accuracy: 0.9195
Epoch 19: val_accuracy did not improve from 0.86475
507/507 [==============================] - 170s 336ms/step - loss: 0.2212 - accuracy: 0.9195 - val_loss: 0.5085
- val_accuracy: 0.8636 - lr: 5.0000e-04
Epoch 20/20
507/507 [==============================] - ETA: 0s - loss: 0.2118 - accuracy: 0.9269
Epoch 20: val_accuracy did not improve from 0.86475
507/507 [==============================] - 171s 338ms/step - loss: 0.2118 - accuracy: 0.9269 - val_loss: 0.4878
- val_accuracy: 0.8537 - lr: 5.0000e-04
```

```
model= load_model('/content/drive/MyDrive/SC Lab/Saved Model/irnv2.h5')
```

```
epochs = 10
batch_size = 16
```

```
history = model.fit(datagen.flow(train_data, train_labels, batch_size=batch_size),
                    validation_data=(val_data, val_labels),
                    epochs=epochs,
                    callbacks=callback_list)
```

```
Epoch 1/10
507/507 [==============================] - ETA: 0s - loss: 0.2349 - accuracy: 0.9163
Epoch 1: val_accuracy improved from -inf to 0.85366, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 201s 360ms/step - loss: 0.2349 - accuracy: 0.9163 - val_loss: 0.4985
- val_accuracy: 0.8537 - lr: 5.0000e-04
Epoch 2/10
507/507 [==============================] - ETA: 0s - loss: 0.2259 - accuracy: 0.9181
Epoch 2: val_accuracy did not improve from 0.85366
507/507 [==============================] - 173s 341ms/step - loss: 0.2259 - accuracy: 0.9181 - val_loss: 0.5481
- val_accuracy: 0.8492 - lr: 5.0000e-04
Epoch 3/10
507/507 [==============================] - ETA: 0s - loss: 0.2276 - accuracy: 0.9199
Epoch 3: val_accuracy improved from 0.85366 to 0.85698, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 190s 374ms/step - loss: 0.2276 - accuracy: 0.9199 - val_loss: 0.4619
- val_accuracy: 0.8570 - lr: 5.0000e-04
Epoch 4/10
507/507 [==============================] - ETA: 0s - loss: 0.2088 - accuracy: 0.9281
Epoch 4: val_accuracy did not improve from 0.85698
507/507 [==============================] - 175s 344ms/step - loss: 0.2088 - accuracy: 0.9281 - val_loss: 0.5596
- val_accuracy: 0.8570 - lr: 5.0000e-04
Epoch 5/10
507/507 [==============================] - ETA: 0s - loss: 0.2082 - accuracy: 0.9278
Epoch 5: val_accuracy did not improve from 0.85698
507/507 [==============================] - 174s 343ms/step - loss: 0.2082 - accuracy: 0.9278 - val_loss: 0.4712
- val_accuracy: 0.8503 - lr: 5.0000e-04
Epoch 6/10
507/507 [==============================] - ETA: 0s - loss: 0.2059 - accuracy: 0.9305
Epoch 6: val_accuracy did not improve from 0.85698
507/507 [==============================] - 173s 342ms/step - loss: 0.2059 - accuracy: 0.9305 - val_loss: 0.6082
- val_accuracy: 0.8559 - lr: 5.0000e-04
Epoch 7/10
507/507 [==============================] - ETA: 0s - loss: 0.1988 - accuracy: 0.9292
Epoch 7: val_accuracy did not improve from 0.85698
507/507 [==============================] - 173s 342ms/step - loss: 0.1988 - accuracy: 0.9292 - val_loss: 0.5572
- val_accuracy: 0.8559 - lr: 5.0000e-04
Epoch 8/10
507/507 [==============================] - ETA: 0s - loss: 0.1911 - accuracy: 0.9324
Epoch 8: val_accuracy improved from 0.85698 to 0.86585, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 237s 468ms/step - loss: 0.1911 - accuracy: 0.9324 - val_loss: 0.4856
- val_accuracy: 0.8659 - lr: 5.0000e-04
Epoch 9/10
507/507 [==============================] - ETA: 0s - loss: 0.1701 - accuracy: 0.9414
Epoch 9: val_accuracy did not improve from 0.86585
507/507 [==============================] - 172s 339ms/step - loss: 0.1701 - accuracy: 0.9414 - val_loss: 0.5460
```

