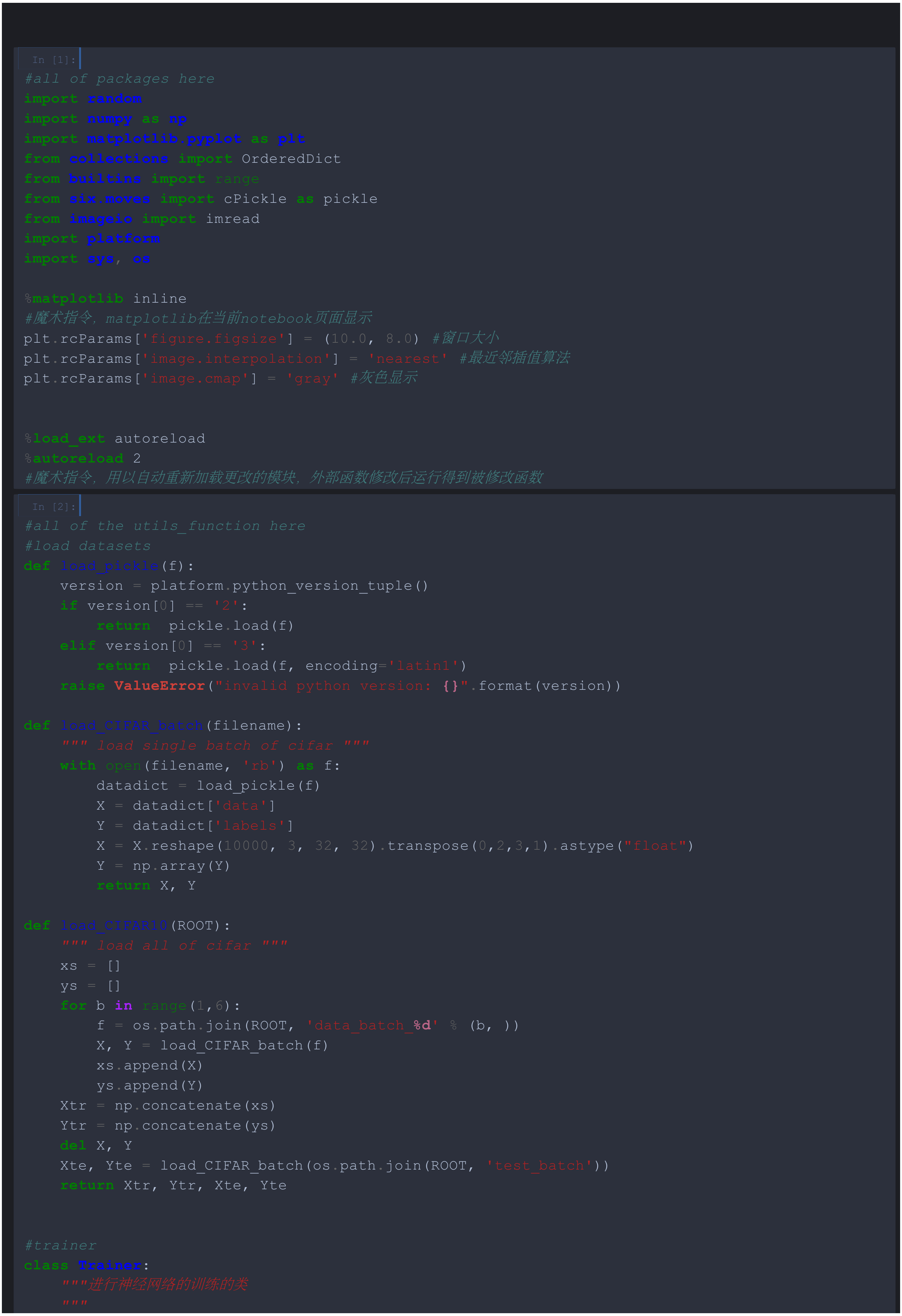


```
In [1]:
#all of packages here
import random
import numpy as np
import matplotlib.pyplot as plt
from collections import OrderedDict
from builtins import range
from six.moves import cPickle as pickle
from imageio import imread
import platform
import sys, os

%matplotlib inline
#魔术指令，matplotlib在当前notebook页面显示
plt.rcParams['figure.figsize'] = (10.0, 8.0) #窗口大小
plt.rcParams['image.interpolation'] = 'nearest' #最近邻插值算法
plt.rcParams['image.cmap'] = 'gray' #灰色显示


%load_ext autoreload
%autoreload 2
#魔术指令，用以自动重新加载更改的模块，外部函数修改后运行得到被修改函数
```

```
In [2]:
#all of the utils_function here
#load datasets
def load_pickle(f):
    version = platform.python_version_tuple()
    if version[0] == '2':
        return  pickle.load(f)
    elif version[0] == '3':
        return  pickle.load(f, encoding='latin1')
    raise ValueError("invalid python version: {}".format(version))

def load_CIFAR_batch(filename):
    """ load single batch of cifar """
    with open(filename, 'rb') as f:
        datadict = load_pickle(f)
        X = datadict['data']
        Y = datadict['labels']
        X = X.reshape(10000, 3, 32, 32).transpose(0,2,3,1).astype("float")
        Y = np.array(Y)
        return X, Y

def load_CIFAR10(ROOT):
    """ load all of cifar """
    xs = []
    ys = []
    for b in range(1,6):
        f = os.path.join(ROOT, 'data_batch_%d' % (b, ))
        X, Y = load_CIFAR_batch(f)
        xs.append(X)
        ys.append(Y)
    Xtr = np.concatenate(xs)
    Ytr = np.concatenate(ys)
    del X, Y
    Xte, Yte = load_CIFAR_batch(os.path.join(ROOT, 'test_batch'))
    return Xtr, Ytr, Xte, Yte


#trainer
class Trainer:
    """进行神经网络的训练的类
    """
    def __init__(self, network, x_train, t_train, x_test, t_test,
                 epochs=20, mini_batch_size=100,
                 optimizer='SGD', optimizer_param={'lr':0.01},
                 evaluate_sample_num_per_epoch=None, verbose=True):
        self.network = network
        self.verbose = verbose
        self.x_train = x_train
        self.t_train = t_train
        self.x_test = x_test
        self.t_test = t_test
        self.epochs = epochs
        self.batch_size = mini_batch_size
        self.evaluate_sample_num_per_epoch = evaluate_sample_num_per_epoch

        # optimzer
        optimizer_class_dict = {'sgd':SGD, 'momentum':Momentum, 'nesterov':Nesterov,
                                'adagrad':AdaGrad, 'rmsprpo':RMSprop, 'adam':Adam}
        self.optimizer = optimizer_class_dict[optimizer.lower()](**optimizer_param)

        self.train_size = x_train.shape[0]
        self.iter_per_epoch = max(self.train_size / mini_batch_size, 1)
        self.max_iter = int(epochs * self.iter_per_epoch)
        self.current_iter = 0
        self.current_epoch = 0

        self.train_loss_list = []
        self.train_acc_list = []
        self.test_acc_list = []

    def train_step(self):
        batch_mask = np.random.choice(self.train_size, self.batch_size)
        x_batch = self.x_train[batch_mask]
        t_batch = self.t_train[batch_mask]

        grads = self.network.gradient(x_batch, t_batch)
        self.optimizer.update(self.network.params, grads)

        loss = self.network.loss(x_batch, t_batch)
        self.train_loss_list.append(loss)
        #if self.verbose: print("train loss:" + str(loss))

        if self.current_iter % self.iter_per_epoch == 0:
            self.current_epoch += 1

            x_train_sample, t_train_sample = self.x_train, self.t_train
            x_test_sample, t_test_sample = self.x_test, self.t_test
            if not self.evaluate_sample_num_per_epoch is None:
                t = self.evaluate_sample_num_per_epoch
                x_train_sample, t_train_sample = self.x_train[:t], self.t_train[:t]
                x_test_sample, t_test_sample = self.x_test[:t], self.t_test[:t]

            train_acc = self.network.accuracy(x_train_sample, t_train_sample)
            test_acc = self.network.accuracy(x_test_sample, t_test_sample)
            self.train_acc_list.append(train_acc)
            self.test_acc_list.append(test_acc)

            if self.verbose: print("=== epoch:" + str(self.current_epoch) + ", train acc:" +
str(train_acc) + ", test acc:" + str(test_acc) + " ===")
        self.current_iter += 1

    def train(self):
        for i in range(self.max_iter):
            self.train_step()

        test_acc = self.network.accuracy(self.x_test, self.t_test)
        if self.verbose:
            print("=============== Final Test Accuracy ===============")
            print("test acc:" + str(test_acc))

#optimizer
class SGD:

    """随机梯度下降法（Stochastic Gradient Descent）"""

    def __init__(self, lr=0.01):
        self.lr = lr

    def update(self, params, grads):
        for key in params.keys():
            params[key] -= self.lr * grads[key]


class Momentum:

    """Momentum SGD"""

    def __init__(self, lr=0.01, momentum=0.9):
        self.lr = lr
        self.momentum = momentum
        self.v = None

    def update(self, params, grads):
        if self.v is None:
            self.v = {}
            for key, val in params.items():
                self.v[key] = np.zeros_like(val)

        for key in params.keys():
            self.v[key] = self.momentum*self.v[key] - self.lr*grads[key]
            params[key] += self.v[key]


class Nesterov:

    """Nesterov's Accelerated Gradient (http://arxiv.org/abs/1212.0901)"""

    def __init__(self, lr=0.01, momentum=0.9):
        self.lr = lr
        self.momentum = momentum
        self.v = None

    def update(self, params, grads):
        if self.v is None:
            self.v = {}
            for key, val in params.items():
                self.v[key] = np.zeros_like(val)

        for key in params.keys():
            self.v[key] *= self.momentum
            self.v[key] -= self.lr * grads[key]
            params[key] += self.momentum * self.momentum * self.v[key]
            params[key] -= (1 + self.momentum) * self.lr * grads[key]


class AdaGrad:

    """AdaGrad"""

    def __init__(self, lr=0.01):
        self.lr = lr
        self.h = None

    def update(self, params, grads):
        if self.h is None:
            self.h = {}
            for key, val in params.items():
                self.h[key] = np.zeros_like(val)

        for key in params.keys():
            self.h[key] += grads[key] * grads[key]
            params[key] -= self.lr * grads[key] / (np.sqrt(self.h[key]) + 1e-7)


class RMSprop:

    """RMSprop"""

    def __init__(self, lr=0.01, decay_rate = 0.99):
        self.lr = lr
        self.decay_rate = decay_rate
        self.h = None

    def update(self, params, grads):
        if self.h is None:
            self.h = {}
            for key, val in params.items():
                self.h[key] = np.zeros_like(val)

        for key in params.keys():
            self.h[key] *= self.decay_rate
            self.h[key] += (1 - self.decay_rate) * grads[key] * grads[key]
            params[key] -= self.lr * grads[key] / (np.sqrt(self.h[key]) + 1e-7)


class Adam:

