ESE 531 Project Proposal
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Project Title: Denoising Diffusion Models
Project Type: Methodological survey

Project Description:
It will be a survey of the paper '**Denoising Diffusion Probabilistic Model**s' by Jonathan Ho, Ajay Jain, Pieter Abbeel.

The denoising diffusion probabilistic model is designed with the motivation of generating high-quality samples of natural images from noise. The model is a parameterized Markov chain trained using variational inference to match the data distribution after a finite time. The forward process, denoted as $q(x_t|x_{t-1})$, transforms a natural image into noise, while the reverse of the forward process, $q(x_{t-1}|x_t, x_0)$, turns noise into a natural image. Additionally, the reverse process $p(x_{t-1}|x_t)$ is involved in the modeling.

Diffusion models are straightforward to define and efficient to train, this project will show they are capable of generating high quality samples. The project will also show that a certain parameterization of diffusion models reveals an equivalence with denoising score matching over multiple noise levels during training and with annealed Langevin dynamics during sampling. The paper showed the best sample quality results using this parameterization.
The project will represent a more refined analysis of lossy compression phenomenon, and show that the sampling procedure of diffusion models is a type of progressive decoding that resembles autoregressive decoding along a bit ordering that vastly generalizes what is normally possible with autoregressive models.

The project will be a deep dive into the motivation behind the denoising diffusion model and detailed derivations for the loss function. The focus will be on - generating an image iteratively (forward process turns a natural image into noise, reverse process turns noise into a natural image), minimization of parameter learning by the likelihood of the data, optimization(find proper parameter values for those neural networks), analytical formula for L via sample-averaging using small number of samples with high variance.

Report Outline:
The report will include the abstract, introduction, background, diffusion models and denoising autoencoders(forward process, reverse process, Data scaling, reverse process decoder, Simplified training objective), Experiments(Sample quality, Reverse process parameterization and training objective ablation, Progressive coding), Interpolation and Conclusion.

References:

1. https://arxiv.org/pdf/2006.11239.pdf
2. https://towardsdatascience.com/understanding-the-denoising-diffusion-probabilistic-model-the-socratic-way-445c1bdc5756
3. https://github.com/hojonathanho/diffusion
4. https://proceedings.mlr.press/v139/nichol21a.html
5. https://www.nature.com/articles/s41598-023-34341-2
6. https://www.youtube.com/watch?v=H45lF4sUgiE
7. And lastly our very own chatgpt :)