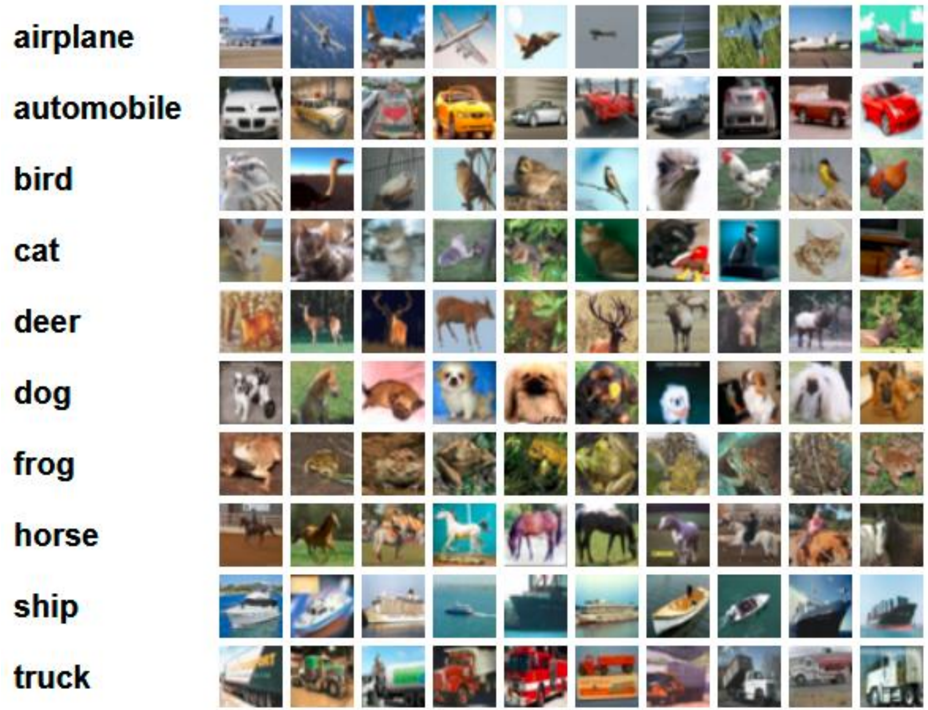
案例：CIFAR-10图像识别

CIFAR-10数据集



- CIFAR-10是一个用于识别普适物体的小型数据集，它包含了10个类别的RGB彩色图片。
- 图片尺寸： 32 x 32
- 训练图片50000张，测试图片10000张

https://www.cs.toronoto.edu/~kriz/cifar.html

下载数据集

```python
import urllib.request
import os
import tarfile

# 下载
url = 'https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz'
filepath = 'data/cifar-10-python.tar.gz'
if not os.path.isfile(filepath):
    result=urllib.request.urlretrieve(url,filepath)
    print('downloaded:',result)
else:
    print('Data file already exists.')

# 解压
if not os.path.exists("data/cifar-10-batches-py"):
    tfile = tarfile.open("data/cifar-10-python.tar.gz", 'r:gz')
    result=tfile.extractall('data/')
    print('Extracted to ./data/cifar-10-batches-py/')
else:
    print('Directory already exists.')
```

导入CIFAR数据集


```python
def load_CIFAR_batch(filename):
    """ load single batch of cifar """
    with open(filename, 'rb')as f:
        # 一个样本由标签和图像数据组成
        # <1 x label><3072 x pixel> (3072=32x32x3)
        # ...
        # <1 x label><3072 x pixel>
        data_dict = p.load(f, encoding='bytes')
        images= data_dict[b'data']
        labels = data_dict[b'labels']

        # 把原始数据结构调整为: BCWH
        images = images.reshape(10000, 3, 32, 32)
        # tensorflow处理图像数据的结构：BWHC
        # 把通道数据C移动到最后一个维度
        images = images.transpose (0,2,3,1)

        labels = np.array(labels)

        return images, labels
```

```python
def load_CIFAR_data(data_dir):
    """load CIFAR data"""

    images_train=[]
    labels_train=[]
    for i in range(5):
        f=os.path.join(data_dir,'data_batch_%d' % (i+1))
        print('loading ',f)
        # 调用 load_CIFAR_batch( )获得批量的图像及其对应的标签
        image_batch,label_batch=load_CIFAR_batch(f)
        images_train.append(image_batch)
        labels_train.append(label_batch)
        Xtrain=np.concatenate(images_train)
        Ytrain=np.concatenate(labels_train)
        del image_batch ,label_batch

    Xtest,Ytest=load_CIFAR_batch(os.path.join(data_dir,'test_batch'))
    print('finished loadding CIFAR-10 data')

    # 返回训练集的图像和标签，测试集的图像和标签
    return Xtrain,Ytrain,Xtest,Ytest

data_dir = 'data/cifar-10-batches-py/'
Xtrain,Ytrain,Xtest,Ytest = load_CIFAR_data(data_dir)
```

显示数据集信息

```
print('training data shape:',Xtrain.shape)
print('training labels shape:',Ytrain.shape)
print('test data shape:',Xtest.shape)
print('test labels shape:',Ytest.shape)
```

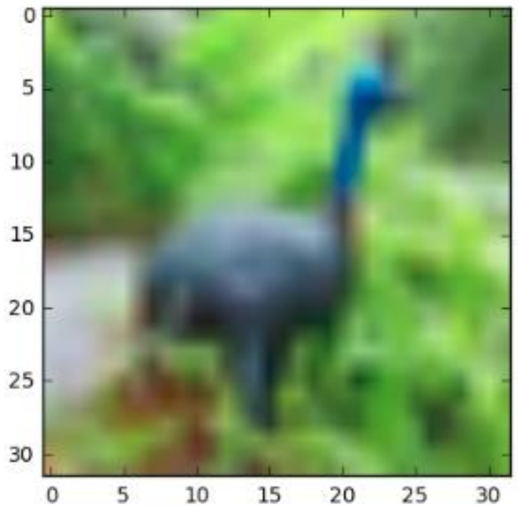
```
training data shape: (50000, 32, 32, 3)
training labels shape: (50000,)
test data shape: (10000, 32, 32, 3)
test labels shape: (10000,)
```

查看单项image和label

In [4]:
```
%matplotlib inline
import matplotlib.pyplot as plt

# 查看image
plt.imshow(Xtrain[6])
```

Out[4]: <matplotlib.image.AxesImage at 0x7fc48d0>



In [5]:
```
# 查看label
# 对应类别信息可查看：http://www.cs.toronto.edu/~kriz/cifar.html
print(Ytrain[6])
```

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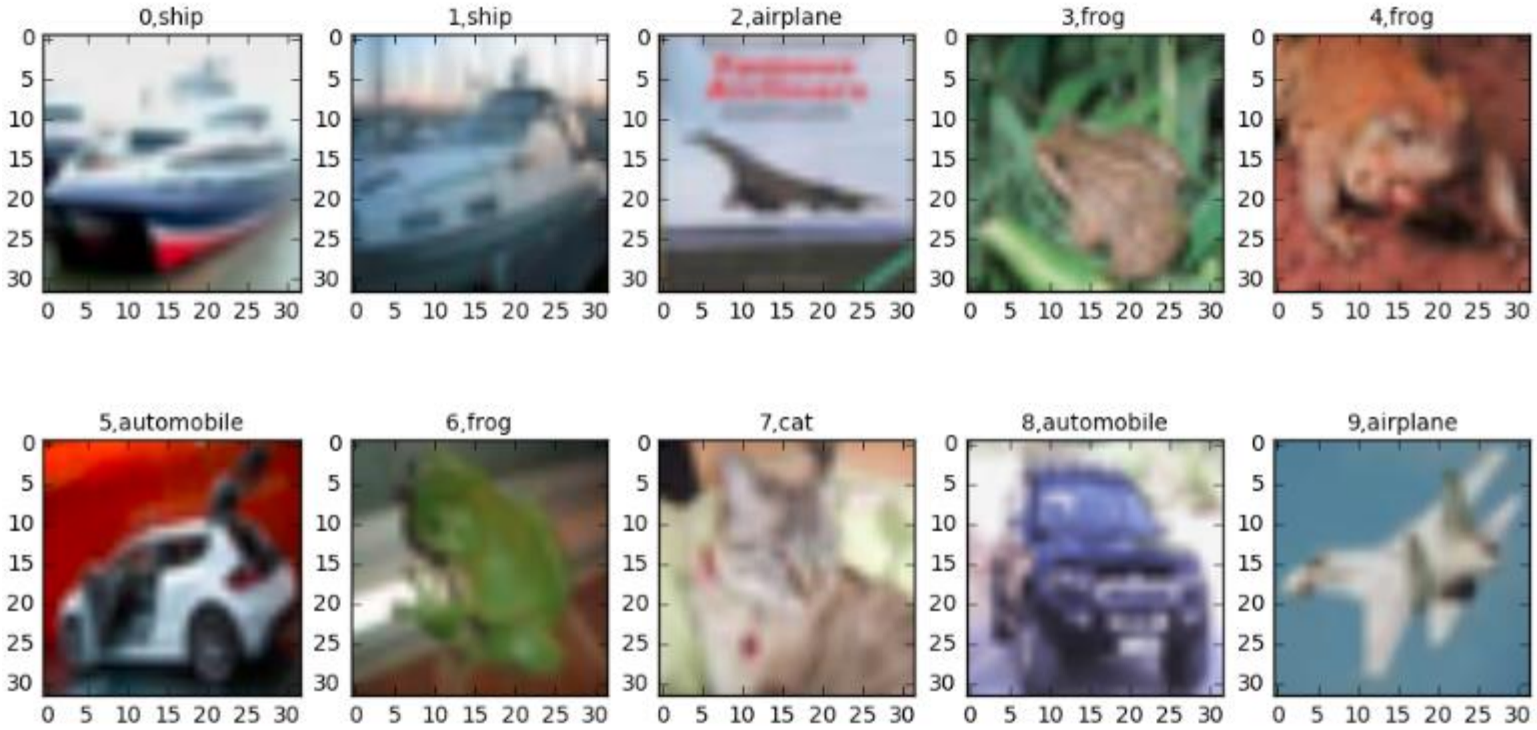
定义网络结构

- **图像的特征提取**：通过卷积层1，降采样层1，卷积层2以及降采样层2的处理，提取图像的特征
- **全连接神经网络**：全连接层、输出层所组成的网络结构

查看多项images与label

```python
import matplotlib.pyplot as plt

#定义标签字典，每一个数字所代表的图像类别的名称
label_dict={0:"airplane",1:"automobile",2:"bird",3:"cat",4:"deer",
            5:"dog",6:"frog",7:"horse",8:"ship",9:"truck"}

#定义显示图像数据及其对应标签的函数
def plot_images_labels_prediction(images,labels,prediction,idx,num=10):
    fig = plt.gcf()
    fig.set_size_inches(12, 6)
    if num>10:
        num=10
    for i in range(0, num):
        ax=plt.subplot(2,5, 1+i)
        ax.imshow(images[idx],cmap='binary')

        title=str(i)+','+label_dict[labels[idx]]
        if len(prediction)>0:
            title+='=>'+label_dict[prediction[idx]]

        ax.set_title(title,fontsize=10)

        idx+=1
    plt.show()

# 显示图像数据及其对应标签
plot_images_labels_prediction(Xtest,Ytest,[],1,10)
```

查看多项images与label



数据预处理

图像数据预处理

```
#查看图像数据信息
#显示第一个图的第一个像素点
Xtrain[0][0][0]
```

```
# 将图像进行数字标准化
Xtrain_normalize = Xtrain.astype('float32') / 255.0
Xtest_normalize = Xtest.astype('float32') / 255.0
```

```
# 查看预处理后图像数据信息
Xtrain_normalize[0][0][0]
```

数据预处理

标签数据预处理——独热编码

- 能够处理非连续型数值特征
- 在一定程度上也扩充了特征

```
from sklearn.preprocessing import OneHotEncoder

encoder = OneHotEncoder(sparse=False)

yy =[[0],[1],[2],[3],[4],[5],[6],[7],[8],[9]]
encoder.fit(yy)
Ytrain_reshape = Ytrain.reshape(-1, 1)
Ytrain_onehot = encoder.transform(Ytrain_reshape)
Ytest_reshape = Ytest.reshape(-1,1)
Ytest_onehot = encoder.transform(Ytest_reshape)
```

```
# 查看标签数据
Ytrain[:10]
```

```
array([6, 9, 9, 4, 1, 1, 2, 7, 8, 3])
```

```
Ytrain_onehot.shape
```

```
(50000, 10)
```

```
Ytrain[:5]
```

```
array([6, 9, 9, 4, 1])
```

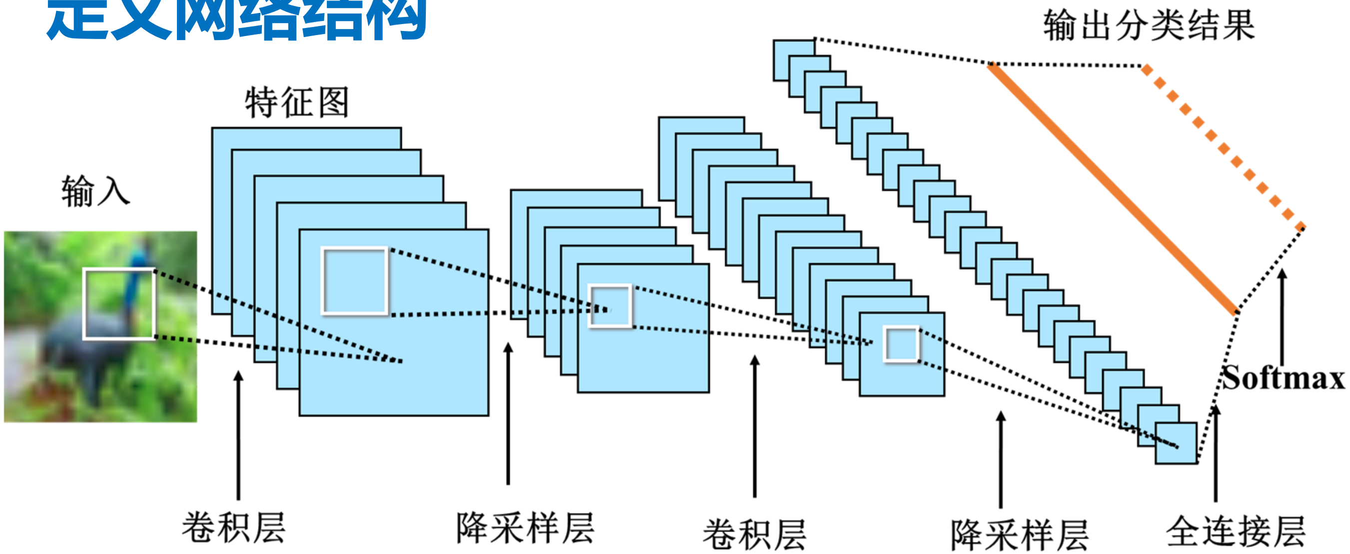
```
Ytrain_onehot[:5]
```

```
array([[ 0.,  0.,  0.,  0.,  0.,  0.,  1.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.],
       [ 0.,  0.,  0.,  0.,  1.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  1.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.]])
```

定义共享函数


```
# 定义权值
def weight(shape):
    # 在构建模型时，需要使用tf.Variable来创建一个变量
    # 在训练时，这个变量不断更新
    # 使用函数tf.truncated_normal（截断的正态分布）生成标准差为0.1的随机数来初始化权值
    return tf.Variable(tf.truncated_normal(shape, stddev=0.1), name ='W')

# 定义偏置
# 初始化为0.1
def bias(shape):
    return tf.Variable(tf.constant(0.1, shape=shape), name = 'b')

# 定义卷积操作
# 步长为1，padding为'SAME'
def conv2d(x, W):
    # tf.nn.conv2d(input, filter, strides, padding, use_cudnn_on_gpu=None, name=None)
    return tf.nn.conv2d(x, W, strides=[1,1,1,1], padding='SAME')

# 定义池化操作
# 步长为2，即原尺寸的长和宽各除以2
def max_pool_2x2(x):
    # tf.nn.max_pool(value, ksize, strides, padding, name=None)
    return tf.nn.max_pool(x, ksize=[1,2,2,1], strides=[1,2,2,1], padding='SAME')
```

定义网络结构



输入层	卷积层1	降采样层1	卷积层2	降采样层2	全连接层	输出层
32x32图像，通道为3（RGB）	第一次卷积： 输入通道：3 输出通道：32 卷积后图像尺寸不变，依然是32x32	第一次降采样： 将32x32图像缩小为16x16；池化不改变通道数量，因此依然是32个	第二次卷积： 输入通道：32 输出通道：64 卷积后图像尺寸不变，依然是16x16	第二次降采样： 将16x16图像缩小为8x8；池化不改变通道数量，因此依然是64个	将64个8x8的图像转换为长度是4096的一维向量，该层有128个神经元	输出层共有10个神经元，对应到0-9这10个类别

定义网络结构

- **图像的特征提取**：通过卷积层1，降采样层1，卷积层2以及降采样层2的处理，提取图像的特征
- **全连接神经网络**：全连接层、输出层所组成的网络结构

定义网络结构

```
# 输入层
# 32x32图像，通道为3（RGB）
with tf.name_scope('input_layer'):
    x = tf.placeholder('float',shape=[None, 32, 32, 3],name="x")

# 第1个卷积层
# 输入通道：3，输出通道：32，卷积后图像尺寸不变，依然是32x32
with tf.name_scope('conv_1'):
    W1 = weight([3,3,3,32]) # [k_width, k_height, input_chn, output_chn]
    b1 = bias([32])  # 与output_chn 一致
    conv_1=conv2d(x, W1)+ b1
    conv_1 = tf.nn.relu(conv_1 )

# 第1个池化层
# 将32x32图像缩小为16x16，池化不改变通道数量，因此依然是32个
with tf.name_scope('pool_1'):
    pool_1 = max_pool_2x2(conv_1)

# 第2个卷积层
# 输入通道：32，输出通道：64，卷积后图像尺寸不变，依然是16x16
with tf.name_scope('conv_2'):
    W2 = weight([3,3,32,64])
    b2 = bias([64])
    conv_2=conv2d(pool_1, W2)+ b2
    conv_2 = tf.nn.relu(conv_2)
```

定义网络结构

```
# 第2个池化层
# 将16x16图像缩小为8x8，池化不改变通道数量，因此依然是64个
with tf.name_scope('pool_2'):
    pool_2 = max_pool_2x2(conv_2)

# 全连接层
# 将池第2个池化层的64个8x8的图像转换为一维的向量，长度是 64*8*8=4096
# 128个神经元
with tf.name_scope('fc'):
    W3= weight([4096, 128]) #有128个神经元
    b3= bias([128])
    flat = tf.reshape(pool_2, [-1, 4096])
    h = tf.nn.relu(tf.matmul(flat, W3) + b3)
    h_dropout= tf.nn.dropout(h, keep_prob=0.8)

# 输出层
# 输出层共有10个神经元，对应到0-9这10个类别
with tf.name_scope('output_layer'):
    W4 = weight([128,10])
    b4 = bias([10])
    pred= tf.nn.softmax(tf.matmul(h_dropout, W4)+b4)
```

构建模型

```
with tf.name_scope("optimizer"):
    #定义占位符
    y = tf.placeholder("float", shape=[None, 10],
                              name="label")
    # 定义损失函数
    loss_function = tf.reduce_mean(
                    tf.nn.softmax_cross_entropy_with_logits
                      (logits=pred ,
                       labels=y))
    # 选择优化器
    optimizer = tf.train.AdamOptimizer(learning_rate=0.0001) \
                  .minimize(loss_function)
```

定义准确率

```
with tf.name_scope("evaluation"):
    correct_prediction = tf.equal(tf.argmax(pred, 1),
                                  tf.argmax(y, 1))
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
```

启动会话

```
import os
from time import time

train_epochs =25
batch_size = 50
total_batch = int(len(Xtrain)/batch_size)
epoch_list=[];accuracy_list=[];loss_list=[];

epoch = tf.Variable(0,name='epoch',trainable=False)

startTime=time()

sess = tf.Session()
init = tf.global_variables_initializer()
sess.run(init)
```

断点续训

```
# 设置检查点存储目录
ckpt_dir = "CIFAR10_log/"
if not os.path.exists(ckpt_dir):
    os.makedirs(ckpt_dir)

#生成saver
saver = tf.train.Saver(max_to_keep=1)

# 如果有检查点文件，读取最新的检查点文件，恢复各种变量值
ckpt = tf.train.latest_checkpoint(ckpt_dir )
if ckpt != None:
    saver.restore(sess, ckpt) #加载所有的参数
    # 从这里开始就可以直接使用模型进行预测，或者接着继续训练了
else:
    print("Training from scratch.")

# 获取续训参数
start = sess.run(epoch)
print("Training starts form {} epoch.".format(start+1))
```

迭代训练


```
def get_train_batch(number, batch_size):
    return Xtrain_normalize[number*batch_size:(number+1)*batch_size], \
                    Ytrain_onehot[number*batch_size:(number+1)*batch_size]

for ep in range(start, train_epochs):

    for i in range(total_batch):
        batch_x, batch_y = get_train_batch(i,batch_size)
        sess.run(optimizer,feed_dict={x: batch_x, y: batch_y})
        if i % 100 == 0:
            print("Step {}".format(i), "finished")

    loss,acc = sess.run([loss_function,accuracy],feed_dict={x: batch_x, y: batch_y})
    epoch_list.append(ep+1)
    loss_list.append(loss);
    accuracy_list.append(acc)

    print("Train epoch:", '%02d' % (sess.run(epoch)+1), \
          "Loss=","{:.6f}".format(loss)," Accuracy=",acc)

    #保存检查点
    saver.save(sess,ckpt_dir+"CIFAR10_cnn_model.cpkt",global_step=ep+1)
    sess.run(epoch.assign(ep+1))

duration =time()-startTime
print("Train finished takes:",duration)
```

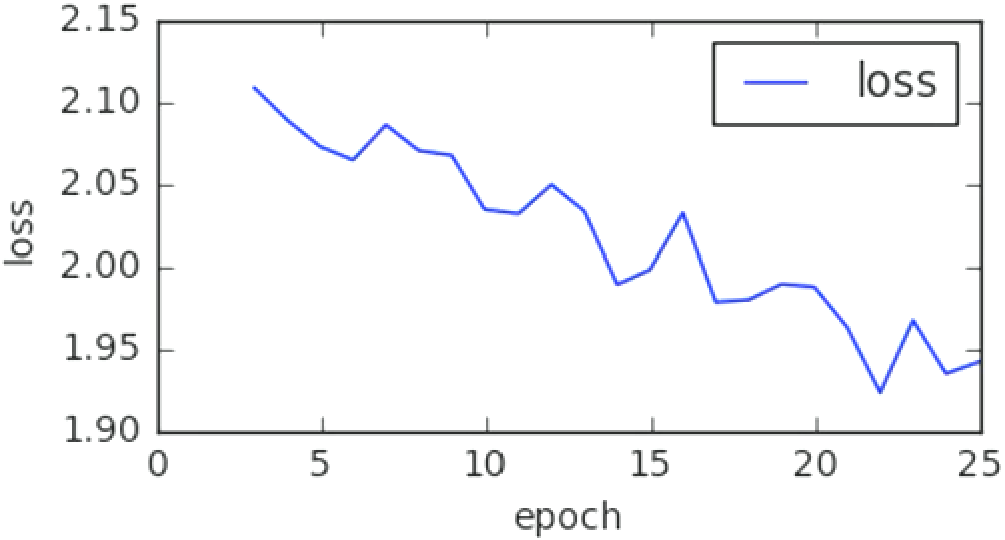
迭代训练

改进方式（根据个人可利用的计算资源）：

- 增加网络层数
- 增加迭代次数
- 增加全连接层数
- 增加全连接层的神经元个数
- 数据扩增， 等等

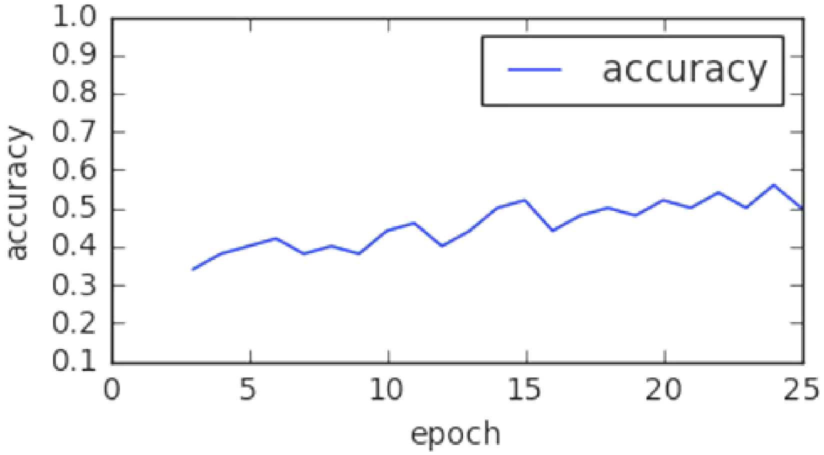
可视化损失值

```
%matplotlib inline
import matplotlib.pyplot as plt

fig = plt.gcf()
fig.set_size_inches(4,2)
plt.plot(epoch_list, loss_list, label = 'loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['loss'], loc='upper right')
```



可视化准确率

```
plt.plot(epoch_list, accuracy_list,label="accuracy" )
fig = plt.gcf()
fig.set_size_inches(4,2)
plt.ylim(0.1,1)
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend()
plt.show()
```



评估模型及预测

计算测试集上的准确率

```
test_total_batch = int(len(Xtest_normalize)/batch_size)
test_acc_sum = 0.0
for i in range(test_total_batch):
    test_image_batch = Xtest_normalize[i*batch_size:(i+1)*batch_size]
    test_label_batch = Ytest_onehot[i*batch_size:(i+1)*batch_size]
    test_batch_acc = sess.run(accuracy, feed_dict = {x:test_image_batch,y:test_label_batch})
    test_acc_sum += test_batch_acc
test_acc = float(test_acc_sum/test_total_batch)
print("Test accuracy:{:.6f}".format(test_acc))
```

利用模型进行预测

```
test_pred=sess.run(pred, feed_dict={x: Xtest_normalize[:10]})
prediction_result = sess.run(tf.argmax(test_pred,1))
```

可视化预测结果

```
plot_images_labels_prediction(Xtest,Ytest,prediction_result,0,10)
```