    """Adam (http://arxiv.org/abs/1412.6980v8)"""

    def __init__(self, lr=0.001, beta1=0.9, beta2=0.999):
        self.lr = lr
        self.beta1 = beta1
        self.beta2 = beta2
        self.iter = 0
        self.m = None
        self.v = None

    def update(self, params, grads):
        if self.m is None:
            self.m, self.v = {}, {}
            for key, val in params.items():
                self.m[key] = np.zeros_like(val)
                self.v[key] = np.zeros_like(val)

        self.iter += 1
        lr_t  = self.lr * np.sqrt(1.0 - self.beta2**self.iter) / (1.0 - self.beta1**self.iter
)

        for key in params.keys():
            #self.m[key] = self.beta1*self.m[key] + (1-self.beta1)*grads[key]
            #self.v[key] = self.beta2*self.v[key] + (1-self.beta2)*(grads[key]**2)
            self.m[key] += (1 - self.beta1) * (grads[key] - self.m[key])
            self.v[key] += (1 - self.beta2) * (grads[key]**2 - self.v[key])

            params[key] -= lr_t * self.m[key] / (np.sqrt(self.v[key]) + 1e-7)

            #unbias_m += (1 - self.beta1) * (grads[key] - self.m[key]) # correct bias
            #unbias_m += (1 - self.beta1) * (grads[key] - self.m[key]) # correct bias
            #unbisa_b += (1 - self.beta2) * (grads[key]*grads[key] - self.v[key]) # correct b
ias
            #params[key] += self.lr * unbias_m / (np.sqrt(unbisa_b) + 1e-7)

#funtions
def smooth_curve(x):
    """用于使损失函数的图形变圆滑

    参考：http://glowingpython.blogspot.jp/2012/02/convolution-with-numpy.html
    """
    window_len = 11
    s = np.r_[x[window_len-1:0:-1], x, x[-1:-window_len:-1]]
    w = np.kaiser(window_len, 2)
    y = np.convolve(w/w.sum(), s, mode='valid')
    return y[5:len(y)-5]


def shuffle_dataset(x, t):
    """打乱数据集

    Parameters
    ----------
    x : 训练数据
    t : 监督数据

    Returns
    -------
    x, t : 打乱的训练数据和监督数据
    """
    permutation = np.random.permutation(x.shape[0])
    x = x[permutation,:] if x.ndim == 2 else x[permutation,:,:,:]
    t = t[permutation]

    return x, t

def conv_output_size(input_size, filter_size, stride=1, pad=0):
    return (input_size + 2*pad - filter_size) / stride + 1


def im2col(input_data, filter_h, filter_w, stride=1, pad=0):
    """

    Parameters
    ----------
    input_data : 由(数据量, 通道, 高, 长)的4维数组构成的输入数据
    filter_h : 滤波器的高
    filter_w : 滤波器的长
    stride : 步幅
    pad : 填充

    Returns
    -------
    col : 2维数组
    """
    N, C, H, W = input_data.shape
    out_h = (H + 2*pad - filter_h)//stride + 1
    out_w = (W + 2*pad - filter_w)//stride + 1

    img = np.pad(input_data, [(0,0), (0,0), (pad, pad), (pad, pad)], 'constant')
    col = np.zeros((N, C, filter_h, filter_w, out_h, out_w))

    for y in range(filter_h):
        y_max = y + stride*out_h
        for x in range(filter_w):
            x_max = x + stride*out_w
            col[:, :, y, x, :, :] = img[:, :, y:y_max:stride, x:x_max:stride]

    col = col.transpose(0, 4, 5, 1, 2, 3).reshape(N*out_h*out_w, -1)
    return col


def col2im(col, input_shape, filter_h, filter_w, stride=1, pad=0):
    """

    Parameters
    ----------
    col :
    input_shape : 输入数据的形状（例: (10, 1, 28, 28)）
    filter_h :
    filter_w
    stride
    pad

    Returns
    -------

    """
    N, C, H, W = input_shape
    out_h = (H + 2*pad - filter_h)//stride + 1
    out_w = (W + 2*pad - filter_w)//stride + 1
    col = col.reshape(N, out_h, out_w, C, filter_h, filter_w).transpose(0, 3, 4, 5, 1, 2)

    img = np.zeros((N, C, H + 2*pad + stride - 1, W + 2*pad + stride - 1))
    for y in range(filter_h):
