In [91]:

```
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
```

In [92]:

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

Out[92]:

	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

In [93]:

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

Out[93]:

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

In [94]:

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

In [95]:

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

Out[95]:

```
0
```

In [96]:

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

Out[96]:

	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

	lesion_id	image_id	dx	dx_type	age	sex	localization
4	HAM_0001466	ISIC_0031633	bkl	histo	75.0	male	ear

In [97]:

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

Out[97]:

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

In [98]:

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

In [99]:

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

Out[99]:

```
0
```

In [100]:

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

Out[100]:

	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 [101]:

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

Out[101]:

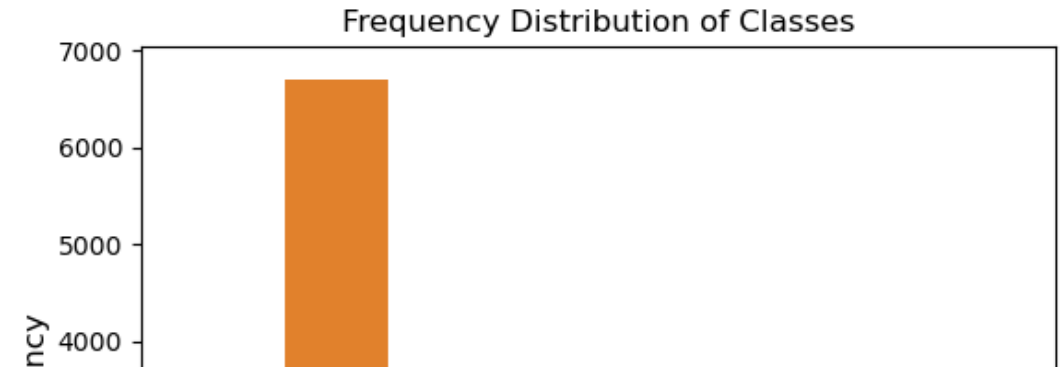
```
array(['bkl', 'nv', 'df', 'mel', 'vasc', 'bcc', 'akiec'], dtype=object)
```

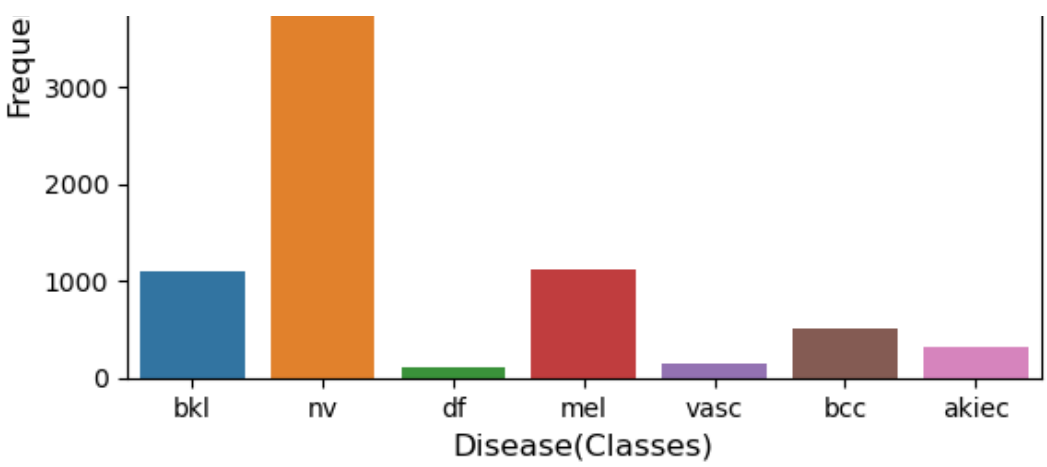
In [102]:

```
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[102]:

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





In [103]:

```
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 [104]:

```
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 [105]:

```
# 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 [106]:

```
# 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 [107]:

```
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_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8 (Conv2D)           (None, 28, 28, 16)        448

 max_pooling2d_8 (MaxPooling  (None, 14, 14, 16)       0
 2D)

 conv2d_9 (Conv2D)           (None, 14, 14, 32)        4640

 max_pooling2d_9 (MaxPooling  (None, 7, 7, 32)         0
 2D)

 conv2d_10 (Conv2D)          (None, 7, 7, 64)          18496

 max_pooling2d_10 (MaxPoolin  (None, 4, 4, 64)         0
 g2D)

 conv2d_11 (Conv2D)          (None, 4, 4, 128)         73856

 max_pooling2d_11 (MaxPoolin  (None, 2, 2, 128)        0
 g2D)

 flatten_2 (Flatten)         (None, 512)               0

 dense_6 (Dense)             (None, 64)                32832

 dense_7 (Dense)             (None, 32)                2080

 activation_4 (Activation)   (None, 32)                0

 dense_8 (Dense)             (None, 7)                 231

 activation_5 (Activation)   (None, 7)                 0

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

In [108]:

```
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 [==============================] - 5s 6ms/step - loss: 1.8727 - accuracy: 0.4563
- val_loss: 1.0033 - val_accuracy: 0.6270 - lr: 0.0010
Epoch 2/50
470/470 [==============================] - 3s 6ms/step - loss: 0.8683 - accuracy: 0.6741
- val_loss: 0.7102 - val_accuracy: 0.7502 - lr: 0.0010
Epoch 3/50
470/470 [==============================] - 3s 5ms/step - loss: 0.6263 - accuracy: 0.7668
- val_loss: 0.5594 - val_accuracy: 0.7924 - lr: 0.0010
Epoch 4/50
470/470 [==============================] - 3s 5ms/step - loss: 0.4923 - accuracy: 0.8184
- val_loss: 0.4800 - val_accuracy: 0.8112 - lr: 0.0010
Epoch 5/50
470/470 [==============================] - 3s 5ms/step - loss: 0.3760 - accuracy: 0.8638
- val_loss: 0.3858 - val_accuracy: 0.8571 - lr: 0.0010
Epoch 6/50
470/470 [==============================] - 3s 6ms/step - loss: 0.3122 - accuracy: 0.8880
- val_loss: 0.2938 - val_accuracy: 0.8892 - lr: 0.0010
Epoch 7/50
470/470 [==============================] - 3s 5ms/step - loss: 0.2424 - accuracy: 0.9133
- val_loss: 0.2317 - val_accuracy: 0.9197 - lr: 0.0010
Epoch 8/50
470/470 [==============================] - 3s 6ms/step - loss: 0.2223 - accuracy: 0.9200
- val_loss: 0.2686 - val_accuracy: 0.9049 - lr: 0.0010
Epoch 9/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1883 - accuracy: 0.9344
- val_loss: 0.2028 - val_accuracy: 0.9274 - lr: 0.0010
Epoch 10/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1756 - accuracy: 0.9374
- val_loss: 0.3365 - val_accuracy: 0.8742 - lr: 0.0010
Epoch 11/50
470/470 [==============================] - 3s 5ms/step - loss: 0.1810 - accuracy: 0.9353
- val_loss: 0.1792 - val_accuracy: 0.9390 - lr: 0.0010
Epoch 12/50
470/470 [==============================] - 3s 5ms/step - loss: 0.1181 - accuracy: 0.9580
- val_loss: 0.1799 - val_accuracy: 0.9454 - lr: 0.0010
Epoch 13/50
470/470 [==============================] - 3s 5ms/step - loss: 0.1393 - accuracy: 0.9514
- val_loss: 0.3115 - val_accuracy: 0.9115 - lr: 0.0010
Epoch 14/50
470/470 [==============================] - 3s 5ms/step - loss: 0.1483 - accuracy: 0.9479
- val_loss: 0.1667 - val_accuracy: 0.9427 - lr: 0.0010
Epoch 15/50
470/470 [==============================] - 3s 6ms/step - loss: 0.1204 - accuracy: 0.9584
- val_loss: 0.1893 - val_accuracy: 0.9430 - lr: 0.0010
Epoch 16/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0979 - accuracy: 0.9651
- val_loss: 0.2536 - val_accuracy: 0.9297 - lr: 0.0010
Epoch 17/50
463/470 [============================>.] - ETA: 0s - loss: 0.1217 - accuracy: 0.9590
Epoch 17: ReduceLROnPlateau reducing learning rate to 0.00010000000474974513.
470/470 [==============================] - 3s 5ms/step - loss: 0.1208 - accuracy: 0.9593
- val_loss: 0.2010 - val_accuracy: 0.9509 - lr: 0.0010
Epoch 18/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0190 - accuracy: 0.9944
- val_loss: 0.1004 - val_accuracy: 0.9748 - lr: 1.0000e-04
Epoch 19/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0100 - accuracy: 0.9980
- val_loss: 0.1081 - val_accuracy: 0.9752 - lr: 1.0000e-04
Epoch 20/50
470/470 [==============================] - 3s 7ms/step - loss: 0.0071 - accuracy: 0.9989
- val_loss: 0.1026 - val_accuracy: 0.9770 - lr: 1.0000e-04
Epoch 21/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0053 - accuracy: 0.9993
- val_loss: 0.0992 - val_accuracy: 0.9780 - lr: 1.0000e-04
Epoch 22/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0040 - accuracy: 0.9996
- val_loss: 0.1058 - val_accuracy: 0.9783 - lr: 1.0000e-04
Epoch 23/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0030 - accuracy: 0.9998
- val_loss: 0.1022 - val_accuracy: 0.9788 - lr: 1.0000e-04
```

```
Epoch 24/50
463/470 [============================>.] - ETA: 0s - loss: 0.0023 - accuracy: 0.9998
Epoch 24: ReduceLROnPlateau reducing learning rate to 1.0000000474974514e-05.
470/470 [==============================] - 3s 5ms/step - loss: 0.0023 - accuracy: 0.9998
- val_loss: 0.1102 - val_accuracy: 0.9783 - lr: 1.0000e-04
Epoch 25/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0016 - accuracy: 0.9999
- val_loss: 0.1094 - val_accuracy: 0.9782 - lr: 1.0000e-05
Epoch 26/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0015 - accuracy: 0.9999
- val_loss: 0.1095 - val_accuracy: 0.9784 - lr: 1.0000e-05
Epoch 27/50
467/470 [============================>.] - ETA: 0s - loss: 0.0014 - accuracy: 0.9999
Epoch 27: ReduceLROnPlateau reducing learning rate to 1.0000000656873453e-06.
470/470 [==============================] - 3s 6ms/step - loss: 0.0014 - accuracy: 0.9999
- val_loss: 0.1104 - val_accuracy: 0.9784 - lr: 1.0000e-05
Epoch 28/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0013 - accuracy: 0.9999
- val_loss: 0.1105 - val_accuracy: 0.9783 - lr: 1.0000e-06
Epoch 29/50
470/470 [==============================] - 3s 5ms/step - loss: 0.0013 - accuracy: 0.9999
- val_loss: 0.1106 - val_accuracy: 0.9783 - lr: 1.0000e-06
Epoch 30/50
462/470 [============================>.] - ETA: 0s - loss: 0.0013 - accuracy: 0.9999
Epoch 30: ReduceLROnPlateau reducing learning rate to 1.0000001111620805e-07.
470/470 [==============================] - 3s 6ms/step - loss: 0.0013 - accuracy: 0.9999
- val_loss: 0.1105 - val_accuracy: 0.9783 - lr: 1.0000e-06
Epoch 31/50
470/470 [==============================] - 3s 6ms/step - loss: 0.0013 - accuracy: 0.9999
- val_loss: 0.1106 - val_accuracy: 0.9783 - lr: 1.0000e-07
Epoch 31: early stopping
```

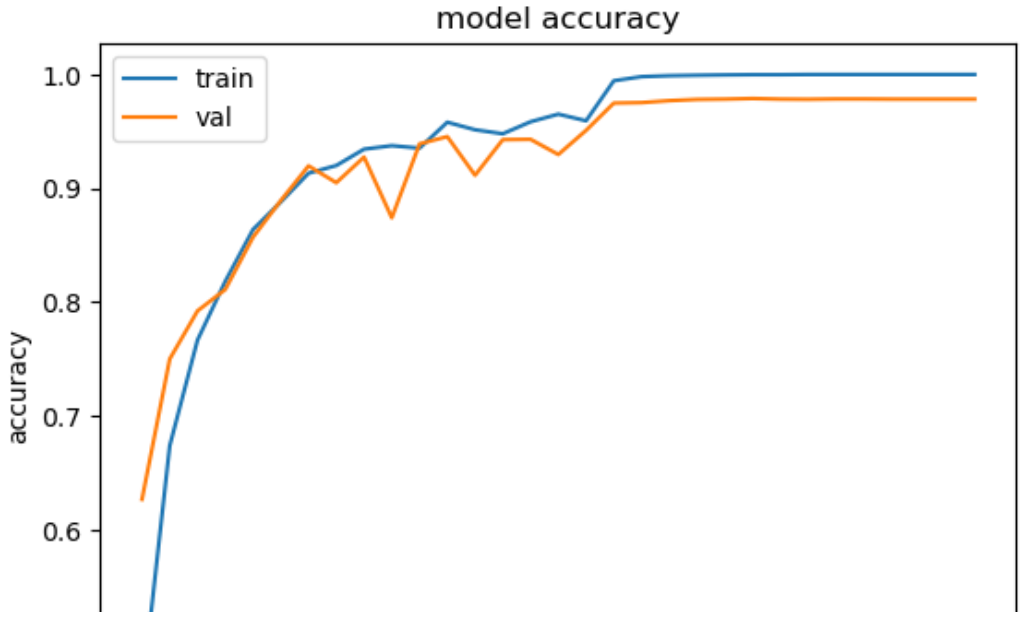
In [109]:

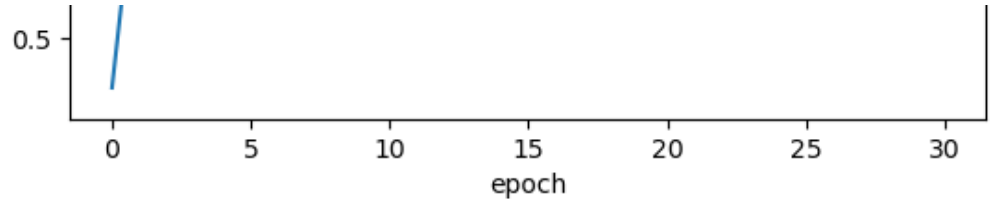
```
results = model_CNN.evaluate(X_test , Y_test, verbose=0)

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

```
    Test Loss: 0.13174
Test Accuracy: 97.87%
```

In [110]:

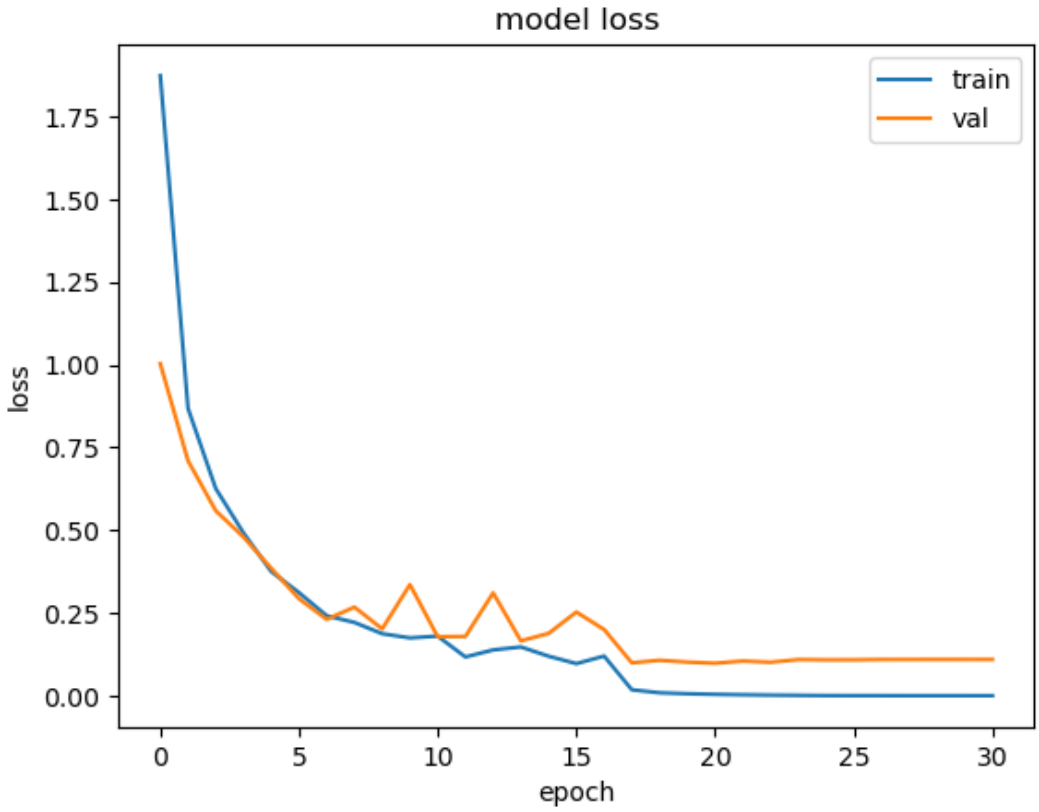
```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
```





In [111]:

```
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 [112]:

```
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('Y Actual Values :' , y_true_CNN[0:10])
print('Y Predicted Values :' , y_pred_CNN[0:10])
```

```
294/294 [==============================] - 1s 2ms/step
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 [113]:

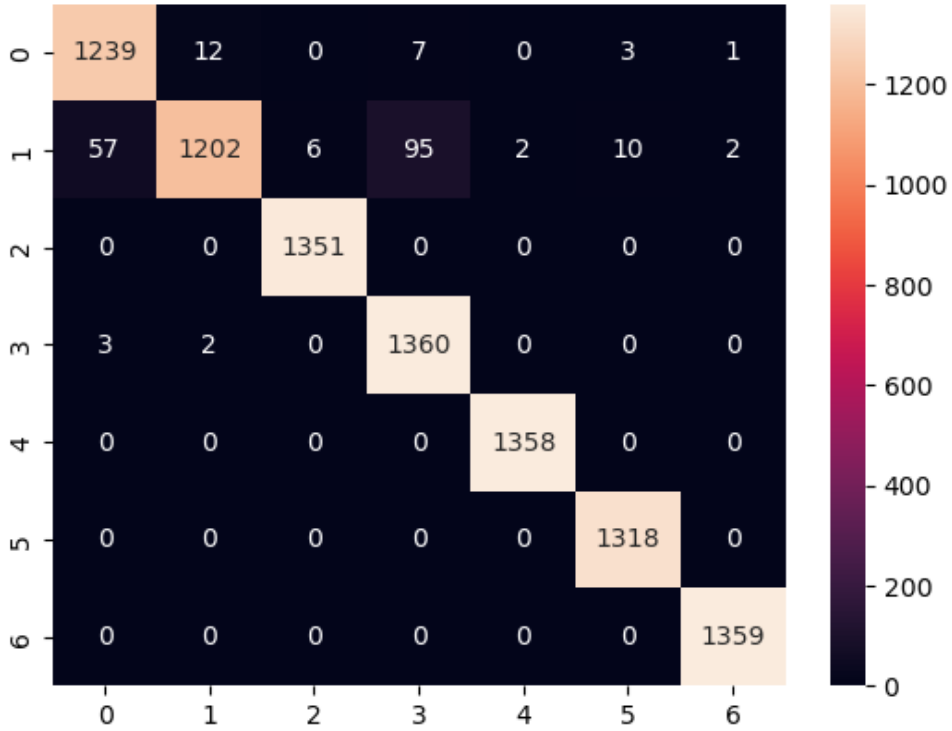
```
cm_CNN = confusion_matrix(y_true_CNN,y_pred_CNN,labels=classes_labels)
print(confusion_matrix(y_true_CNN,y_pred_CNN,labels=classes_labels))
sns.heatmap(cm_CNN, annot = True, fmt='')
```

```
[[1239   12    0    7    0    3    1]
 [  57 1202    6   95    2   10    2]
 [   0    0 1351    0    0    0    0]
 [   3    2    0 1360    0    0    0]
 [   0    0    0    0 1358    0    0]
 [   0    0    0    0    0 1318    0]
```

```
 [    0     0     0     0     0     0 1359]]
```

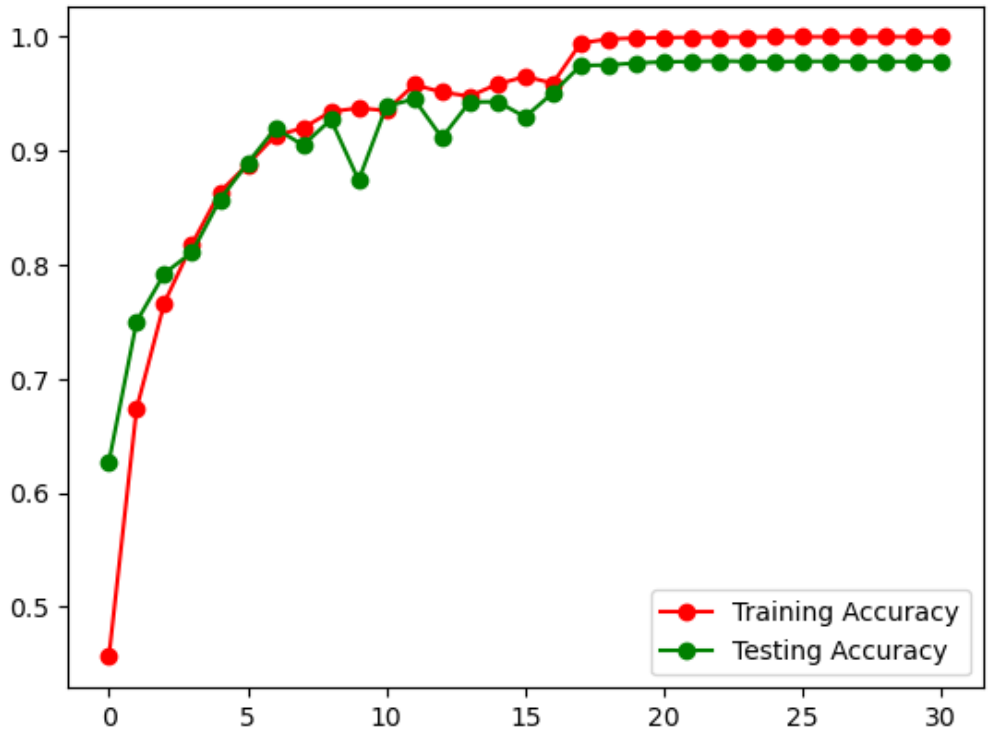
Out[113]:

<AxesSubplot:>



In [114]:

```
#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 [115]:

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

```
print(classification_report(Y_test , y_pred_CNN,target_names=target_names))
```

```
294/294 [==============================] - 1s 2ms/step
9387    9387
              precision    recall  f1-score   support

       akiec       1.00      1.00      1.00      1359
         bcc       0.99      1.00      1.00      1318
         bkl       0.95      0.98      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       0.93      1.00      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 [116]:

```
# 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 0x7f3f0dc6a210>
1 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3f0dc6a810>
2 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f3eec94bb90>
3 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3eee559c10>
4 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f3f0d646f90>
5 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3eed0973d0>
6 <keras.layers.convolutional.conv2d.Conv2D object at 0x7f3eee22aed0>
7 <keras.layers.pooling.max_pooling2d.MaxPooling2D object at 0x7f3f0eb68b50>
8 <keras.layers.reshaping.flatten.Flatten object at 0x7f3eecf18c10>
9 <keras.layers.core.dense.Dense object at 0x7f3f0ead9250>
10 <keras.layers.core.dense.Dense object at 0x7f3f0d5519d0>
11 <keras.layers.core.activation.Activation object at 0x7f3eed094f50>
12 <keras.layers.core.dense.Dense object at 0x7f3eeb9f1e90>
13 <keras.layers.core.activation.Activation object at 0x7f3f0d45e210>
```

In [117]:

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

```
tensorflow
```

In [118]:

```
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[-2]
.output)
```

In [119]:

```
# 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
```

In [120]:

```
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)
```

```
SVM Accuracy: 98.50857568978374
```

In [121]:

```
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)
```

```
SVM Accuracy: 98.50857568978374
SVC(C=1000, gamma=0.0001)
```

Out[121]:

```
SVC(C=1000, gamma=0.0001)
```

In [122]:

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

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

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1359
           1       0.99      1.00      1.00      1318
           2       0.96      0.99      0.98      1262
           3       1.00      1.00      1.00      1351
           4       0.99      0.91      0.95      1374
           5       1.00      1.00      1.00      1358
           6       0.95      1.00      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: 98.50857568978374
```

In [123]:

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

parameters = {"max_depth": [3],
              "max_features": [1],
              "min_samples_split": [3],
              "min_samples_leaf": [3],
              "bootstrap": [True],
              "criterion": ["entropy"],
              "n_estimators": [10]}
rclf = RandomForestClassifier()
rgclf = GridSearchCV(rclf, param_grid=parameters)
rgclf.fit(X_test_cnn, Y_test)
RFC_accuracy = clf.score(X_test_cnn, Y_test)
print('Random Forest Classifier Accuracy:', RFC_accuracy*100)
```

```
Random Forest Classifier Accuracy: 98.50857568978374
```

In [124]:

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

```
RandomForestClassifier(criterion='entropy', max_depth=3, max_features=1,
                       min_samples_leaf=3, min_samples_split=3,
                       n_estimators=10)
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1359
           1       0.90      1.00      0.95      1318
           2       0.95      0.90      0.92      1262
           3       0.96      1.00      0.98      1351
           4       0.98      0.68      0.81      1374
           5       0.96      1.00      0.98      1358
           6       0.86      1.00      0.92      1365

    accuracy                           0.94      9387
   macro avg       0.94      0.94      0.94      9387
weighted avg       0.94      0.94      0.94      9387

Accuracy: 93.92777245126238
```

In [125]:

```
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_test_cnn, Y_test)
KNN_accuracy = kgclf.score(X_test_cnn, Y_test)
print('KNN Classifier Accuracy:', KNN_accuracy*100)
```

```
KNN Classifier Accuracy: 100.0
```

In [126]:

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

```
KNeighborsClassifier(metric='manhattan', n_neighbors=1)
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1359
           1       1.00      1.00      1.00      1318
           2       1.00      1.00      1.00      1262
           3       1.00      1.00      1.00      1351
           4       1.00      1.00      1.00      1374
           5       1.00      1.00      1.00      1358
           6       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
```

In [127]:

```
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_test_cnn, Y_test)

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

print(classification_report(Y_test, y_testKNN))
print("Accuracy: {0}".format(accuracy_score(Y_test, y_testKNN)*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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Please also refer to the documentation for alternative solver options:
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/opt/conda/lib/python3.7/site-packages/sklearn/linear_model/_logistic.py:818: Convergence
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```

```
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/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:
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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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```

```
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
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/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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  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
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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/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 0.97752236        nan 0.983
16848        nan 0.98380752
        nan 0.98380746        nan 0.98391396        nan 0.9838074 ]
  category=UserWarning,
```

```
Best hyperparameters:  {'C': 10, 'penalty': 'l2'}
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1359
           1       1.00      1.00      1.00      1318
           2       0.95      0.98      0.97      1262
           3       1.00      1.00      1.00      1351
           4       0.98      0.92      0.95      1374
           5       1.00      1.00      1.00      1358
           6       0.96      0.99      0.98      1365

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

Accuracy: 98.43400447427292
```

```
/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,
```

In [ ]:

```

```

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