```
- val_accuracy: 0.8592 - lr: 5.0000e-04
Epoch 10/10
507/507 [==============================] - ETA: 0s - loss: 0.1774 - accuracy: 0.9376
Epoch 10: val_accuracy improved from 0.86585 to 0.87140, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 490s 967ms/step - loss: 0.1774 - accuracy: 0.9376 - val_loss: 0.4682
- val_accuracy: 0.8714 - lr: 5.0000e-04
```

```
model= load_model('/content/drive/MyDrive/SC Lab/Saved Model/InceptionResNetV2.h5')
```

```
history = model.fit(datagen.flow(train_data, train_labels, batch_size=batch_size),
                    validation_data=(val_data, val_labels),
                    epochs=15,
                    callbacks=callback_list)
```

```
Epoch 1/15
507/507 [==============================] - ETA: 0s - loss: 0.1767 - accuracy: 0.9351
Epoch 1: val_accuracy improved from -inf to 0.86807, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 219s 380ms/step - loss: 0.1767 - accuracy: 0.9351 - val_loss: 0.4719
- val_accuracy: 0.8681 - lr: 5.0000e-04
Epoch 2/15
507/507 [==============================] - ETA: 0s - loss: 0.1686 - accuracy: 0.9416
Epoch 2: val_accuracy did not improve from 0.86807
507/507 [==============================] - 172s 338ms/step - loss: 0.1686 - accuracy: 0.9416 - val_loss: 0.6097
- val_accuracy: 0.8592 - lr: 5.0000e-04
Epoch 3/15
507/507 [==============================] - ETA: 0s - loss: 0.1610 - accuracy: 0.9444
Epoch 3: val_accuracy did not improve from 0.86807
507/507 [==============================] - 173s 342ms/step - loss: 0.1610 - accuracy: 0.9444 - val_loss: 0.5116
- val_accuracy: 0.8614 - lr: 5.0000e-04
Epoch 4/15
507/507 [==============================] - ETA: 0s - loss: 0.1570 - accuracy: 0.9459
Epoch 4: val_accuracy did not improve from 0.86807
507/507 [==============================] - 173s 340ms/step - loss: 0.1570 - accuracy: 0.9459 - val_loss: 0.6134
- val_accuracy: 0.8625 - lr: 5.0000e-04
Epoch 5/15
507/507 [==============================] - ETA: 0s - loss: 0.1459 - accuracy: 0.9485
Epoch 5: val_accuracy did not improve from 0.86807
507/507 [==============================] - 173s 341ms/step - loss: 0.1459 - accuracy: 0.9485 - val_loss: 0.7644
- val_accuracy: 0.8348 - lr: 5.0000e-04
Epoch 6/15
507/507 [==============================] - ETA: 0s - loss: 0.1416 - accuracy: 0.9499
Epoch 6: val_accuracy improved from 0.86807 to 0.87029, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 256s 504ms/step - loss: 0.1416 - accuracy: 0.9499 - val_loss: 0.5946
- val_accuracy: 0.8703 - lr: 5.0000e-04
Epoch 7/15
507/507 [==============================] - ETA: 0s - loss: 0.1434 - accuracy: 0.9465
Epoch 7: val_accuracy did not improve from 0.87029
507/507 [==============================] - 176s 346ms/step - loss: 0.1434 - accuracy: 0.9465 - val_loss: 0.6378
- val_accuracy: 0.8614 - lr: 5.0000e-04
```

```
Epoch 8/15
507/507 [==============================] - ETA: 0s - loss: 0.1551 - accuracy: 0.9439
Epoch 8: val_accuracy did not improve from 0.87029
507/507 [==============================] - 175s 344ms/step - loss: 0.1551 - accuracy: 0.9439 - val_loss: 0.6739
- val_accuracy: 0.8703 - lr: 5.0000e-04
Epoch 9/15
507/507 [==============================] - ETA: 0s - loss: 0.1434 - accuracy: 0.9496
Epoch 9: val_accuracy did not improve from 0.87029
507/507 [==============================] - 174s 343ms/step - loss: 0.1434 - accuracy: 0.9496 - val_loss: 0.5165
- val_accuracy: 0.8614 - lr: 5.0000e-04
Epoch 10/15
507/507 [==============================] - ETA: 0s - loss: 0.1247 - accuracy: 0.9565
Epoch 10: val_accuracy did not improve from 0.87029
507/507 [==============================] - 175s 345ms/step - loss: 0.1247 - accuracy: 0.9565 - val_loss: 0.6168
- val_accuracy: 0.8537 - lr: 5.0000e-04
Epoch 11/15
507/507 [==============================] - ETA: 0s - loss: 0.1416 - accuracy: 0.9530
Epoch 11: val_accuracy did not improve from 0.87029

Epoch 11: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.
507/507 [==============================] - 174s 344ms/step - loss: 0.1416 - accuracy: 0.9530 - val_loss: 0.6520
- val_accuracy: 0.8636 - lr: 5.0000e-04
Epoch 12/15
507/507 [==============================] - ETA: 0s - loss: 0.0988 - accuracy: 0.9656
Epoch 12: val_accuracy improved from 0.87029 to 0.87251, saving model to /content/drive/MyDrive/4.2/SC
Lab/Project/Saved Model/irnv2.h5
507/507 [==============================] - 377s 745ms/step - loss: 0.0988 - accuracy: 0.9656 - val_loss: 0.6262
- val_accuracy: 0.8725 - lr: 2.5000e-04
Epoch 13/15
507/507 [==============================] - ETA: 0s - loss: 0.0870 - accuracy: 0.9704
Epoch 13: val_accuracy did not improve from 0.87251
507/507 [==============================] - 174s 342ms/step - loss: 0.0870 - accuracy: 0.9704 - val_loss: 0.6820
- val_accuracy: 0.8537 - lr: 2.5000e-04
Epoch 14/15
507/507 [==============================] - ETA: 0s - loss: 0.0812 - accuracy: 0.9731
Epoch 14: val_accuracy did not improve from 0.87251
507/507 [==============================] - 170s 336ms/step - loss: 0.0812 - accuracy: 0.9731 - val_loss: 0.6839
- val_accuracy: 0.8681 - lr: 2.5000e-04
Epoch 15/15
507/507 [==============================] - ETA: 0s - loss: 0.0748 - accuracy: 0.9741
Epoch 15: val_accuracy did not improve from 0.87251
507/507 [==============================] - 170s 335ms/step - loss: 0.0748 - accuracy: 0.9741 - val_loss: 0.6616
- val_accuracy: 0.8681 - lr: 2.5000e-04
```

```python
model= load_model('/content/drive/MyDrive/SC Lab/Saved Model/InceptionResNetV2.h5')
```

Test Accuracy

```python
test_loss, test_accuracy = model.evaluate(test_data, test_labels)
print("Test Accuracy:", test_accuracy)
```

```
32/32 [==============================] - 10s 210ms/step - loss: 0.6894 - accuracy: 0.8573
Test Accuracy: 0.8572854399681091
```

Classification Report

```
# Make predictions on the test data
predictions = model.predict(test_data)

# Convert predictions and true labels to integer format
predicted_labels = np.argmax(predictions, axis=1)
# test_labels = test_data.classes
true_labels = np.argmax(test_labels, axis=1)

# Calculate the classification report
report = classification_report(true_labels, predicted_labels)

# Print the classification report
print("Classification Report:")
print(report)
```

```
32/32 [==============================] - 19s 174ms/step
Classification Report:
              precision    recall  f1-score   support

           0       0.68      0.45      0.55        33
           1       0.81      0.69      0.74        51
           2       0.64      0.79      0.71       110
           3       0.50      0.58      0.54        12
           4       0.80      0.54      0.65       111
           5       0.92      0.96      0.94       671
           6       0.92      0.79      0.85        14

    accuracy                           0.86      1002
   macro avg       0.75      0.69      0.71      1002
weighted avg       0.86      0.86      0.85      1002
```

Confusion Matrix

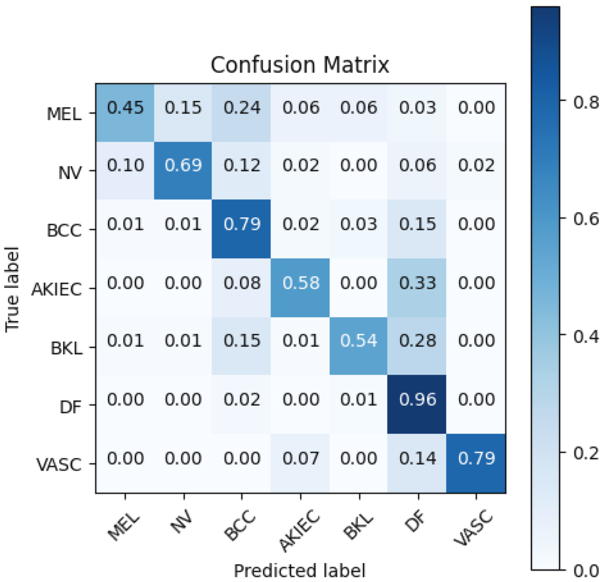
```
# Calculate the confusion matrix
cm = confusion_matrix(true_labels, predicted_labels)

cm
```

```
array([[ 15,   5,   8,   2,   2,   1,   0],
       [  5,  35,   6,   1,   0,   3,   1],
       [  1,   1,  87,   2,   3,  16,   0],
       [  0,   0,   1,   7,   0,   4,   0],
       [  1,   1,  17,   1,  60,  31,   0],
       [  0,   1,  16,   0,  10, 644,   0],
       [  0,   0,   0,   1,   0,   2,  11]])
```

```
def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
```

```
                             cmap=plt.cm.Blues):
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    # print(cm)

    plt.figure(figsize=(5, 5))
    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")
    plt.ylabel('True label')
    plt.xlabel('Predicted label')
    plt.tight_layout()


cm_plot_labels = ["MEL", "NV", "BCC", "AKIEC", "BKL", "DF", "VASC"]

plot_confusion_matrix(cm, cm_plot_labels, title='Confusion Matrix', normalize=True)
```

```
Normalized confusion matrix
```

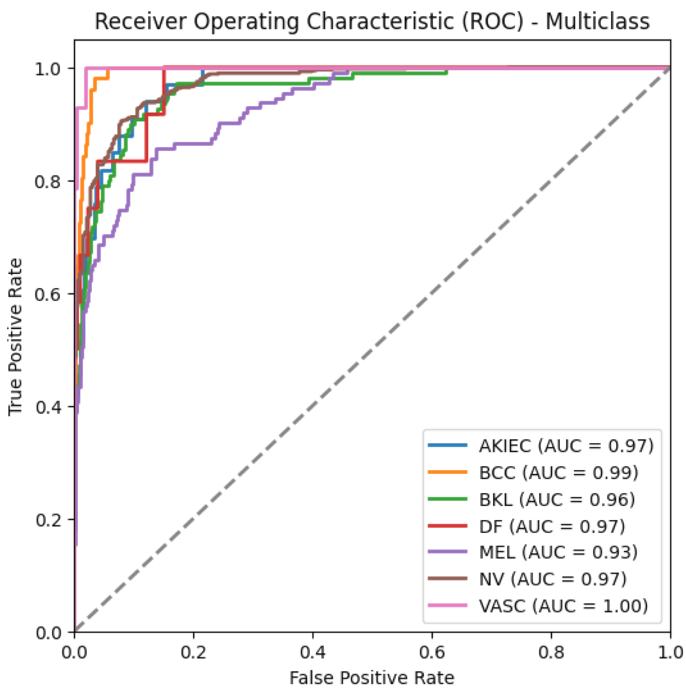


ROC-AUC curve

```
# Define class names
class_names = ['AKIEC', 'BCC', 'BKL', 'DF', 'MEL', 'NV', 'VASC']

# Make predictions on the test data
predictions = model.predict(test_data)
```

```
# Get the number of classes
num_classes = test_labels.shape[1]

# Initialize a figure to plot ROC curves
plt.figure(figsize=(6, 6))

# Loop through each class
for class_index in range(num_classes):
    # Compute ROC curve and ROC AUC for the current class
    fpr, tpr, thresholds = roc_curve(test_labels[:, class_index], predictions[:, class_index])
    roc_auc = auc(fpr, tpr)

    # Plot ROC curve for the current class
    plt.plot(fpr, tpr, lw=2, label=f'{class_names[class_index]} (AUC = {roc_auc:.2f})')

# Plot the diagonal line (random chance)
plt.plot([0, 1], [0, 1], color='gray', linestyle='--', lw=2)

# Set plot properties
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic (ROC) - Multiclass')
plt.legend(loc='lower right')

# Display the plot
plt.show()
```

```
32/32 [==============================] - 5s 160ms/step
```



Misclass Classification

```
!pip install tf-keras-vis
```

```
Collecting tf-keras-vis
  Downloading tf_keras_vis-0.8.5-py3-none-any.whl (52 kB)
```

```
[?25l    [90m━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ [0m [32m0.0/52.1 kB [0m [31m? [0m eta [36m-:--:-- [0m
```

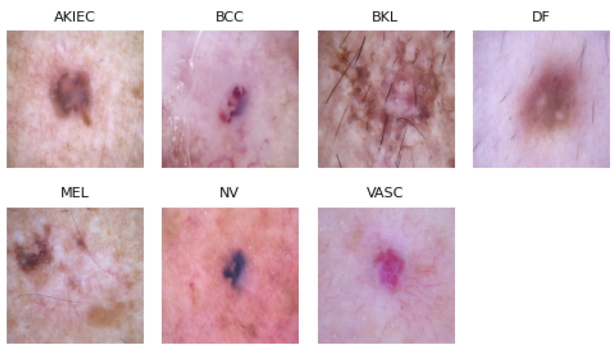
[2K [90m━━ [0m [32m52.1/52.1 kB [0m [31m1.4 MB/s [0m eta [36m0:00:00 [0m [?25hRequirement already satisfied: scipy in /usr/local/lib/python3.10/dist-packages (from tf-keras-vis) (1.10.1) Requirement already satisfied: pillow in /usr/local/lib/python3.10/dist-packages (from tf-keras-vis) (9.4.0) Collecting deprecated (from tf-keras-vis) Downloading Deprecated-1.2.14-py2.py3-none-any.whl (9.6 kB) Requirement already satisfied: imageio in /usr/local/lib/python3.10/dist-packages (from tf-keras-vis) (2.31.1) Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-packages (from tf-keras-vis) (23.1) Requirement already satisfied: wrapt<2,>=1.10 in /usr/local/lib/python3.10/dist-packages (from deprecated->tf-keras-vis) (1.14.1) Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from imageio->tf-keras-vis) (1.23.5) Installing collected packages: deprecated, tf-keras-vis Successfully installed deprecated-1.2.14 tf-keras-vis-0.8.5

```
%reload_ext autoreload
%autoreload 2
%matplotlib inline
from tensorflow.python.client import device_lib
device_list = device_lib.list_local_devices()
gpus = [device.name for device in device_list if device.device_type == 'GPU']
print('TensorFlow recognized {} GPUs'.format(len(gpus)))
```

```
TensorFlow recognized 1 GPUs
```

```
image_titles = ['AKIEC', 'BCC', 'BKL', 'DF', 'MEL', 'NV', 'VASC']
num_images = len(image_titles)

# Convert one-hot encoded labels to integer labels
test_labels_int = np.argmax(test_labels, axis=1)
# Find the indices of the first image from each class
class_indices = [np.where(test_labels_int == i)[0][0] for i in range(len(image_titles))]

# Create an array to store the images
image_array = []

# Create subplots with 2 rows
num_rows = 2
num_cols = (num_images + 1) // num_rows
fig, ax = plt.subplots(num_rows, num_cols, figsize=(5, 3))

for i, title in enumerate(image_titles):
    row = i // num_cols
    col = i % num_cols
    ax[row, col].set_title(title, fontsize=8)

    # Display the image from test data
    img = test_data[class_indices[i]]
    image_array.append(img)  # Store the image in the array

    ax[row, col].imshow(img)
    ax[row, col].axis('off')

# Remove any empty subplots
for i in range(len(image_titles), num_rows * num_cols):
    row = i // num_cols
    col = i % num_cols
    fig.delaxes(ax[row, col])

plt.tight_layout()
plt.show()
```

```
X = base_preprocess(np.array(image_array))
```




```
from tf_keras_vis.utils.model_modifiers import ReplaceToLinear

replace2linear = ReplaceToLinear()

# Instead of using the ReplaceToLinear instance above,
# you can also define the function from scratch as follows:
def model_modifier_function(cloned_model):
    cloned_model.layers[-1].activation = tf.keras.activations.linear
```

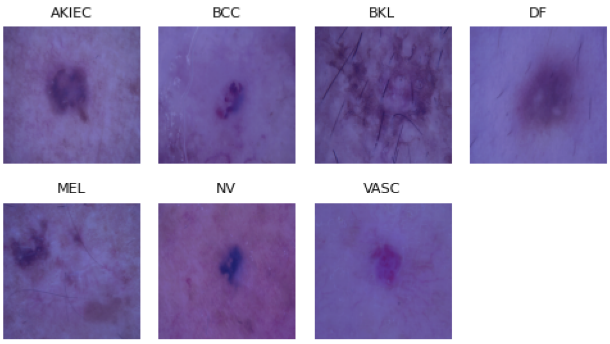
```
from tf_keras_vis.utils.scores import CategoricalScore

# 1 is the imagenet index corresponding to Goldfish, 294 to Bear and 413 to Assault Rifle.
score = CategoricalScore([0, 1, 2, 3, 4, 5, 6])

# Instead of using CategoricalScore object,
# you can also define the function from scratch as follows:
def score_function(output):
    # The `output` variable refers to the output of the model,
    # so, in this case, `output` shape is `(3, 1000)` i.e., (samples, classes).
    return (output[0][1][2][3][4][5][6])
```

Faster Scorecam

```
%%time
from matplotlib import cm
from tf_keras_vis.scorecam import Scorecam

# Create ScoreCAM object
scorecam = Scorecam(model, model_modifier=replace2linear)

# Generate heatmap with Faster-ScoreCAM
cam = scorecam(score,
               X,
               penultimate_layer=-1,
               max_N=10)

## Since v0.6.0, calling `normalize()` is NOT necessary.
# cam = normalize(cam)

# Calculate the number of rows and columns for subplots
num_rows = 2
num_cols = (num_images + 1) // num_rows

# Render
f, ax = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(5, 3))
```

```
for i, title in enumerate(image_titles):
    row = i // num_cols
    col = i % num_cols

    heatmap = np.uint8(cm.jet(cam[i])[..., :3] * 255)
    ax[row, col].set_title(title, fontsize=8)
    ax[row, col].imshow(image_array[i])
    ax[row, col].imshow(heatmap, cmap='jet', alpha=0.5)
    ax[row, col].axis('off')

# Remove any empty subplots
for i in range(len(image_titles), num_rows * num_cols):
    row = i // num_cols
    col = i % num_cols
    f.delaxes(ax[row, col])

plt.tight_layout()
plt.show()
```

```
3/3 [==============================] - 6s 654ms/step
```

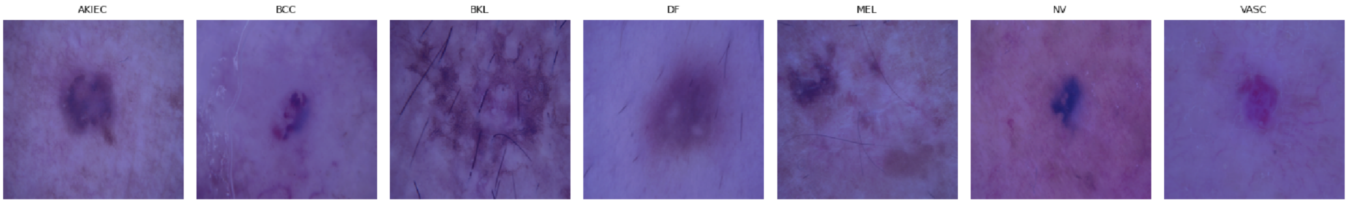



```
CPU times: user 17.4 s, sys: 351 ms, total: 17.7 s
Wall time: 27.4 s
```

```
%%time
from matplotlib import pyplot as plt, cm
from tf_keras_vis.scorecam import Scorecam

# Assuming you have already defined model and replace2linear

# Create ScoreCAM object
scorecam = Scorecam(model, model_modifier=replace2linear)

# Generate heatmaps with Faster-ScoreCAM
cam = scorecam(score, X, penultimate_layer=-1, max_N=10)

# Calculate the number of images
num_images = len(image_titles)

# Create a single row plot
fig, axes = plt.subplots(1, num_images, figsize=(15, 5))

for i, title in enumerate(image_titles):
    heatmap = np.uint8(cm.jet(cam[i])[..., :3] * 255)

    combined_image = cv2.addWeighted(image_array[i], 0.5, heatmap, 0.5, 0)

    axes[i].set_title(title, fontsize=8)
```

```
    axes[i].imshow(combined_image)
    axes[i].axis('off')

plt.tight_layout()
plt.show()
```

```
3/3 [==============================] - 19s 1s/step
```

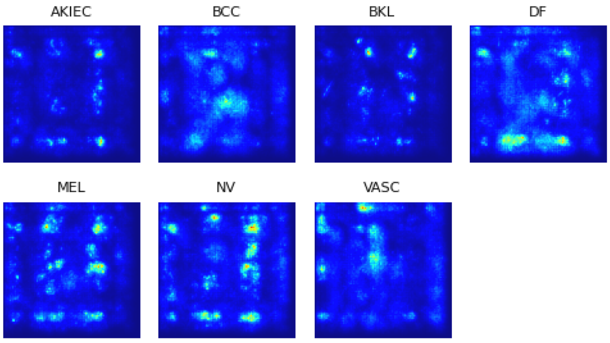



```
CPU times: user 19.9 s, sys: 1.01 s, total: 20.9 s
Wall time: 40.4 s
```

SmoothGrad

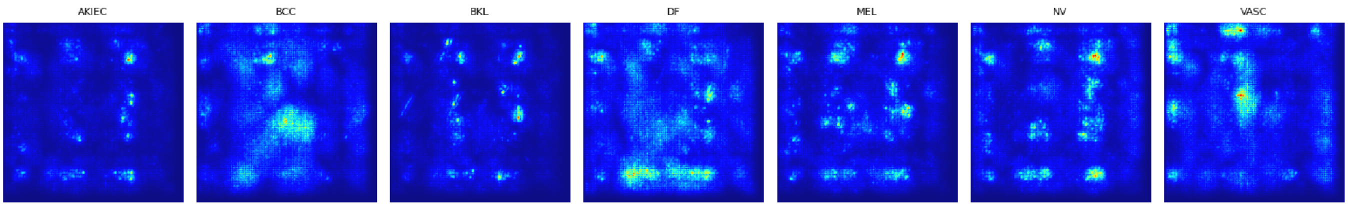
```
%%time
from tensorflow.keras import backend as K
from tf_keras_vis.saliency import Saliency

# Create Saliency object.
saliency = Saliency(model,
                    model_modifier=replace2linear,
                    clone=True)

# Generate saliency map with smoothing that reduce noise by adding noise
saliency_map = saliency(score,
                        X,
                        smooth_samples=20, # The number of calculating gradients iterations.
                        smooth_noise=0.20) # noise spread level.

## Since v0.6.0, calling `normalize()` is NOT necessary.
# saliency_map = normalize(saliency_map)

# Calculate the number of rows and columns for subplots
num_rows = 2
num_cols = (num_images + 1) // num_rows

# Render
f, ax = plt.subplots(nrows=num_rows, ncols=num_cols, figsize=(5, 3))

for i, title in enumerate(image_titles):
    row = i // num_cols
    col = i % num_cols

    ax[row, col].set_title(title, fontsize=8)
    ax[row, col].imshow(saliency_map[i], cmap='jet')
    ax[row, col].axis('off')

# Remove any empty subplots
for i in range(len(image_titles), num_rows * num_cols):
    row = i // num_cols
    col = i % num_cols
    f.delaxes(ax[row, col])
```

```
plt.tight_layout()
plt.show()
```




```
CPU times: user 25.5 s, sys: 545 ms, total: 26 s
Wall time: 29.3 s
```

```
%%time
from tensorflow.keras import backend as K
from tf_keras_vis.saliency import Saliency

# Create Saliency object.
saliency = Saliency(model, model_modifier=replace2linear, clone=True)

# Generate saliency maps with smoothing that reduces noise by adding noise
saliency_maps = saliency(score, X, smooth_samples=20, smooth_noise=0.20)

# Calculate the number of images
num_images = len(image_titles)

# Create a single row plot
fig, axes = plt.subplots(1, num_images, figsize=(15, 5))

for i, title in enumerate(image_titles):
    axes[i].set_title(title, fontsize=8)
    axes[i].imshow(saliency_maps[i], cmap='jet')
    axes[i].axis('off')

plt.tight_layout()
plt.show()
```




```
CPU times: user 29.8 s, sys: 754 ms, total: 30.6 s
Wall time: 50.3 s
```