In [2]:

```
import torch
import torchvision
import torchvision.transforms as transforms
import numpy as np
```

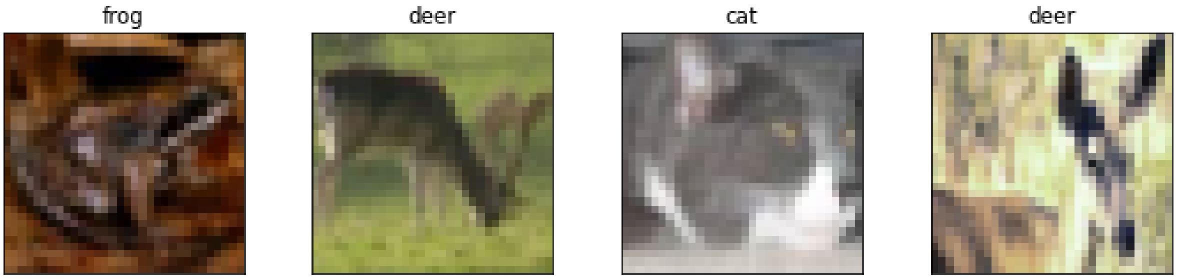
In [3]:

```
transform = transforms.Compose(
    [transforms.ToTensor(),
     transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))])

trainset = torchvision.datasets.CIFAR10(root='/home/CIFAR-10 Classifier Using
 CNN in PyTorch/data/',
                                        train=True,
                                        download=True,
                                        transform=transform)
trainloader = torch.utils.data.DataLoader(trainset,
                                          batch_size=4,
                                          shuffle=True)
testset = torchvision.datasets.CIFAR10(root='./data',
                                       train=False,
                                       download=True,
                                       transform=transform)
testloader = torch.utils.data.DataLoader(testset,
                                         batch_size=4,
                                         shuffle=False)

classes = ('plane', 'car', 'bird', 'cat', 'deer',
           'dog', 'frog', 'horse', 'ship', 'truck')
```

```
Files already downloaded and verified
Files already downloaded and verified
```

In [17]:

```python
def convert_to_imshow_format(image):
    # first convert back to [0,1] range from [-1,1] range
    image = image / 2 + 0.5
    image = image.numpy()
    # convert from CHW to HWC
    # from 3x32x32 to 32x32x3
    return image.transpose(1,2,0)

dataiter = iter(trainloader)
images, labels = dataiter.next()

fig, axes = plt.subplots(1, len(images), figsize=(12,2.5))
for idx, image in enumerate(images):
    axes[idx].imshow(convert_to_imshow_format(image))
    axes[idx].set_title(classes[labels[idx]])
    axes[idx].set_xticks([])
    axes[idx].set_yticks([])
```



In [4]:

```python
import torch.nn as nn
import torch.nn.functional as F

class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.conv1 = nn.Conv2d(3, 6, 5)
        self.pool = nn.MaxPool2d(2, 2)
        self.conv2 = nn.Conv2d(6, 16, 5)
        self.fc1 = nn.Linear(16 * 5 * 5, 120)
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        x = x.view(-1, 16 * 5 * 5)
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
        return x

net = Net()
```

In [5]:

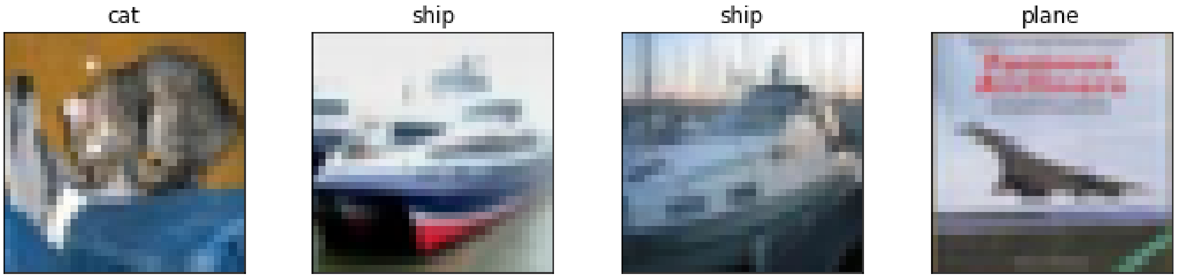
```
import torch.optim as optim

criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(net.parameters(), lr=0.001, momentum=0.9)
```

