Task 5: Learning and Using Diffusion Models *Raunak*

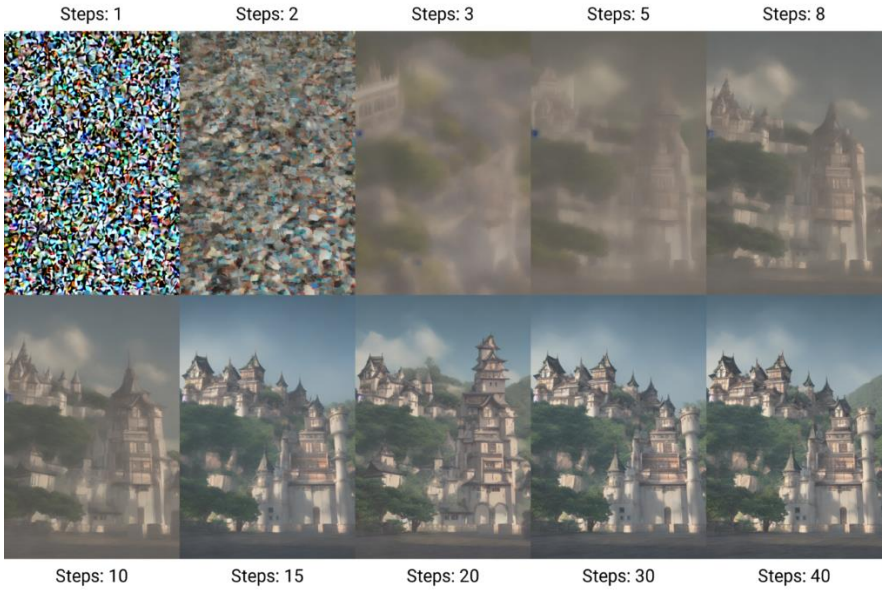

Fig. 3: The Denoising Process used by *Stable Diffusion*

Submission Deadline Task5: Thursday, April 26, 11:59p
Last Updated: April 12, 8a
Task Weight: 35 points

This assignment is a short exploration of a basic diffusion model. You'll be working with a pre-trained diffusion model in a Jupyter notebook environment to generate images and analyze how different settings influence the results.
Link: https://github.com/RaunakDune/BasicDiffusionModel/

Learning Objectives:

1. Gain hands-on experience with diffusion models using a Jupyter notebook.
2. Experiment with tuning hyperparameters in a pre-trained diffusion model.
3. Analyze the generated images and interpret the impact of parameter changes.
4. Effectively document and visualize your findings within the notebook.

Dataset
Link: https://drive.google.com/file/d/1NF-JNSVkdu_lG7UVVtTAUMWIRQANqtav/view?usp=sharing

The Stanford Cars dataset is a widely used benchmark dataset in the field of computer vision and machine learning, particularly for tasks related to object recognition and classification. It is curated and maintained by researchers at Stanford University.

The Stanford Cars dataset consists of images of cars belonging to 196 classes, where each class represents a different car model. The dataset is further divided into training and test sets, with a total of 16,185 images in the training set and 8,054 images in the test set.

Each image in the dataset is annotated with bounding boxes around the car, along with additional metadata such as the make, model, and year of the car. This annotation facilitates fine-grained classification tasks, where the goal is to classify images into specific car models. However, we will *not* be using these annotations for this task.

Task 5 Subtasks

- **Understanding the Existing Diffusion Model (No Points)**
    1. Review the provided Jupyter Notebook file containing an existing diffusion model implementation.
    2. Familiarize yourself with the structure of the code and understand how the diffusion process is simulated.
    3. Identify key parameters in the diffusion model, such as the diffusion rate, initial conditions, and time steps.
    4. Run the model once from the start to get a benchmark of the result and the time taken.
- **Implementing Parameter Tuning for Forward Diffusion (10 Points)**
    1. Explain what these parameters from the existing diffusion model do: T, IMG_SIZE, BATCH_SIZE.
    2. Create a new code cell in the Jupyter Notebook to modify the selected parameters.
    3. Conduct a series of simulations by varying the values of the chosen parameters while keeping other parameters constant:
        1. T: 250/300/350
        2. IMG_SIZE: 16/32/64/128
        3. BATCH_SIZE: 64/128/256
    4. Record the results of each simulation, including the quality of image and time taken for diffusion.
- **Modify the Backward Process and Loss: (10 Points)**
    1. Explore the U-Net implementation and understand what it's doing. Write a 1 to 3 line summary.
    2. Implement two different activation functions of your choice. Some suggestions are present in the notebook. Explain your choice.
    3. Explore two different loss functions of your choice in addition to the one present in code. Explain your choice.
- **Training and Experimentation (10 Points)**
    1. Choose the fastest and second fastest parameter values from **Question 2** for your training.
    2. Explore the results for each of the activation functions and loss functions.
    3. Create a variable to track the loss values and plot it.
    4. Observe how the generated cars look. Why do they look so poor? How does the quality change with IMG_SIZE?
- **Analysis (5 Points)**
    1. Summarize your findings from all the experiments.
    2. Discuss any trends or patterns observed in the results.

3. Provide insights into how each parameter affects the rate and extent of diffusion.
4. Reflect on the strengths and limitations of the existing diffusion model.

Deliverables

- Save your modified Jupyter Notebook with your changes and analysis.
- Ensure that your Notebook includes clear explanations, code comments, and visualizations.
- *Submit your Notebook file (.ipynb)* along with any additional resources (e.g., data files) to Teams. **Don't zip your submission.**
- Make sure to adhere to academic integrity guidelines and cite any external sources used in your assignment.

References:

- **Jupyter Notebook: https://github.com/RaunakDune/BasicDiffusionModel/**
- **Dataset: https://drive.google.com/file/d/1NF-JNSVkdu_lG7UVVtTAUMWIRQANqtav/view?usp=sharing**