        y_max = y + stride*out_h
        for x in range(filter_w):
            x_max = x + stride*out_w
            img[:, :, y:y_max:stride, x:x_max:stride] += col[:, :, y, x, :, :]

    return img[:, :, pad:H + pad, pad:W + pad]

#functions of loss calculations
def identity_function(x):
    return x


def step_function(x):
    return np.array(x > 0, dtype=np.int)


def sigmoid(x):
    return 1 / (1 + np.exp(-x))


def sigmoid_grad(x):
    return (1.0 - sigmoid(x)) * sigmoid(x)


def relu(x):
    return np.maximum(0, x)


def relu_grad(x):
    grad = np.zeros(x)
    grad[x>=0] = 1
    return grad


def softmax(x):
    if x.ndim == 2:
        x = x.T
        x = x.T
        x = x - np.max(x, axis=0)
        y = np.exp(x) / np.sum(np.exp(x), axis=0)
        return y.T

    x = x - np.max(x) # 溢出对策
    return np.exp(x) / np.sum(np.exp(x))


def mean_squared_error(y, t):
    return 0.5 * np.sum((y-t)**2)


def cross_entropy_error(y, t):
    if y.ndim == 1:
        t = t.reshape(1, t.size)
        y = y.reshape(1, y.size)

    # 监督数据是one-hot-vector的情况下，转换为正确解标签的索引
    if t.size == y.size:
        t = t.argmax(axis=1)

    batch_size = y.shape[0]
    return -np.sum(np.log(y[np.arange(batch_size), t] + 1e-7)) / batch_size


def softmax_loss(X, t):
    y = softmax(X)
    return cross_entropy_error(y, t)
'''
def numerical_gradient(f, x):
    h = 1e-4 # 0.0001
    grad = np.zeros_like(x)

    it = np.nditer(x, flags=['multi_index'], op_flags=['readwrite'])
    while not it.finished:
        idx = it.multi_index
        tmp_val = x[idx]
        x[idx] = float(tmp_val) + h
        fxh1 = f(x) # f(x+h)

        x[idx] = tmp_val - h
        fxh2 = f(x) # f(x-h)
        grad[idx] = (fxh1 - fxh2) / (2*h)

        x[idx] = tmp_val # 还原值
        it.iternext()

    return grad
'''
```

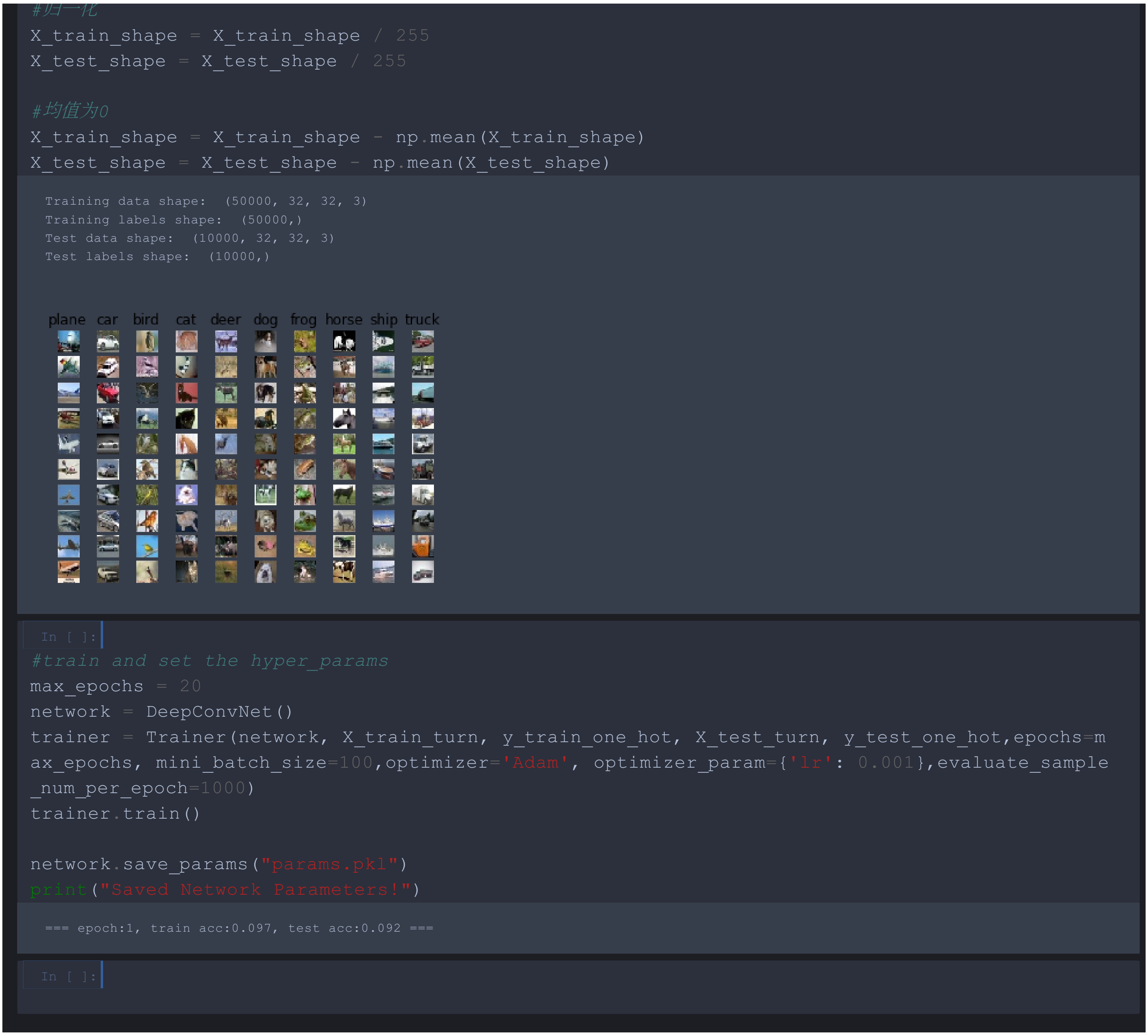
In [3]:

```
#all of the layers defined here
class Relu:
    def __init__(self):
        self.mask = None
        self.mask1 = None

    def forward(self, x):
        self.mask = (x <= 0)
        self.mask1 = (x >= 6)
        out = x.copy()
        out[self.mask] = 0
        out[self.mask1] = 6

        return out
```

```python
    def backward(self, dout):
        dout[self.mask] = 0
        dout[self.mask1] = 0
        dx = dout

        return dx


class Sigmoid:
    def __init__(self):
        self.out = None

    def forward(self, x):
        out = sigmoid(x)
        self.out = out
        return out

    def backward(self, dout):
        dx = dout * (1.0 - self.out) * self.out

        return dx


class Affine:
    def __init__(self, W, b):
        self.W =W
        self.b = b

        self.x = None
        self.original_x_shape = None
        # 权重和偏置参数的导数
        self.dW = None
        self.db = None

    def forward(self, x):
        # 对应张量
        self.original_x_shape = x.shape
        x = x.reshape(x.shape[0], -1)
        self.x = x

        out = np.dot(self.x, self.W) + self.b

        return out

    def backward(self, dout):
        dx = np.dot(dout, self.W.T)
        self.dW = np.dot(self.x.T, dout)
        self.db = np.sum(dout, axis=0)

        dx = dx.reshape(*self.original_x_shape)  # 还原输入数据的形状（对应张量）
        return dx


class SoftmaxWithLoss:
    def __init__(self):
        self.loss = None
        self.y = None # softmax的输出
        self.t = None # 监督数据

    def forward(self, x, t):
        self.t = t
        self.y = softmax(x)
        self.loss = cross_entropy_error(self.y, self.t)

        return self.loss
    def backward(self, dout=1):
        batch_size = self.t.shape[0]
        if self.t.size == self.y.size: # 监督数据是one-hot-vector的情况
            dx = (self.y - self.t) / batch_size
        else:
            dx = self.y.copy()
            dx[np.arange(batch_size), self.t] -= 1
            dx = dx / batch_size

        return dx


class Dropout:
    """
    http://arxiv.org/abs/1207.0580
    """
    def __init__(self, dropout_ratio=0.5):
        self.dropout_ratio = dropout_ratio
        self.mask = None

    def forward(self, x, train_flg=True):
        if train_flg:
            self.mask = np.random.rand(*x.shape) > self.dropout_ratio
            return x * self.mask
        else:
            return x * (1.0 - self.dropout_ratio)

    def backward(self, dout):
        return dout * self.mask


class BatchNormalization:
    """
    http://arxiv.org/abs/1502.03167
    """
    def __init__(self, gamma, beta, momentum=0.9, running_mean=None, running_var=None):
        self.gamma = gamma
        self.beta = beta
        self.momentum = momentum
        self.input_shape = None # Conv层的情况下为4维，全连接层的情况下为2维

        # 测试时使用的平均值和方差
        self.running_mean = running_mean
        self.running_var = running_var

        # backward时使用的中间数据
        self.batch_size = None
        self.xc = None
        self.std = None
        self.dgamma = None
        self.dbeta = None

    def forward(self, x, train_flg=True):
        self.input_shape = x.shape
        if x.ndim != 2:
            N, C, H, W = x.shape
            x = x.reshape(N, -1)

        out = self.__forward(x, train_flg)

        return out.reshape(*self.input_shape)

    def __forward(self, x, train_flg):
        if self.running_mean is None:
            N, D = x.shape
            self.running_mean = np.zeros(D)
            self.running_var = np.zeros(D)

        if train_flg:
            mu = x.mean(axis=0)
            xc = x - mu
            var = np.mean(xc**2, axis=0)
            std = np.sqrt(var + 10e-7)
            xn = xc / std

            self.batch_size = x.shape[0]
            self.xc = xc
            self.xn = xn
            self.std = std
            self.running_mean = self.momentum * self.running_mean + (1-self.momentum) * mu
            self.running_var = self.momentum * self.running_var + (1-self.momentum) * var

        else:
            xc = x - self.running_mean
            xn = xc / ((np.sqrt(self.running_var + 10e-7)))

        out = self.gamma * xn + self.beta
        return out

    def backward(self, dout):
        if dout.ndim != 2:
            N, C, H, W = dout.shape
            dout = dout.reshape(N, -1)

        dx = self.__backward(dout)

        dx = dx.reshape(*self.input_shape)
        return dx

    def __backward(self, dout):
        dbeta = dout.sum(axis=0)
        dgamma = np.sum(self.xn * dout, axis=0)
        dxn = self.gamma * dout
        dxc = dxn / self.std
        dstd = -np.sum((dxn * self.xc) / (self.std * self.std), axis=0)
        dvar = 0.5 * dstd / self.std
        dxc += (2.0 / self.batch_size) * self.xc * dvar
        dmu = np.sum(dxc, axis=0)
        dx = dxc - dmu / self.batch_size

        self.dgamma = dgamma
        self.dbeta = dbeta

        return dx


class Convolution:
    def __init__(self, W, b, stride=1, pad=0):
        self.W = W
        self.b = b
        self.stride = stride
        self.pad = pad

        # 中间数据（backward时使用）
        self.x = None
        self.col = None
        self.col_W = None

        # 权重和偏置参数的梯度
        self.dW = None
        self.db = None
        self.db = None

    def forward(self, x):
        FN, C, FH, FW = self.W.shape
        N, C, H, W = x.shape
        out_h = 1 + int((H + 2*self.pad - FH) / self.stride)
        out_w = 1 + int((W + 2*self.pad - FW) / self.stride)

        col = im2col(x, FH, FW, self.stride, self.pad)
        col_W = self.W.reshape(FN, -1).T

        out = np.dot(col, col_W) + self.b
        out = out.reshape(N, out_h, out_w, -1).transpose(0, 3, 1, 2)

        self.x = x
        self.col = col
        self.col_W = col_W

        return out

    def backward(self, dout):
        FN, C, FH, FW = self.W.shape
        dout = dout.transpose(0,2,3,1).reshape(-1, FN)

        self.db = np.sum(dout, axis=0)
        self.dW = np.dot(self.col.T, dout)
        self.dW = self.dW.transpose(1, 0).reshape(FN, C, FH, FW)

        dcol = np.dot(dout, self.col_W.T)
        dx = col2im(dcol, self.x.shape, FH, FW, self.stride, self.pad)

        return dx


class Pooling:
    def __init__(self, pool_h, pool_w, stride=1, pad=0):
        self.pool_h = pool_h
        self.pool_w = pool_w
        self.stride = stride
        self.pad = pad

        self.x = None
        self.arg_max = None

    def forward(self, x):
        N, C, H, W = x.shape
        out_h = int(1 + (H - self.pool_h) / self.stride)
        out_w = int(1 + (W - self.pool_w) / self.stride)

        col = im2col(x, self.pool_h, self.pool_w, self.stride, self.pad)
        col = col.reshape(-1, self.pool_h*self.pool_w)

        arg_max = np.argmax(col, axis=1)
        out = np.max(col, axis=1)
        out = out.reshape(N, out_h, out_w, C).transpose(0, 3, 1, 2)

        self.x = x
        self.arg_max = arg_max

        return out

    def backward(self, dout):
        dout = dout.transpose(0, 2, 3, 1)

        pool_size = self.pool_h * self.pool_w
        dmax = np.zeros((dout.size, pool_size))
        dmax[np.arange(self.arg_max.size), self.arg_max.flatten()] = dout.flatten()
        dmax = dmax.reshape(dout.shape + (pool_size,))

        dcol = dmax.reshape(dmax.shape[0] * dmax.shape[1] * dmax.shape[2], -1)
        dx = col2im(dcol, self.x.shape, self.pool_h, self.pool_w, self.stride, self.pad)

        return dx

#calss of network
class DeepConvNet:
    """识别率为99%以上的高精度的ConvNet

    网络结构如下所示
        conv - relu - conv- relu - pool -
        conv - relu - conv- relu - pool -
        conv - relu - conv- relu - pool -
        affine - relu - dropout - affine - dropout - softmax
    """
    def __init__(self, input_dim=(3, 32, 32),
                 conv_param_1 = {'filter_num':16, 'filter_size':3, 'pad':1, 'stride':1},
                 conv_param_2 = {'filter_num':16, 'filter_size':3, 'pad':1, 'stride':1},
                 conv_param_3 = {'filter_num':32, 'filter_size':3, 'pad':1, 'stride':1},
                 conv_param_4 = {'filter_num':32, 'filter_size':3, 'pad':2, 'stride':1},
                 conv_param_5 = {'filter_num':64, 'filter_size':3, 'pad':1, 'stride':1},
                 conv_param_6 = {'filter_num':64, 'filter_size':3, 'pad':1, 'stride':1},
                 hidden_size=50, output_size=10):
        # 初始化权重===========
        # 各层的神经元平均与前一层的几个神经元有连接（TODO:自动计算）
        pre_node_nums = np.array([1*3*3, 16*3*3, 16*3*3, 32*3*3, 32*3*3, 64*3*3, 64*4*4, hidd
en_size])
        wight_init_scales = np.sqrt(2.0 / pre_node_nums)  # 使用ReLU的情况下推荐的初始值

        self.params = {}
        pre_channel_num = input_dim[0]
        for idx, conv_param in enumerate([conv_param_1, conv_param_2, conv_param_3, conv_param
_4, conv_param_5, conv_param_6]):
            self.params['W' + str(idx+1)] = wight_init_scales[idx] * np.random.randn(conv_para
m['filter_num'], pre_channel_num, conv_param['filter_size'], conv_param['filter_size'])
            self.params['b' + str(idx+1)] = np.zeros(conv_param['filter_num'])
            pre_channel_num = conv_param['filter_num']
        self.params['W7'] = wight_init_scales[6] * np.random.randn(64*4*4, hidden_size)
        self.params['b7'] = np.zeros(hidden_size)
        self.params['W8'] = wight_init_scales[7] * np.random.randn(hidden_size, output_size)
        self.params['b8'] = np.zeros(output_size)

        # 生成层===========
        self.layers = []
        self.layers.append(Convolution(self.params['W1'], self.params['b1'],
                           conv_param_1['stride'], conv_param_1['pad']))
        self.layers.append(Relu())
        self.layers.append(Convolution(self.params['W2'], self.params['b2'],
                           conv_param_2['stride'], conv_param_2['pad']))
        self.layers.append(Relu())
        self.layers.append(Pooling(pool_h=2, pool_w=2, stride=2))
        self.layers.append(Convolution(self.params['W3'], self.params['b3'],
                           conv_param_3['stride'], conv_param_3['pad']))
        self.layers.append(Relu())
        self.layers.append(Convolution(self.params['W4'], self.params['b4'],
                           conv_param_4['stride'], conv_param_4['pad']))
        self.layers.append(Relu())
        self.layers.append(Pooling(pool_h=2, pool_w=2, stride=2))
        self.layers.append(Convolution(self.params['W5'], self.params['b5'],
                           conv_param_5['stride'], conv_param_5['pad']))
        self.layers.append(Relu())
        self.layers.append(Convolution(self.params['W6'], self.params['b6'],
                           conv_param_6['stride'], conv_param_6['pad']))
                           conv_param_6['stride'], conv_param_6['pad']))
        self.layers.append(Relu())
        self.layers.append(Pooling(pool_h=2, pool_w=2, stride=2))
        self.layers.append(Affine(self.params['W7'], self.params['b7']))
        self.layers.append(Relu())
        self.layers.append(Dropout(0.5))
        self.layers.append(Affine(self.params['W8'], self.params['b8']))
        self.layers.append(Dropout(0.5))

        self.last_layer = SoftmaxWithLoss()

    def predict(self, x, train_flg=False):
        for layer in self.layers:
            if isinstance(layer, Dropout):
                x = layer.forward(x, train_flg)
            else:
                x = layer.forward(x)
        return x

    def loss(self, x, t):
        y = self.predict(x, train_flg=True)
        return self.last_layer.forward(y, t)

    def accuracy(self, x, t, batch_size=100):
        if t.ndim != 1 : t = np.argmax(t, axis=1)

        acc = 0.0

        for i in range(int(x.shape[0] / batch_size)):
            tx = x[i*batch_size:(i+1)*batch_size]
            tt = t[i*batch_size:(i+1)*batch_size]
            y = self.predict(tx, train_flg=False)
            y = np.argmax(y, axis=1)
            acc += np.sum(y == tt)

        return acc / x.shape[0]

    def gradient(self, x, t):
        # forward
        self.loss(x, t)

        # backward
        dout = 1
        dout = self.last_layer.backward(dout)

        tmp_layers = self.layers.copy()
        tmp_layers.reverse()
        for layer in tmp_layers:
            dout = layer.backward(dout)

        # 设定
        grads = {}
        for i, layer_idx in enumerate((0, 2, 5, 7, 10, 12, 15, 18)):
            grads['W' + str(i+1)] = self.layers[layer_idx].dW
            grads['b' + str(i+1)] = self.layers[layer_idx].db

        return grads

'''############微分求梯度
    def numerical_gradient(self, X, T):

        loss_W = lambda W: self.loss(X, T)

        grads = {}
        for idx in range(1,9):
            grads['W' + str(idx)] = numerical_gradient(loss_W, self.params['W' + str(idx)])
            grads['b' + str(idx)] = numerical_gradient(loss_W, self.params['b' + str(idx)])

        return grads

###############'''

    def save_params(self, file_name="params.pkl"):
        params = {}
        for key, val in self.params.items():
            params[key] = val
        with open(file_name, 'wb') as f:
            pickle.dump(params, f)

    def load_params(self, file_name="params.pkl"):
        with open(file_name, 'rb') as f:
            params = pickle.load(f)
        for key, val in params.items():
            self.params[key] = val

        for i, layer_idx in enumerate((0, 2, 5, 7, 10, 12, 15, 18)):
            self.layers[layer_idx].W = self.params['W' + str(i+1)]
            self.layers[layer_idx].b = self.params['b' + str(i+1)]
```

In [8]:

```
#process the data
cifar10_dir = 'cifar-10-batches-py/'
X_train, y_train, X_test, y_test = load_CIFAR10(cifar10_dir)
#打印训练集与测试集数量、图片大小
print('Training data shape: ', X_train.shape)   #np.array数组的shape属性，返回各维度的维数
print('Training labels shape: ', y_train.shape)
print('Test data shape: ', X_test.shape)
print('Test labels shape: ', y_test.shape)


#Training data shape:  (50000, 32, 32, 3)
#从左到右分别为训练集图像数量、高、宽以及通道数

classes = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'truck']
num_classes = len(classes)
samples_per_class = 10 #每个类别取10张
for y, clss in enumerate(classes): #enumerate遍历输出函数，输出下标及列表数据，y为下标，cls为类名
    idxs = np.flatnonzero(y_train == y) #输出非零元素位置，获取图片对应标签的下标，按种类分类
    idxs = np.random.choice(idxs, samples_per_class, replace=False)
    #随机选取每个类的10个下标值，replace参数决定是否有重复随机数
    for i, idx in enumerate(idxs): #返回图
        plt_idx = i * num_classes + y + 1 #输出的图片的序号，作为绘图函数参数
        plt.subplot(samples_per_class, num_classes, plt_idx) #种类、数量以及位置索引
        plt.imshow(X_train[idx].astype('uint8'))
        plt.axis('off') #不要坐标轴
        if i == 0:  #主题为该组标签
            plt.title(clss)
plt.show()
#数据处理
y_train_one_hot = np.zeros((50000,10)) #二维需要双括号，三维需要三括号
y_test_one_hot = np.zeros((10000,10))
for i, num in enumerate(y_train):  #转换为one-hot编码
    y_train_one_hot[i][num] = 1

for i, num in enumerate(y_test):
    y_test_one_hot[i][num] = 1

X_train_turn = X_train.reshape((50000, 3, 32, 32))
X_test_turn = X_test.reshape((10000, 3, 32, 32))
X_train_shape = X_train.reshape((50000, 3072))
X_test_shape = X_test.reshape((10000, 3072))

#归一化
```



```
#归一化
X_train_shape = X_train_shape / 255
X_test_shape = X_test_shape / 255

#均值为0
X_train_shape = X_train_shape - np.mean(X_train_shape)
X_test_shape = X_test_shape - np.mean(X_test_shape)
```

```
Training data shape:  (50000, 32, 32, 3)
Training labels shape:  (50000,)
Test data shape:  (10000, 32, 32, 3)
Test labels shape:  (10000,)
```

In [ ]:

```
#train and set the hyper_params
max_epochs = 20
network = DeepConvNet()
trainer = Trainer(network, X_train_turn, y_train_one_hot, X_test_turn, y_test_one_hot,epochs=m
ax_epochs, mini_batch_size=100,optimizer='Adam', optimizer_param={'lr': 0.001},evaluate_sample
_num_per_epoch=1000)
trainer.train()

network.save_params("params.pkl")
print("Saved Network Parameters!")
```

```
=== epoch:1, train acc:0.097, test acc:0.092 ===
```

In [ ]: