In [ ]:

```

```

Dataset Overview

HAM10000 ("Human Against Machine with 10000 training images") dataset - a large collection of multi-source dermatoscopic images of pigmented lesions

The dermatoscopic images are collected from different populations, acquired and stored by different modalities. The final dataset consists of 10015 dermatoscopic images.

It has 7 different classes of skin cancer which are listed below :

- **Melanocytic nevi**
- **Melanoma**
- **Benign keratosis-like lesions**
- **Basal cell carcinoma**
- **Actinic keratoses**
- **Vascular lesions**
- **Dermatofibroma**

Importing libraries

In [1]:

```
import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt
from imblearn.over_sampling import RandomOverSampler
import numpy as np
from sklearn.model_selection import train_test_split
import os, cv2
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, Flatten, Dense, MaxPool2D, Activation
from sklearn.metrics import classification_report, accuracy_score
```

Reading the Data

In [2]:

```
data = pd.read_csv('/kaggle/input/skin-cancer-mnist-ham10000/hmnist_28_28_RGB.csv')
data.head()
```

Out[2]:

	pixel0000	pixel0001	pixel0002	pixel0003	pixel0004	pixel0005	pixel0006	pixel0007	pixel0008	pixel0009	...	pixel2343	pix
0	192	153	193	195	155	192	197	154	185	202	...	173	
1	25	14	30	68	48	75	123	93	126	158	...	60	
2	192	138	153	200	145	163	201	142	160	206	...	167	
3	38	19	30	95	59	72	143	103	119	171	...	44	
4	158	113	139	194	144	174	215	162	191	225	...	209	

5 rows × 2353 columns

Data Preprocessing

Data Cleaning

In [3]:

```
data['label'].unique()
```

Out[3]:

```
array([2, 4, 3, 6, 5, 1, 0])
```

In [4]:

```
y = data['label']
x = data.drop(columns = ['label'])
```

In [5]:

```
data.isnull().sum().sum()  #no null values present
```

Out[5]:

```
0
```

In [6]:

```
meta_data = pd.read_csv('/kaggle/input/skin-cancer-mnist-ham10000/HAM10000_metadata.csv')
meta_data.head()
```

Out[6]:

	lesion_id	image_id	dx	dx_type	age	sex	localization
0	HAM_0000118	ISIC_0027419	bkl	histo	80.0	male	scalp
1	HAM_0000118	ISIC_0025030	bkl	histo	80.0	male	scalp
2	HAM_0002730	ISIC_0026769	bkl	histo	80.0	male	scalp
3	HAM_0002730	ISIC_0025661	bkl	histo	80.0	male	scalp
4	HAM_0001466	ISIC_0031633	bkl	histo	75.0	male	ear

In [7]:

```
meta_data['dx'].unique()
```

Out[7]:

```
array(['bkl', 'nv', 'df', 'mel', 'vasc', 'bcc', 'akiec'], dtype=object)
```

In [8]:

```
y = data['label']
x = data.drop(columns = ['label'])
```

In [9]:

```
data.isnull().sum().sum()  #no null values present
```

Out[9]:

```
0
```

In [10]:

```
meta_data = pd.read_csv('/kaggle/input/skin-cancer-mnist-ham10000/HAM10000_metadata.csv')
meta_data.head()
```

Out[10]:

	lesion_id	image_id	dx	dx_type	age	sex	localization
0	HAM_0000118	ISIC_0027419	bkl	histo	80.0	male	scalp
1	HAM_0000118	ISIC_0025030	bkl	histo	80.0	male	scalp
2	HAM_0002730	ISIC_0026769	bkl	histo	80.0	male	scalp
3	HAM_0002730	ISIC_0025661	bkl	histo	80.0	male	scalp
4	HAM_0001466	ISIC_0031633	bkl	histo	75.0	male	ear

In [11]:

```
meta_data['dx'].unique()
```

Out[11]:

```
array(['bkl', 'nv', 'df', 'mel', 'vasc', 'bcc', 'akiec'], dtype=object)
```

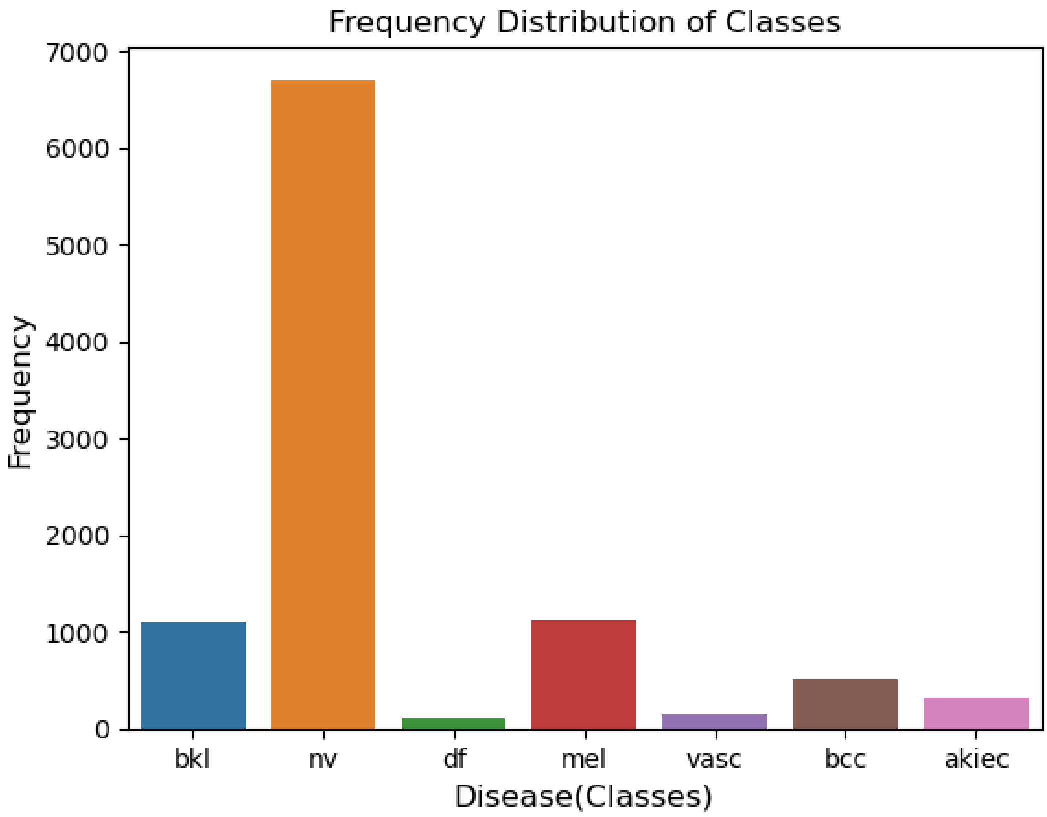
Exploratory Data Analysis

In [12]:

```
sns.countplot(x = 'dx', data = meta_data)
plt.xlabel('Disease(Classes)', size=12)
plt.ylabel('Frequency', size=12)
plt.title('Frequency Distribution of Classes')
```

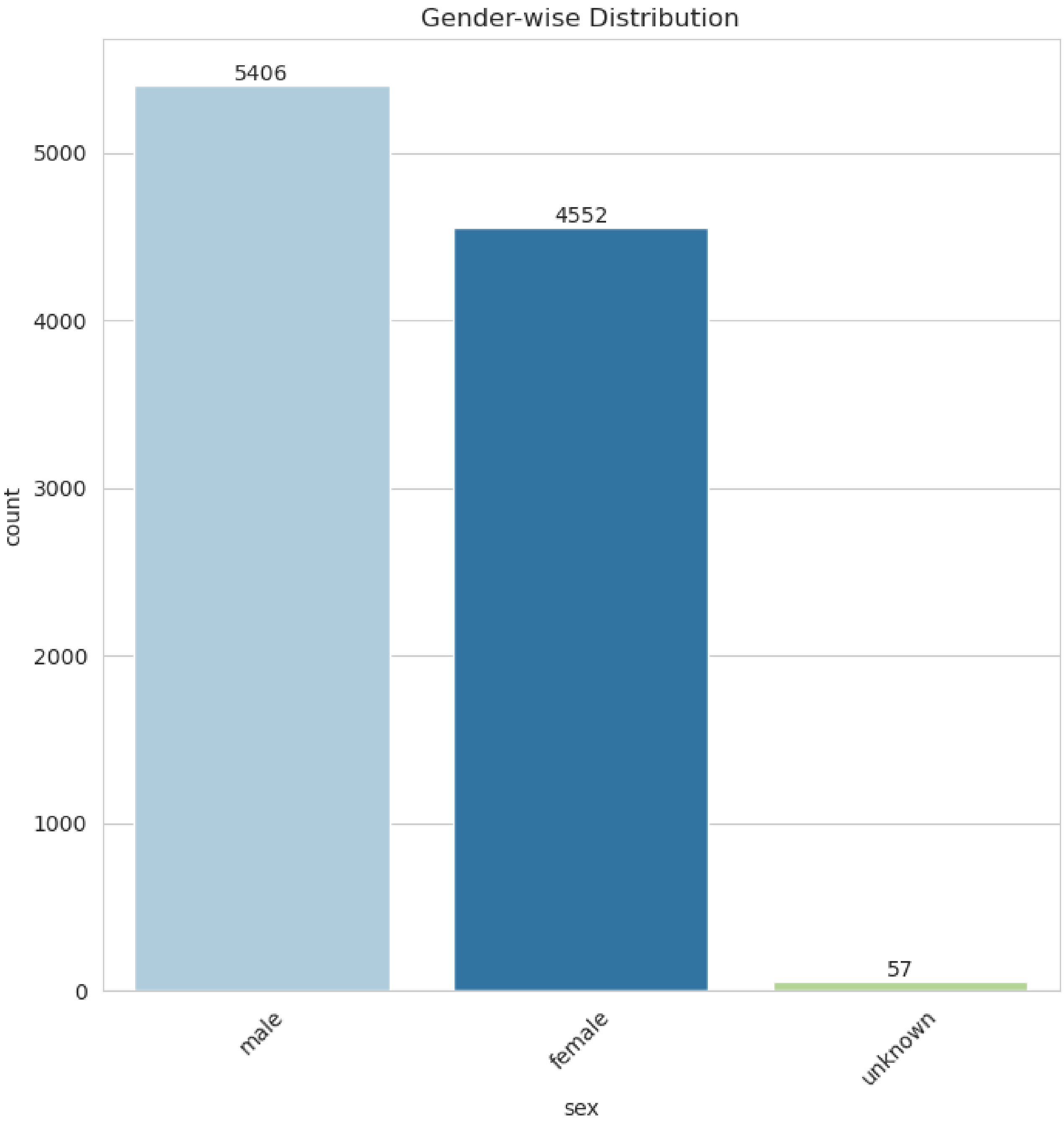
Out[12]:

```
Text(0.5, 1.0, 'Frequency Distribution of Classes')
```



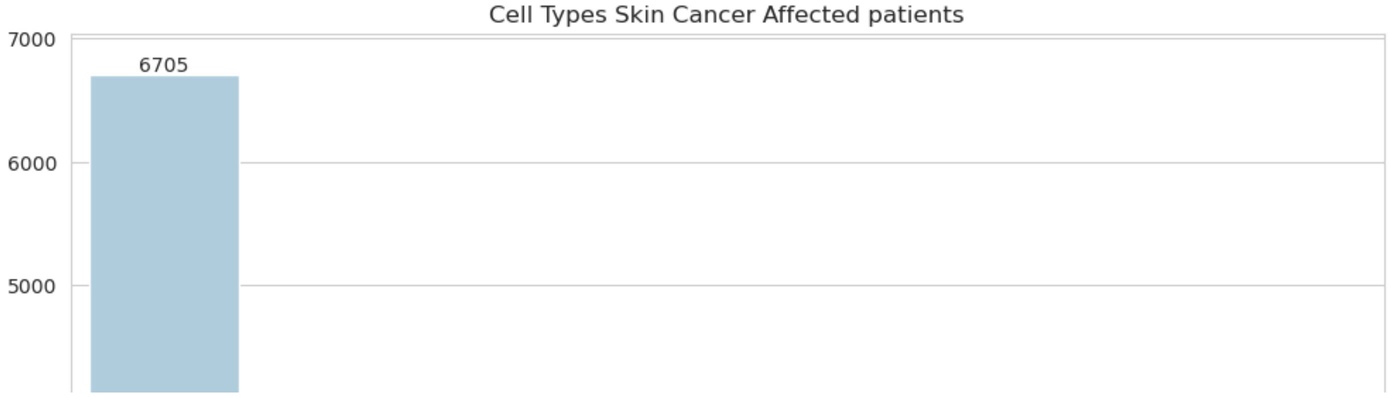
In [13]:

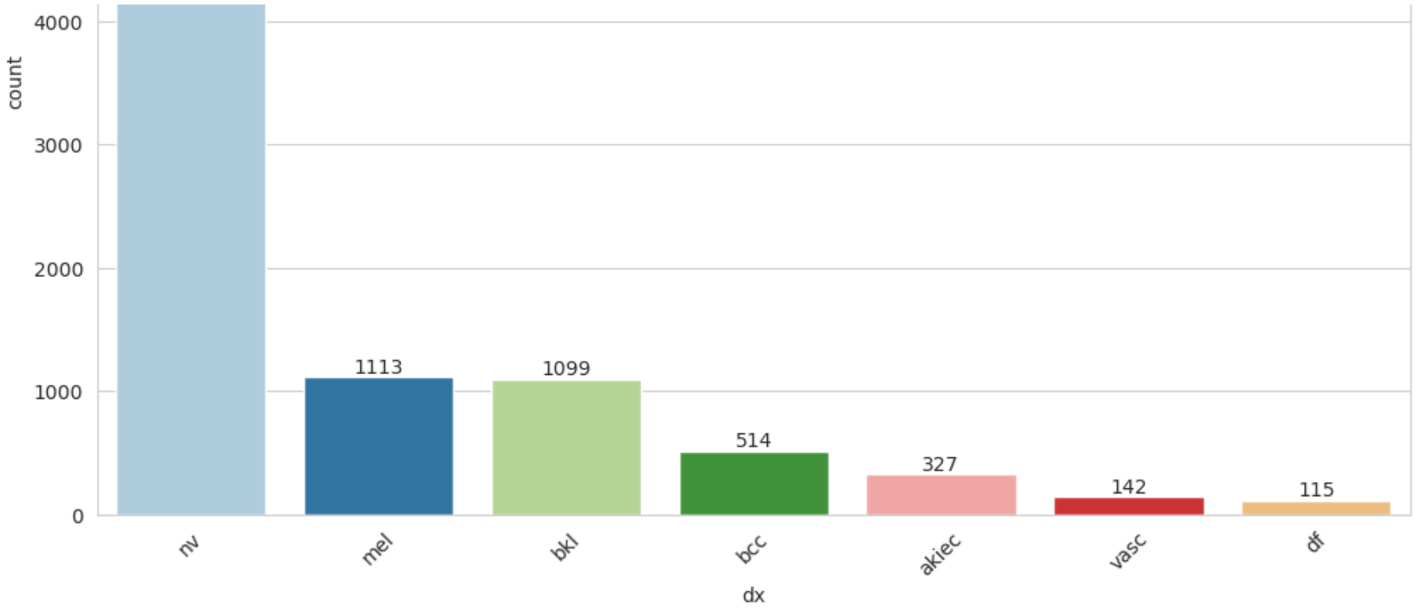
```
sns.set_style('whitegrid')
colors = ['#87ace8','#e3784d', 'green']
fig,axes = plt.subplots(figsize=(8,8))

ax = sns.countplot(x='sex',data=meta_data, palette = 'Paired')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Gender-wise Distribution')
plt.xticks(rotation=45)
plt.show()
```



In [14]:

```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.countplot(x='dx',data=meta_data, order = meta_data['dx'].value_counts().index,
palette = 'Paired')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Cell Types Skin Cancer Affected patients')
plt.xticks(rotation=45)
plt.show()
```





In [ ]:

```
```

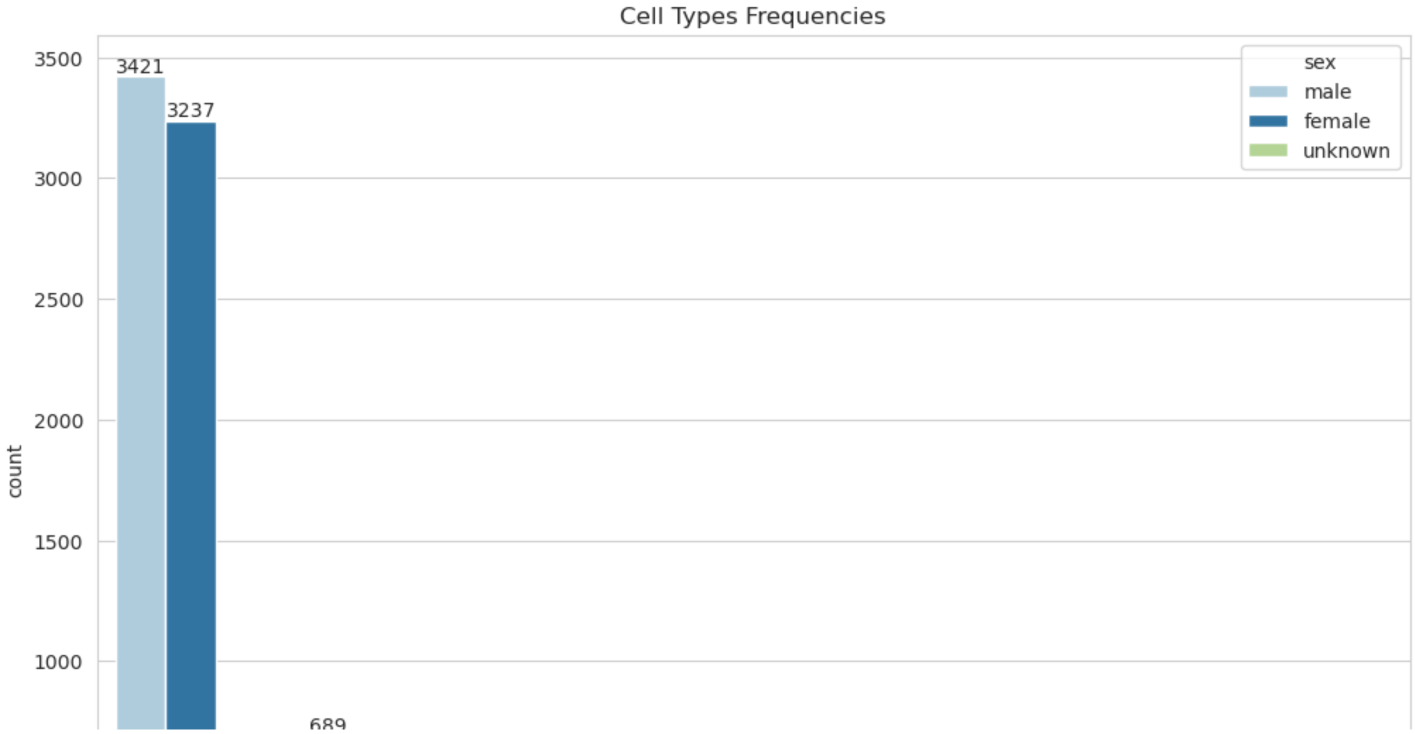
In [15]:

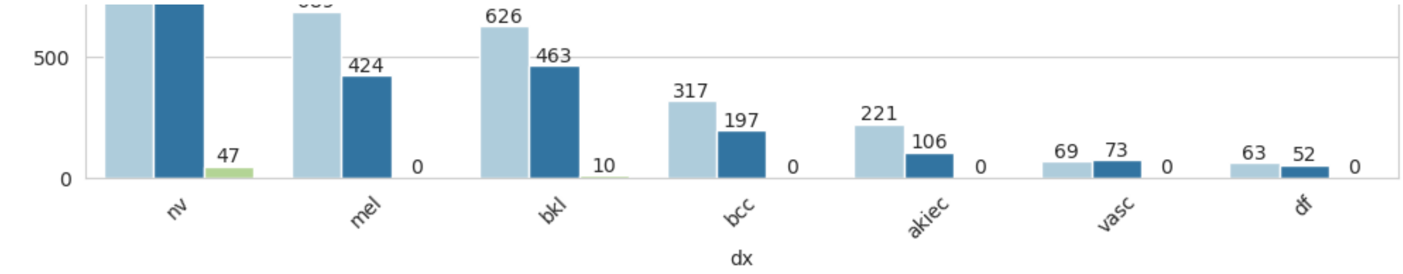
```
classes = {2:'bkl', 4:'nv', 3:'df', 6:'mel', 5:'vasc', 1:'bcc', 0:'akiec'}

classes_labels=[]
for key in classes.keys():
    classes_labels.append(key)
print(classes_labels)
```

```
[2, 4, 3, 6, 5, 1, 0]
```

In [16]:

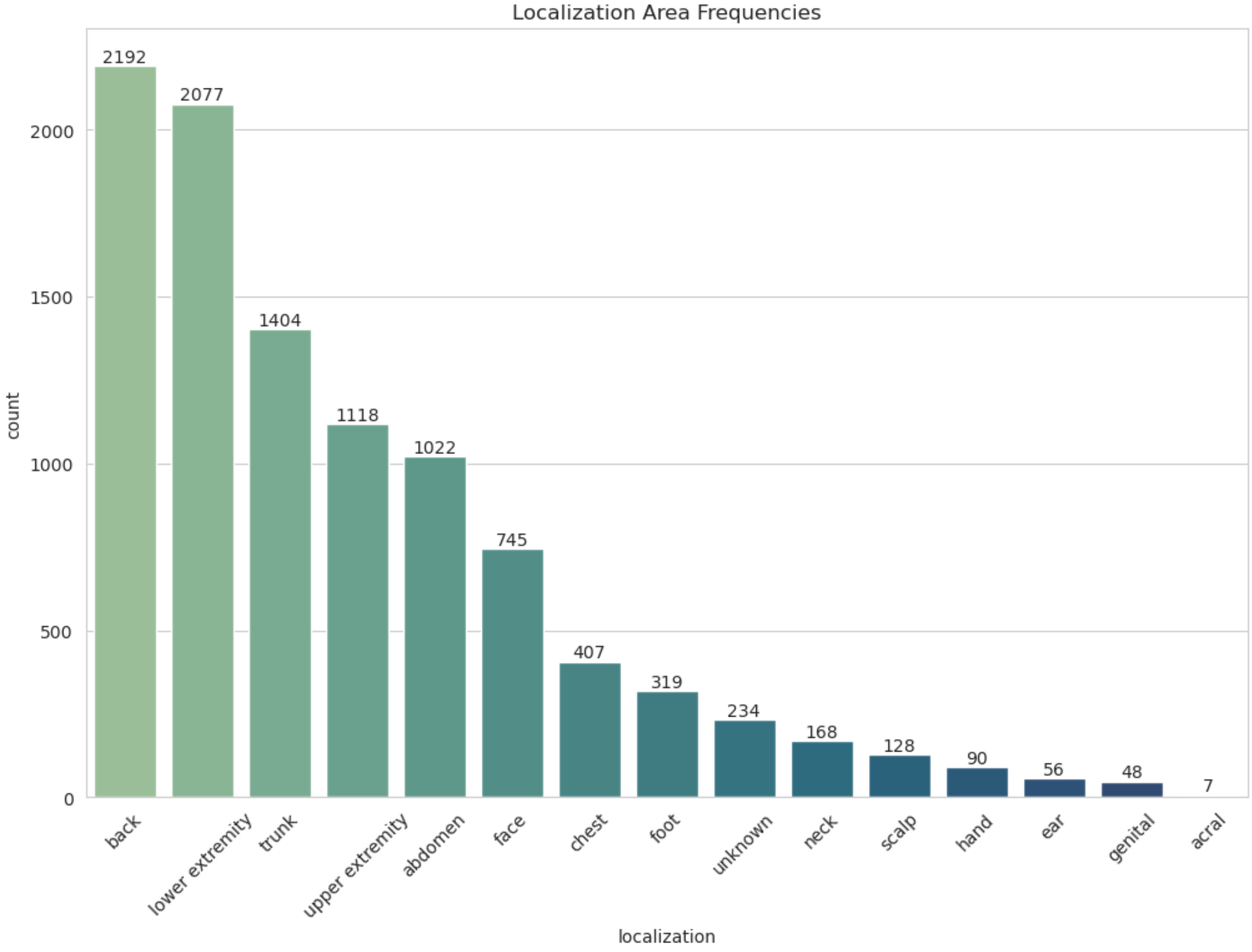
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.countplot(x='dx',hue='sex', data=meta_data, order = meta_data['dx'].value_count
s().index, palette = 'Paired')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Cell Types Frequencies')
plt.xticks(rotation=45)
plt.show()
```





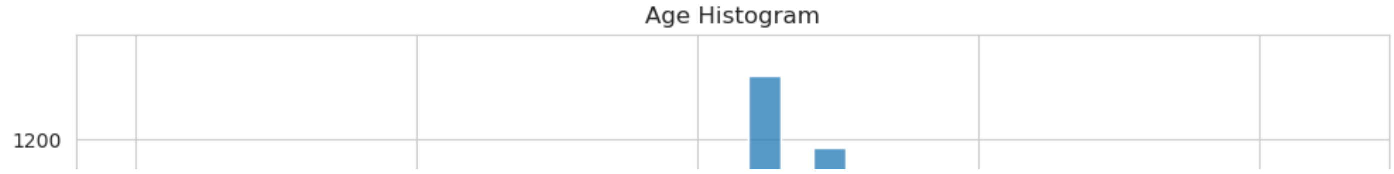
In [17]:

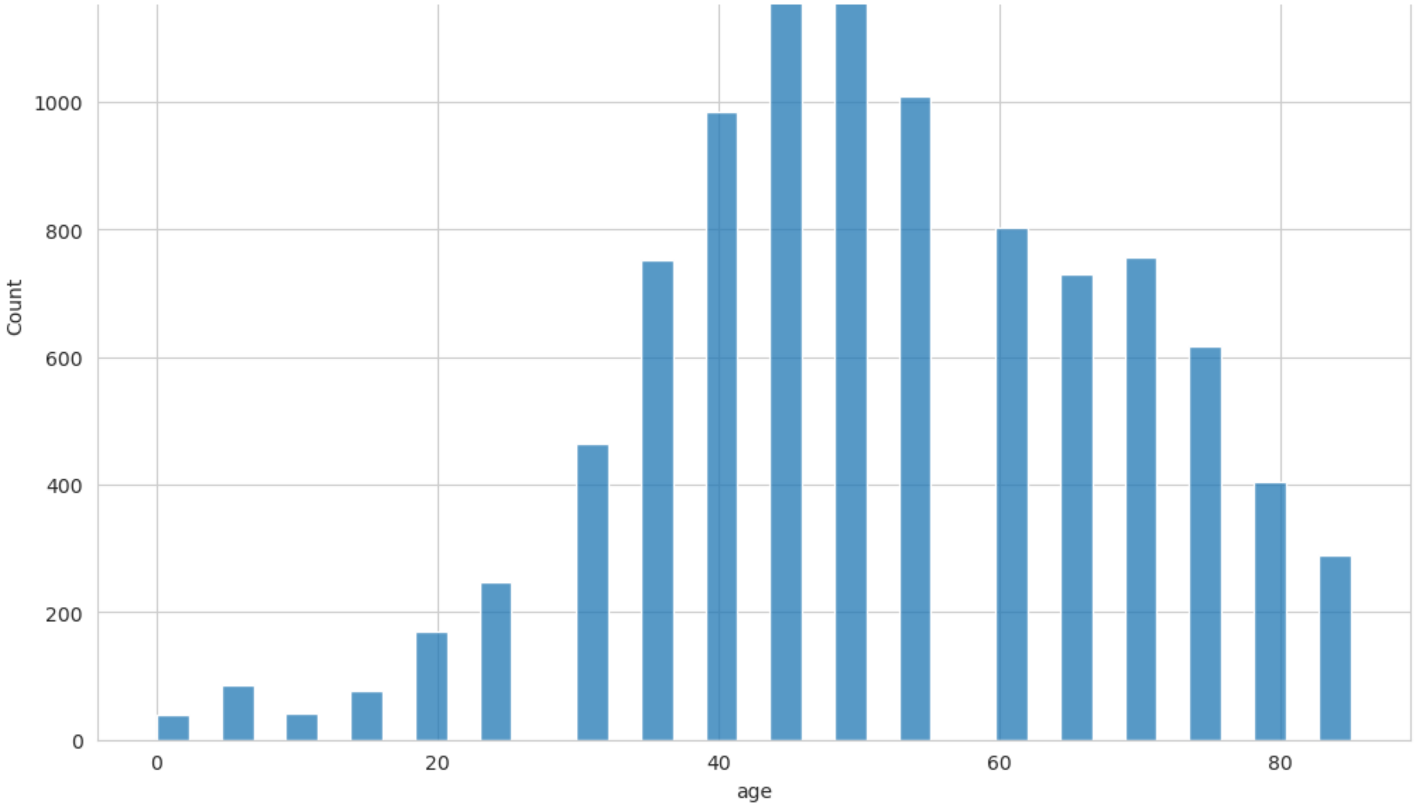
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.countplot(x='localization',data=meta_data, order = meta_data['localization'].val
ue_counts().index, palette = 'crest')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Localization Area Frequencies')
plt.xticks(rotation=45)
plt.show()
```



In [18]:

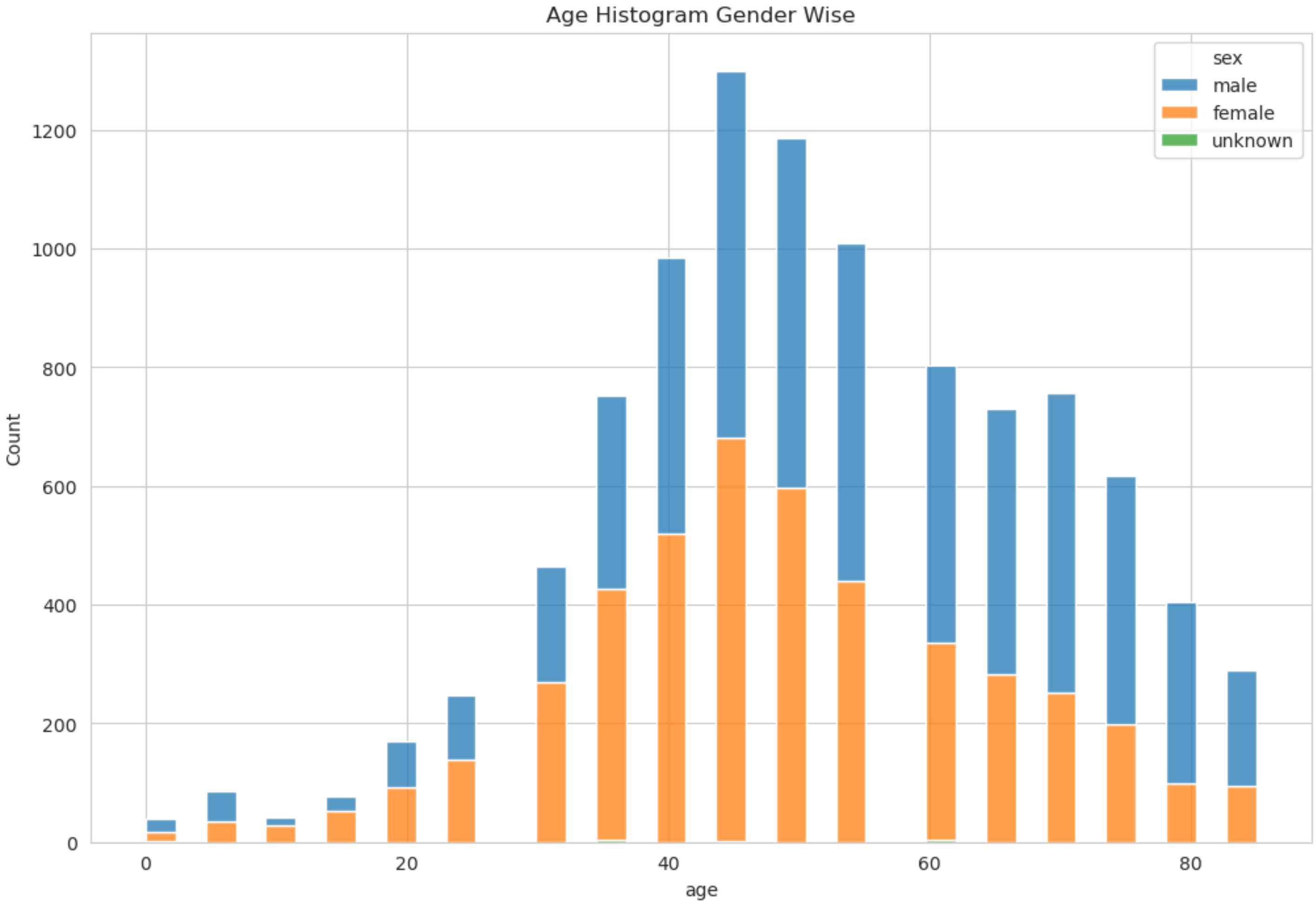
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.histplot(data=meta_data, x='age')
plt.title('Age Histogram')
plt.show()
```





In [19]:

```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.histplot(data=meta_data, x='age',hue='sex',multiple='stack')
plt.title('Age Histogram Gender Wise')
plt.show()
```



In [20]:

```
print(x.shape,y.shape)
# To overcome class imbalace
oversample = RandomOverSampler()
x,y  = oversample.fit_resample(x,y)
print(x.shape,y.shape)
```

```
(10015, 2352) (10015,)
(46935, 2352) (46935,)
```

In [21]:

```
# reshaping the data so that it can be taken by convolution neural network(without disturbing the no. of samples)
x = np.array(x).reshape(-1,28,28,3)
print('Shape of X :',x.shape)
print('Shape of y :',y.shape)
```

```
Shape of X : (46935, 28, 28, 3)
Shape of y : (46935,)
```

In [22]:

```
# Splitting Data
X_train, X_test, Y_train, Y_test = train_test_split(x,y, test_size=0.2, random_state=1)
print(X_train.shape,Y_train.shape)
print(X_test.shape , Y_test.shape)
```

```
(37548, 28, 28, 3) (37548,)
(9387, 28, 28, 3) (9387,)
```

In [23]:

```
model_CNN = Sequential()
model_CNN.add(Conv2D(16, kernel_size = (3,3), input_shape = (28, 28, 3), activation = 'relu', padding = 'same'))
model_CNN.add(MaxPool2D(pool_size = (2,2)))

model_CNN.add(Conv2D(32, kernel_size = (3,3), activation = 'relu', padding = 'same'))
model_CNN.add(MaxPool2D(pool_size = (2,2), padding = 'same'))

model_CNN.add(Conv2D(64, kernel_size = (3,3), activation = 'relu', padding = 'same'))
model_CNN.add(MaxPool2D(pool_size = (2,2), padding = 'same'))
model_CNN.add(Conv2D(128, kernel_size = (3,3), activation = 'relu', padding = 'same'))
model_CNN.add(MaxPool2D(pool_size = (2,2), padding = 'same'))

model_CNN.add(Flatten())
model_CNN.add(Dense(64, activation = 'relu'))
model_CNN.add(Dense(32))
model_CNN.add(Activation(activation='relu'))
model_CNN.add(Dense(16))
model_CNN.add(Activation(activation='relu'))
model_CNN.add(Dense(7))
model_CNN.add(Activation(activation='softmax'))

optimizer = tf.keras.optimizers.Adam(learning_rate = 0.001)

model_CNN.compile(loss = 'sparse_categorical_crossentropy',
                  optimizer = optimizer,
                   metrics = ['accuracy'])
print(model_CNN.summary())
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 16)        448       
                                                                 
 max_pooling2d (MaxPooling2D  (None, 14, 14, 16)       0         
 )                                                               
                                                                 
 conv2d_1 (Conv2D)           (None, 14, 14, 32)        4640      
                                                                 
 max_pooling2d_1 (MaxPooling  (None, 7, 7, 32)         0         
 max_pooling2d_1 (MaxPooling  (None, 7, 7, 32)         0
 2D)

 conv2d_2 (Conv2D)           (None, 7, 7, 64)          18496

 max_pooling2d_2 (MaxPooling  (None, 4, 4, 64)         0
 2D)

 conv2d_3 (Conv2D)           (None, 4, 4, 128)         73856

 max_pooling2d_3 (MaxPooling  (None, 2, 2, 128)        0
 2D)

 flatten (Flatten)           (None, 512)               0

 dense (Dense)               (None, 64)                32832

 dense_1 (Dense)             (None, 32)                2080

 activation (Activation)     (None, 32)                0

 dense_2 (Dense)             (None, 16)                528

 activation_1 (Activation)   (None, 16)                0

 dense_3 (Dense)             (None, 7)                 119

 activation_2 (Activation)   (None, 7)                 0

=================================================================
Total params: 132,999
Trainable params: 132,999
Non-trainable params: 0
_________________________________________________________________
None
```

In [24]:

```python
from tensorflow.keras.callbacks import ReduceLROnPlateau, EarlyStopping
early_stop = EarlyStopping(monitor='val_loss', patience=10, verbose=1, mode='auto')
reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.1, patience=3, verbose=1, mod
e='auto')
history = model_CNN.fit(X_train,
                    Y_train,
                    validation_split=0.2,
                    batch_size = 64,
                    epochs = 50,
                    callbacks = [reduce_lr, early_stop])
```

```
Epoch 1/50
470/470 [==============================] - 11s 7ms/step - loss: 1.7157 - accuracy: 0.3471
- val_loss: 1.2781 - val_accuracy: 0.4830 - lr: 0.0010
Epoch 2/50
470/470 [==============================] - 3s 6ms/step - loss: 1.0987 - accuracy: 0.5657
- val_loss: 0.9553 - val_accuracy: 0.6338 - lr: 0.0010
Epoch 3/50
470/470 [==============================] - 3s 7ms/step - loss: 0.8349 - accuracy: 0.6819
- val_loss: 0.6886 - val_accuracy: 0.7507 - lr: 0.0010
Epoch 4/50
470/470 [==============================] - 3s 6ms/step - loss: 0.6062 - accuracy: 0.7712
- val_loss: 0.7442 - val_accuracy: 0.7342 - lr: 0.0010
Epoch 5/50
470/470 [==============================] - 3s 6ms/step - loss: 0.4719 - accuracy: 0.8209
- val_loss: 0.4136 - val_accuracy: 0.8529 - lr: 0.0010
Epoch 6/50
470/470 [==============================] - 3s 6ms/step - loss: 0.3896 - accuracy: 0.8535
- val_loss: 0.3984 - val_accuracy: 0.8538 - lr: 0.0010
Epoch 7/50
470/470 [==============================] - 3s 6ms/step - loss: 0.3245 - accuracy: 0.8803
- val_loss: 0.3157 - val_accuracy: 0.8830 - lr: 0.0010
Epoch 8/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2754 - accuracy: 0.8990
```

```
- val_loss: 0.3076 - val_accuracy: 0.8850 - lr: 0.0010
Epoch 9/50
470/470 [==============================] - 3s 7ms/step - loss: 0.2296 - accuracy: 0.9164
- val_loss: 0.2591 - val_accuracy: 0.9055 - lr: 0.0010
Epoch 10/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2079 - accuracy: 0.9241
- val_loss: 0.2411 - val_accuracy: 0.9144 - lr: 0.0010
Epoch 11/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2018 - accuracy: 0.9287
- val_loss: 0.2200 - val_accuracy: 0.9252 - lr: 0.0010
Epoch 12/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2000 - accuracy: 0.9314
- val_loss: 0.4627 - val_accuracy: 0.8383 - lr: 0.0010
Epoch 13/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1490 - accuracy: 0.9469
- val_loss: 0.1622 - val_accuracy: 0.9431 - lr: 0.0010
Epoch 14/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1144 - accuracy: 0.9603
- val_loss: 0.1858 - val_accuracy: 0.9395 - lr: 0.0010
Epoch 15/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1433 - accuracy: 0.9494
- val_loss: 0.2750 - val_accuracy: 0.9096 - lr: 0.0010
Epoch 16/50
468/470 [============================>.] - ETA: 0s - loss: 0.1072 - accuracy: 0.9618
Epoch 16: ReduceLROnPlateau reducing learning rate to 0.00010000000474974513.
470/470 [==============================] - 3s 6ms/step - loss: 0.1076 - accuracy: 0.9617
- val_loss: 0.1838 - val_accuracy: 0.9466 - lr: 0.0010
Epoch 17/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0338 - accuracy: 0.9904
- val_loss: 0.1023 - val_accuracy: 0.9727 - lr: 1.0000e-04
Epoch 18/50
470/470 [==============================] - 3s 7ms/step - loss: 0.0184 - accuracy: 0.9956
- val_loss: 0.0986 - val_accuracy: 0.9751 - lr: 1.0000e-04
Epoch 19/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0134 - accuracy: 0.9970
- val_loss: 0.1018 - val_accuracy: 0.9770 - lr: 1.0000e-04
Epoch 20/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0102 - accuracy: 0.9980
- val_loss: 0.1041 - val_accuracy: 0.9760 - lr: 1.0000e-04
Epoch 21/50
462/470 [============================>.] - ETA: 0s - loss: 0.0078 - accuracy: 0.9987
Epoch 21: ReduceLROnPlateau reducing learning rate to 1.0000000474974514e-05.
470/470 [==============================] - 3s 6ms/step - loss: 0.0077 - accuracy: 0.9988
- val_loss: 0.1009 - val_accuracy: 0.9787 - lr: 1.0000e-04
Epoch 22/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0054 - accuracy: 0.9993
- val_loss: 0.1002 - val_accuracy: 0.9792 - lr: 1.0000e-05
Epoch 23/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0050 - accuracy: 0.9994
- val_loss: 0.1014 - val_accuracy: 0.9790 - lr: 1.0000e-05
Epoch 24/50
469/470 [============================>.] - ETA: 0s - loss: 0.0048 - accuracy: 0.9994
Epoch 24: ReduceLROnPlateau reducing learning rate to 1.0000000656873453e-06.
470/470 [==============================] - 3s 6ms/step - loss: 0.0047 - accuracy: 0.9994
- val_loss: 0.1005 - val_accuracy: 0.9790 - lr: 1.0000e-05
Epoch 25/50
470/470 [==============================] - 3s 7ms/step - loss: 0.0045 - accuracy: 0.9995
- val_loss: 0.1013 - val_accuracy: 0.9787 - lr: 1.0000e-06
Epoch 26/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0044 - accuracy: 0.9995
- val_loss: 0.1013 - val_accuracy: 0.9787 - lr: 1.0000e-06
Epoch 27/50
462/470 [============================>.] - ETA: 0s - loss: 0.0044 - accuracy: 0.9995
Epoch 27: ReduceLROnPlateau reducing learning rate to 1.0000001111620805e-07.
470/470 [==============================] - 3s 6ms/step - loss: 0.0044 - accuracy: 0.9995
- val_loss: 0.1013 - val_accuracy: 0.9788 - lr: 1.0000e-06
Epoch 28/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0044 - accuracy: 0.9995
- val_loss: 0.1013 - val_accuracy: 0.9787 - lr: 1.0000e-07
Epoch 28: early stopping
```

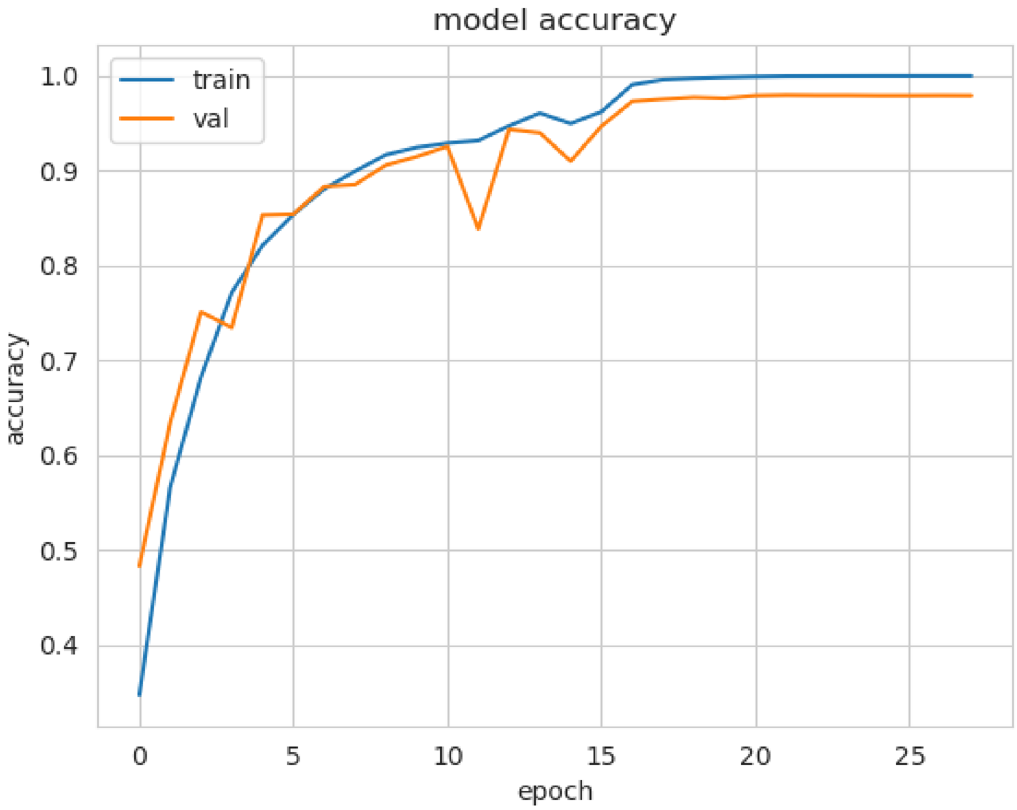
In [25]:

```
results = model_CNN.evaluate(X_test , Y_test, verbose=0)

print("CNN Model Test Results")
print("        Test Loss: {:.5f}".format(results[0]))
print("    Test Accuracy: {:.2f}%".format(results[1] * 100))
```

```
CNN Model Test Results
        Test Loss: 0.10943
    Test Accuracy: 97.72%
```

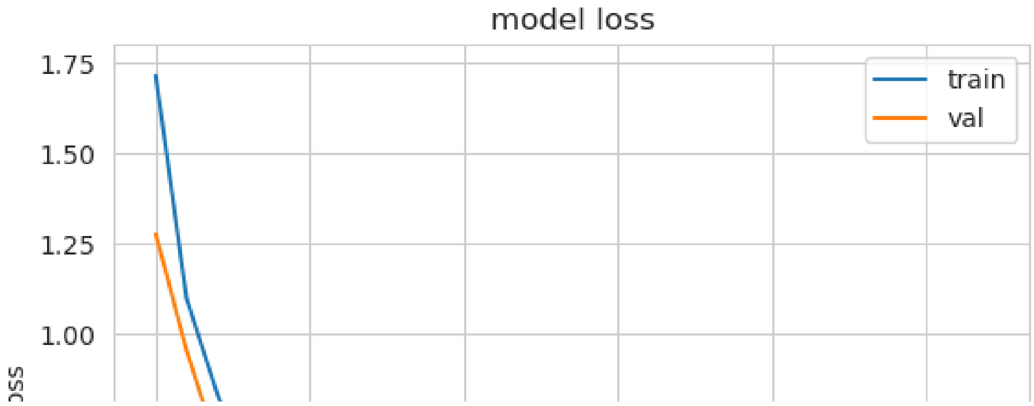
In [26]:

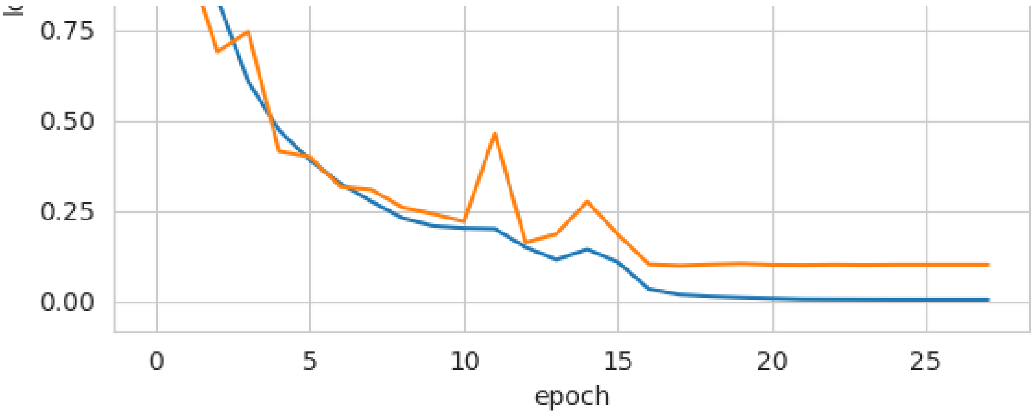
```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
```



In [27]:

```
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper right')
plt.show()
```





In [28]:

```
from sklearn.metrics import confusion_matrix , classification_report

y_true_CNN = list(Y_test)
y_pred_CNN = model_CNN.predict(X_test)
y_pred_CNN = list(map(lambda x: np.argmax(x), y_pred_CNN))
print("Predicting First Ten Rows:")
print('Y Actual Values :' , y_true_CNN[0:10])
print('Y Predicted Values :' , y_pred_CNN[0:10])
```

```
294/294 [==============================] - 1s 2ms/step
Predicting First Ten Rows:
Y Actual Values : [5, 1, 4, 0, 5, 0, 2, 0, 3, 2]
Y Predicted Values : [5, 1, 4, 0, 5, 0, 2, 0, 3, 2]
```

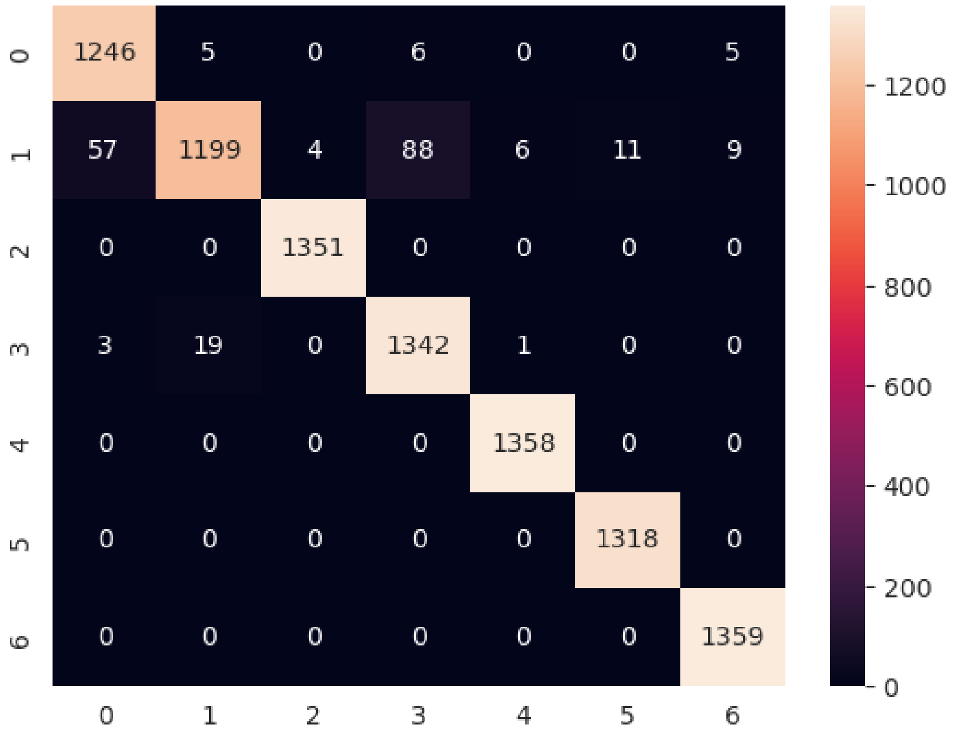
In [29]:

```
cm_CNN = confusion_matrix(y_true_CNN,y_pred_CNN,labels=classes_labels)
print(confusion_matrix(y_true_CNN,y_pred_CNN,labels=classes_labels))
sns.heatmap(cm_CNN, annot = True, fmt='')
```

```
[[1246    5    0    6    0    0    5]
 [  57 1199    4   88    6   11    9]
 [   0    0 1351    0    0    0    0]
 [   3   19    0 1342    1    0    0]
 [   0    0    0    0 1358    0    0]
 [   0    0    0    0    0 1318    0]
 [   0    0    0    0    0    0 1359]]
```

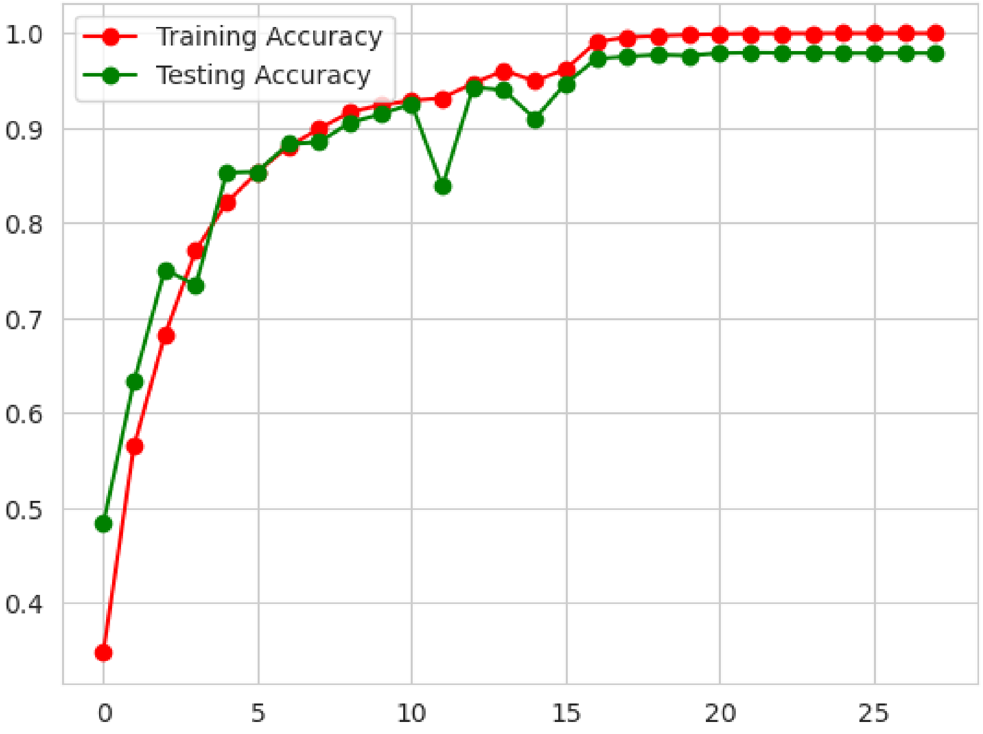
Out[29]:

```
<AxesSubplot:>
```



In [30]:

```
#training acc vs testing acc graph
plt.plot(history.history["accuracy"] , 'ro-' , label = "Training Accuracy")
plt.plot(history.history["val_accuracy"] , 'go-' , label = "Testing Accuracy")
plt.legend()
plt.show()
```



In [31]:

```
#predicting
y_pred_CNN  = model_CNN.predict(X_test)
target_names = [f"{classes[i]}" for i in range(7)]
y_pred_CNN = list(map(lambda x: np.argmax(x), y_pred_CNN))
print("CNN Model Prediction Results")
print(classification_report(Y_test , y_pred_CNN,target_names=target_names))
```

```
294/294 [==============================] - 1s 2ms/step
CNN Model Prediction Results
              precision    recall  f1-score   support

       akiec       0.99      1.00      0.99      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.95      0.99      0.97      1262
          df       1.00      1.00      1.00      1351
          nv       0.98      0.87      0.92      1374
        vasc       0.99      1.00      1.00      1358
         mel       0.93      0.98      0.96      1365

    accuracy                           0.98      9387
   macro avg       0.98      0.98      0.98      9387
weighted avg       0.98      0.98      0.98      9387
```

In [32]:

```
# Layers definitions
from keras import backend as K
for l in range(len(model_CNN.layers)):
    print(l, model_CNN.layers[l])
```

```
0 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f242e2fa2d0>
1 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f23c003a090>
2 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f23bfc5e0d0>
3 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f23bfc5e4d0>
```

```
4 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f242e078590>
5 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f23bfc7ebd0>
6 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f23bfc778d0>
7 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f23bfc85090>
8 <keras.layers.reshaping.flatten.Flatten object at 0x7f23bfa4b9d0>
9 <keras.layers.core.dense.Dense object at 0x7f23bfa4b250>
10 <keras.layers.core.dense.Dense object at 0x7f242e0b3b50>
11 <keras.layers.core.activation.Activation object at 0x7f23bfc69c10>
12 <keras.layers.core.dense.Dense object at 0x7f23bfc5e150>
13 <keras.layers.core.activation.Activation object at 0x7f242e0fd2d0>
14 <keras.layers.core.dense.Dense object at 0x7f23bfc77190>
15 <keras.layers.core.activation.Activation object at 0x7f23bfa4bcd0>
```

In [33]:

```
model_CNN.layers[-2]
```

Out[33]:

```
<keras.layers.core.dense.Dense at 0x7f23bfc77190>
```

In [34]:

```
import os
os.environ["KERAS_BACKEND"] = "tensorflow"
kerasBKED = os.environ["KERAS_BACKEND"]
print(kerasBKED)
```

```
tensorflow
```

Separating Features Layers from the CNN Model

In [35]:

```
import tensorflow as tf
# feature_extractor = tf.keras.Model(inputs=model_CNN.input,
#                                     outputs=model_CNN.get_layer(-2).output)
# output_layers_model =tf.keras.Model(inputs=model_CNN.input, outputs=model_CNN.output)
# cnn_layer_output = model_CNN.layers[-2].output
# cnn_model_features = tf.keras.Model(inputs=model_CNN.input, outputs=cnn_layer_output)
cnn_model_features = tf.keras.Model(inputs=model_CNN.input, outputs=model_CNN.layers[-3]
.output)
```

Extracting Features from CNN Model

In [36]:

```
# Extract features from input data using the CNN model
X_train_cnn = cnn_model_features.predict(X_train)
X_test_cnn = cnn_model_features.predict(X_test)
```

```
1174/1174 [==============================] - 3s 2ms/step
294/294 [==============================] - 1s 2ms/step
```

Integrating CNN with SVM Classifier using Grid Search for Best Perameters

In [37]:

```
import numpy as np
from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV

parameters = {'kernel':['rbf'],
              'C':[1, 10, 100, 1000],
              'gamma':[1e-3, 1e-4]}
```

```
clf = GridSearchCV(SVC(), parameters)
clf.fit(X_train_cnn, Y_train)
# Evaluate the combined CNN-SVM model on a test dataset
svm_accuracy = clf.score(X_test_cnn, Y_test)
print('SVM Accuracy:', svm_accuracy*100)
y_testSVM = clf.predict(X_test_cnn)
```

```
SVM Accuracy: 98.22094385852776
```

In [38]:

```
svm_accuracy = clf.score(X_test_cnn, Y_test)
print('SVM Accuracy:', svm_accuracy*100)
svmclf = clf.best_estimator_
print(svmclf)
svmclf.fit(X_train_cnn, Y_train)
print("Accuracy: {0}".format(accuracy_score(Y_test, y_testSVM)*100))
```

```
SVM Accuracy: 98.22094385852776
SVC(C=10, gamma=0.001)
Accuracy: 98.22094385852776
```

In [39]:

```
y_testSVM = svmclf.predict(X_test_cnn)
from sklearn.metrics import confusion_matrix, classification_report, accuracy_score

print(classification_report(Y_test, y_testSVM,target_names=target_names))
print("Accuracy: {0}".format(accuracy_score(Y_test, y_testSVM)*100))
```

```
              precision    recall  f1-score   support

       akiec       0.99      1.00      1.00      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.97      0.99      0.98      1262
          df       1.00      1.00      1.00      1351
          nv       0.98      0.90      0.94      1374
        vasc       1.00      1.00      1.00      1358
         mel       0.95      0.99      0.97      1365

    accuracy                           0.98      9387
   macro avg       0.98      0.98      0.98      9387
weighted avg       0.98      0.98      0.98      9387

Accuracy: 98.22094385852776
```

In [ ]:

```

```

Integrating CNN with Random Forest Classifier using Grid Search for Best Perameters

In [40]:

```
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV

parameters = {"max_depth": [3, None],
              "max_features": [1, 3, 10],
              "min_samples_split": [1.0, 3, 10],
              "min_samples_leaf": [1, 3, 10],
              "bootstrap": [True, False],
              "criterion": ["gini", "entropy"],
              "n_estimators": [10, 20, 50]}
rclf = RandomForestClassifier()
rgclf = GridSearchCV(rclf, param_grid=parameters)
rgclf.fit(X_train_cnn, Y_train)
RFC_accuracy = rgclf.score(X_test_cnn, Y_test)
```

```
print('Random Forest Classifier Accuracy:', RFC_accuracy*100)
y_test_RF = rgclf.predict(X_test_cnn)
print("Accuracy: {0}".format(accuracy_score(Y_test, y_test_RF)*100))
```

```
Random Forest Classifier Accuracy: 98.46596356663471
Accuracy: 98.46596356663471
```

In [41]:

```
y_test_RF = rgclf.predict(X_test_cnn)
print("Accuracy: {0}".format(accuracy_score(Y_test, y_test_RF)*100))
RFclf = rgclf.best_estimator_
RFclf.fit(X_test_cnn, Y_test)
print(RFclf)
y_testRFC = RFclf.predict(X_test_cnn)
from sklearn.metrics import confusion_matrix, classification_report, accuracy_score

print(classification_report(Y_test, y_testRFC,target_names=target_names))
print("Accuracy: {0}".format(accuracy_score(Y_test, y_testRFC)*100))
```

```
Accuracy: 98.46596356663471
RandomForestClassifier(bootstrap=False, criterion='entropy', max_features=1,
                       min_samples_split=3, n_estimators=50)
              precision    recall  f1-score   support

       akiec       1.00      1.00      1.00      1359
         bcc       1.00      1.00      1.00      1318
         bkl       1.00      1.00      1.00      1262
          df       1.00      1.00      1.00      1351
          nv       1.00      1.00      1.00      1374
        vasc       1.00      1.00      1.00      1358
         mel       1.00      1.00      1.00      1365

    accuracy                           1.00      9387
   macro avg       1.00      1.00      1.00      9387
weighted avg       1.00      1.00      1.00      9387

Accuracy: 100.0
```

Integrating CNN with KNN Classifier using Grid Search for Best Perameters

In [42]:

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import GridSearchCV

parameters = {"n_neighbors": [1, 5, 10,30],
              "weights": ['uniform', 'distance'],
              "metric": ['minkowski','euclidean','manhattan'],
              "algorithm": ['auto', 'ball_tree', 'kd_tree', 'brute']}
kclf = KNeighborsClassifier()
kgclf = GridSearchCV(kclf, param_grid=parameters)
kgclf.fit(X_train_cnn, Y_train)
KNN_accuracy = kgclf.score(X_test_cnn, Y_test)
print('KNN Classifier Accuracy:', KNN_accuracy*100)
```

```
KNN Classifier Accuracy: 98.50857568978374
```

In [43]:

```
y_testKNN = kgclf.predict(X_test_cnn)
KNNclf = kgclf.best_estimator_
print(KNNclf)
from sklearn.metrics import confusion_matrix, classification_report, accuracy_score

print(classification_report(Y_test, y_testKNN,target_names=target_names))
print("Accuracy Score: {0}".format(accuracy_score(Y_test, y_testKNN)*100))
```

```
KNeighborsClassifier(n_neighbors=1)
```

```
              precision    recall  f1-score   support

       akiec       0.99      1.00      1.00      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.96      1.00      0.98      1262
          df       1.00      1.00      1.00      1351
          nv       0.99      0.91      0.95      1374
        vasc       1.00      1.00      1.00      1358
         mel       0.95      0.99      0.97      1365

    accuracy                           0.99      9387
   macro avg       0.99      0.99      0.98      9387
weighted avg       0.99      0.99      0.98      9387

Accuracy Score: 98.50857568978374
```

Integrating CNN with Logistic Regression Classifier using Grid Search for Best Perameters

In [44]:

```python
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import accuracy_score
from sklearn.metrics import confusion_matrix, classification_report, accuracy_score



# Create a logistic regression object
lr = LogisticRegression()

# Define the hyperparameter grid to search over
param_grid = {'C': [0.001, 0.01, 0.1, 1, 10, 100],
              'penalty': ['l1', 'l2']}

# Perform grid search with 5-fold cross-validation
grid_search_LR = GridSearchCV(lr, param_grid, cv=5)
grid_search_LR.fit(X_train_cnn, Y_train)

# Print the best hyperparameters and the corresponding accuracy score
print("Best hyperparameters: ", grid_search_LR.best_params_)
y_test_LR = grid_search_LR.predict(X_test_cnn)

print(classification_report(Y_test, y_test_LR,target_names=target_names))
print("Accuracy: {0}".format(accuracy_score(Y_test, y_test_LR)*100))
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
```

```
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
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    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
```

```
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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    https://scikit-learn.org/stable/modules/preprocessing.html
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
```

```
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
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Warning: lbfgs failed to converge (status=1):
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Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

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Please also refer to the documentation for alternative solver options:
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/opt/conda/lib/python3.7/site-packages/sklearn/model_selection/_validation.py:372: FitFai
ledWarning:
30 fits failed out of a total of 60.
The score on these train-test partitions for these parameters will be set to nan.
If these failures are not expected, you can try to debug them by setting error_score='rai
se'.

Below are more details about the failures:
--------------------------------------------------------------------------------
30 fits failed with the following error:
Traceback (most recent call last):
  File "/opt/conda/lib/python3.7/site-packages/sklearn/model_selection/_validation.py", l
ine 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py", line 1
461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py", line 4
49, in _check_solver
    % (solver, penalty)
ValueError: Solver lbfgs supports only 'l2' or 'none' penalties, got l1 penalty.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/opt/conda/lib/python3.7/site-packages/sklearn/model_selection/_search.py:972: UserWarnin
g: One or more of the test scores are non-finite: [       nan 0.99432689        nan 0.995
33896        nan 0.99579175
        nan 0.99573848        nan 0.99584502        nan 0.99595156]
  category=UserWarning,
```

```
Best hyperparameters:  {'C': 100, 'penalty': 'l2'}
              precision    recall  f1-score   support

       akiec       0.99      1.00      1.00      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.96      0.98      0.97      1262
          df       1.00      1.00      1.00      1351
          nv       0.98      0.90      0.94      1374
        vasc       1.00      1.00      1.00      1358
         mel       0.94      0.98      0.96      1365

    accuracy                           0.98      9387
   macro avg       0.98      0.98      0.98      9387
weighted avg       0.98      0.98      0.98      9387
weighted avg       0.98      0.98      0.98      9587

Accuracy: 98.07180142750612
```

```
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