Lab3 - MaskGIT for Image Inpainting

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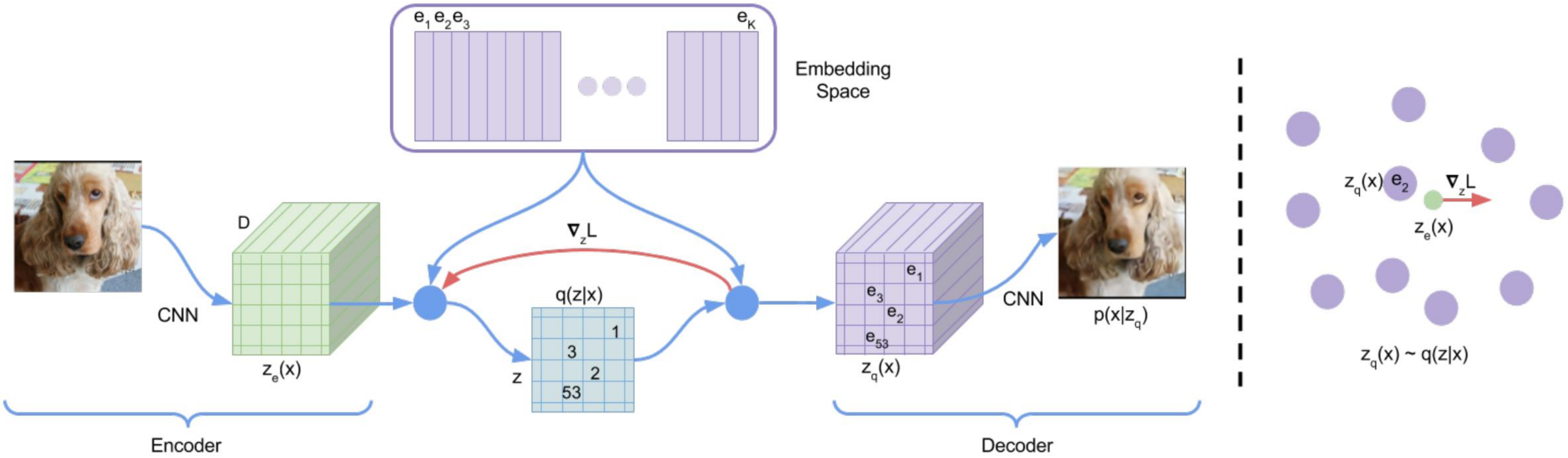
Key Concepts You Should Know First(1/3)

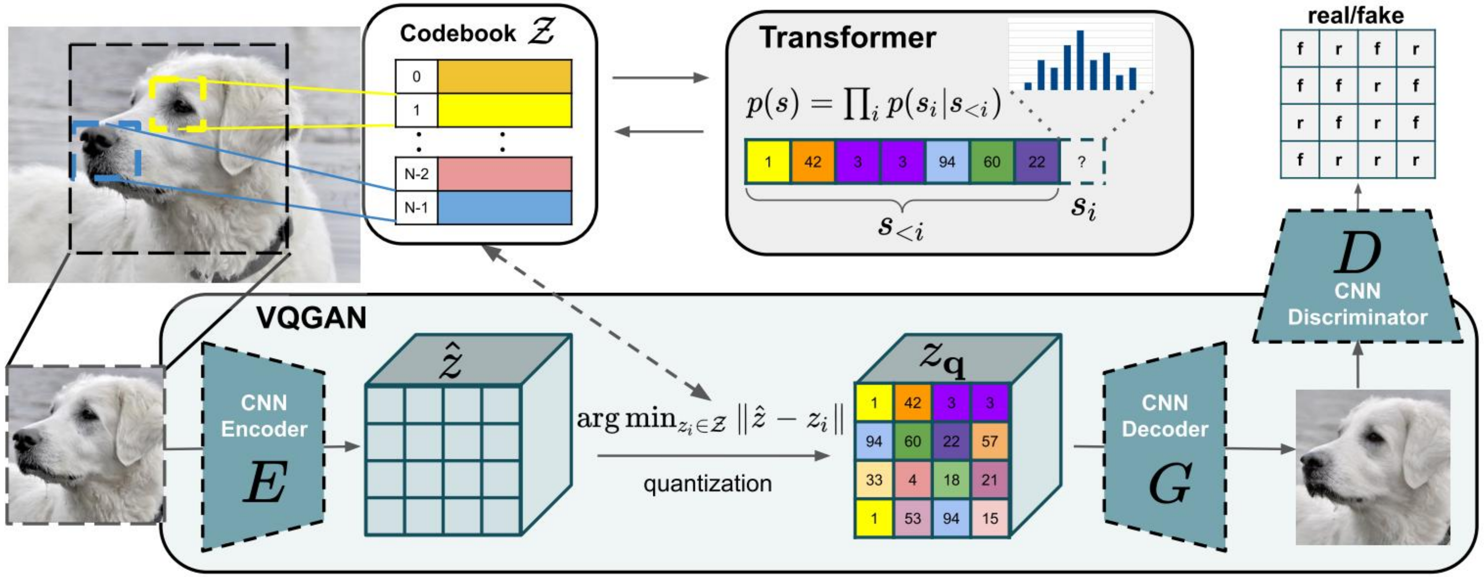
- VQ-VAE
  - Vector quantization: Maps each channel vector in latent space to the nearest codebook entry.



$$q(z=k|x) = \begin{cases} 1 & \text{for } \mathrm{k} = \mathrm{argmin}_j \|z_e(x) - e_j\|_2, \\ 0 & \text{otherwise} \end{cases}$$

Key Concepts You Should Know First(2/3)

- VQ-GAN: use autoregressive transformer to predict tokens (zq)



Perceptual loss replace L2 loss

$$\mathcal{L}_{\mathrm{VQ}}(E, G, \mathcal{Z}) = \boxed{\|x - \hat{x}\|^2} + \|\mathrm{sg}[E(x)] - z_{\mathbf{q}}\|_2^2 + \|\mathrm{sg}[z_{\mathbf{q}}] - E(x)\|_2^2.$$

Adversarial training

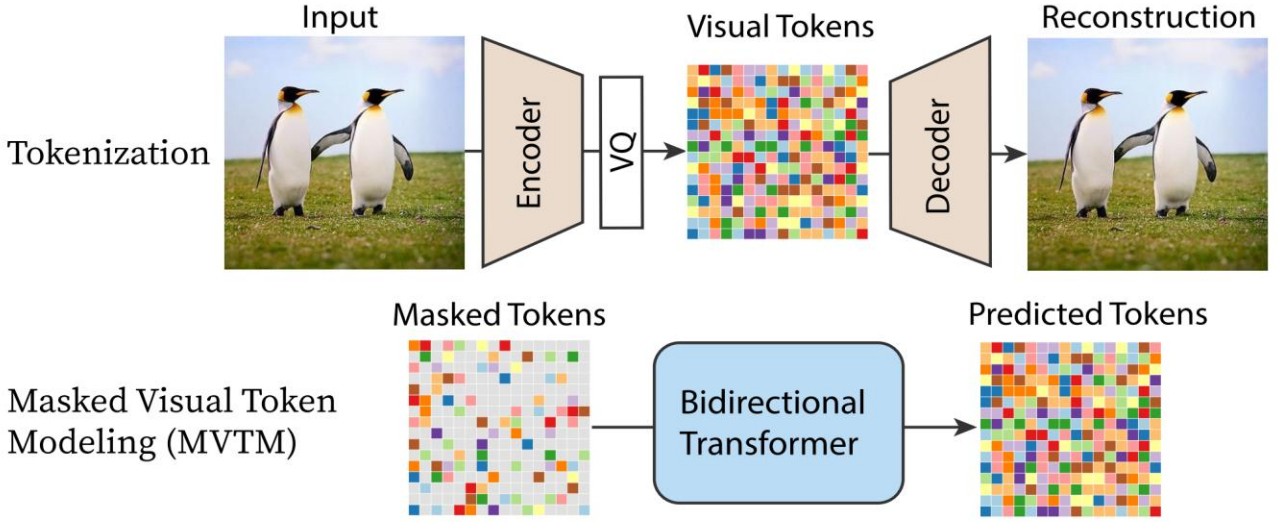
$$\mathcal{L}_{\mathrm{GAN}}(\{E, G, \mathcal{Z}\}, D) = [\log D(x) + \log(1 - D(\hat{x}))]$$

Key Concepts You Should Know First(3/3)

- MaskGIT: use bidirectional transformer to generate parallel token

STAGE1

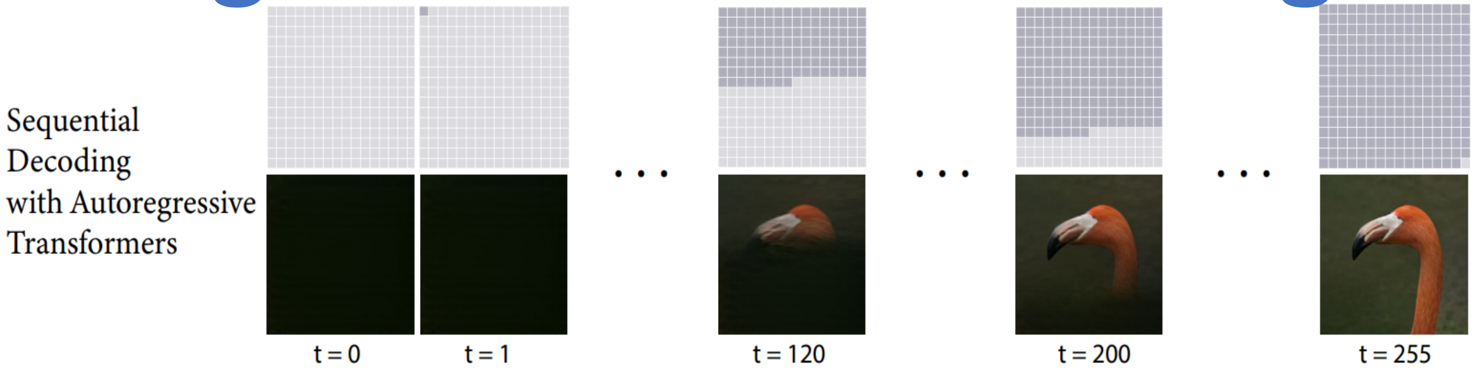
STAGE2



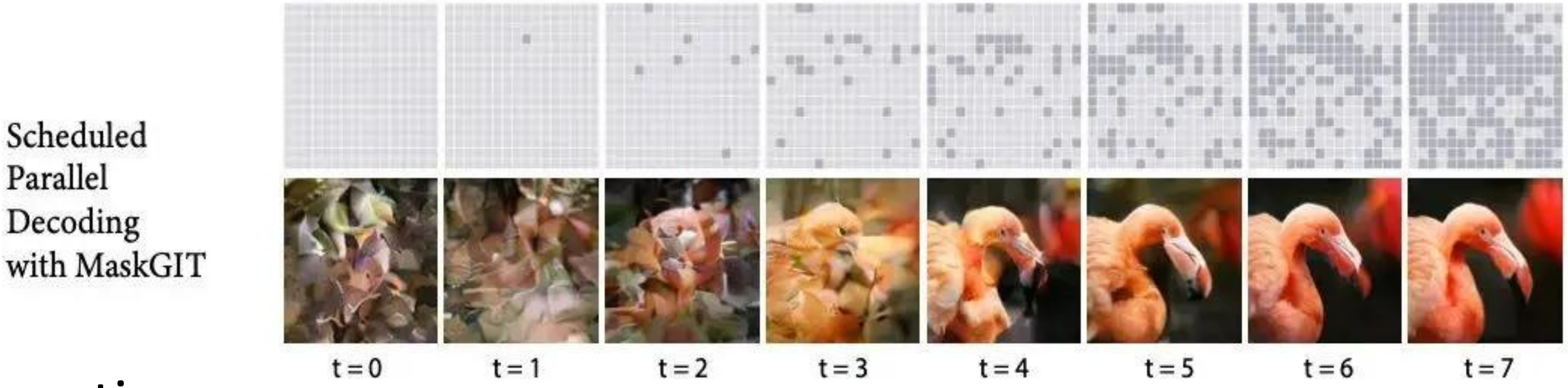
- Masked Visual Token Modeling in Training
  - Mask Ratio: $\gamma(r) \in (0, 1]$
  - Cross Entropy Loss: $\mathcal{L}_{\text{mask}} = - \mathop{\mathbb{E}}_{\mathbf{Y} \in \mathcal{D}} \Big[\sum_{\forall i \in [1,N], m_i = 1} \log p(y_i | Y_{\overline{\mathbf{M}}}) \Big]$

Sequential Decoding v.s Iterative Decoding

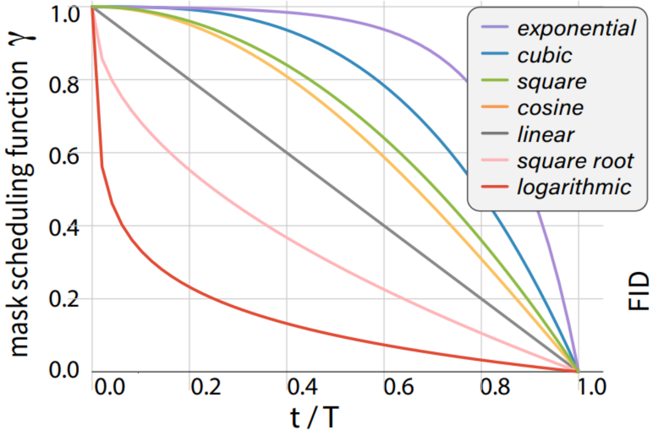
VQGAN



MaskGIT



- Mask Scheduling Function:



- # of Masked tokens in t iteration:

$$n = \lceil \gamma(\frac{t}{T}) N \rceil$$

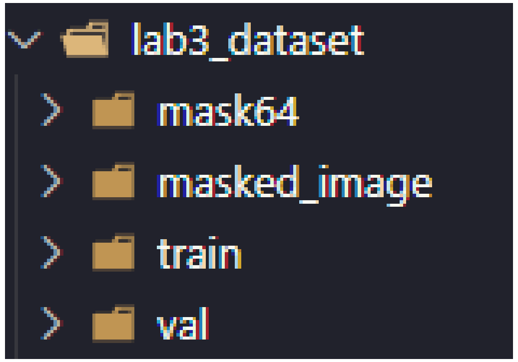
- Mask or retain in t+1 iteration:

$$m_i^{(t+1)} = \begin{cases} 1, & \text{if } c_i < \text{sorted}_j(c_j)[n]. \\ 0, & \text{otherwise.} \end{cases}$$

Lab Objective

- Focus on implementing MaskGIT for the inpainting task
- During testing, images contain gray regions indicating missing information, which we aim to restore using MaskGIT.
- The key practical emphasis of this lab lies in three main areas:
  - Multi-head attention
  - Transformer training
  - Inference inpainting

Dataset



a. Training dataset

image: 12000 png files **(./lab5_dataset/train)**

b. Validation dataset

image: 3000 png files **(./lab5_dataset/val)**

c. Testing dataset

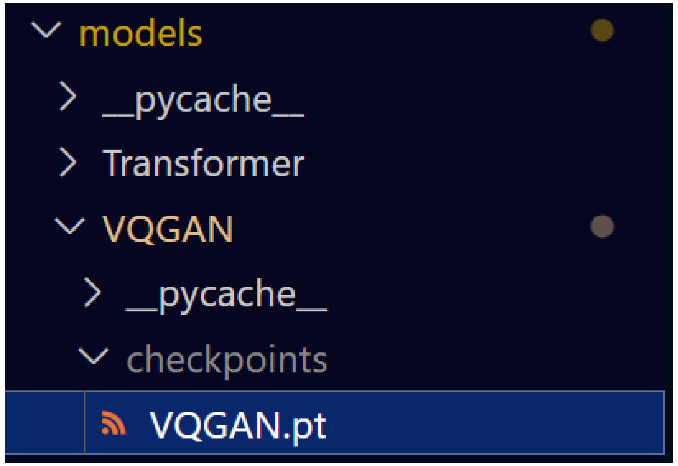
masked image: 747 png files **(./lab5_dataset/masked_image)**

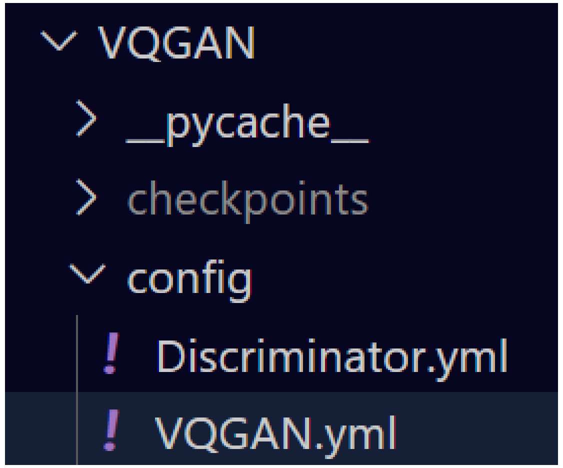
mask: 747 png files **(./lab5_dataset/mask64)**

Reference: https://www.kaggle.com/datasets/spandan2/cats-faces-64x64-for-generative-models

VQGAN Stage1 Pretrained Weight

- **You can't modify any model structure or retrain stage1.**





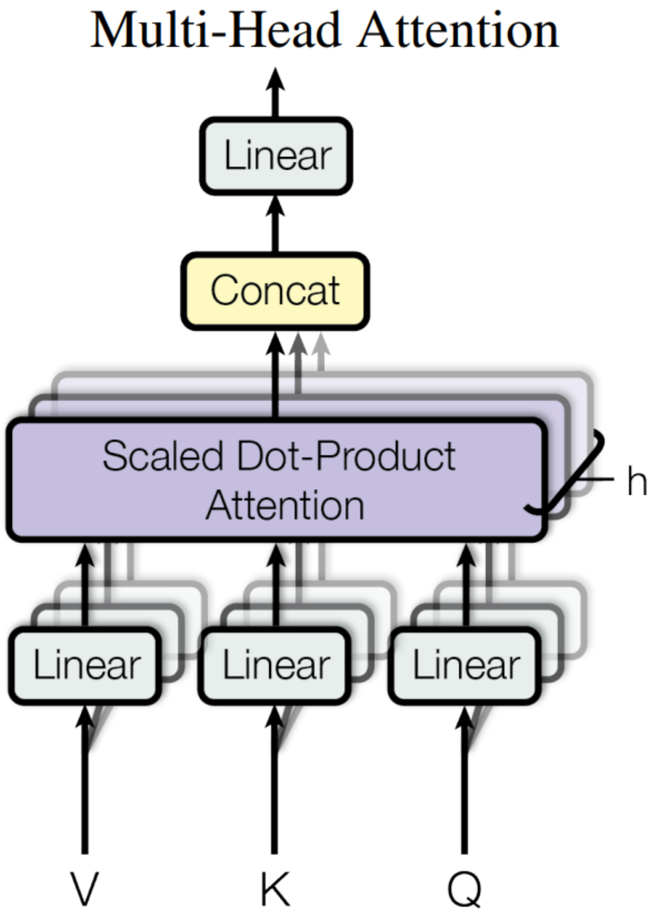

```yaml
---
MODEL_NAME: VQ_GAN

model_param:
  image_channels: 3
  enc_channels: [128, 128, 128, 256, 256, 512]
  dec_channels: [128, 128, 256, 256, 512]
  latent_dim: 256
  img_resolution: 64
  latent_resolution: 16
  num_codebook_vectors: 1024
  beta: 0.25
```

Multi-Head Self-Attention

- You can't use any functions directly ex. torch.nn.MutiheadAttention
- Multi-Head Attention: total #s of head set to 16.
- Total d_k , d_v set to 768
- d_k , d_v for one head will be 768//16.

$$\mathrm{MultiHead}(Q, K, V) = \mathrm{Concat}(\mathrm{head_1}, ..., \mathrm{head_h})W^O$$
$$\text{where } \mathrm{head_i} = \mathrm{Attention}(QW_i^Q, KW_i^K, VW_i^V)$$

$$\mathrm{Attention}(Q, K, V) = \mathrm{softmax}(\frac{QK^T}{\sqrt{d_k}})V$$



MaskGIT Stage2 Training

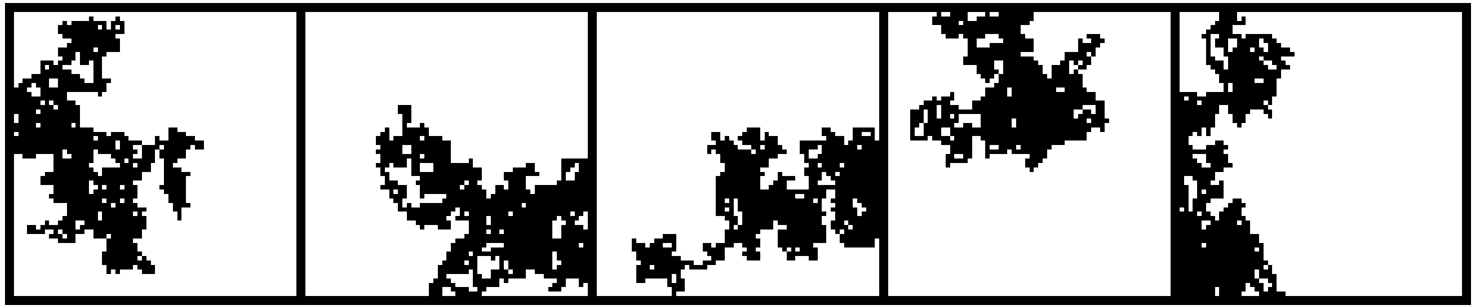
- **You can't modify any model structure.**
- **Multi-Head Attention: total #s of head set to 16.**
- config
  - ! MaskGit.yml


```yaml
---
MODEL_NAME: MaskGit


model_param:

  VQ_Configs:
    VQ_config_path: models/VQGAN/config/VQGAN.yml
    VQ_CKPT_path: models/VQGAN/checkpoints/VQGAN.pt

  num_image_tokens: 256
  num_codebook_vectors: 1024
  choice_temperature: 4.5
  gamma_type: cosine

  Transformer_param:
    num_image_tokens: 256
    num_codebook_vectors: 1024
    dim: 768
    n_layers: 15
    hidden_dim: 1536
```

Inference for Image Inpainting Task

Masked image

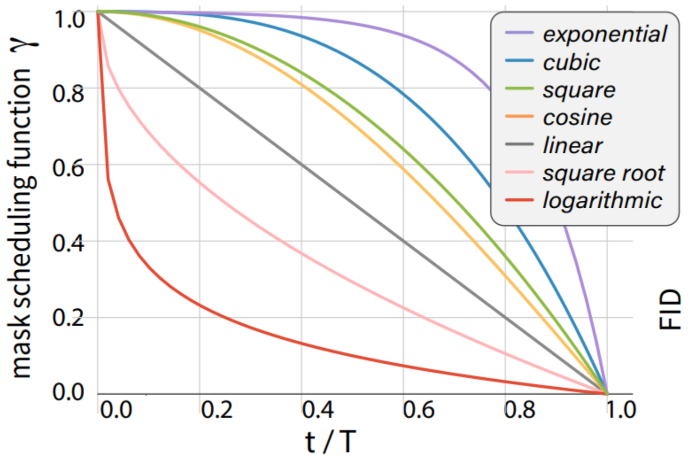
Binary Mask

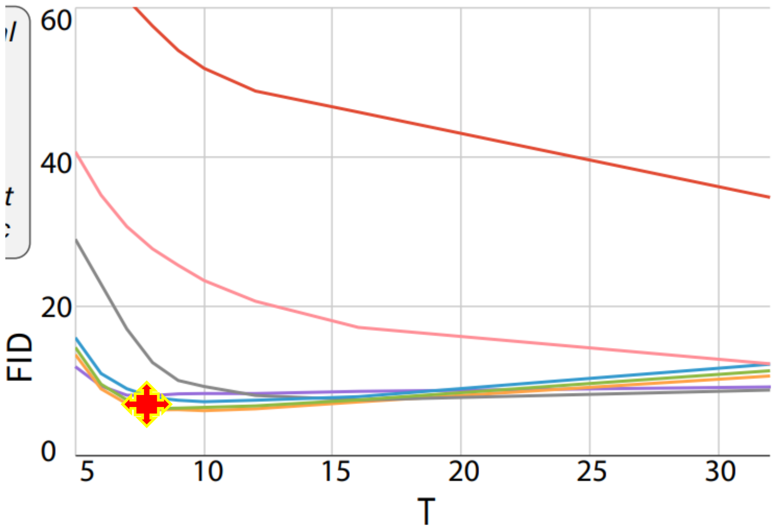


- Tokenize the masked image
- Interpret the **inpainting mask** as the initial mask in iterative decoding

Iterative Decoding

- **Mask Scheduling Functions** $\gamma(\frac{t}{T})$
  - •cosine • linear • square
- **Number of iterations** T
  (you can adjust)
- **Sweet spot** t
  (you can adjust)





Requirements

1. Download the dataset and pretrained weight of VQGAN (MaskGIT stage1).
2. Implement the Multi-head attention module on your own, if you use any function directly, your score will -15.
3. Train your transformer model (MaskGIT stage2) from scratch.
4. Implement iterative decoding for inpainting task.
5. Compare the FID score with different settings of mask scheduling parameters and visualize the iterative decoding for mask in latent domain or predicted images.

Report Spec (100%)

1. Introduction (5%)

2. Implementation Details (45%)

A. The details of your model (Multi-Head Self-Attention)

(if you directly call any function, you can’t get any score in this part.)

B. The details of your stage2 training (MVTM, forward, loss)

C. The details of your inference for inpainting task (iterative decoding)

3. Discussion(bonus: 10%)

A. Anything you want to share

4. Experiment Score (50%)

Experiment Score

(Prove your code implementation is correct)

- **Experimental results (30%)**
  - show iterative decoding
    - cosine
    - linear
    - square

1.Mask in latent domain

2.Predicted image

Experiment Score

- **The Best FID Score(20%)**

```
cd faster-pytorch-fid
python fid_score_gpu.py --predicted-path /path/your_inpainting_results_folder --device cuda:0
```

Average FID	Score
$40 \geq \text{FID}$	20
$45 \geq \text{FID} > 40$	17
$50 \geq \text{FID} > 45$	14
$55 \geq \text{FID} > 50$	11
$60 \geq \text{FID} > 55$	8
$65 \geq \text{FID} > 60$	5
$\text{FID} > 65$	0

- Screenshot
- Masked Images v.s MaskGIT Inpainting Results
- The setting about training strategy, mask scheduling parameters, and so on

Submission

- If the zip file name or the report spec has any format errors, you will receive a **10-point penalty**.
- Submission Deadline: **7/29 (Tue) 23:59.**
- Submit File:
  - 1. Experiment Report (.pdf)
    - Example: DL_LAB3_313554062_何銘哲.pdf
  - 2. Source code (.zip)
    - Compress all your source code into a single zip file.
    - Example: DL_LAB3_313554062_何銘哲.zip

References

1. Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Lukasz Kaiser, and Illia Polosukhin. Attention is all you need. In NeurIPS, 2017. https://arxiv.org/abs/1706.03762

2. A. van den Oord, O. Vinyals, et al., "Neural discrete representation learning," in Advances in Neural Information Processing Systems, pp. 6306–6315, 2017. https://arxiv.org/abs/1711.00937

3. Esser, P., Rombach, R., and Ommer, B.: Taming Transformers for High-Resolution Image Synthesis. In: Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 12873–12883 (2021) https://arxiv.org/abs/2012.09841

4. Huiwen Chang, Han Zhang, Lu Jiang, Ce Liu, and William T. Freeman. Maskgit: Masked generative image transformer. In: Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, June 2022. https://arxiv.org/abs/2202.04200