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)
```

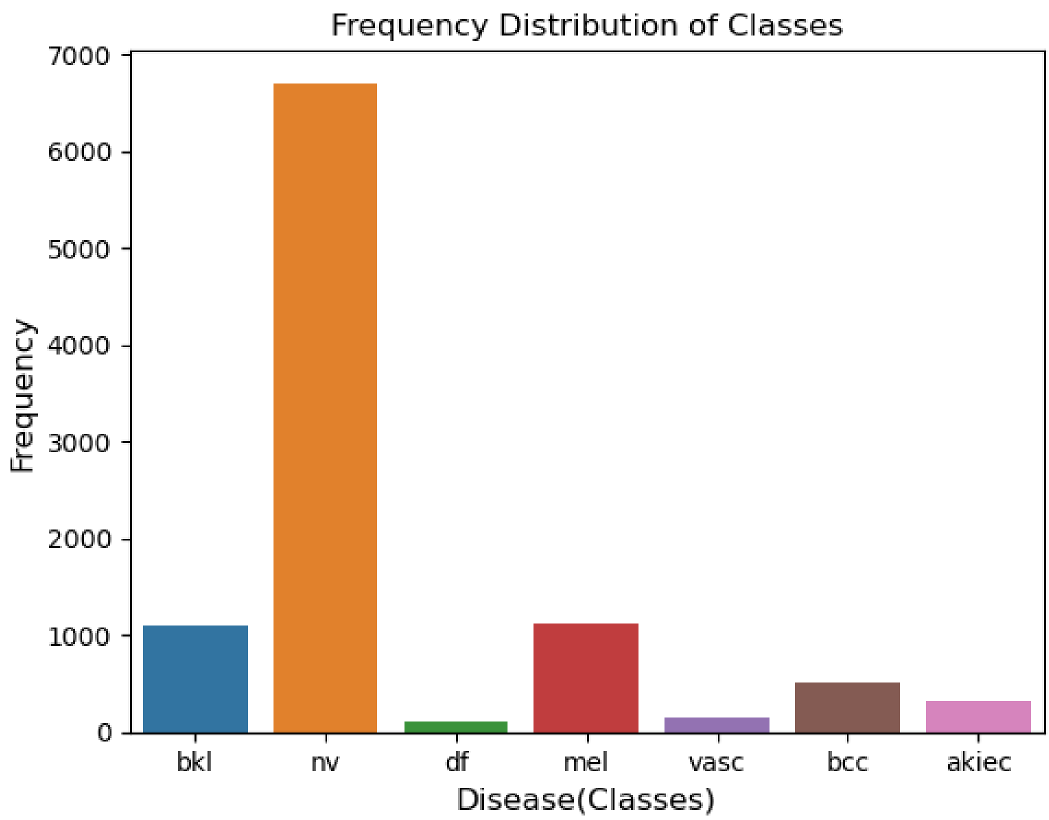
Exploratory Data Analysis

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]:

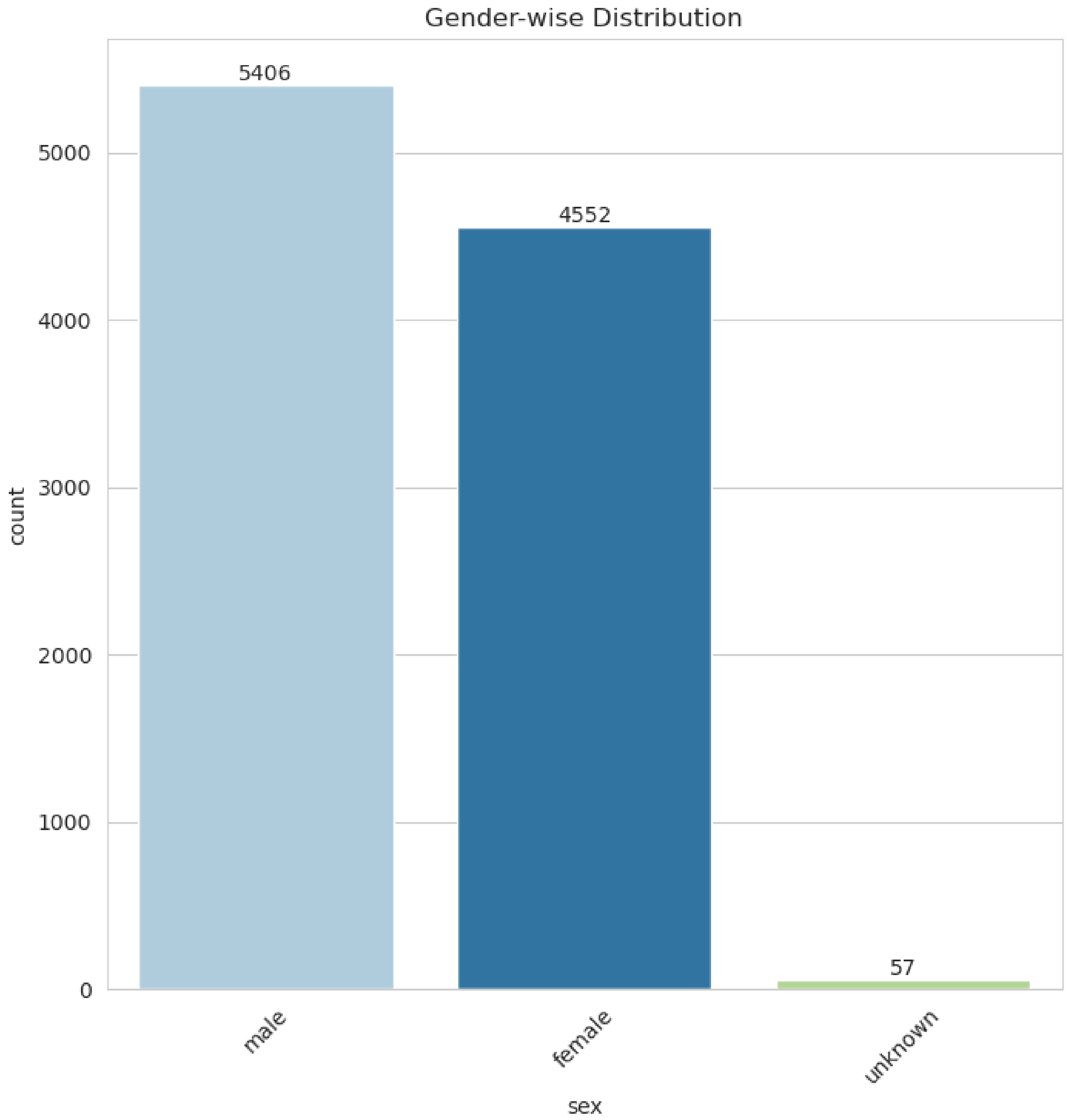
