In [1]:

```
import numpy as np # linear algebra
import matplotlib.pyplot as plt # create static, animated and interactive visualisations
from keras.layers import Conv2D, Flatten, MaxPooling2D, Dense, Dropout, BatchNormalization,
from keras.models import Sequential
from keras.utils import to_categorical
from sklearn.metrics import classification_report, accuracy_score, confusion_matrix, f1_sco

import glob, os, random, re

import pandas as pd # for data processing and read CSV

import seaborn as sns

from tensorflow.keras.preprocessing.image import ImageDataGenerator, load_img, img_to_array
import tensorflow.keras.layers as L
from tensorflow.keras.models import Model
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.applications import Xception
from tensorflow.keras.applications.xception import preprocess_input
```

In [2]:

```
base_path = 'data'

img_list = glob.glob(os.path.join(base_path, '*/*.jpg'))

print("The total amount of images in the data is " , len(img_list))
```

```
The total amount of images in the data is  8233
```

In [3]:

```
categories = {0: 'arp', 1: 'baglama', 2: 'elektroGitar', 3: 'gitar', 4: 'kanun'
             , 5: 'keman', 6: 'kemence', 7: 'mandolin', 8: 'ud', 9: 'yayliTambur'}
# Etiket isimlerimizi belirliyoruz.
def add_class_name_prefix(df, col_name):
    df[col_name] = df[col_name].apply(lambda x: x[:re.search("\d",x).start()] + '/' + x)
    return df

filenames_list = []
categories_list = []

for category in categories:
    filenames = os.listdir(base_path +'/' + categories[category])

    filenames_list = filenames_list  +filenames
    categories_list = categories_list + [category] * len(filenames)

df = pd.DataFrame({
    'filename': filenames_list,
    'category': categories_list
})

df = add_class_name_prefix(df, 'filename')

# Shuffle dataframe
df = df.sample(frac=1).reset_index(drop=True)

print('Görüntü Sayısı = ' , len(df))
df # show dataframe
```

```
Görüntü Sayısı =  8233
```

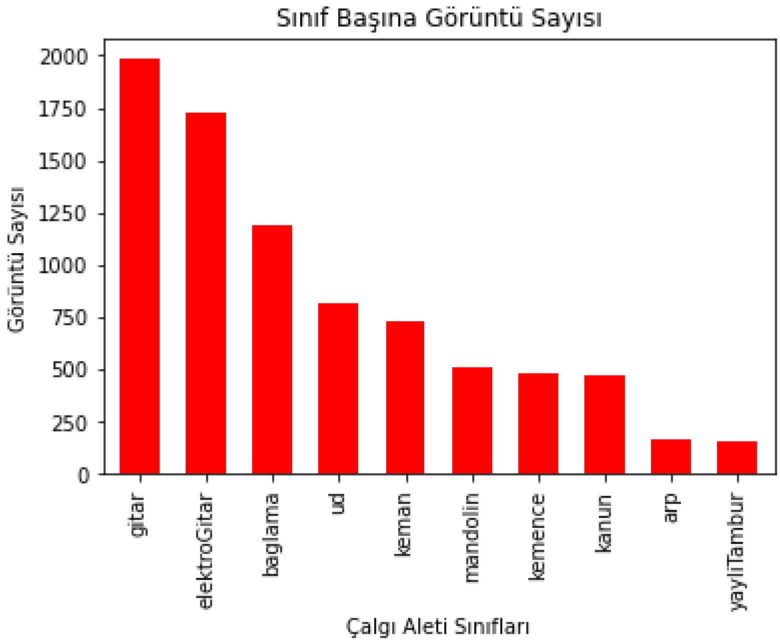
Out[3]:

	filename	category
0	kanun(/kanun(158).jpg	4
1	gitar(/gitar(702).jpg	3
2	baglama(/baglama(936).jpg	1
3	baglama(/baglama(226).jpg	1
4	keman(/keman(567).jpg	5
...	...	...
8228	elektroGitar(/elektroGitar(1254).jpg	2
8229	arp(/arp(120).jpg	0
8230	elektroGitar(/elektroGitar(338).jpg	2
8231	elektroGitar(/elektroGitar(1344).jpg	2
8232	baglama(/baglama(399).jpg	1

8233 rows × 2 columns

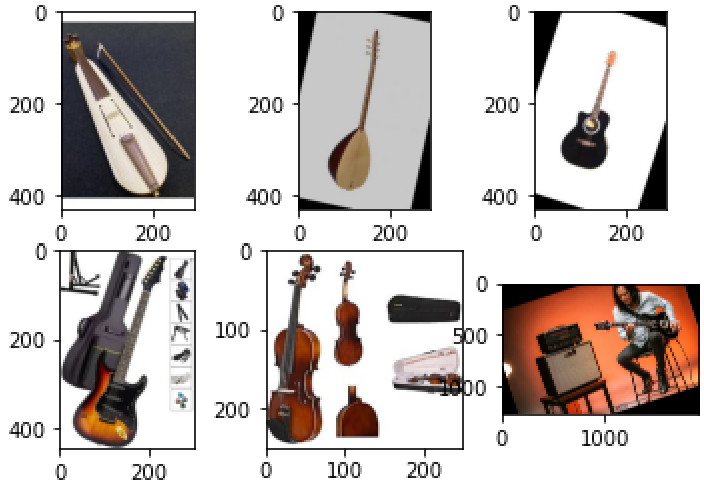
In [4]:

```
df_visualization = df.copy()
# Replace numerical category with names for labeling purpose
df_visualization['category'] = df_visualization['category'].apply(lambda x:categories[x] )

df_visualization['category'].value_counts().plot.bar(x = 'count', y = 'category', color = '
# plot graph to show the number of images in each class
plt.title("Sınıf Başına Görüntü Sayısı")
plt.ylabel("Görüntü Sayısı")
plt.xlabel("Çalgı Aleti Sınıfları");
```



In [5]:

```
for i, img_path in enumerate(random.sample(img_list, 6)): # randomly pick 6 photos from the
    img = load_img(img_path)
    img = img_to_array(img, dtype=np.uint8)
    plt.subplot(2, 3, i+1)
    plt.imshow(img.squeeze())
```



In [6]:

```
train_datagen = ImageDataGenerator(
    rescale=1./255,
    shear_range=0.1,
    zoom_range=0.1,
    width_shift_range=0.1,
    height_shift_range=0.1,
    horizontal_flip=True,
    vertical_flip=True,
    validation_split=0.2
)

test_datagen = ImageDataGenerator(
    rescale=1./255,
    validation_split=0.2
)

train_generator = train_datagen.flow_from_directory(
    base_path,
    target_size=(300, 300),
    batch_size=32,
    class_mode='categorical',
    subset='training',
    seed=0
)

validation_generator = test_datagen.flow_from_directory(
    base_path,
    target_size=(300, 300),
    batch_size=32,
    class_mode='categorical',
    subset='validation',
    seed=0
)

labels = (train_generator.class_indices)
labels = dict((v,k) for k,v in labels.items())

print(labels)
```

```
Found 6592 images belonging to 10 classes.
Found 1641 images belonging to 10 classes.
{0: 'arp', 1: 'baglama', 2: 'elektroGitar', 3: 'gitar', 4: 'kanun', 5: 'kema
n', 6: 'kemence', 7: 'mandolin', 8: 'ud', 9: 'yayliTambur'}
```

In [7]:

```
# Build Model
model = Sequential([
    Conv2D(filters=32, kernel_size=3, padding='same', activation='relu', input_shape=(300,
    MaxPooling2D(pool_size=2),
    Conv2D(filters=64, kernel_size=3, padding='same', activation='relu'),
    MaxPooling2D(pool_size=2),
    Conv2D(filters=32, kernel_size=3, padding='same', activation='relu'),
    MaxPooling2D(pool_size=2),
    Conv2D(filters=32, kernel_size=3, padding='same', activation='relu'),
    MaxPooling2D(pool_size=2),
    Flatten(),
    Dense(64, activation='relu'),
    Dense(10, activation='softmax')
])

model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc'])

model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d (Conv2D)             (None, 300, 300, 32)      896       
                                                                 
 max_pooling2d (MaxPooling2D  (None, 150, 150, 32)     0         
 )                                                               
                                                                 
 conv2d_1 (Conv2D)           (None, 150, 150, 64)      18496     
                                                                 
 max_pooling2d_1 (MaxPooling  (None, 75, 75, 64)       0         
 2D)                                                             
                                                                 
 conv2d_2 (Conv2D)           (None, 75, 75, 32)        18464     
                                                                 
 max_pooling2d_2 (MaxPooling  (None, 37, 37, 32)       0         
 2D)                                                             
                                                                 
 conv2d_3 (Conv2D)           (None, 37, 37, 32)        9248      
                                                                 
 max_pooling2d_3 (MaxPooling  (None, 18, 18, 32)       0         
 2D)                                                             
                                                                 
 flatten (Flatten)           (None, 10368)             0         
                                                                 
 dense (Dense)               (None, 64)                663616    
                                                                 
 dense_1 (Dense)             (None, 10)                650       
                                                                 
=================================================================
Total params: 711,370
Trainable params: 711,370
Non-trainable params: 0
_________________________________________________________________
```

In [8]:

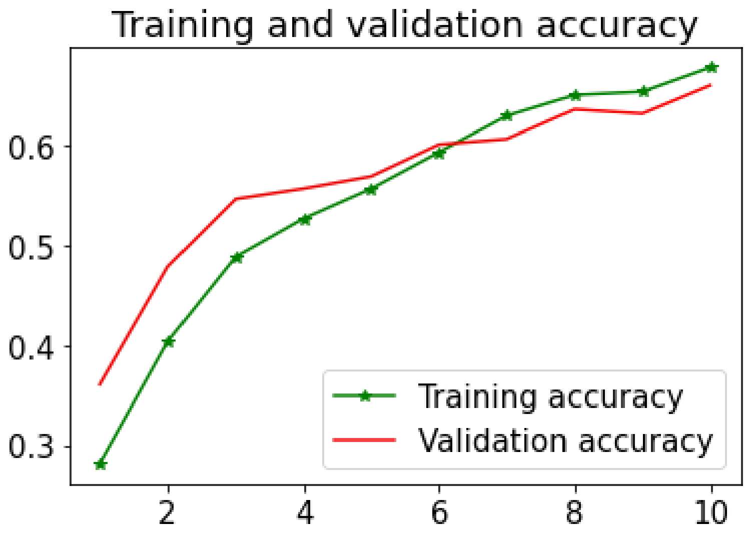
```
import tensorflow as tf

cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath='training/cp.ckpt',
                                                 save_weights_only=True,
                                                 verbose=1)

history = model.fit_generator(train_generator, epochs=10, validation_data=validation_genera
```

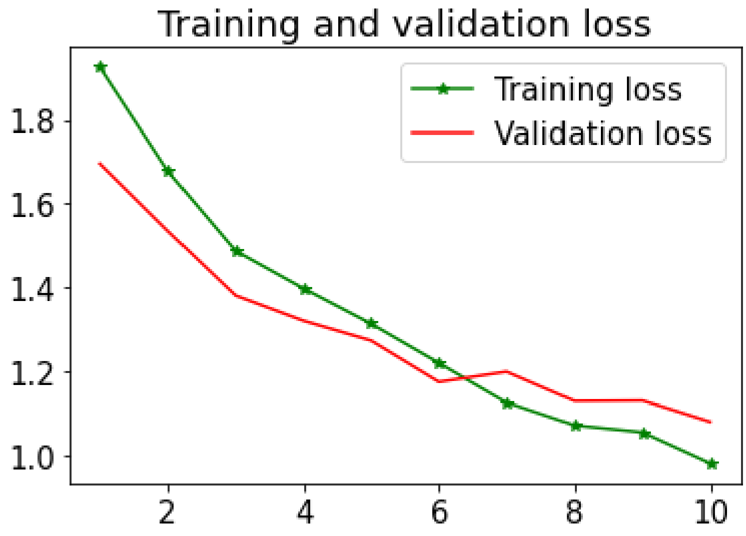
```
<ipython-input-8-61e8d9233cc9>:7: UserWarning: `Model.fit_generator` is depr
ecated and will be removed in a future version. Please use `Model.fit`, whic
h supports generators.
  history = model.fit_generator(train_generator, epochs=10, validation_data=
validation_generator, callbacks=[cp_callback])

Epoch 1/10
 17/206 [=>............................] - ETA: 4:27 - loss: 2.1239 - acc:
0.2335

C:\Users\YakupAkdin\AppData\Roaming\Python\Python38\site-packages\PIL\Image.
py:979: UserWarning: Palette images with Transparency expressed in bytes sho
uld be converted to RGBA images
  warnings.warn(


206/206 [==============================] - ETA: 0s - loss: 1.9258 - acc:
0.2814
Epoch 1: saving model to training\cp.ckpt
206/206 [==============================] - 328s 2s/step - loss: 1.9258 - a
cc: 0.2814 - val_loss: 1.6958 - val_acc: 0.3608
Epoch 2/10
206/206 [==============================] - ETA: 0s - loss: 1.6781 - acc:
0.4035
Epoch 2: saving model to training\cp.ckpt
206/206 [==============================] - 329s 2s/step - loss: 1.6781 - a
cc: 0.4035 - val_loss: 1.5356 - val_acc: 0.4784
Epoch 3/10
206/206 [==============================] - ETA: 0s - loss: 1.4878 - acc:
0.4882
Epoch 3: saving model to training\cp.ckpt
206/206 [==============================] - 334s 2s/step - loss: 1.4878 - a
cc: 0.4882 - val_loss: 1.3812 - val_acc: 0.5460
Epoch 4/10
206/206 [==============================] - ETA: 0s - loss: 1.3983 - acc:
0.5264
Epoch 4: saving model to training\cp.ckpt
206/206 [==============================] - 330s 2s/step - loss: 1.3983 - a
cc: 0.5264 - val_loss: 1.3212 - val_acc: 0.5564
Epoch 5/10
206/206 [==============================] - ETA: 0s - loss: 1.3140 - acc:
0.5563
Epoch 5: saving model to training\cp.ckpt
206/206 [==============================] - 331s 2s/step - loss: 1.3140 - a
cc: 0.5563 - val_loss: 1.2739 - val_acc: 0.5686
Epoch 6/10
206/206 [==============================] - ETA: 0s - loss: 1.2206 - acc:
0.5925
Epoch 6: saving model to training\cp.ckpt
206/206 [==============================] - 327s 2s/step - loss: 1.2206 - a
cc: 0.5925 - val_loss: 1.1757 - val_acc: 0.6002
```

```
Epoch 7/10
206/206 [==============================] - ETA: 0s - loss: 1.1263 - acc:
0.6291
Epoch 7: saving model to training\cp.ckpt
206/206 [==============================] - 328s 2s/step - loss: 1.1263 - a
cc: 0.6291 - val_loss: 1.1999 - val_acc: 0.6057
Epoch 8/10
206/206 [==============================] - ETA: 0s - loss: 1.0718 - acc:
0.6497
Epoch 8: saving model to training\cp.ckpt
206/206 [==============================] - 328s 2s/step - loss: 1.0718 - a
cc: 0.6497 - val_loss: 1.1303 - val_acc: 0.6356
Epoch 9/10
206/206 [==============================] - ETA: 0s - loss: 1.0554 - acc:
0.6531
Epoch 9: saving model to training\cp.ckpt
206/206 [==============================] - 328s 2s/step - loss: 1.0554 - a
cc: 0.6531 - val_loss: 1.1313 - val_acc: 0.6313
Epoch 10/10
206/206 [==============================] - ETA: 0s - loss: 0.9818 - acc:
0.6772
Epoch 10: saving model to training\cp.ckpt
206/206 [==============================] - 329s 2s/step - loss: 0.9818 - a
cc: 0.6772 - val_loss: 1.0802 - val_acc: 0.6594
```

In [58]:

```
train_acc = history.history['acc'] # store training accuracy in history
val_acc = history.history['val_acc'] # store validation accuracy in history
train_loss = history.history['loss'] # store training loss in history
val_loss = history.history['val_loss'] # store validation loss in history

epochs = range(1, len(train_acc) + 1)

plt.plot(epochs, train_acc, 'g*-', label = 'Training accuracy')
plt.plot(epochs, val_acc, 'r', label = 'Validation accuracy')
plt.title('Training and validation accuracy')
plt.legend()

plt.figure()

plt.plot(epochs, train_loss, 'g*-', label = 'Training loss')
plt.plot(epochs, val_loss, 'r', label = 'Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```

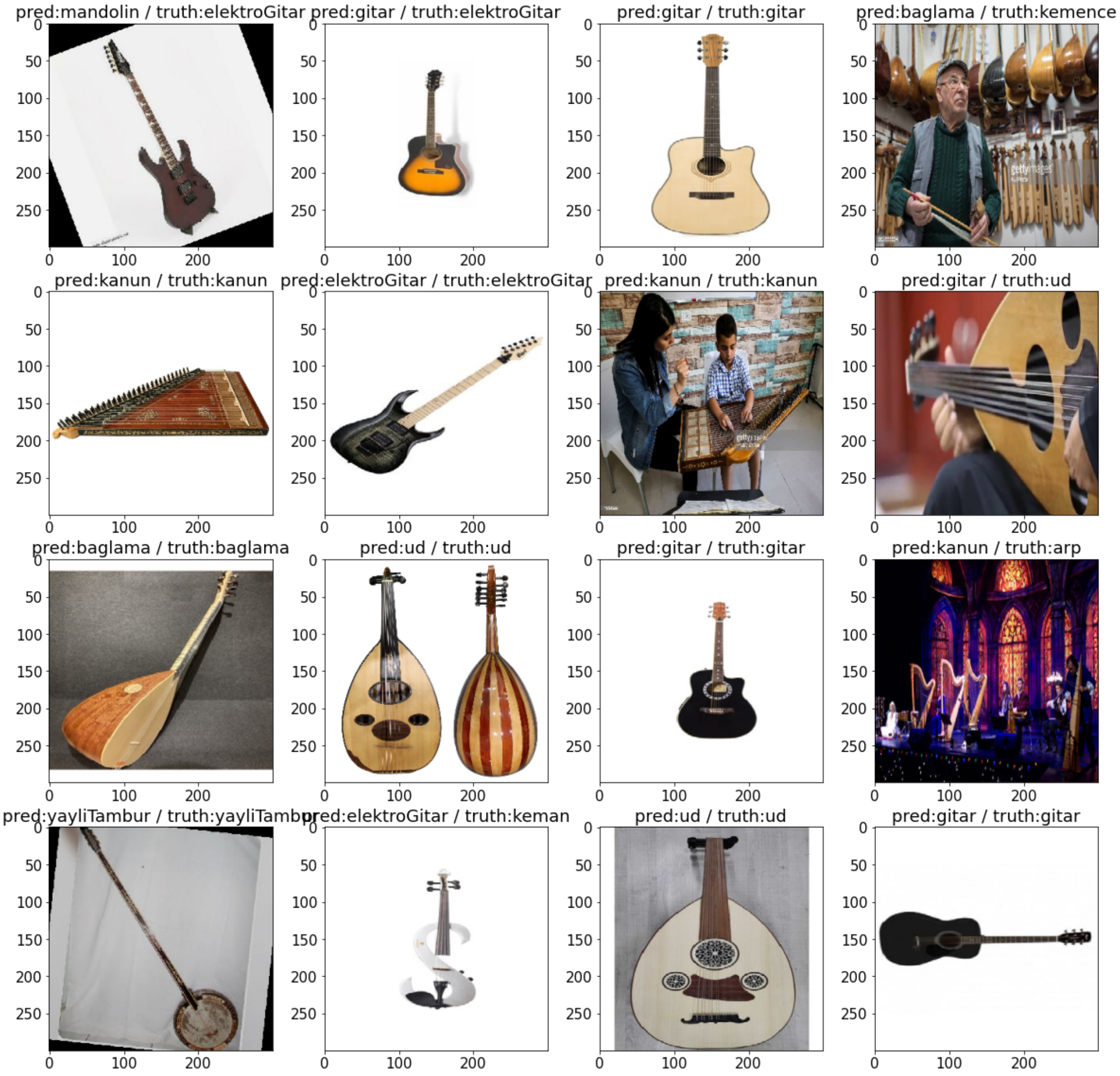

Training and validation accuracy


Training and validation loss

In [76]:

```
test_x, test_y = validation_generator.__getitem__(1)
# test_x - train data
# test_y - actual answer of the testing set data
# preds - predicted class
preds = model.predict(test_x)

print(preds[0])

plt.figure(figsize=(20, 20))
for i in range(16):
    plt.subplot(4, 4, i+1)
    plt.title('pred:%s / truth:%s' % (labels[np.argmax(preds[i])], labels[np.argmax(test_y[
    plt.imshow(test_x[i])
#show testing results
```

```
1/1 [==============================] - 0s 307ms/step
[3.0993816e-04 8.3135612e-02 2.8643575e-01 3.1702045e-02 3.3309178e-03
 1.7824505e-02 2.9377377e-02 4.4887552e-01 5.4937944e-02 4.4070445e-02]
```



In [77]:

```
print("-- Evaluate --")
scores = model.evaluate_generator(validation_generator, steps=5)
print("%s: %.2f%%" %(model.metrics_names[1], scores[1]*100))
```

```
-- Evaluate --


<ipython-input-77-92ea95cd1814>:2: UserWarning: `Model.evaluate_generator` i
s deprecated and will be removed in a future version. Please use `Model.eval
uate`, which supports generators.
  scores = model.evaluate_generator(validation_generator, steps=5)


acc: 60.62%
```

In [78]:

```
# show model details
test_true = np.argmax(test_y, axis=1)
test_pred = np.argmax(preds, axis=1)
print(classification_report(test_true, test_pred))
```

```
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         1
           1       0.80      0.80      0.80         5
           2       0.57      0.67      0.62         6
           3       0.71      0.71      0.71         7
           4       0.67      1.00      0.80         2
           5       1.00      0.50      0.67         2
           6       0.00      0.00      0.00         3
           7       0.33      1.00      0.50         1
           8       0.50      0.67      0.57         3
           9       1.00      0.50      0.67         2

    accuracy                           0.62        32
   macro avg       0.56      0.58      0.53        32
weighted avg       0.61      0.62      0.60        32
```

In [79]:

```
from sklearn.model_selection import train_test_split

#Change categories from numbers to names
df["category"] = df["category"].replace(categories)

# Split the data into two sets and then split the validate_df to two sets
train_df, validate_df = train_test_split(df, test_size=0.2, random_state=42)
validate_df, test_df = train_test_split(validate_df, test_size=0.5, random_state=42)

train_df = train_df.reset_index(drop=True)
validate_df = validate_df.reset_index(drop=True)
test_df = test_df.reset_index(drop=True)

total_train = train_df.shape[0]
total_validate = validate_df.shape[0]

print('train size = ', total_validate , 'validate size = ', total_validate, 'test size = ',
```

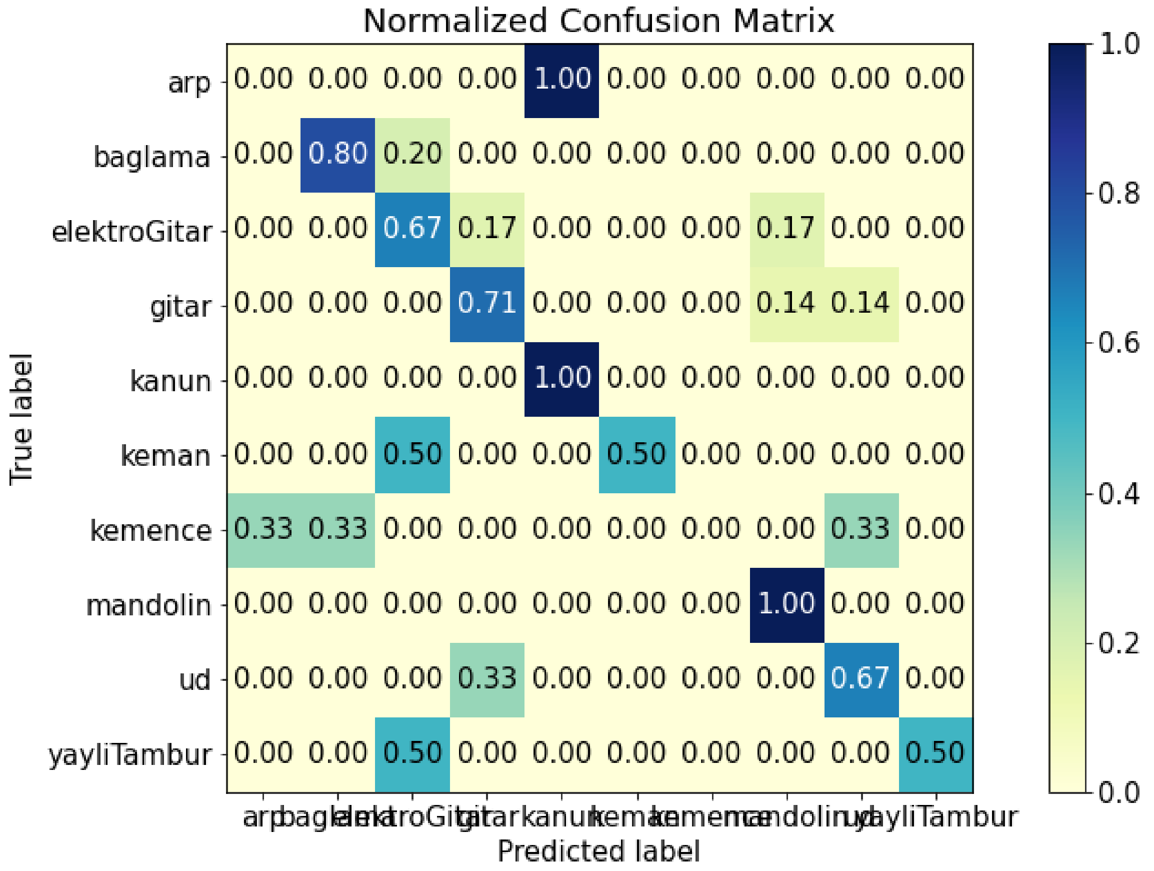
```
train size =  823 validate size =  823 test size =  824
```

In [ ]:

```

```

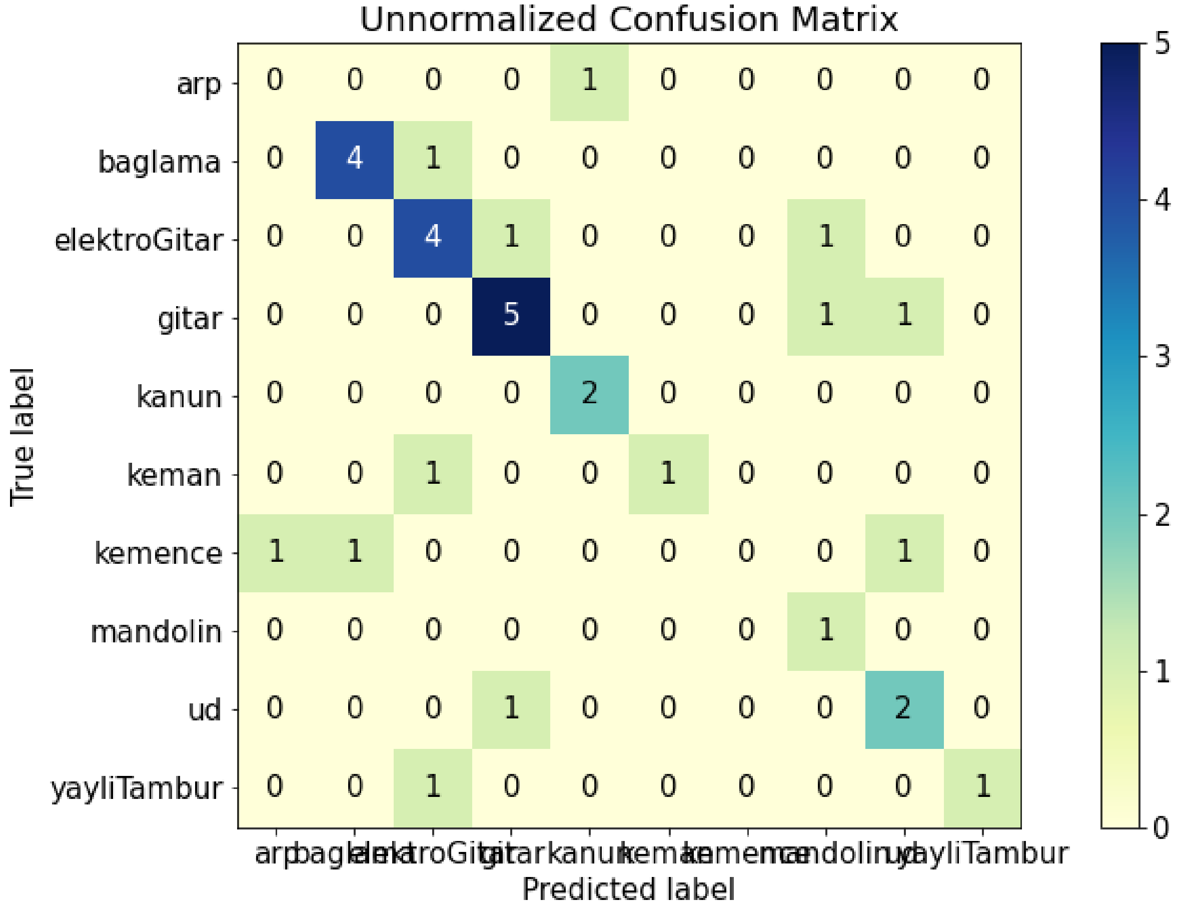
In [80]:

```
# produce the confusion matrix of the results (normalized)
from sklearn.metrics import confusion_matrix
def plot_confusion_matrix(y_true, y_pred, classes, normalize=False, title=None, cmap=plt.cm

    if not title: # set title based on normalize setting
        if normalize:
            title = 'Normalized confusion matrix'
        else:
            title = 'Confusion matrix, without normalization'

    # Compute confusion matrix
    cm = confusion_matrix(test_true, test_pred)
    # Use labels that appear in data
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]

    # Print table
    fig, ax = plt.subplots(figsize=(12,7))
    im = ax.imshow(cm, interpolation='nearest', cmap=cmap)
    ax.figure.colorbar(im, ax=ax)
    # show all ticks and label with respective categories
    ax.set(xticks=np.arange(cm.shape[1]),
           yticks=np.arange(cm.shape[0]),
           xticklabels=classes, yticklabels=classes,
           title=title,
           ylabel='True label',
           xlabel='Predicted label')


    # Loop over data dimensions and create text annotations.
    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i in range(cm.shape[0]):
        for j in range(cm.shape[1]):
            ax.text(j, i, format(cm[i, j], fmt),
                    ha="center", va="center",
                    color="white" if cm[i, j] > thresh else "black")
    fig.tight_layout()
    return ax

plt.rc('font', family='sans-serif', size=15)
classes = ['arp','baglama','elektroGitar','gitar','kanun','keman','kemence','mandolin','ud'
# Plot normalized confusion matrix
plot_confusion_matrix(test_true, test_pred, classes=classes, normalize=True, title='Normali
plt.show()
# Plot unnormalized confusion matrix
plot_confusion_matrix(test_true, test_pred, classes=classes, normalize=False, title='Unnorm
plt.show()
```



Normalized Confusion Matrix

True label \ Predicted label	arp	baglama	elektroGitar	gitar	kanun	keman	kemence	mandolin	ud	yayliTambur
arp	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
baglama	0.00	0.80	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
elektroGitar	0.00	0.00	0.67	0.17	0.00	0.00	0.00	0.17	0.00	0.00
gitar	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.14	0.14	0.00
kanun	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
keman	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00
kemence	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
mandolin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
ud	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.67	0.00
yayliTambur	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50



Unnormalized Confusion Matrix

True label \ Predicted label	arp	baglama	elektroGitar	gitar	kanun	keman	kemence	mandolin	ud	yayliTambur
arp	0	0	0	0	1	0	0	0	0	0
baglama	0	4	1	0	0	0	0	0	0	0
elektroGitar	0	0	4	1	0	0	0	1	0	0
gitar	0	0	0	5	0	0	0	1	1	0
kanun	0	0	0	0	2	0	0	0	0	0
keman	0	0	1	0	0	1	0	0	0	0
kemence	1	1	0	0	0	0	0	0	1	0
mandolin	0	0	0	0	0	0	0	1	0	0
ud	0	0	0	1	0	0	0	0	2	0
yayliTambur	0	0	1	0	0	0	0	0	0	1

In [81]:

```
# calculate accuracy of each class
from sklearn.metrics import confusion_matrix

predictions_one_hot = model.predict(test_x)
cm = confusion_matrix(test_true, test_pred)
print(cm)
```

```
1/1 [==============================] - 0s 312ms/step
[[0 0 0 0 1 0 0 0 0 0]
 [0 4 1 0 0 0 0 0 0 0]
 [0 0 4 1 0 0 0 1 0 0]
 [0 0 0 5 0 0 0 1 1 0]
 [0 0 0 0 2 0 0 0 0 0]
 [0 0 1 0 0 1 0 0 0 0]
 [1 1 0 0 0 0 0 0 1 0]
 [0 0 0 0 0 0 0 1 0 0]
 [0 0 0 1 0 0 0 0 2 0]
 [0 0 1 0 0 0 0 0 0 1]]
```

In [83]:

```
# identify accuracy of each class
FP = cm.sum(axis=0) - np.diag(cm)
FN = cm.sum(axis=1) - np.diag(cm)
TP = np.diag(cm)
TN = cm.sum() - (FP + FN + TP)


# Overall accuracy
print ("'arp','baglama','elektroGitar','gitar','kanun','keman','kemence','mandolin','ud','y
ACC = (TP+TN)/(TP+FP+FN+TN)
print (ACC)
```

```
'arp','baglama','elektroGitar','gitar','kanun','keman','kemence','mandoli
n','ud','yayliTambur'
[0.9375  0.9375  0.84375 0.875   0.96875 0.96875 0.90625 0.9375  0.90625
 0.96875]
```

In [ ]: