

Learning Joint Latent Space EBM Prior Model for Multi-layer Generator

Jiali Cui¹ Ying Nian Wu² Tian Han¹

¹Stevens Institute of Technology

²University of California, Los Angeles (UCLA)

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Multi-layer Generator Model

- **Generator Model** can be specified using joint distribution:

$$p_{\beta}(\mathbf{x}, \mathbf{z}) = p_{\beta_0}(\mathbf{x}|\mathbf{z})p_{\beta_{>0}}(\mathbf{z})$$

- **Multi-layer Generator Model** consists of multiple layers of latent variables:

$$p_{\beta_{>0}}(\mathbf{z}) = \prod_{i=1}^{L-1} p_{\beta_i}(\mathbf{z}_i|\mathbf{z}_{i+1})p(\mathbf{z}_L)$$

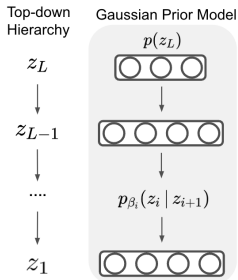
Gaussian Prior Model

- Conditional Gaussian

$$p_{\beta_i}(\mathbf{z}_i | \mathbf{z}_{i+1}) \sim \mathcal{N}(\mu_{\beta_i}(\mathbf{z}_{i+1}), V_{\beta_i}(\mathbf{z}_{i+1}))$$

Limitation

- 1 Only focus on inter-layer relation
- 2 Ignore intra-layer relation
- 3 conditional independent

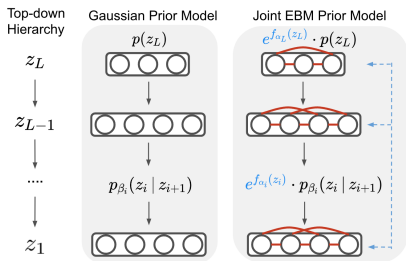


Joint Latent Space EBM

- Our Joint Latent Space EBM Prior

$$p_{\alpha, \beta > 0}(\mathbf{z}) = \frac{1}{Z_{\alpha, \beta > 0}} \exp \left[\sum_{i=1}^L f_{\alpha_i}(\mathbf{z}_i) \right] \prod_{i=1}^{L-1} p_{\beta_i}(\mathbf{z}_i | \mathbf{z}_{i+1}) p(\mathbf{z}_L)$$

- 1 Black solid lines with arrow: inter-layer relations modelling.
- 2 Red solid lines: intra-layer contextual relations modelling.
- 3 Blue dashed lines: joint modelling upon all layers.



Synthesis Quality

Method	IS	FID
NVAE*	5.30	37.73
Ours	8.99	11.34
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NCP-VAE	-	24.08
VAEBM	8.43	12.19
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Other EBMs		
IGEBM	6.78	38.2
ImprovedCD	7.85	25.1
Divergence Triangle	-	30.10
Adv-EBM	9.10	13.21
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Other Likelihood Models		
GLOW	3.92	48.9
PixelCNN	4.60	65.93
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GANs+Score-based Models		
BigGAN	9.22	14.73
StyleGANv2 w/o ADA	8.99	9.9
NCSN	8.87	25.32
DDPM	9.46	3.17

Table: IS(\uparrow) and FID(\downarrow) on CIFAR-10.

Figure: CelebA-HQ-256.



Figure: LSUN-Church-64

Hierarchical Representation



Figure: Hierarchical sampling.



Figure: Hierarchical reconstruction.

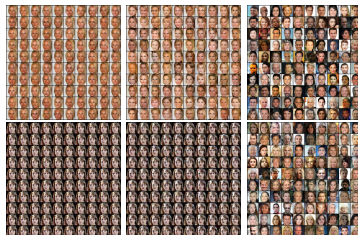


Figure: Hierarchical sampling.

Analysis of Latent Space

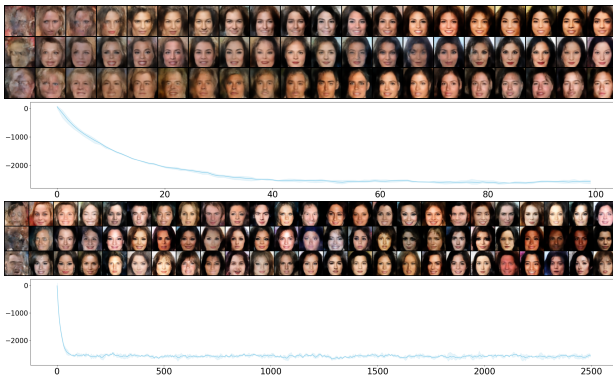


Figure: Top: short-run Langevin transition. Bottom: long-run Langevin transition.