IMAGE INPAINTING USING LATENT DIFFUSION MODELS

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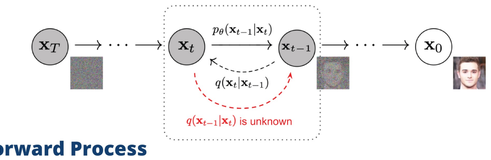
Problem Statement

Editing masked patches by generating areas in the image masked out by the patch from a learnt latent diffusion model without specifically training it for this inpainting task.

Original Image Mask-removed Image Inpainted Image from LDM

Diffusion Process



Forward Process

$$q(\mathbf{x}_t|\mathbf{x}_{t-1}) = \mathcal{N}(\mathbf{x}_t; \sqrt{1-\beta_t}\mathbf{x}_{t-1}, \beta_t\mathbb{I})$$

Reverse Process

$$q(\mathbf{x}_{t-1}|\mathbf{x}_t) = \mathcal{N}(\mathbf{x}_{t-1}; \left(\frac{(1-\bar{\alpha}_{t-1})\sqrt{\alpha_t}}{1-\bar{\alpha}_t}\mathbf{x}_t + \frac{(1-\alpha_t)\sqrt{\bar{\alpha}_{t-1}}}{1-\bar{\alpha}_t}\mathbf{x}_0\right), \frac{(1-\alpha_t)\cdot(1-\bar{\alpha}_{t-1})}{(1-\bar{\alpha}_t)}\mathbb{I})$$

Loss Function

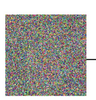
$$L_t^{\text{Simple}} = \mathbb{E}_{t\sim[1,T],\mathbf{x}_0,\boldsymbol{\epsilon}_t}\left[\|\boldsymbol{\epsilon}_\theta((\sqrt{\bar{\alpha}_t})\mathbf{x}_0 + (\sqrt{1-\bar{\alpha}_t})\boldsymbol{\epsilon}_t, t) - \boldsymbol{\epsilon}_t\|^2\right]$$

By simply learning to **predict the noise** in the image, the model learns the parameters of the reverse distribution

$\boldsymbol{\epsilon}_t$

Denoising Diffusion

Probabilistic Model



$\boldsymbol{\epsilon}_\theta$

$$p_\theta(\mathbf{x}_{t-1}|\mathbf{x}_t) = \mathcal{N}(\mathbf{x}_{t-1}; \boldsymbol{\mu}_\theta(\mathbf{x}_t, t), \boldsymbol{\Sigma}_\theta(\mathbf{x}_t, t))$$

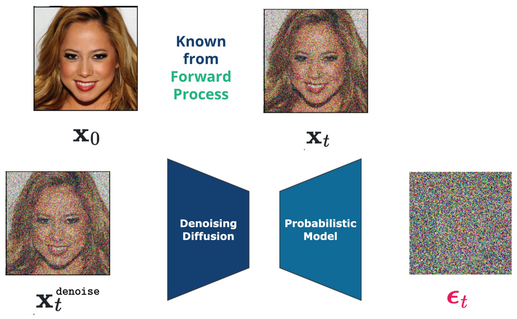
Sample from the reverse distribution

$\mathbf{x}_{t-1}$

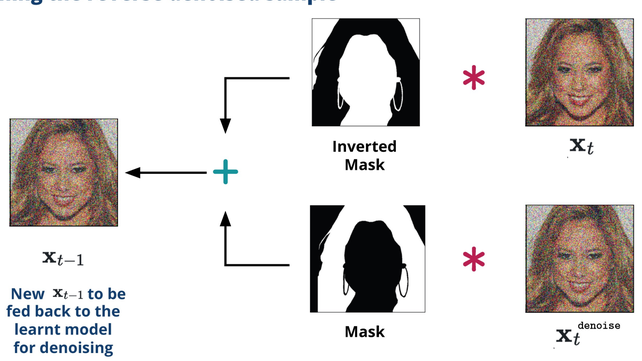
$$\mathbf{x}_{t-1} = \boldsymbol{\mu}_\theta + \sigma_t\mathbf{z} \quad \mathbf{z}\sim\mathcal{N}(\mathbf{0}, \mathbb{I})$$

Methodology

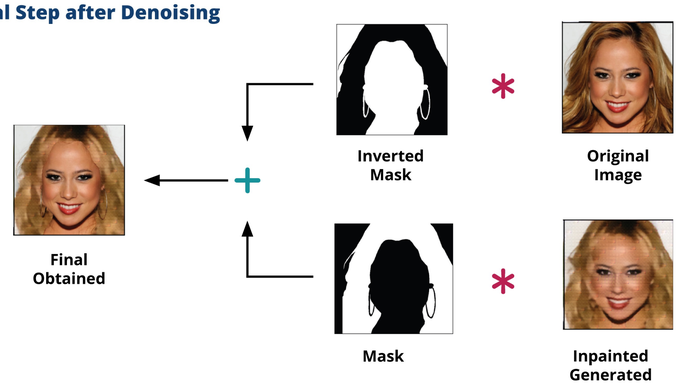
During Inference/Reverse Sampling



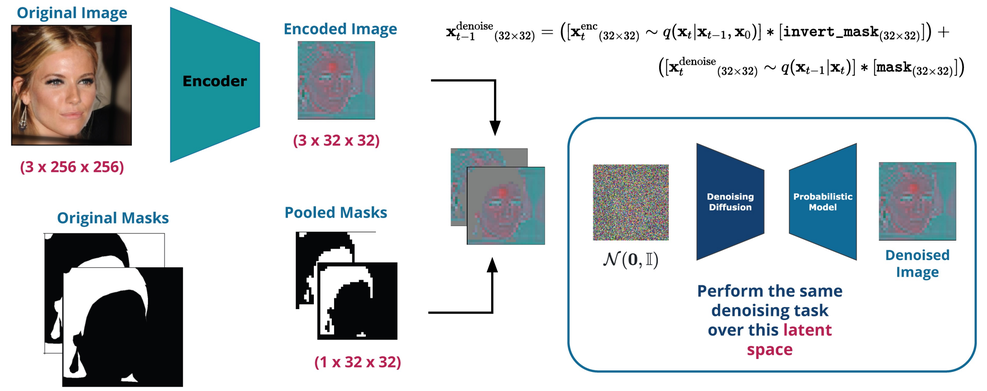
Obtaining the reverse denoised sample

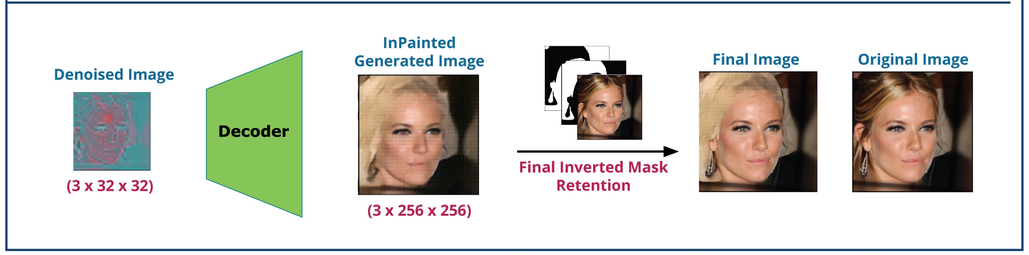


Final Step after Denoising



The Latent Space





Results