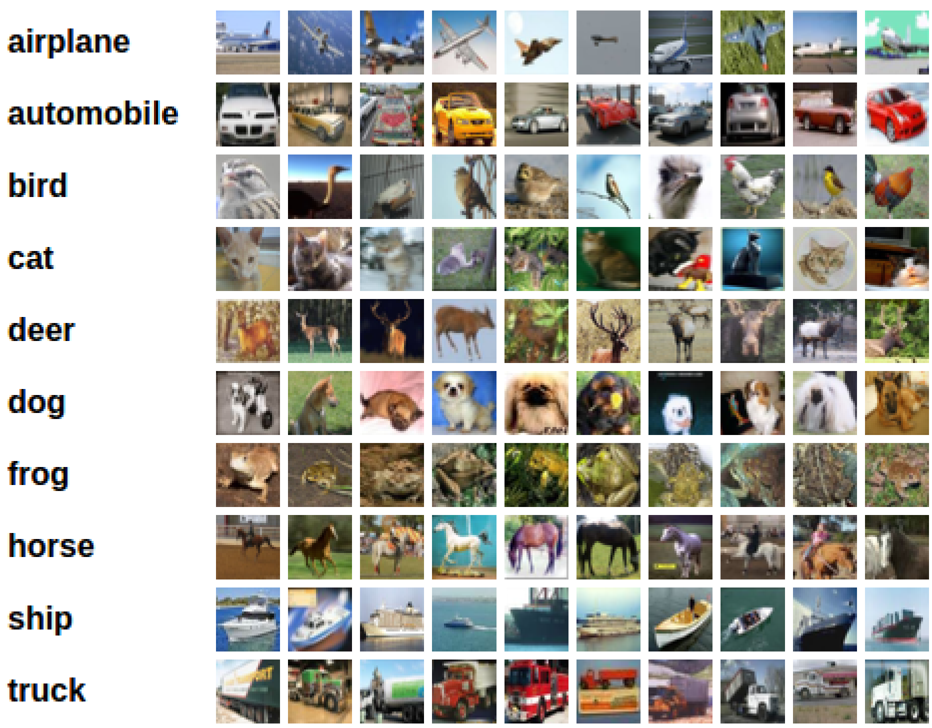
CNN

```
import numpy as np

import torch
import torchvision
import torchvision.transforms as transforms

import matplotlib.pyplot as plt
import os
```

```
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
```

CIFAR Image

```
from IPython.display import Image
image_url = 'https://bitbucket.org/hyuk125/lg_dic/raw/ae5f66c58a905dd778a803ba
Image(image_url)
```



CIFAR data import

OFFline pickle data

```
# def unpickle(file):
#     with open(file, 'rb') as fo:
#         dict = pickle.load(fo, encoding='bytes')
#     return dict
# data = unpickle(os.path.join(os.path.join(path, 'cifar-10-batches-py') ,'/da
```

OFFline PIL data

```
# OFFline PIL data
# trainset = torchvision.datasets.CIFAR10(root=path, train=True,
#                                         download=False)
```

Online PIL image data

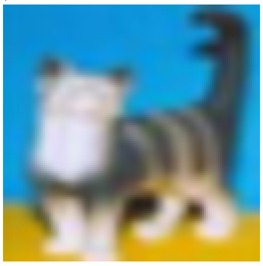
```
# # For online situation
trainset = torchvision.datasets.CIFAR10(root='./data', train=True,
                                        download=True)
```

```
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to ./data/cifar-10-pythor
170499072/? [00:05<00:00, 32370798.04it/s]
Extracting ./data/cifar-10-python.tar.gz to ./data
```

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

```
for i in range(5):
    index = np.random.randint(len(trainset), dtype=int)
    image, label = trainset[index]
    image = image.resize((128, 128))
    display(image)
    print(classes[label])
```

plane



cat

ship

Transform PIL data to torch data and normalization

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

trainset = torchvision.datasets.CIFAR10(root='./data', train=True,
                                        download=False, transform=transform)

```

```
a, _ =trainset[0]
a
```

```
tensor([[[-0.5373, -0.6627, -0.6078,  ...,  0.2392,  0.1922,  0.1608],
         [-0.8745, -1.0000, -0.8588,  ..., -0.0353, -0.0667, -0.0431],
         [-0.8039, -0.8745, -0.6157,  ..., -0.0745, -0.0588, -0.1451],
         ...,
         [ 0.6314,  0.5765,  0.5529,  ...,  0.2549, -0.5608, -0.5843],
         [ 0.4118,  0.3569,  0.4588,  ...,  0.4431, -0.2392, -0.3490],
         [ 0.3882,  0.3176,  0.4039,  ...,  0.6941,  0.1843, -0.0353]],

        [[-0.5137, -0.6392, -0.6235,  ...,  0.0353, -0.0196, -0.0275],
         [-0.8431, -1.0000, -0.9373,  ..., -0.3098, -0.3490, -0.3176],
         [-0.8118, -0.9451, -0.7882,  ..., -0.3412, -0.3412, -0.4275],
         ...,
         [ 0.3333,  0.2000,  0.2627,  ...,  0.0431, -0.7569, -0.7333],
         [ 0.0902, -0.0353,  0.1294,  ...,  0.1608, -0.5137, -0.5843],
         [ 0.1294,  0.0118,  0.1137,  ...,  0.4431, -0.0745, -0.2784]],
```

```
         [[-0.5059, -0.6471, -0.6627,  ..., -0.1529, -0.2000, -0.1922],
          [-0.8431, -1.0000, -1.0000,  ..., -0.5686, -0.6078, -0.5529],
          [-0.8353, -1.0000, -0.9373,  ..., -0.6078, -0.6078, -0.6706],
          ...,
          [-0.2471, -0.7333, -0.7961,  ..., -0.4510, -0.9451, -0.8431],
          [-0.2471, -0.6706, -0.7647,  ..., -0.2627, -0.7333, -0.7333],
          [-0.0902, -0.2627, -0.3176,  ...,  0.0980, -0.3412, -0.4353]]]])
```

Make Dataloader

```
trainloader = torch.utils.data.DataLoader(trainset, batch_size=4,
                                          shuffle=True, num_workers=2)
```

Define Model

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

New modules

- torch.nn.Conv2d(in_channels, out_channels, kernel_size, stride=1, padding=0, ..., padding_mode='zeros', ...)
- torch.nn.MaxPool2d(kernel_size, stride=None, padding=0, ...)

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.conv1 = nn.Conv2d(3, 6, 5) # Convolution layer
        self.pool = nn.MaxPool2d(2, 2)  # Pooling layer

        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()
net.to(device)
```

```
Net(
  (conv1): Conv2d(3, 6, kernel_size=(5, 5), stride=(1, 1))
  (pool): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  (conv2): Conv2d(6, 16, kernel_size=(5, 5), stride=(1, 1))
  (fc1): Linear(in_features=400, out_features=120, bias=True)
  (fc2): Linear(in_features=120, out_features=84, bias=True)
  (fc3): Linear(in_features=84, out_features=10, bias=True)
)
```

Tips for complicated convolution layer (same as above model)

```
def conv_block(in_dim, out_dim):
    model = nn.Sequential(
        nn.Conv2d(in_dim, out_dim, kernel_size = 5),
        nn.ReLU(),
        nn.MaxPool2d(2, 2)
    )
    return model
```

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.feature = nn.Sequential(
            conv_block(3, 6),
            conv_block(6, 16)
        )

        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.conv1(x)
#         x = self.pool(F.relu(self.conv2(x)))
        x = self.feature(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()
net.to(device)

```

Learning the model

```
learning_rate = 0.001
```

```
import torch.optim as optim

criterion = nn.CrossEntropyLoss().to(device)
optimizer = optim.Adam(net.parameters(), lr = learning_rate)
```

```
epochs = 20
```

```
for epoch in range(epochs):
    running_cost = 0.0

    for step, (batch_data) in enumerate(trainloader):
        batch_x, batch_y = batch_data[0].to(device), batch_data[1].to(device)

        optimizer.zero_grad()

        outputs = net(batch_x)
        cost = criterion(outputs, batch_y)

        cost.backward()
        optimizer.step()

        running_cost += cost.item()
        if step % 2000 == 1999:
            print('[%d, %5d] cost: %.3f' % (epoch + 1, step + 1, running_cost
            running_cost = 0.0

```

```
/usr/local/lib/python3.7/dist-packages/torch/nn/functional.py:718: UserWarning: Named ten
  return torch.max_pool2d(input, kernel_size, stride, padding, dilation, ceil_mode)
[1,  2000] cost: 1.852
[1,  4000] cost: 1.612
[1,  6000] cost: 1.526
[1,  8000] cost: 1.456
[1, 10000] cost: 1.421
[1, 12000] cost: 1.374
[2,  2000] cost: 1.310
[2,  4000] cost: 1.304
[2,  6000] cost: 1.260
[2,  8000] cost: 1.252
[2, 10000] cost: 1.276
[2, 12000] cost: 1.237
[3,  2000] cost: 1.169
[3,  4000] cost: 1.180
[3,  6000] cost: 1.176
[3,  8000] cost: 1.171
[3, 10000] cost: 1.185
[3, 12000] cost: 1.176
[4,  2000] cost: 1.120
[4,  4000] cost: 1.104
[4,  6000] cost: 1.105
```

```
[4,  8000] cost: 1.127
[4, 10000] cost: 1.106
[4, 12000] cost: 1.102
[5,  2000] cost: 1.046
[5,  4000] cost: 1.041
[5,  6000] cost: 1.058
[5,  8000] cost: 1.082
[5, 10000] cost: 1.079
[5, 12000] cost: 1.080
[6,  2000] cost: 1.015
[6,  4000] cost: 1.013
[6,  6000] cost: 1.011
[6,  8000] cost: 1.034
[6, 10000] cost: 1.033
[6, 12000] cost: 1.053
[7,  2000] cost: 0.963
[7,  4000] cost: 0.968
[7,  6000] cost: 0.978
[7,  8000] cost: 1.006
[7, 10000] cost: 1.015
[7, 12000] cost: 0.993
[8,  2000] cost: 0.909
[8,  4000] cost: 0.962
[8,  6000] cost: 0.953
[8,  8000] cost: 0.963
[8, 10000] cost: 0.980
[8, 12000] cost: 0.990
[9,  2000] cost: 0.890
[9,  4000] cost: 0.931
[9,  6000] cost: 0.948
[9,  8000] cost: 0.949
[9, 10000] cost: 0.944
[9, 12000] cost: 0.965
[10,  2000] cost: 0.862
[10,  4000] cost: 0.904
```

정확도 판단

Test dataset import

```
testset = torchvision.datasets.CIFAR10(root='./data', train=False,
                                       download=True, transform=transform)
testloader = torch.utils.data.DataLoader(testset, batch_size=len(testset),
                                         shuffle=False, num_workers=2)
```

```
Files already downloaded and verified
```

Confusion matrix and scores

```
test_iter = iter(testloader)
test_x, test_labels = test_iter.next()
```

```
outputs = net(test_x.to(device))
_, predicted = torch.max(outputs, 1)
```

```
predicted
```

```
tensor([3, 8, 1,  ..., 5, 1, 7], device='cuda:0')
```

Confusion matrix

```
from sklearn.metrics import confusion_matrix
predicted = predicted.cpu()
print(confusion_matrix(test_labels, predicted))
```

```
[[691  44  31  35  34  15   8  33  55  54]
 [ 25 762   1  18   6   9  16  20  11 132]
 [ 87   7 383 103 147  82  74  83  15  19]
 [ 29  12  44 427  77 217  62  93  10  29]
 [ 21   4  42  96 541  59  91 130   8   8]
 [ 21   7  37 182  56 545  16 123   1  12]
 [  5   9  27 113  74  39 680  27  10  16]
 [ 10   2  13  63  73  79   8 735   2  15]
 [146  87  19  33  24  12   7  10 590  72]
 [ 43 103   5  26   8  22  16  62  15 700]]
```

Precision

```
from sklearn.metrics import precision_score
print(precision_score(test_labels, predicted, average=None))
print(precision_score(test_labels, predicted, average='weighted'))
```

```
[0.64100186 0.73481196 0.63621262 0.38959854 0.52019231 0.50509731
 0.69529652 0.55851064 0.82287308 0.66225166]
0.6165846497338424
```

Recall

```
from sklearn.metrics import recall_score
print(recall_score(test_labels, predicted, average=None))
print(recall_score(test_labels, predicted, average='weighted'))
```

```
[0.691 0.762 0.383 0.427 0.541 0.545 0.68  0.735 0.59  0.7  ]
0.6054
```