In [6]:

```
import os

model_directory_path = '/home/CIFAR-10 Classifier Using CNN in PyTorch/model/'
model_path = model_directory_path + 'cifar-10-cnn-model.pt'

if not os.path.exists(model_directory_path):
    os.makedirs(model_directory_path)

if os.path.isfile(model_path):
    # load trained model parameters from disk
    net.load_state_dict(torch.load(model_path))
    print('Loaded model parameters from disk.')
else:
    for epoch in range(2):  # loop over the dataset multiple times

        running_loss = 0.0
        for i, data in enumerate(trainloader, 0):
            # get the inputs
            inputs, labels = data

            # zero the parameter gradients
            optimizer.zero_grad()

            # forward + backward + optimize
            outputs = net(inputs)
            loss = criterion(outputs, labels)
            loss.backward()
            optimizer.step()

            # print statistics
            running_loss += loss.item()
            if i % 2000 == 1999:    # print every 2000 mini-batches
                print('[%d, %5d] loss: %.3f' %
                      (epoch + 1, i + 1, running_loss / 2000))
                running_loss = 0.0
    print('Finished Training.')
    torch.save(net.state_dict(), model_path)
    print('Saved model parameters to disk.')
```

```
Loaded model parameters from disk.
```

In [18]:
```
dataiter = iter(testloader)
images, labels = dataiter.next()

fig, axes = plt.subplots(1, len(images), figsize=(12,2.5))
for idx, image in enumerate(images):
    axes[idx].imshow(convert_to_imshow_format(image))
    axes[idx].set_title(classes[labels[idx]])
    axes[idx].set_xticks([])
    axes[idx].set_yticks([])
```



In [8]:
```
outputs = net(images)
```

In [9]:
```
outputs
```

Out[9]:
```
tensor([[-0.5587, -1.3294, -0.0147,  1.7789, -0.9728,  0.8734,  0.2706, -0.60
86,
         -0.2059,  0.2847],
        [ 4.8533,  5.2669, -0.6852, -2.5590, -2.6156, -4.4962, -2.6582, -4.18
07,
          5.4332,  3.9467],
        [ 2.4263,  2.5022, -0.4277, -1.3331, -1.3506, -2.5808, -1.3142, -2.63
37,
          3.4305,  2.0966],
        [ 3.4028,  1.2159,  0.6023, -1.1971, -1.3105, -2.9989, -1.2615, -2.89
25,
          4.5330,  0.9981]], grad_fn=<AddmmBackward>)
```

In [10]:
```
sm = nn.Softmax(dim=1)
sm_outputs = sm(outputs)
print(sm_outputs)
```

```
tensor([[3.9401e-02, 1.8229e-02, 6.7883e-02, 4.0804e-01, 2.6041e-02, 1.6498e-
01,
         9.0294e-02, 3.7484e-02, 5.6070e-02, 9.1576e-02],
        [2.1242e-01, 3.2121e-01, 8.3527e-04, 1.2825e-04, 1.2120e-04, 1.8481e-
05,
         1.1614e-04, 2.5336e-05, 3.7934e-01, 8.5787e-02],
        [1.7642e-01, 1.9033e-01, 1.0164e-02, 4.1103e-03, 4.0391e-03, 1.1803e-
03,
         4.1887e-03, 1.1195e-03, 4.8157e-01, 1.2688e-01],
        [2.2771e-01, 2.5563e-02, 1.3840e-02, 2.2892e-03, 2.0437e-03, 3.7772e-
04,
         2.1464e-03, 4.2012e-04, 7.0505e-01, 2.0561e-02]],
       grad_fn=<SoftmaxBackward>)
```

In [11]:

```
probs, index = torch.max(sm_outputs, dim=1)

for p, i in zip(probs, index):
    print('{0} - {1:.4f}'.format(classes[i], p))
```

```
cat - 0.4080
ship - 0.3793
ship - 0.4816
ship - 0.7051
```

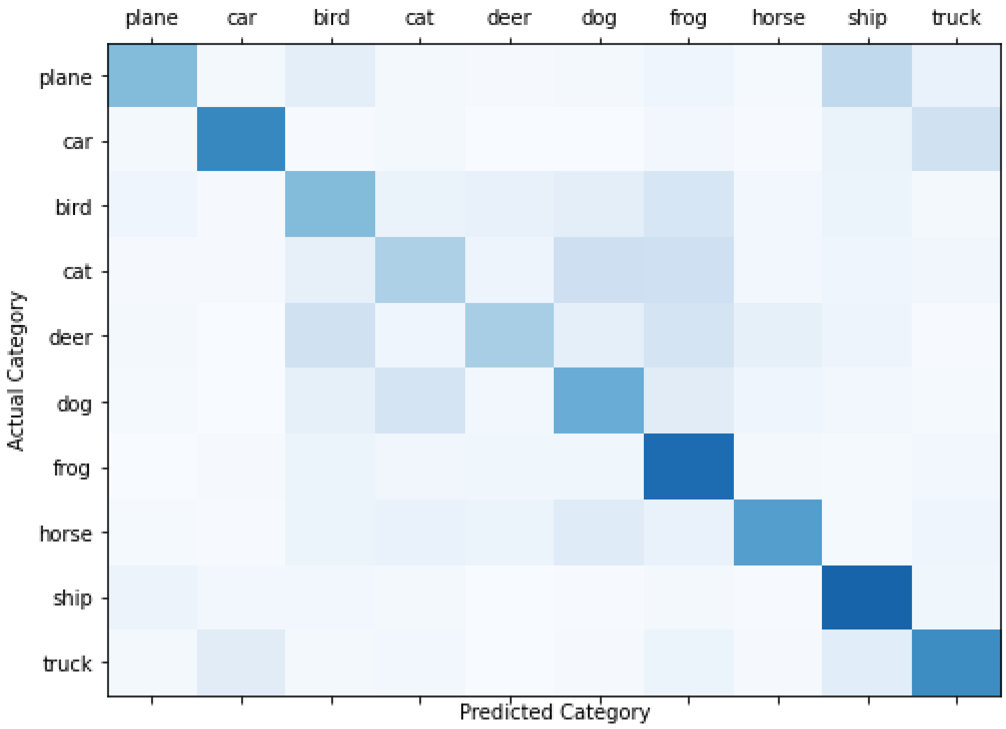
In [12]:

```
total_correct = 0
total_images = 0
confusion_matrix = np.zeros([10,10], int)
with torch.no_grad():
    for data in testloader:
        images, labels = data
        outputs = net(images)
        _, predicted = torch.max(outputs.data, 1)
        total_images += labels.size(0)
        total_correct += (predicted == labels).sum().item()
        for i, l in enumerate(labels):
            confusion_matrix[l.item(), predicted[i].item()] += 1

model_accuracy = total_correct / total_images * 100
print('Model accuracy on {0} test images: {1:.2f}%'.format(total_images, model
_accuracy))
```

```
Model accuracy on 10000 test images: 54.98%
```

In [14]:

```
from matplotlib import pyplot as plt

fig, ax = plt.subplots(1,1,figsize=(8,6))
ax.matshow(confusion_matrix, aspect='auto', vmin=0, vmax=1000, cmap=plt.get_cm
ap('Blues'))
plt.ylabel('Actual Category')
plt.yticks(range(10), classes)
plt.xlabel('Predicted Category')
plt.xticks(range(10), classes)
plt.show()
```



In [19]:

```
print('{0:10s} - {1}'.format('Category','Accuracy'))
for i, r in enumerate(confusion_matrix):
    print('{0:10s} - {1:.1f}'.format(classes[i], r[i]/np.sum(r)*100))
```

```
Category   - Accuracy
plane      - 44.1
car        - 66.2
bird       - 44.1
cat        - 32.5
deer       - 34.4
dog        - 50.5
frog       - 76.9
horse      - 56.9
ship       - 79.8
truck      - 64.4
```

In [20]:

```
print('actual/pred'.ljust(16), end='')
for i,c in enumerate(classes):
    print(c.ljust(10), end='')
print()
for i,r in enumerate(confusion_matrix):
    print(classes[i].ljust(16), end='')
    for idx, p in enumerate(r):
        print(str(p).ljust(10), end='')
    print()

    r = r/np.sum(r)
    print(''.ljust(16), end='')
    for idx, p in enumerate(r):
        print(str(p).ljust(10), end='')
    print()
```

```
actual/pred     plane     car       bird      cat       deer      dog       f
rog      horse     ship      truck
plane           441       19        99        21        9         23        4
1        13        265        69
                0.441     0.019     0.099     0.021     0.009     0.023
0.041     0.013     0.265     0.069
car             18        662       6         17        3         3         2
4        6         64         197
                0.018     0.662     0.006     0.017     0.003     0.003
0.024     0.006     0.064     0.197
bird            46        11        441       66        73        100       1
60       30        52         21
                0.046     0.011     0.441     0.066     0.073     0.1
0.16      0.03      0.052     0.021
cat             10        10        79        325       48        214       2
09       29        42         34
                0.01      0.01      0.079     0.325     0.048     0.214
0.209     0.029     0.042     0.034
deer            21        3         197       41        344       86        1
72       83        47       6
                0.021     0.003     0.197     0.041     0.344     0.086
0.172     0.083     0.047     0.006
dog             12        1         85        174       30        505       1
13       40        27         13
                0.012     0.001     0.085     0.174     0.03      0.505
0.113     0.04      0.027     0.013
frog            3         8         59        35        36        36        7
69       16        14         24
                0.003     0.008     0.059     0.035     0.036     0.036
0.769     0.016     0.014     0.024
horse           12        4         51        70        54        120       6
7        569       13         40
                0.012     0.004     0.051     0.07      0.054     0.12
0.067     0.569     0.013     0.04
ship            58        31        31        18        2         6         1
6        4         798        36
                0.058     0.031     0.031     0.018     0.002     0.006
0.016     0.004     0.798     0.036
truck           16        110       17        30        2         8         5
3        11        109       644
                0.016     0.11      0.017     0.03      0.002     0.008
0.053     0.011     0.109     0.644
```

In [23]:

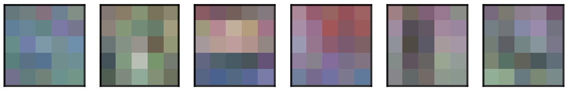
```
net.conv1
```

Out[23]:

```
Conv2d(3, 6, kernel_size=(5, 5), stride=(1, 1))
```

In [29]:

```
conv1 = net.conv1
weight = conv1.weight.data

fig, axes = plt.subplots(1, len(weight), figsize=(5,5))
for idx, image in enumerate(weight):
    axes[idx].imshow(convert_to_imshow_format(image))
    axes[idx].set_xticks([])
    axes[idx].set_yticks([])
```



In [52]:

```
NUM_CLASSES = 10

class AlexNet(nn.Module):
    def __init__(self, num_classes=NUM_CLASSES):
        super(AlexNet, self).__init__()
        self.features = nn.Sequential(
            nn.Conv2d(3, 64, kernel_size=3, stride=2, padding=1),
            nn.ReLU(inplace=True),
            nn.MaxPool2d(kernel_size=2),
            nn.Conv2d(64, 192, kernel_size=3, padding=1),
            nn.ReLU(inplace=True),
            nn.MaxPool2d(kernel_size=2),
            nn.Conv2d(192, 384, kernel_size=3, padding=1),
            nn.ReLU(inplace=True),
            nn.Conv2d(384, 256, kernel_size=3, padding=1),
            nn.ReLU(inplace=True),
            nn.Conv2d(256, 256, kernel_size=3, padding=1),
            nn.ReLU(inplace=True),
            nn.MaxPool2d(kernel_size=2),
        )
        self.classifier = nn.Sequential(
            nn.Dropout(),
            nn.Linear(256 * 2 * 2, 2048),
            nn.ReLU(inplace=True),
            nn.Dropout(),
            nn.Linear(2048, 2048),
            nn.ReLU(inplace=True),
            nn.Linear(2048, num_classes),
        )

    def forward(self, x):
        x = self.features(x)
        x = x.view(x.size(0), 256 * 2 * 2)
        x = self.classifier(x)
        return x

alex_net = AlexNet()
```

In [53]:

```
import torch.optim as optim

criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(alex_net.parameters(), lr=0.001, momentum=0.9)
```

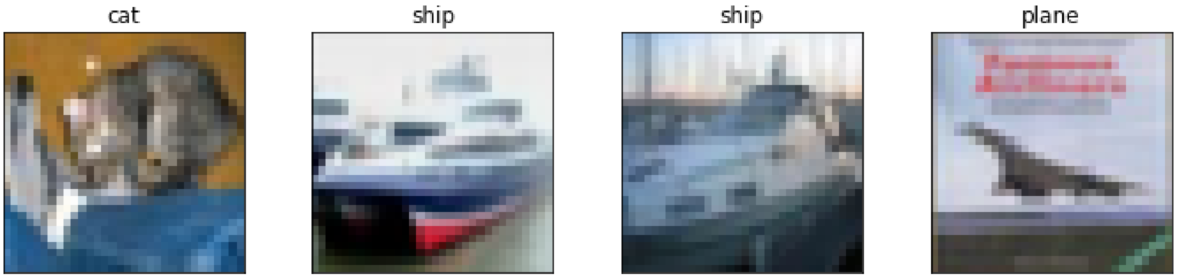
In [54]:

```
import os

model_directory_path = '/home/CIFAR-10 Classifier Using CNN in PyTorch/model/'
model_path = model_directory_path + 'cifar-10-cnn-model_alex_net.pt'

if not os.path.exists(model_directory_path):
    os.makedirs(model_directory_path)

if os.path.isfile(model_path):
    # load trained model parameters from disk
    alex_net.load_state_dict(torch.load(model_path))
    print('Loaded model parameters from disk.')
else:
    for epoch in range(2):  # loop over the dataset multiple times

        running_loss = 0.0
        for i, data in enumerate(trainloader, 0):
            # get the inputs
            inputs, labels = data

            # zero the parameter gradients
            optimizer.zero_grad()

            # forward + backward + optimize
            outputs = alex_net(inputs)
            loss = criterion(outputs, labels)
            loss.backward()
            optimizer.step()

            # print statistics
            running_loss += loss.item()
            if i % 2000 == 1999:    # print every 2000 mini-batches
                print('[%d, %5d] loss: %.3f' %
                      (epoch + 1, i + 1, running_loss / 2000))
                running_loss = 0.0
    print('Finished Training.')
    torch.save(alex_net.state_dict(), model_path)
    print('Saved model parameters to disk.')
```

```
[1,  2000] loss: 2.303
[1,  4000] loss: 2.261
[1,  6000] loss: 2.063
[1,  8000] loss: 1.906
[1, 10000] loss: 1.802
[1, 12000] loss: 1.728
[2,  2000] loss: 1.622
[2,  4000] loss: 1.568
[2,  6000] loss: 1.456
[2,  8000] loss: 1.418
[2, 10000] loss: 1.374
[2, 12000] loss: 1.324
Finished Training.
Saved model parameters to disk.
```

In [45]:

```
dataiter = iter(testloader)
images, labels = dataiter.next()

fig, axes = plt.subplots(1, len(images), figsize=(12,2.5))
for idx, image in enumerate(images):
    axes[idx].imshow(convert_to_imshow_format(image))
    axes[idx].set_title(classes[labels[idx]])
    axes[idx].set_xticks([])
    axes[idx].set_yticks([])
```



In [46]:

```
outputs = alex_net(images)
sm = nn.Softmax(dim=1)
sm_outputs = sm(outputs)
print(sm_outputs)
```

```
tensor([[0.0633, 0.0763, 0.1413, 0.1392, 0.0593, 0.1062, 0.1346, 0.0423, 0.13
77,
         0.1000],
        [0.1124, 0.3729, 0.0102, 0.0065, 0.0060, 0.0033, 0.0047, 0.0070, 0.24
56,
         0.2314],
        [0.1307, 0.1137, 0.1016, 0.0657, 0.0553, 0.0562, 0.1327, 0.0286, 0.19
48,
         0.1207],
        [0.2044, 0.0921, 0.0160, 0.0032, 0.0033, 0.0014, 0.0021, 0.0016, 0.64
81,
         0.0278]], grad_fn=<SoftmaxBackward>)
```

In [47]:

```
probs, index = torch.max(sm_outputs, dim=1)

for p, i in zip(probs, index):
    print('{0} - {1:.4f}'.format(classes[i], p))
```

```
bird - 0.1413
car - 0.3729
ship - 0.1948
ship - 0.6481
```

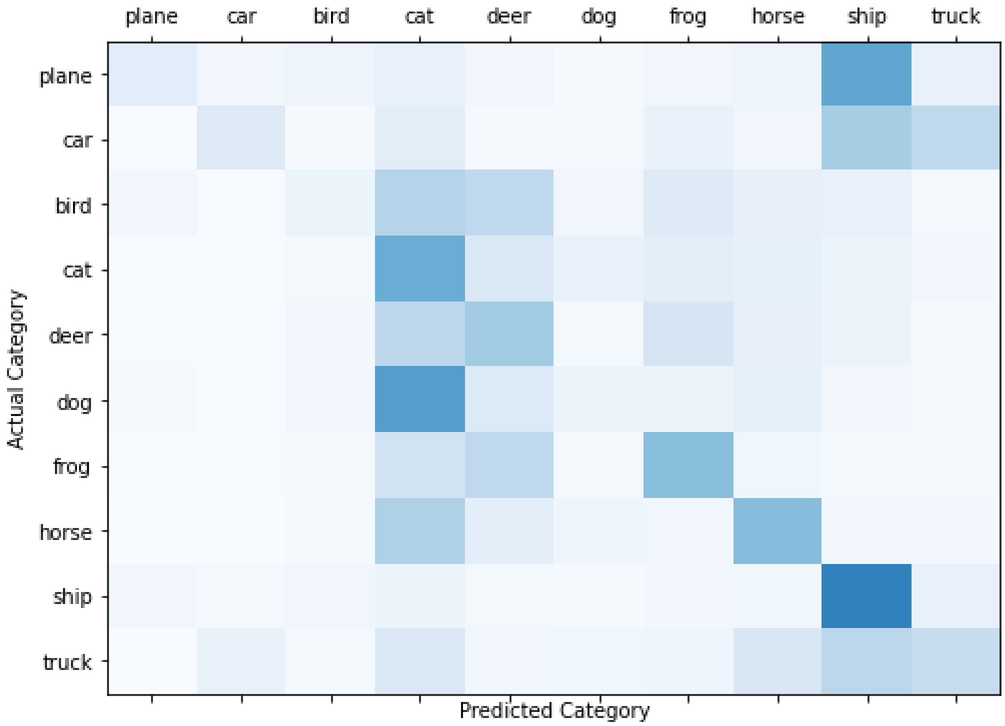
In [48]:

```
total_correct = 0
total_images = 0
confusion_matrix = np.zeros([10,10], int)
with torch.no_grad():
    for data in testloader:
        images, labels = data
        outputs = alex_net(images)
        _, predicted = torch.max(outputs.data, 1)
        total_images += labels.size(0)
        total_correct += (predicted == labels).sum().item()
        for i, l in enumerate(labels):
            confusion_matrix[l.item(), predicted[i].item()] += 1

model_accuracy = total_correct / total_images * 100
print('Model accuracy on {0} test images: {1:.2f}%'.format(total_images, model_accuracy))
```

```
Model accuracy on 10000 test images: 30.14%
```

In [49]:

```
from matplotlib import pyplot as plt

fig, ax = plt.subplots(1,1,figsize=(8,6))
ax.matshow(confusion_matrix, aspect='auto', vmin=0, vmax=1000, cmap=plt.get_cmap('Blues'))
plt.ylabel('Actual Category')
plt.yticks(range(10), classes)
plt.xlabel('Predicted Category')
plt.xticks(range(10), classes)
plt.show()
```



In [ ]: