CIFAR

December 4, 2018

```
In [1]: use_gpu = True
        data_dir = '/home/kartik/data'
```

```
In [2]: import sys
        sys.path.append('../')

        %load_ext autoreload
        %autoreload 1
        %aimport alphagan
```

```
In [3]: from collections import defaultdict
        from psutil import cpu_count

        import numpy as np
        import pandas as pd

        import torch
        from torch import nn
        from torch.nn import init, Parameter
        import torch.nn.functional as F
        from torch.autograd import Variable
        from torch.utils.data import DataLoader
        from torchvision import datasets, models, transforms
        from torchvision.utils import make_grid

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

```
In [4]: # get a image data set into a tensor, scale to (-1, 1), discarding labels
        def torchvision_dataset(dset_fn, train=True):
            dset = dset_fn(
                data_dir,
                train=train,
                transform=transforms.Compose([
                    transforms.ToTensor()
                ]),
                target_transform=None,
                download=True)
            return torch.stack(list(zip(*dset))[0])*2-1
```

```
In [5]: cifar = torchvision_dataset(datasets.CIFAR10, train=True)
        cifar_test = torchvision_dataset(datasets.CIFAR10, train=False)
        print(cifar.size())
```

```
Files already downloaded and verified
Files already downloaded and verified
torch.Size([50000, 3, 32, 32])
```

```
In [6]: batch_size = 256
```

```
In [7]: num_workers = cpu_count() if use_gpu else 0

        X_train = DataLoader(cifar, batch_size=batch_size, shuffle=True,
                             num_workers=num_workers, pin_memory=use_gpu)
        X_test = DataLoader(cifar_test, batch_size=batch_size, shuffle=False,
                            num_workers=num_workers, pin_memory=use_gpu)
```

```
In [8]: class ChannelsToLinear(nn.Linear):
            """Flatten a Variable to 2d and apply Linear layer"""
            def forward(self, x):
                b = x.size(0)
                return super().forward(x.view(b,-1))

        class LinearToChannels2d(nn.Linear):
            """Reshape 2d Variable to 4d after Linear layer"""
            def __init__(self, m, n, w=1, h=None, **kw):
                h = h or w
                super().__init__(m, n*w*h, **kw)
                self.w = w
                self.h = h
            def forward(self, x):
                b = x.size(0)
                return super().forward(x).view(b, -1, self.w, self.h)

        class ResBlock(nn.Module):
            """Simple ResNet block"""
            def __init__(self, c,
                         activation=nn.LeakyReLU, norm=nn.BatchNorm2d,
                         init_gain=1, groups=1):
                super().__init__()
                self.a1 = activation()
                self.a2 = activation()
                self.norm1 = norm and norm(c)
                self.norm2 = norm and norm(c)

                to_init = []
                self.conv1 = nn.Conv2d(
                    c, c, 3, 1, 1, bias=bool(norm), groups=groups)
```

```
            to_init.append(self.conv1.weight)
            self.conv2 = nn.Conv2d(
                c, c, 3, 1, 1, bias=bool(norm), groups=groups)
            to_init.append(self.conv2.weight)

            # if using grouping, add a 1x1 convolution to each conv layer
            if groups!=1:
                self.conv1 = nn.Sequential(
                    self.conv1, nn.Conv2d(c,c,1,bias=bool(norm)))
                self.conv2 = nn.Sequential(
                    self.conv2, nn.Conv2d(c,c,1,bias=bool(norm)))
                to_init.extend([self.conv1[1].weight, self.conv2[1].weight])

            # init
            for w in to_init:
                init.xavier_normal(w, init_gain)

        def forward(self, x):
            y = self.conv1(x)
            if self.norm1:
                y = self.norm1(y)
            y = self.a1(y)

            y = self.conv2(y)
            if self.norm2:
                y = self.norm2(y)

            return self.a2(x+y)
```

In [9]:
```
latent_dim = 128
```

In [10]:
```
# encoder network
h = 128
resample = nn.AvgPool2d
norm = nn.BatchNorm2d#None
a, g = nn.ReLU, init.calculate_gain('relu')
groups = 1#h//8
E = nn.Sequential(
    nn.Conv2d(3,h,5,1,2), resample(2), a(),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups),
    ChannelsToLinear(h*16, latent_dim)
)
for layer in (0,8):
    init.xavier_normal(E[layer].weight, g)

t = Variable(torch.randn(batch_size,3,32,32))
assert E(t).size() == (batch_size,latent_dim)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:47: UserWarning: nn.init.xavier_no
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:15: UserWarning: nn.init.xavier_no
  from ipykernel import kernelapp as app
```

In [11]:
```
# generator network
h = 128
norm = nn.BatchNorm2d#None
a, g = nn.ReLU, init.calculate_gain('relu')
groups = 1#h//8
resample = lambda x: nn.Upsample(scale_factor=x)
G = nn.Sequential(
    LinearToChannels2d(latent_dim,h,4,4), a(),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups),
    nn.Conv2d(h, 3, 1), nn.Tanh()
)
for layer in (0,9):
    init.xavier_normal(G[layer].weight, g)

t = Variable(torch.randn(batch_size,latent_dim))
assert G(t).size() == (batch_size,3,32,32)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:47: UserWarning: nn.init.xavier_no
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:16: UserWarning: nn.init.xavier_no
  app.launch_new_instance()
```

In [12]:
```
# discriminator network
h = 128
resample = nn.AvgPool2d
norm = nn.BatchNorm2d
a, g = lambda: nn.LeakyReLU(.2), init.calculate_gain('leaky_relu', .2)
groups = 1

D = nn.Sequential(
    nn.Conv2d(3,h,5,1,2), resample(2), a(),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups), resample(2),
    ResBlock(h, activation=a, norm=norm, init_gain=g, groups=groups),
    ChannelsToLinear(h*16, 1), nn.Sigmoid()
)
for layer in (0,8):
    init.xavier_normal(D[layer].weight, g)

t = Variable(torch.randn(batch_size,3,32,32))
assert D(t).size() == (batch_size,1)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:47: UserWarning: nn.init.xavier_no
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:16: UserWarning: nn.init.xavier_no
  app.launch_new_instance()
```

```
In [13]: # code discriminator network
         # no batch norm in the code discriminator, it causes trouble
         h = 700
         a, g = lambda: nn.LeakyReLU(.2), init.calculate_gain('leaky_relu', .2)
         C = nn.Sequential(
             nn.Linear(latent_dim, h), a(),
             nn.Linear(h, h), a(),
             nn.Linear(h, 1), nn.Sigmoid(),
         )

         for i,layer in enumerate(C):
             if i%2==0:
                 init.xavier_normal(layer.weight, g)

         t = Variable(torch.randn(batch_size,latent_dim))
         assert C(t).size() == (batch_size,1)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:13: UserWarning: nn.init.xavier_no
  del sys.path[0]
```

```
In [14]: model = alphagan.AlphaGAN(E, G, D, C, latent_dim, lambd=40, z_lambd=0)
         if use_gpu:
             model = model.cuda()

In [15]: # model.load_state_dict(torch.load('../models/cifar10_dim_{}_lambda_{}_zlambd_{}_epoch
         #         latent_dim, model.lambd, model.z_lambd, 8
         #     )))

In [16]: diag = []
         def log_fn(d):
             d = pd.DataFrame(d)
             diag.append(d)
             print(d)
         def checkpoint_fn(model, epoch):
             path =  '../models/cifar10_dim_{}_lambda_{}_zlambd_{}_epochs_{}.torch'.format(
                 model.latent_dim, model.lambd, model.z_lambd, epoch
             )
             torch.save(model.state_dict(), path)

In [17]: model.fit(
             X_train, X_test,
             n_iter=(2,1,1), n_epochs=10,
             log_fn=log_fn, log_every=1,
```

```
            checkpoint_fn=checkpoint_fn, checkpoint_every=2
        )
```

```
HBox(children=(IntProgress(value=0, description='epoch', max=10, style=ProgressStyle(descriptio

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                               train      valid
adversarial_loss            1.491249   1.208733
code_adversarial_loss       1.107558   1.244499
code_discriminator_loss     2.846608   4.656633
discriminator_loss          1.254535   1.358313
reconstruction_loss        10.599710  12.200234

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                             train     valid
adversarial_loss          1.158736  0.987269
code_adversarial_loss     1.146322  1.761189
code_discriminator_loss   2.236347  1.193042
discriminator_loss        1.314758  1.382846
reconstruction_loss       8.604012  7.813487

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                             train     valid
adversarial_loss          1.090680  0.892696
code_adversarial_loss     1.134639  1.479062
code_discriminator_loss   2.156851  1.141951
discriminator_loss        1.319052  1.321063
reconstruction_loss       7.808319  7.550529

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle
```

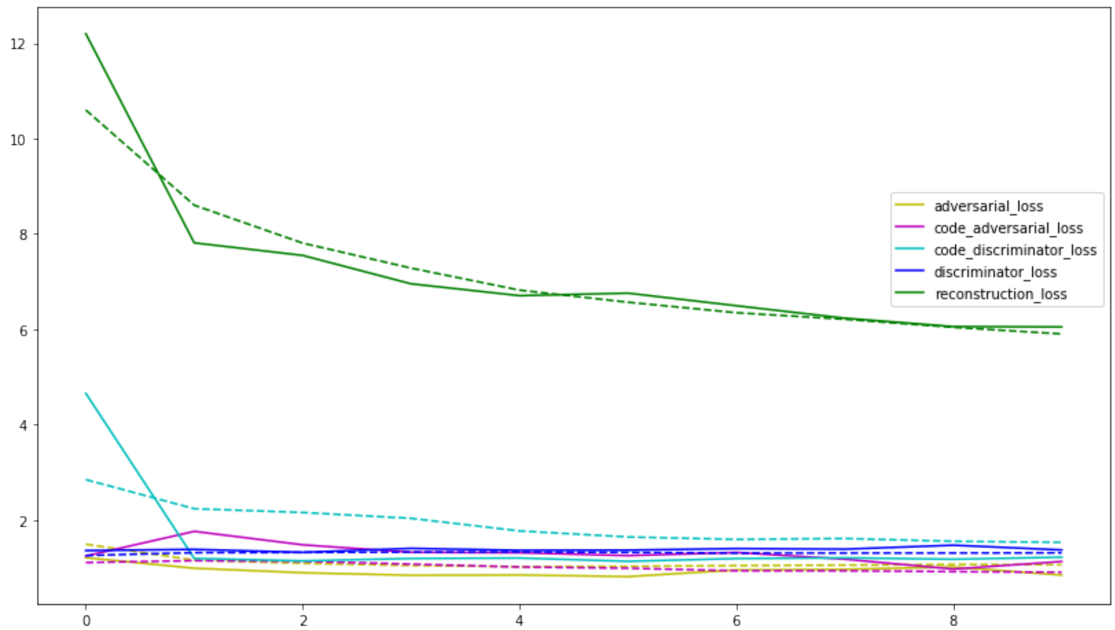
```
HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                           train     valid
adversarial_loss         1.045439  0.839883
code_adversarial_loss    1.074357  1.322083
code_discriminator_loss  2.034314  1.191694
discriminator_loss       1.326508  1.404097
reconstruction_loss      7.283897  6.954408

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                           train     valid
adversarial_loss         1.020808  0.846527
code_adversarial_loss    1.013538  1.313122
code_discriminator_loss  1.769686  1.201549
discriminator_loss       1.330537  1.362522
reconstruction_loss      6.821696  6.706117

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                           train     valid
adversarial_loss         1.025753  0.811732
code_adversarial_loss    0.987070  1.252741
code_discriminator_loss  1.643611  1.132527
discriminator_loss       1.319158  1.366680
reconstruction_loss      6.568081  6.758773

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyle

                           train     valid
adversarial_loss         1.043700  0.950884
code_adversarial_loss    0.934302  1.318607
code_discriminator_loss  1.592984  1.189724
discriminator_loss       1.305093  1.400025
reconstruction_loss      6.348385  6.494437
```

```
HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyl

                            train     valid
adversarial_loss         1.053522  0.962816
code_adversarial_loss    0.933363  1.177023
code_discriminator_loss  1.611025  1.205247
discriminator_loss       1.306511  1.387811
reconstruction_loss      6.211298  6.233727

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyl

                            train     valid
adversarial_loss         1.066927  1.013610
code_adversarial_loss    0.916286  0.969998
code_discriminator_loss  1.553345  1.175605
discriminator_loss       1.307545  1.470947
reconstruction_loss      6.042090  6.057661

HBox(children=(IntProgress(value=0, description='training batch', max=196, style=ProgressStyle

HBox(children=(IntProgress(value=0, description='validating batch', max=40, style=ProgressStyl

                            train     valid
adversarial_loss         1.060852  0.844432
code_adversarial_loss    0.902628  1.128680
code_discriminator_loss  1.530992  1.218899
discriminator_loss       1.311160  1.371434
reconstruction_loss      5.903250  6.049176
```

```
In [18]: fig, ax = plt.subplots(1,1,figsize=(14,8))
         diagnostic = pd.concat([pd.DataFrame(d.stack(), columns=[i]).T for i,d in enumerate(di
         cols = list('rgbcmy')
         colors = defaultdict(lambda: cols.pop())
         for c in diagnostic:
             component, dataset = c
```

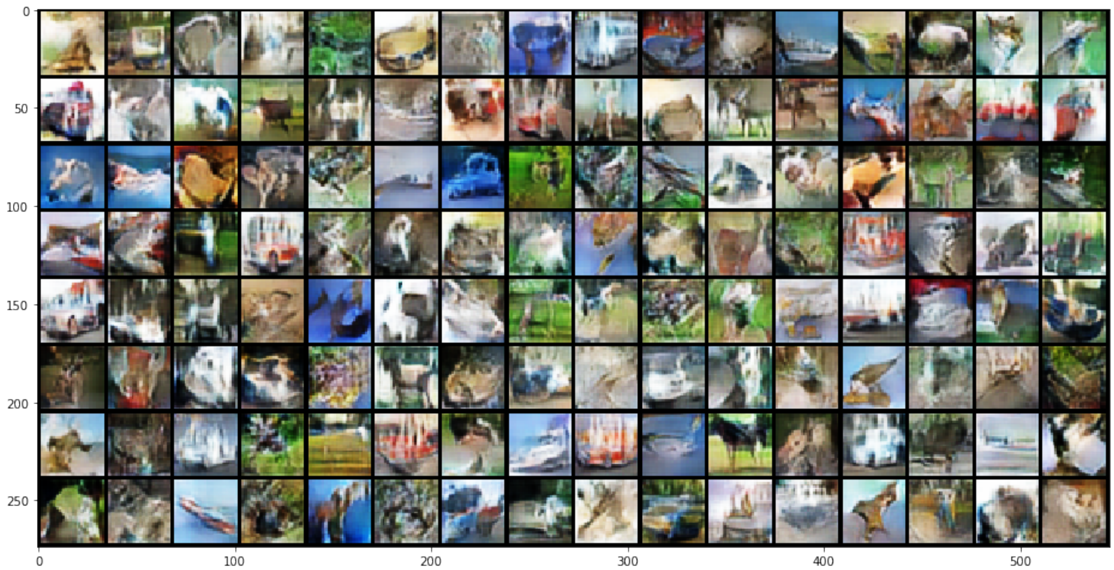
```
        kw = {}
        if dataset=='valid':
            kw['label'] = component
        else:
            kw['ls'] = '--'
        ax.plot(diagnostic[c].values, c=colors[component], **kw)
    ax.legend(bbox_to_anchor=(1, 0.7))
```

Out[18]: <matplotlib.legend.Legend at 0x7f33b345deb8>



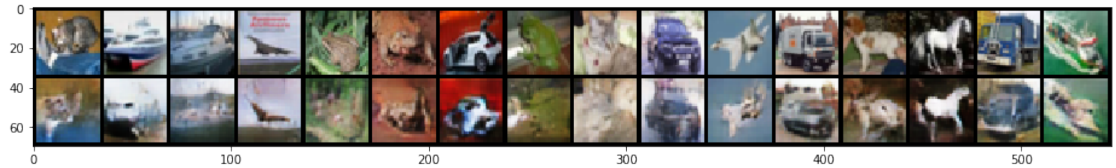
In [19]:
```
model.eval()
pass
```

In [20]:
```
# samples
z, x = model(128, mode='sample')
fig, ax = plt.subplots(1,1,figsize=(16,12))
ax.imshow(make_grid(
    x.data, nrow=16, range=(-1,1), normalize=True
).cpu().numpy().transpose(1,2,0), interpolation='nearest')
pass
```



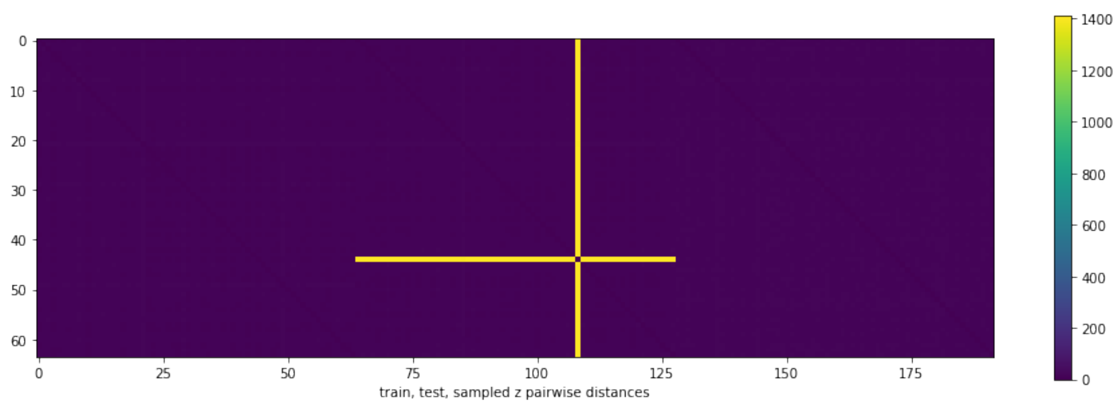

```
In [21]: fig, ax = plt.subplots(1,1,figsize=(16,4))
         # training reconstructions
         x = cifar[:16]
         z, x_rec = model(x)
         ax.imshow(make_grid(
             torch.cat((x, x_rec.cpu().data)), nrow=16, range=(-1,1), normalize=True
         ).cpu().numpy().transpose(1,2,0), interpolation='nearest')
         pass
```


```
In [22]: fig, ax = plt.subplots(1,1,figsize=(16,4))
         # test reconstructions
         x = cifar_test[:16]
         z, x_rec = model(x)
         ax.imshow(make_grid(
             torch.cat((x, x_rec.cpu().data)), nrow=16, range=(-1,1), normalize=True
         ).cpu().numpy().transpose(1,2,0), interpolation='nearest')
         pass
```



0.0.1 pairwise distances give a sense of how encoded z are distributed compared the prior:

In [23]:
```
fig, ax = plt.subplots(1,1,figsize=(16,5))
n = 64

import scipy.spatial
train_z = model(cifar[:n], mode='encode').data.cpu().numpy()
test_z = model(cifar_test[:n], mode='encode').data.cpu().numpy()
sampled_z = model.sample_prior(n).data.cpu().numpy()
train_cdist = scipy.spatial.distance.cdist(train_z,train_z)
test_cdist = scipy.spatial.distance.cdist(test_z,test_z)
sampled_cdist = scipy.spatial.distance.cdist(sampled_z,sampled_z)
cax = ax.imshow(np.concatenate((train_cdist, test_cdist, sampled_cdist),1))
fig.colorbar(cax)
ax.set_xlabel('train, test, sampled z pairwise distances')
pass
```



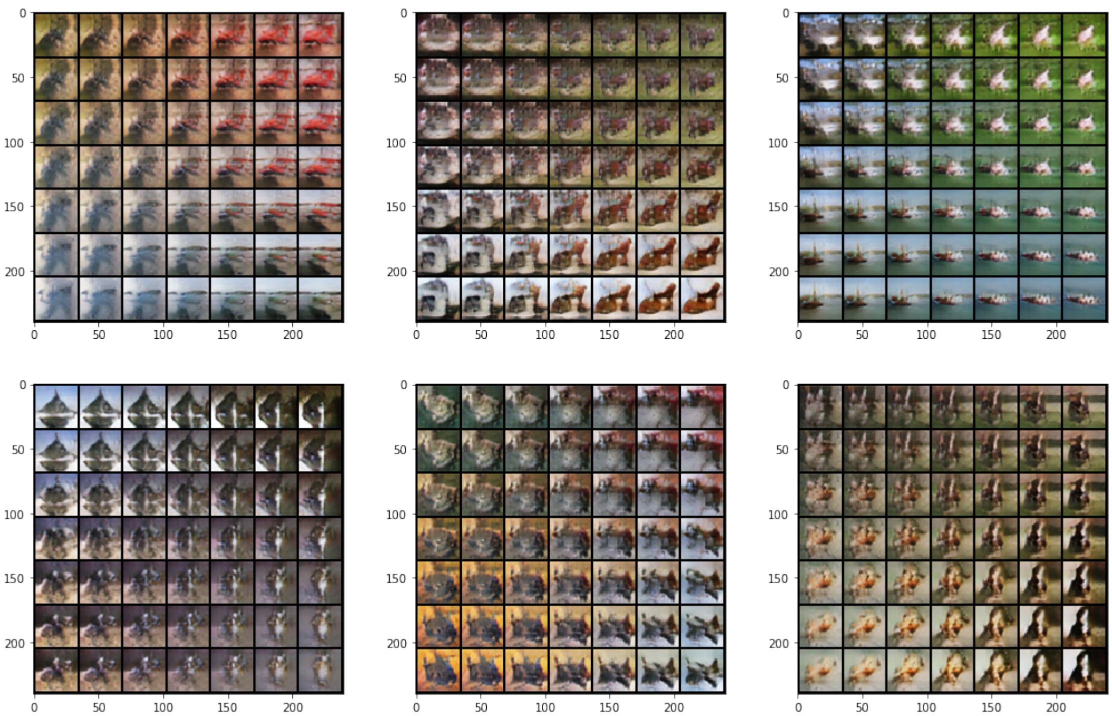
0.0.2 interpolation

In [24]:
```
def slerp(z0, z1, t):
    """Spherical linear interpolation over last dimension:
    z0.shape = z1.shape = (m,...n, d) and t.shape = (q,) -> (q, m,...n, d)
    Project to unit sphere and linearly interpolate magnitudes.
    """
```

```
        m0, m1 = (np.linalg.norm(z, 2, -1) for z in (z0, z1))
        p0, p1 = z0/np.expand_dims(m0,-1), z1/np.expand_dims(m1,-1)
        omega = np.arccos((p0*p1).sum(-1))
        while t.ndim<=omega.ndim:
            t = np.expand_dims(t,-1)
        sin_omega = np.sin(omega)
        t0 = np.sin((1-t)*omega)/sin_omega
        t1 = np.sin(t*omega)/sin_omega
        lim = abs(omega)<1e-15
        t1[lim] = t[lim]
        t0[lim] = (1-t)[lim]
        t0, t1 = np.expand_dims(t0, -1), np.expand_dims(t1, -1)
        m = np.expand_dims((1-t)*m0 + t*m1, -1)
        return m*(t0*p0 + t1*p1)
    def slerp4(z, t):
        # z (4,n) and t (m,) -> z' (m, m, n)
        return slerp(
            slerp(z[0], z[1], t),
            slerp(z[2], z[3], t),
            t)
```

```
In [25]: # torch.manual_seed(2)
```

```
In [26]: n = 7
         fig,ax = plt.subplots(2,3,figsize=(17,11))
         for ax in ax.flatten():
             x = cifar_test[torch.LongTensor(np.random.randint(len(cifar_test),size=4))]
             z = model(x, mode='encode')
             z = slerp4(z.data.cpu().numpy(), np.linspace(0,1,n)).reshape(n*n,-1)
             x_rec = model(z, mode='generate')
             ax.imshow(make_grid(
                 x_rec.cpu().data, nrow=n, range=(-1,1), normalize=True
             ).numpy().transpose(1,2,0), interpolation='nearest')
```



```
In [ ]:
```