Convolutional Neural Networks

In this notebook, we train a CNN on augmented images from the CIFAR-10 database.

1. Load CIFAR-10 Database

In [1]:

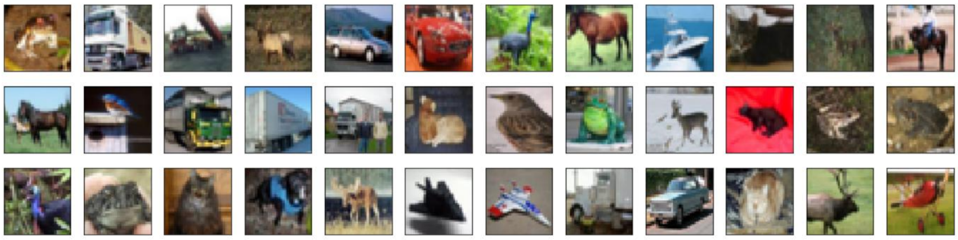
```
import keras
from keras.datasets import cifar10

# load the pre-shuffled train and test data
(x_train, y_train), (x_test, y_test) = cifar10.load_data()
```

```
Using TensorFlow backend.
```

2. Visualize the First 24 Training Images

In [2]:

```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
fig = plt.figure(figsize=(20,5))
for i in range(36):
    ax = fig.add_subplot(3, 12, i + 1, xticks=[], yticks=[])
    ax.imshow(np.squeeze(x_train[i]))
```



3. Rescale the Images by Dividing Every Pixel in Every Image by 255

In [3]:

```
# rescale [0,255] --> [0,1]
x_train = x_train.astype('float32')/255
x_test = x_test.astype('float32')/255
```

4. Break Dataset into Training, Testing, and Validation Sets

In [4]:

```
from keras.utils import np_utils
# break training set into training and validation sets
(x_train, x_valid) = x_train[5000:], x_train[:5000]
(y_train, y_valid) = y_train[5000:], y_train[:5000]

# one-hot encode the labels
num_classes = len(np.unique(y_train))
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
y_valid = keras.utils.to_categorical(y_valid, num_classes)
# print shape of training set
print('x_train shape:', x_train.shape)
# print number of training, validation, and test images
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
print(x_valid.shape[0], 'validation samples')
```

```
x_train shape: (45000, 32, 32, 3)
45000 train samples
10000 test samples
5000 validation samples
```

5. Create and Configure Augmented Image Generator

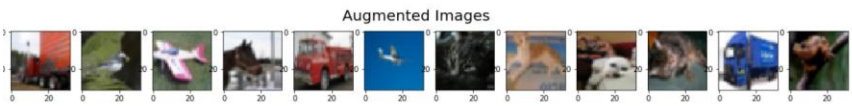
In [6]:

```python
from keras.preprocessing.image import ImageDataGenerator
# create and configure augmented image generator
datagen_train = ImageDataGenerator(
    width_shift_range=0.1,  # randomly shift images horizontally (10% of total width)
    height_shift_range=0.1,  # randomly shift images vertically (10% of total height)
    horizontal_flip=True) # randomly flip images horizontally

# create and configure augmented image generator
datagen_valid = ImageDataGenerator(
    width_shift_range=0.1,  # randomly shift images horizontally (10% of total width)
    height_shift_range=0.1,  # randomly shift images vertically (10% of total height)
    horizontal_flip=True) # randomly flip images horizontally

# fit augmented image generator on data
datagen_train.fit(x_train)
datagen_valid.fit(x_valid)
```

6. Visualize Original and Augmented Images

In [7]:

```python
import matplotlib.pyplot as plt

# take subset of training data
x_train_subset = x_train[:12]

# visualize subset of training data
fig = plt.figure(figsize=(20,2))
for i in range(0, len(x_train_subset)):
    ax = fig.add_subplot(1, 12, i+1)
    ax.imshow(x_train_subset[i])
fig.suptitle('Subset of Original Training Images', fontsize=20)
plt.show()

# visualize augmented images
fig = plt.figure(figsize=(20,2))
for x_batch in datagen_train.flow(x_train_subset, batch_size=12):
    for i in range(0, 12):
        ax = fig.add_subplot(1, 12, i+1)
        ax.imshow(x_batch[i])
    fig.suptitle('Augmented Images', fontsize=20)
    plt.show()
    break;
```



7. Define the Model Architecture

In [8]:

```
from keras.models import Sequential
from keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout

model = Sequential()
model.add(Conv2D(filters=16, kernel_size=2, padding='same', activation='relu',
                        input_shape=(32, 32, 3)))
model.add(MaxPooling2D(pool_size=2))
model.add(Conv2D(filters=32, kernel_size=2, padding='same', activation='relu'))
model.add(MaxPooling2D(pool_size=2))
model.add(Conv2D(filters=64, kernel_size=2, padding='same', activation='relu'))
model.add(MaxPooling2D(pool_size=2))
model.add(Dropout(0.3))
model.add(Flatten())
model.add(Dense(500, activation='relu'))
model.add(Dropout(0.4))
model.add(Dense(10, activation='softmax'))

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 32, 32, 16)        208       
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 16, 16, 16)        0         
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 32)        2080      
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 8, 8, 32)          0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 8, 8, 64)          8256      
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 4, 4, 64)          0         
_________________________________________________________________
dropout_1 (Dropout)          (None, 4, 4, 64)          0         
_________________________________________________________________
flatten_1 (Flatten)          (None, 1024)              0         
_________________________________________________________________
dense_1 (Dense)              (None, 500)               512500    
_________________________________________________________________
dropout_2 (Dropout)          (None, 500)               0         
_________________________________________________________________
dense_2 (Dense)              (None, 10)                5010      
=================================================================
Total params: 528,054
Trainable params: 528,054
Non-trainable params: 0
_________________________________________________________________
```

8. Compile the Model

In [9]:

```
# compile the model
model.compile(loss='categorical_crossentropy', optimizer='rmsprop',
                  metrics=['accuracy'])
```

9. Train the Model

In [ ]:

```
from keras.callbacks import ModelCheckpoint

batch_size = 32
epochs = 100

# train the model
checkpointer = ModelCheckpoint(filepath='aug_model.weights.best.hdf5',
verbose=1,
                               save_best_only=True)
model.fit_generator(datagen_train.flow(x_train, y_train,
batch_size=batch_size),
                    steps_per_epoch=x_train.shape[0] // batch_size,
                    epochs=epochs, verbose=2, callbacks=[checkpointer],
                    validation_data=datagen_valid.flow(x_valid, y_valid,
batch_size=batch_size),
                    validation_steps=x_valid.shape[0] // batch_size)
```

```
Epoch 1/100
Epoch 00000: val_loss improved from inf to 1.39333, saving model to
aug_model.weights.best.hdf5
24s - loss: 1.6266 - acc: 0.4097 - val_loss: 1.3933 - val_acc: 0.5058
Epoch 2/100
Epoch 00001: val_loss improved from 1.39333 to 1.16617, saving model to
aug_model.weights.best.hdf5
26s - loss: 1.3311 - acc: 0.5227 - val_loss: 1.1662 - val_acc: 0.5864
…….
29s - loss: 1.2141 - acc: 0.5904 - val_loss: 1.1259 - val_acc: 0.6063
Epoch 17/100
```

10. Load the Model with the Best Validation Accuracy

In [10]:

```
# load the weights that yielded the best validation accuracy
model.load_weights('aug_model.weights.best.hdf5')
```

11. Calculate Classification Accuracy on Test Set

In [11]:

```
# evaluate and print test accuracy
score = model.evaluate(x_test, y_test, verbose=0)
print('\n', 'Test accuracy:', score[1])
```

```
 Test accuracy: 0.6825
```