Convolutional Neural Networks

In this notebook, we train a CNN to classify 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()
```

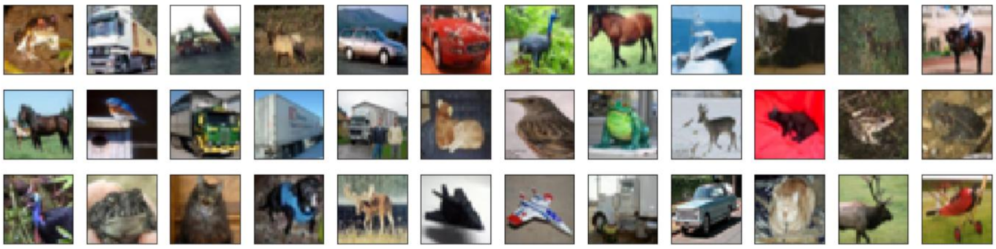
```
Using TensorFlow backend.
```

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

# 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)

# 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]

# 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. Define the Model Architecture

In [5]:

```
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
_________________________________________________________________
```

6. Compile the Model

In [6]:

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

7. Train the Model

In [7]:

```
from keras.callbacks import ModelCheckpoint

# train the model
checkpointer = ModelCheckpoint(filepath='model.weights.best.hdf5', verbose=1,
                               save_best_only=True)
hist = model.fit(x_train, y_train, batch_size=32, epochs=100,
          validation_data=(x_valid, y_valid), callbacks=[checkpointer],
          verbose=2, shuffle=True)
```

```
Train on 45000 samples, validate on 5000 samples
Epoch 1/100
Epoch 00000: val_loss improved from inf to 1.35820, saving model to
model.weights.best.hdf5
46s - loss: 1.6192 - acc: 0.4140 - val_loss: 1.3582 - val_acc: 0.5166
…….
Epoch 100/100
Epoch 00099: val_loss did not improve
48s - loss: 1.9390 - acc: 0.3070 - val_loss: 1.9106 - val_acc: 0.3102
```

8. Load the Model with the Best Validation Accuracy

In [8]:

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

9. Calculate Classification Accuracy on Test Set

In [9]:

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

```
 Test accuracy: 0.68
```

10. Visualize Some Predictions

This may give you some insight into why the network is misclassifying certain objects.

In [10]:

```
# get predictions on the test set
y_hat = model.predict(x_test)

# define text labels (source: https://www.cs.toronto.edu/~kriz/cifar.html)
cifar10_labels = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog',
'frog', 'horse', 'ship', 'truck']
```

In [11]:

```
# plot a random sample of test images, their predicted labels, and ground truth
fig = plt.figure(figsize=(20, 8))
for i, idx in enumerate(np.random.choice(x_test.shape[0], size=32,
replace=False)):
    ax = fig.add_subplot(4, 8, i + 1, xticks=[], yticks=[])
    ax.imshow(np.squeeze(x_test[idx]))
    pred_idx = np.argmax(y_hat[idx])
    true_idx = np.argmax(y_test[idx])
    ax.set_title("{} ({})".format(cifar10_labels[pred_idx],
cifar10_labels[true_idx]),
                 color=("green" if pred_idx == true_idx else "red"))
```