```
Text(0.5, 1.0, 'Frequency Distribution of Classes')
```



In [13]:

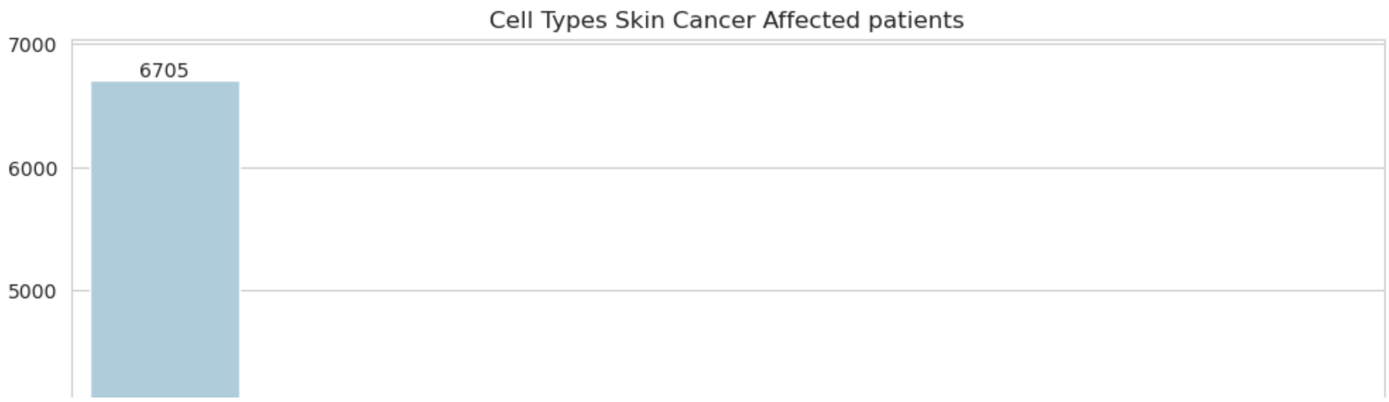
```
sns.set_style('whitegrid')
colors = ['#87ace8','#e3784d', 'green']
fig,axes = plt.subplots(figsize=(8,8))

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)
```

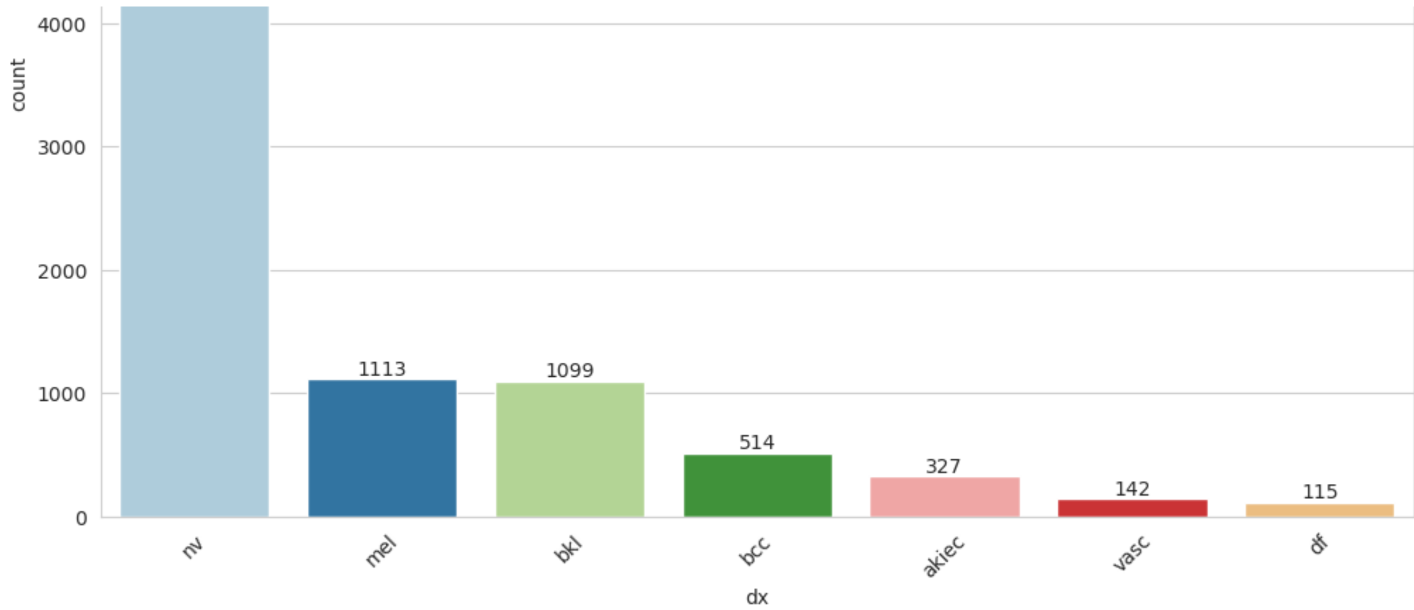
```
plt.show()
```



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 [ ]:

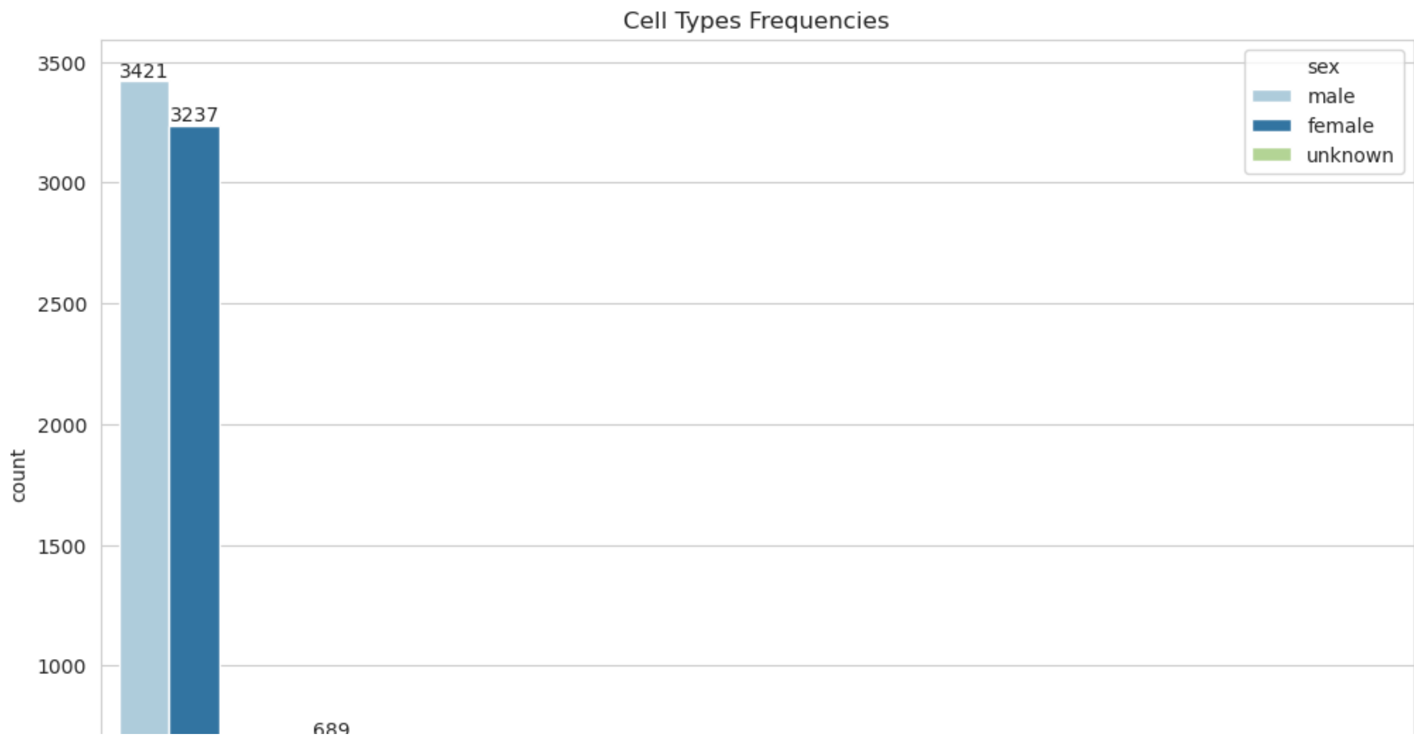
In [15]:

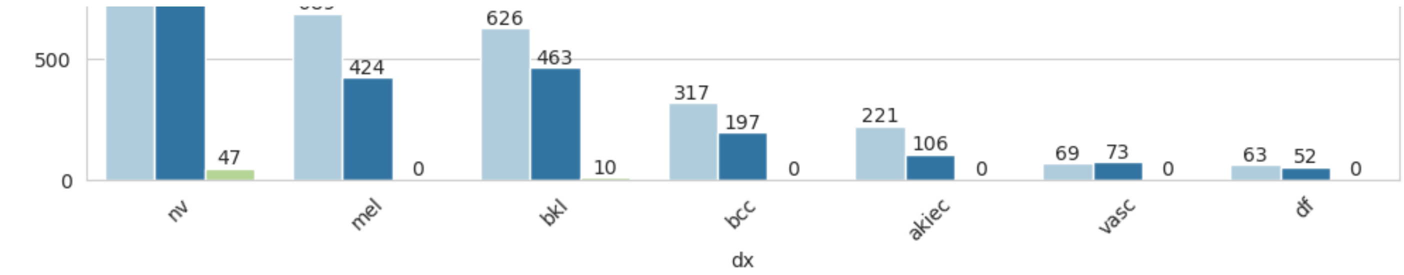
```
classes = {2:'bkl', 4:'nv', 3:'df', 6:'mel', 5:'vasc', 1:'bcc', 0:'akiec'}

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

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

In [16]:

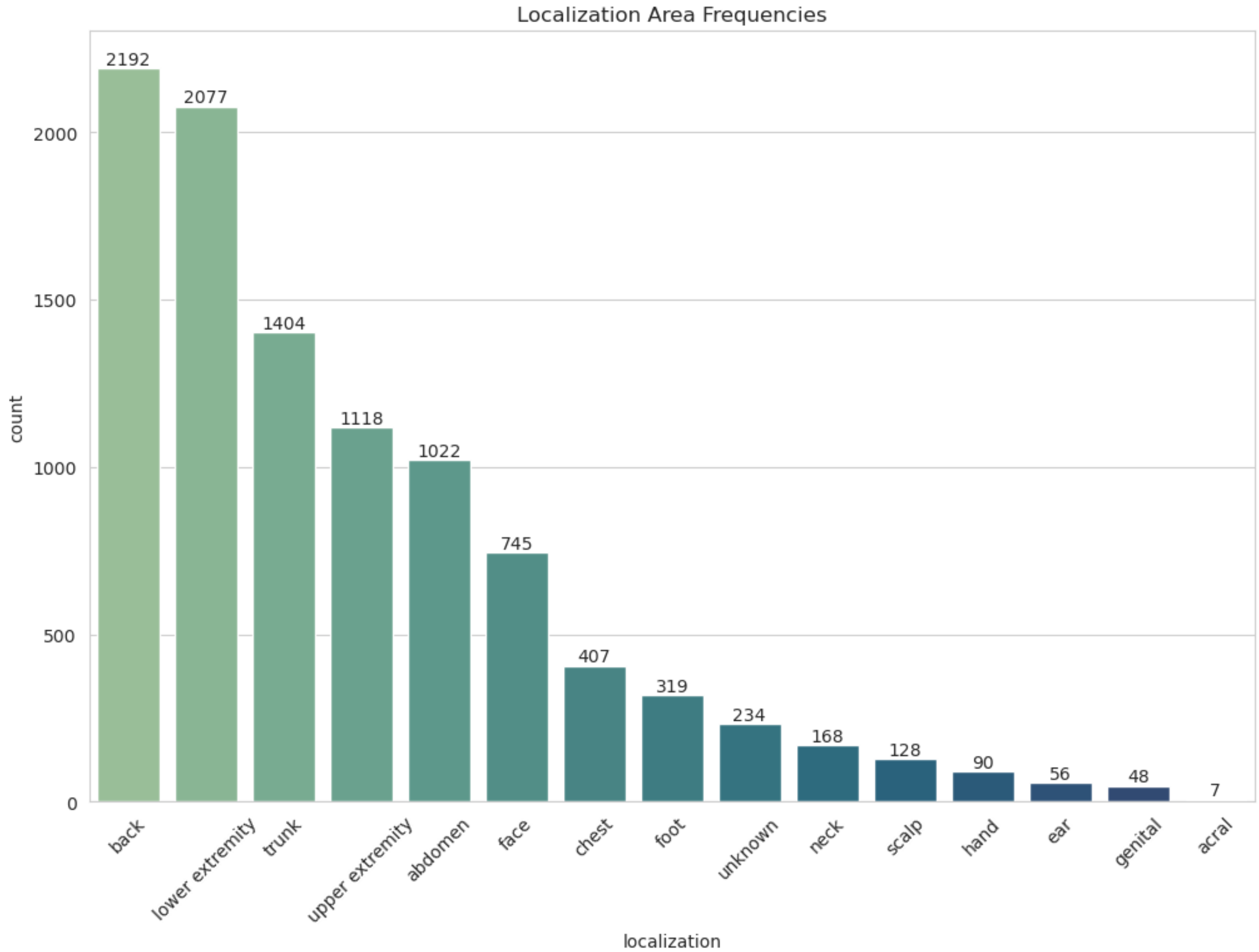
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.countplot(x='dx',hue='sex', data=meta_data, order = meta_data['dx'].value_count
s().index, palette = 'Paired')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Cell Types Frequencies')
plt.xticks(rotation=45)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





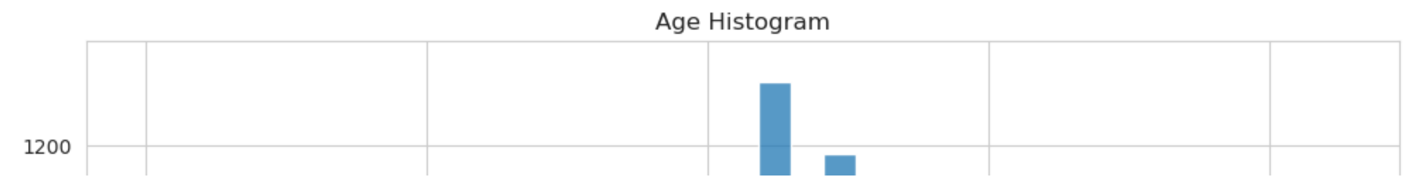
In [17]:

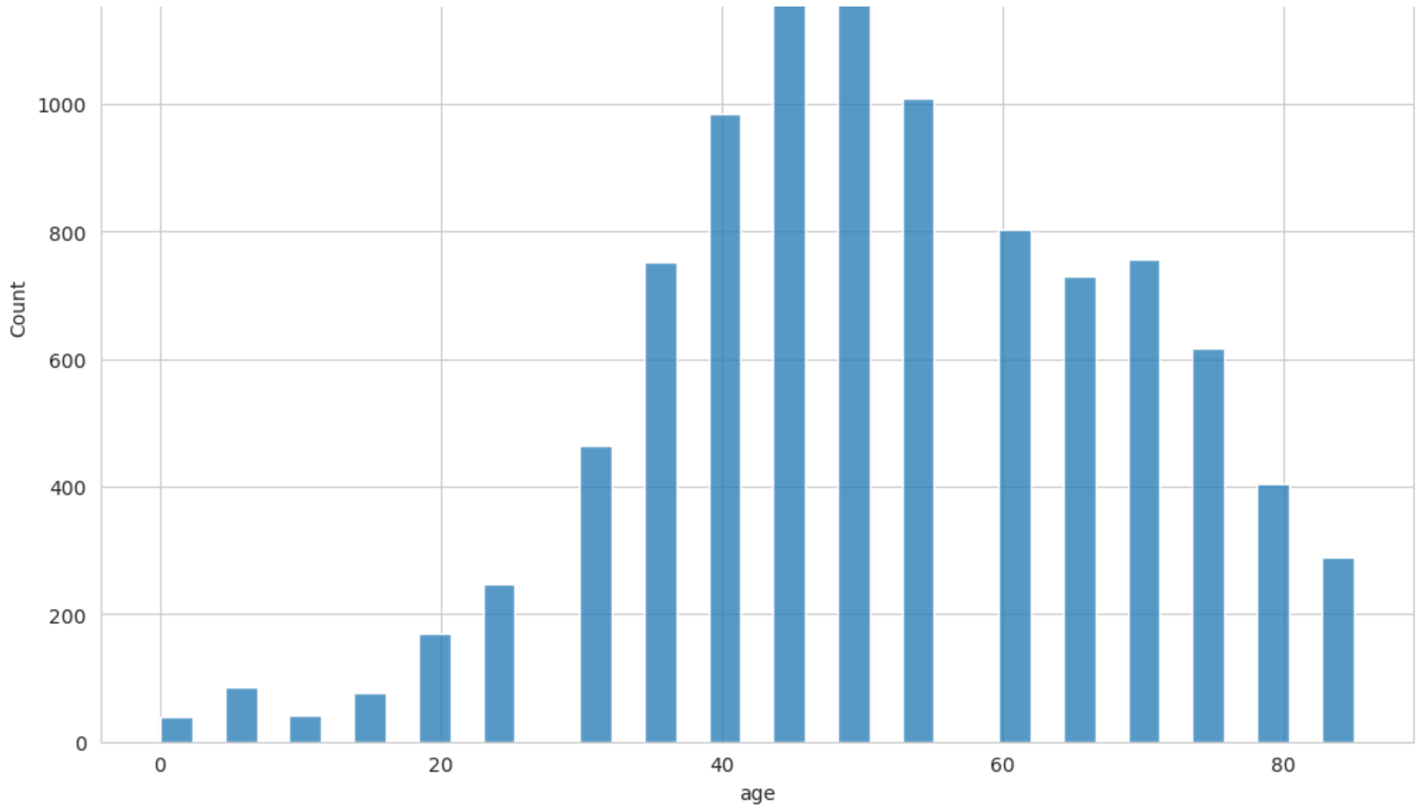
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.countplot(x='localization',data=meta_data, order = meta_data['localization'].val
ue_counts().index, palette = 'crest')
for container in ax.containers:
    ax.bar_label(container)
plt.title('Localization Area Frequencies')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



In [18]:

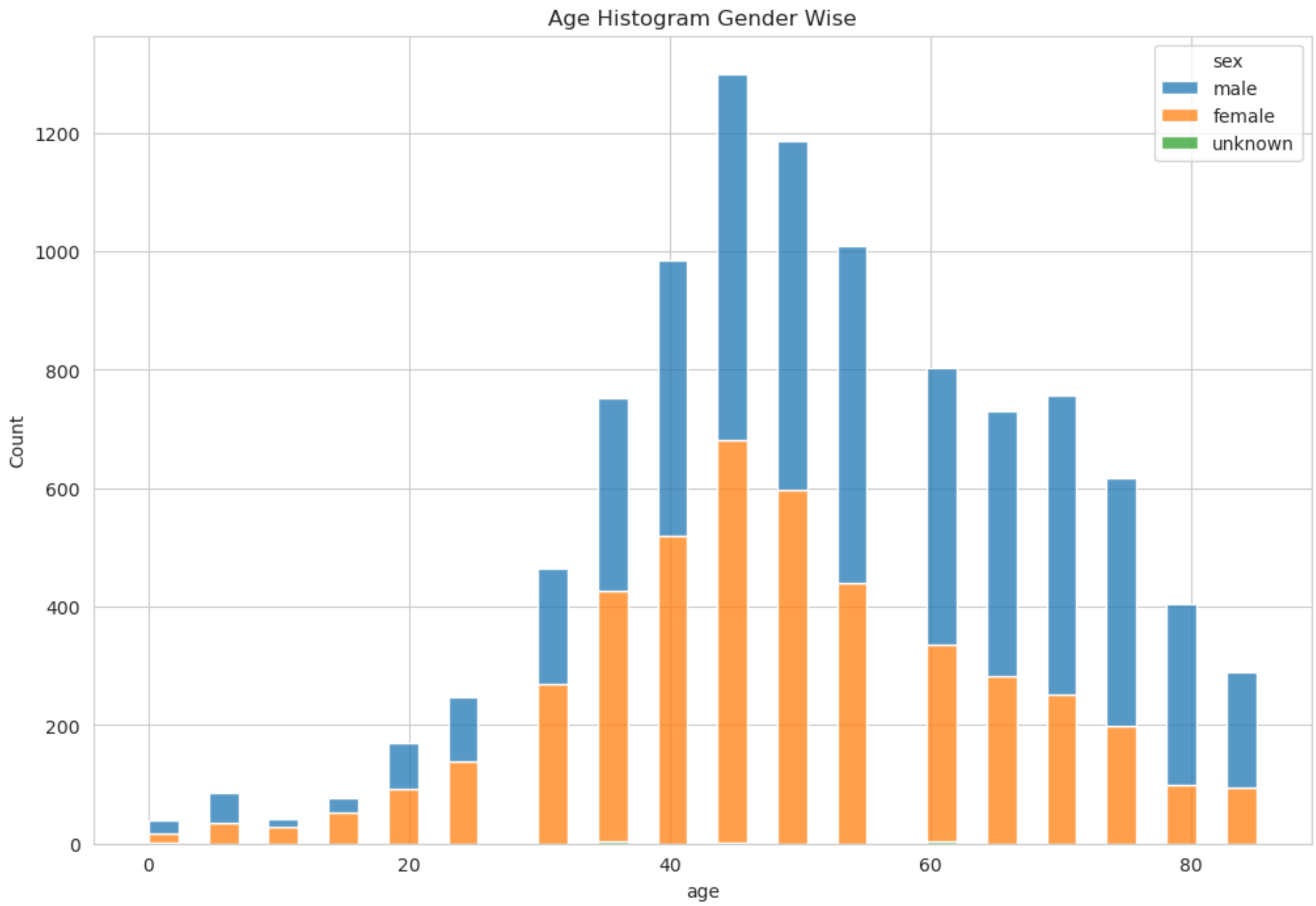
```
sns.set_style('whitegrid')
fig,axes = plt.subplots(figsize=(12,8))
ax = sns.histplot(data=meta_data, x='age')
plt.title('Age Histogram')
plt.show()
```





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 distur
bing 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 = 'r
elu', 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(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         
 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, 7)                 231

 activation_1 (Activation)   (None, 7)                 0

=================================================================
Total params: 132,583
Trainable params: 132,583
Non-trainable params: 0
_________________________________________________________________
None
```

In [24]:

```
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 [==============================] - 12s 6ms/step - loss: 1.3738 - accuracy: 0.5052
- val_loss: 0.9090 - val_accuracy: 0.6686 - lr: 0.0010
Epoch 2/50
470/470 [==============================] - 3s 5ms/step - loss: 0.6964 - accuracy: 0.7383
- val_loss: 0.5437 - val_accuracy: 0.8045 - lr: 0.0010
Epoch 3/50
470/470 [==============================] - 3s 5ms/step - loss: 0.4560 - accuracy: 0.8354
- val_loss: 0.3697 - val_accuracy: 0.8651 - lr: 0.0010
Epoch 4/50
470/470 [==============================] - 3s 6ms/step - loss: 0.3339 - accuracy: 0.8778
- val_loss: 0.3328 - val_accuracy: 0.8727 - lr: 0.0010
Epoch 5/50
470/470 [==============================] - 3s 5ms/step - loss: 0.2635 - accuracy: 0.9048
- val_loss: 0.2747 - val_accuracy: 0.9049 - lr: 0.0010
Epoch 6/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2073 - accuracy: 0.9260
- val_loss: 0.1851 - val_accuracy: 0.9362 - lr: 0.0010
Epoch 7/50
470/470 [==============================] - 3s 5ms/step - loss: 0.1862 - accuracy: 0.9336
- val_loss: 0.3240 - val_accuracy: 0.8792 - lr: 0.0010
Epoch 8/50
470/470 [==============================] - 3s 7ms/step - loss: 0.1674 - accuracy: 0.9391
- val_loss: 0.2133 - val_accuracy: 0.9297 - lr: 0.0010
Epoch 9/50
470/470 [==============================] - ETA: 0s - loss: 0.1333 - accuracy: 0.9513
Epoch 9: ReduceLROnPlateau reducing learning rate to 0.00010000000474974513.
470/470 [==============================] - 3s 5ms/step - loss: 0.1333 - accuracy: 0.9513
- val_loss: 0.2699 - val_accuracy: 0.9097 - lr: 0.0010
```

```
Epoch 10/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0425 - accuracy: 0.9876
- val_loss: 0.0891 - val_accuracy: 0.9726 - lr: 1.0000e-04
Epoch 11/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0249 - accuracy: 0.9937
- val_loss: 0.0818 - val_accuracy: 0.9750 - lr: 1.0000e-04
Epoch 12/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0182 - accuracy: 0.9957
- val_loss: 0.0782 - val_accuracy: 0.9783 - lr: 1.0000e-04
Epoch 13/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0135 - accuracy: 0.9973
- val_loss: 0.0819 - val_accuracy: 0.9787 - lr: 1.0000e-04
Epoch 14/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0102 - accuracy: 0.9981
- val_loss: 0.0814 - val_accuracy: 0.9790 - lr: 1.0000e-04
Epoch 15/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0071 - accuracy: 0.9991
- val_loss: 0.0740 - val_accuracy: 0.9815 - lr: 1.0000e-04
Epoch 16/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0053 - accuracy: 0.9996
- val_loss: 0.0752 - val_accuracy: 0.9816 - lr: 1.0000e-04
Epoch 17/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0036 - accuracy: 0.9999
- val_loss: 0.0843 - val_accuracy: 0.9806 - lr: 1.0000e-04
Epoch 18/50
469/470 [============================>.] - ETA: 0s - loss: 0.0027 - accuracy: 0.9999
Epoch 18: ReduceLROnPlateau reducing learning rate to 1.0000000474974514e-05.
470/470 [==============================] - 3s 5ms/step - loss: 0.0027 - accuracy: 0.9999
- val_loss: 0.0780 - val_accuracy: 0.9827 - lr: 1.0000e-04
Epoch 19/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0018 - accuracy: 0.9999
- val_loss: 0.0883 - val_accuracy: 0.9808 - lr: 1.0000e-05
Epoch 20/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0015 - accuracy: 1.0000
- val_loss: 0.0858 - val_accuracy: 0.9815 - lr: 1.0000e-05
Epoch 21/50
465/470 [============================>.] - ETA: 0s - loss: 0.0014 - accuracy: 1.0000
Epoch 21: ReduceLROnPlateau reducing learning rate to 1.0000000656873453e-06.
470/470 [==============================] - 3s 5ms/step - loss: 0.0014 - accuracy: 1.0000
- val_loss: 0.0874 - val_accuracy: 0.9814 - lr: 1.0000e-05
Epoch 22/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0013 - accuracy: 1.0000
- val_loss: 0.0882 - val_accuracy: 0.9811 - lr: 1.0000e-06
Epoch 23/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0013 - accuracy: 1.0000
- val_loss: 0.0887 - val_accuracy: 0.9810 - lr: 1.0000e-06
Epoch 24/50
463/470 [============================>.] - ETA: 0s - loss: 0.0013 - accuracy: 1.0000
Epoch 24: ReduceLROnPlateau reducing learning rate to 1.0000001111620805e-07.
470/470 [==============================] - 3s 6ms/step - loss: 0.0013 - accuracy: 1.0000
- val_loss: 0.0887 - val_accuracy: 0.9810 - lr: 1.0000e-06
Epoch 25/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0013 - accuracy: 1.0000
- val_loss: 0.0887 - val_accuracy: 0.9808 - lr: 1.0000e-07
Epoch 25: early stopping
```

In [25]:

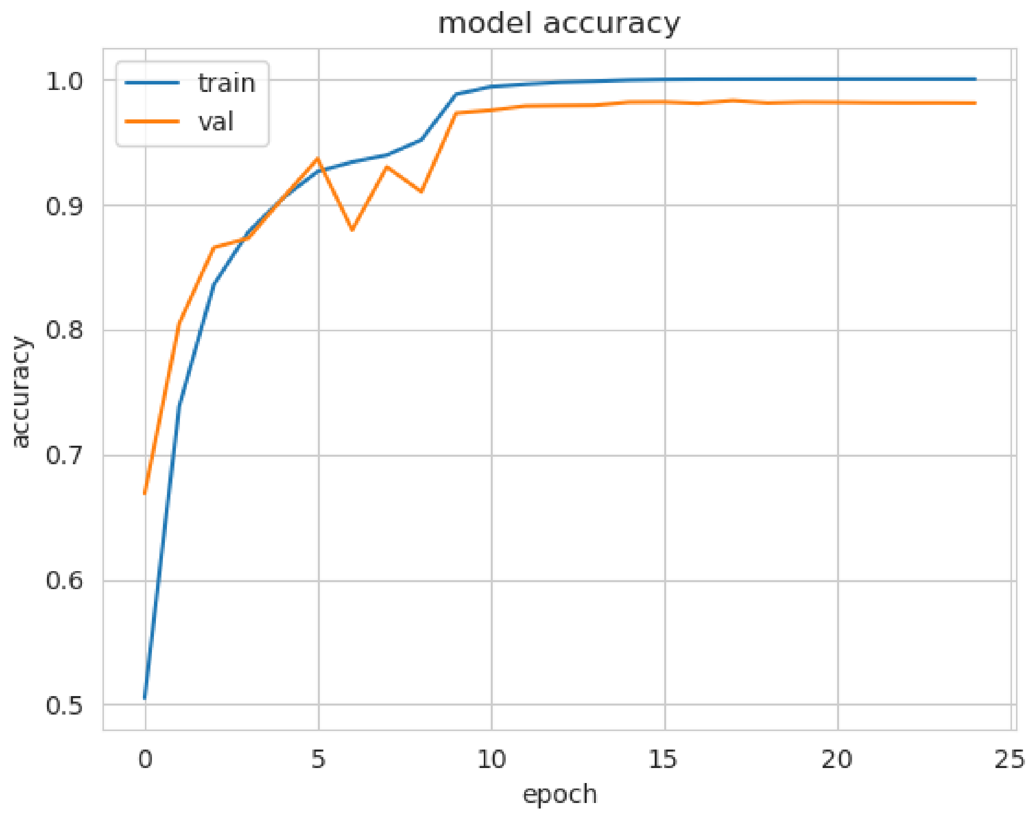
```
results = model_CNN.evaluate(X_test , Y_test, verbose=0)

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: 0.08494
    Test Accuracy: 97.92%
```

In [26]:

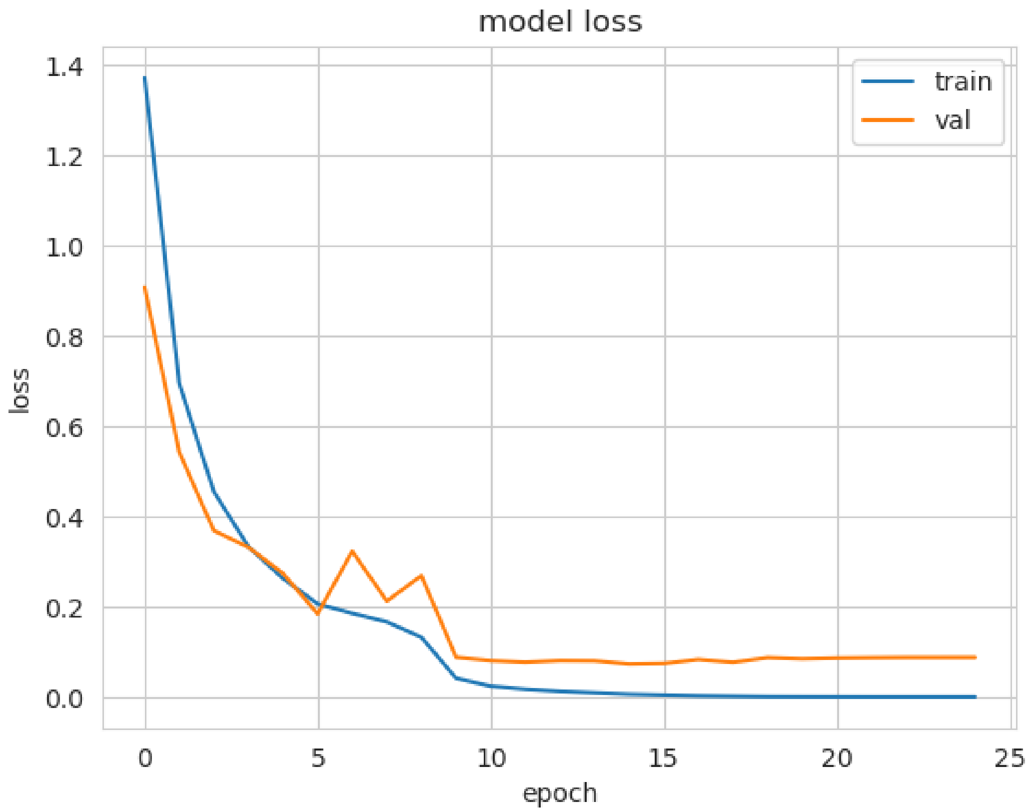
```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
```

```
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]
```

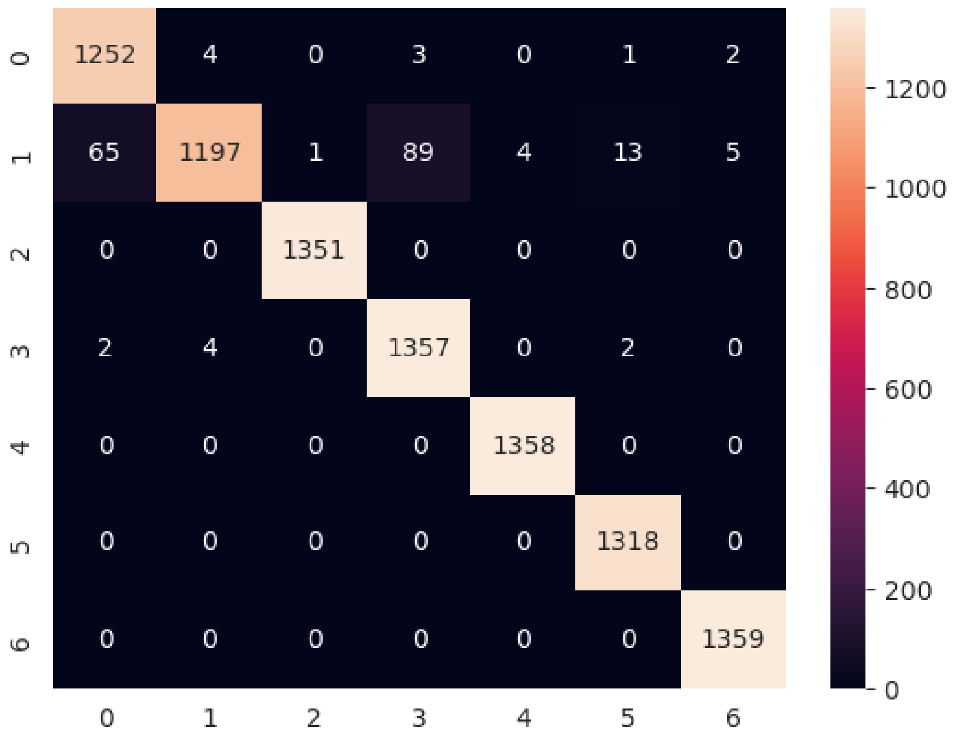
In [29]:

```
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='')
```

```
[[1252    4    0    3    0    1    2]
 [  65 1197    1   89    4   13    5]
 [   0    0 1351    0    0    0    0]
 [   2    4    0 1357    0    2    0]
 [   0    0    0    0 1358    0    0]
 [   0    0    0    0    0 1318    0]
 [   0    0    0    0    0    0 1359]]
```

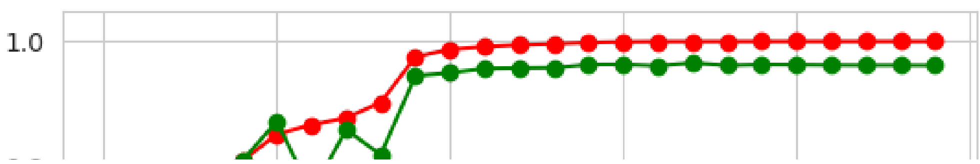
Out[29]:

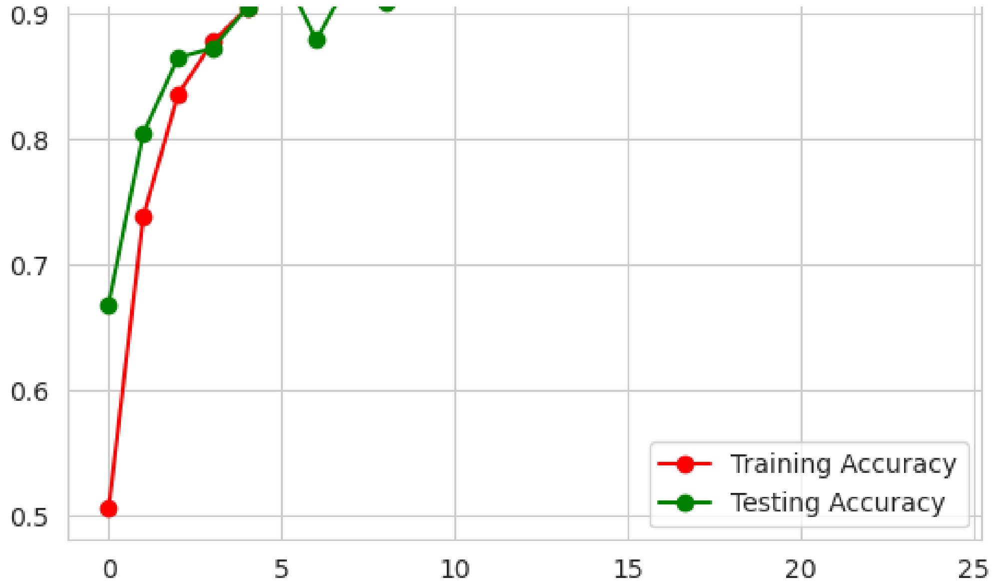
<AxesSubplot:>



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      1.00      1359
         bcc       0.99      1.00      0.99      1318
         bkl       0.95      0.99      0.97      1262
          df       1.00      1.00      1.00      1351
          nv       0.99      0.87      0.93      1374
        vasc       1.00      1.00      1.00      1358
         mel       0.94      0.99      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 0x7f3390d60e50>
1 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f33ff3b7250>
2 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f3390d60710>
3 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f33909bfa90>
4 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f33ff10e790>
5 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3390d75e90>
6 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f3390d82f50>
7 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3390d75550>
8 <keras.layers.reshaping.flatten.Flatten object at 0x7f3390d69cd0>
9 <keras.layers.core.dense.Dense object at 0x7f3390d823d0>
10 <keras.layers.core.dense.Dense object at 0x7f33ff172a50>
11 <keras.layers.core.activation.Activation object at 0x7f3390d6f290>
12 <keras.layers.core.dense.Dense object at 0x7f3390b10950>
13 <keras.layers.core.activation.Activation object at 0x7f33ff1ba1d0>
```

In [33]:

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

Out[33]:

```
<keras.layers.core.dense.Dense at 0x7f3390b10950>
```

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 [==============================] - 2s 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: 98.47661659742197
```

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: 98.47661659742197
SVC(C=10, gamma=0.0001)
Accuracy: 98.47661659742197
```

In [39]:

```python
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       1.00      1.00      1.00      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.96      0.99      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       0.96      0.99      0.97      1365

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

Accuracy: 98.47661659742197
```

In [ ]:

```python

```

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

In [40]:

```python
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: 98.77490145946521
Accuracy: 98.77490145946521
```

In [41]:

```python
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: 98.77490145946521
RandomForestClassifier(bootstrap=False, 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: 98.52988175135826
```

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

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

Accuracy Score: 98.52988175135826
```

Integrating CNN with Logistic Regression Classifier using Grid Search

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

In [44]:

```
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.

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/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
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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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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
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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
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
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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
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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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  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
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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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):
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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
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
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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
Please also refer to the documentation for alternative solver options:
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  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
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    https://scikit-learn.org/stable/modules/preprocessing.html
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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
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:
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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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/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 0.99581836        nan 0.996
19124        nan 0.99635105
        nan 0.99643095        nan 0.99640431        nan 0.99643095]
  category=UserWarning,
```

```
Best hyperparameters:  {'C': 1, 'penalty': 'l2'}
              precision    recall  f1-score   support

       akiec       1.00      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       0.99      0.92      0.95      1374
        vasc       1.00      1.00      1.00      1358
         mel       0.96      0.99      0.98      1365

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

Accuracy: 98.60445296686908
```

```
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In [ ]:

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