Image Processing using Diffusion Models

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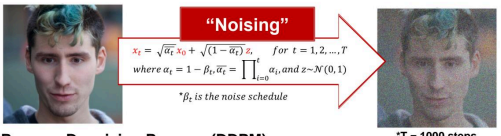
Motivation

This project explores the fundamentals of diffusion models and their capabilities in two key areas: **(1) Image Generation** and **(2) Image Restoration**, specifically inpainting and deconvolution.

Background & Related Work

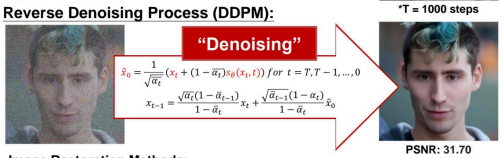
***Key Measurement Metircs:**
- PSNR (Peak Signal-to-Noise Ratio):
  → Measures noise level/reconstruction quality (higher the better)
- LPIPS (Learned Perceptual Image Patch Similarity):
  → Measures perceptual similarity (lower the better)

Forward Noising Process (Variance Preserving(VP)):



*T = 1000 steps

Reverse Denoising Process (DDPM):



PSNR: 31.70
LPIPS: 0.07

Image Restoration Methods:
- SDEdit method [4]: "Naïve" Approach (take measurement after timestep t)
- Score-ALD [3]: additional denoising step: $x_{t-1} = x_{t-1} - \frac{1}{\sigma^2 + \gamma_t^2} \nabla_{x_t} \|\mathcal{A}(x_t) - y\|^2$
- DPS [1]:additional denoising step: $x_{t-1} = x_{t-1} - \frac{\zeta_t}{2\sigma^2} \nabla_{x_t} \|\mathcal{A}(\hat{x}_0) - y\|^2$

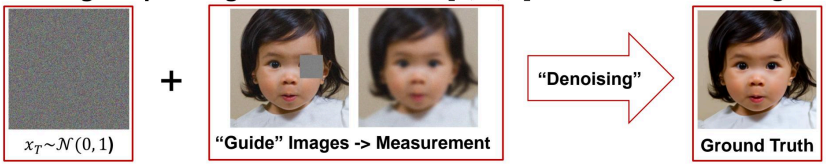
References

[1] Chung, Kim, Mccann, Klasky, and Ye (2023). Diffusion posterior sampling for general noisy inverse problems. In ICLR.
[2] Ho, Jain, and Abbeel (2020). Denoising diffusion probabilistic models. In NeurIPS.
[3] Jalal, Arvinte, Daras, Price, Dimakis, and Tamir (2021). Robust compressed sensing mri with deep generative priors.
[4] Meng, He, Y. Song, J. Song, Wu, Zhu, and Ermon (2022). Sdedit: Guided image synthesis and editing with stochastic differential equations.

Image Generation using DDPM Method [2] -> No "Guide" Image

Every random noise will create different set of "denoised" images

Image Impainting & Deconvolution [1, 3, 4] -> With "Guide" Image



Measurement	SDEdit			Score-ALD	DPS
	Start time: 300 PSNR: 22.76 LPIPS: 0.14	Start time: 500 PSNR: 20.72 LPIPS: 0.18	Start time: 800 PSNR: 14.05 LPIPS: 0.316	PSNR: 22.75 LPIPS: 0.12	PSNR: 34.93 LPIPS: 0.02
Impainting					
Deconvolution	Start time: 300 PSNR: 24.45 LPIPS: 0.21	Start time: 500 PSNR: 22.34 LPIPS: 0.20	Start time: 800 PSNR: 13.32 LPIPS: 0.37	PSNR: 22.49 LPIPS: 0.14	PSNR: 28.36 LPIPS: 0.07