VAE

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1. TaskA

We know that

$$\mathrm{KL}(q_\phi(z|x)||p_\theta(z|x)) \geq 0 \tag{1}$$

Thus

$$\begin{aligned} \log p_\theta(x) &\geq \log p_\theta(x) - \mathrm{KL}\left(q_\phi(z \mid x) \| p_\theta(z \mid x)\right) \\ &= \mathbb{E}_{q_\phi(z|x)}\left[\log p_\theta(x, z) - \log q_\phi(z \mid x)\right] \\ &= \mathcal{L}(\theta, \phi) \end{aligned} \tag{2}$$

And the lower bound $\mathcal{L}(\theta, \phi)$is equal to the marginal log likelihood $\log p_\theta(x)$ if and only if when $q_\phi(z|x) = p_\theta(z|x)$ when the Kullback–Leibler divergence between them $\mathrm{KL}(q_\phi(z|x)||p_\theta(z|x))$ is zero

2. TaskB

The 'TODO'parts in the vae.ipynb are completed. The vae.ipynb file is the final version. And the training results is shown below.

```
Epoch 2982 (1.8s): Lower bound = -65.34930419921875
Epoch 2983 (1.8s): Lower bound = -65.34036254882812
Epoch 2984 (1.7s): Lower bound = -65.39115142822266
Epoch 2985 (1.7s): Lower bound = -65.31253051757812
Epoch 2986 (1.7s): Lower bound = -65.32910919189453
Epoch 2987 (1.9s): Lower bound = -65.3271713256836
Epoch 2988 (1.7s): Lower bound = -65.38765716552734
Epoch 2989 (1.7s): Lower bound = -65.31953430175781
Epoch 2990 (1.7s): Lower bound = -65.33808135986328
Epoch 2991 (1.7s): Lower bound = -65.37020874023438
Epoch 2992 (1.7s): Lower bound = -65.31097412109375
Epoch 2993 (1.7s): Lower bound = -65.3431167602539
Epoch 2994 (1.7s): Lower bound = -65.37666320800781
Epoch 2995 (1.7s): Lower bound = -65.36712646484375
Epoch 2996 (1.7s): Lower bound = -65.28607177734375
Epoch 2997 (1.7s): Lower bound = -65.375244140625
Epoch 2998 (1.7s): Lower bound = -65.34246826171875
Epoch 2999 (1.7s): Lower bound = -65.35955810546875
Epoch 3000 (1.8s): Lower bound = -65.31414794921875
```

Figure 1. Training result

3. TaskC

Visualization of the generations of learned model is under images directory. Here are some samples.

Figure 2. Sample epoch=1000

Figure 3. Sample epoch=2000

Figure 4. Sample epoch=3000