Image Compression using SVD
Complete Project Documentation

This PDF explains the complete **Image Compression using Singular Value Decomposition (SVD)** project. It is written in a beginner-friendly, step-by-step manner so that anyone can understand the logic, mathematics, technologies, and working flow of the project and easily practice it using the source code on GitHub.

1. Project Overview

Image Compression using SVD is a Linear Algebra–based project where we reduce the size of an image by keeping only the most important singular values. The project demonstrates how mathematical matrix decomposition techniques are used in real-world applications such as Generative AI, PCA, and LoRA.

2. Project Objective

- Understand Singular Value Decomposition practically.
- Learn how matrices represent images.
- Apply rank-k approximation for compression.
- Build a clean, modular, and working project.

3. Technologies and Tools Used

1. **Python** – Main programming language.
2. **NumPy** – Used for matrix operations and SVD.
3. **Pillow (PIL)** – Used for image loading, resizing, and conversion.
4. **Gradio** – Used to build a simple frontend UI.
5. **Linear Algebra** – Core mathematics behind SVD.
6. **Git & GitHub** – Version control and project sharing.

4. Project Folder Structure

The project follows a clean and industry-style folder structure:

svd_project/
■■■ backend/ (SVD logic)
■■■ frontend/ (UI code)
■■■ database/ (metrics / future DB)
■■■ main.py (entry point)
■■■ requirements.txt

5. How the Project Works (Step-by-Step)

1. Step 1: User uploads an image using the Gradio interface.
2. Step 2: Image is converted into a matrix (pixel values).

3 Step 3: Image is resized while preserving aspect ratio.

4 Step 4: SVD is applied separately on R, G, and B channels.

5 Step 5: Only top-k singular values are kept.

6 Step 6: Image is reconstructed from reduced matrices.

7 Step 7: Compressed image is displayed to the user.

6. Project Flowchart (Logical Flow)

Start
↓
Upload Image
↓
Convert Image to Matrix
↓
Resize (Preserve Aspect Ratio)
↓
Apply SVD (R, G, B Channels)
↓
Rank-k Approximation
↓
Reconstruct Image
↓
Display Compressed Image
↓
End

7. Mathematical Concept Used

Singular Value Decomposition decomposes a matrix A into three matrices:

A = U Σ V■

By keeping only the top-k singular values in Σ, we reduce the rank of the matrix, which results in image compression while preserving important visual information.

8. Connection with Generative AI

1 • PCA uses eigenvalues and SVD for dimensionality reduction.

2 • LoRA and QLoRA use low-rank matrix approximation.

3 • Embedding compression in LLMs is based on similar math.

9. How to Run the Project

1 1. Create a virtual environment.

2 2. Install required libraries using pip.

3 3. Run main.py.

4 4. Upload image and choose k value.

10. Conclusion

This project demonstrates how core Linear Algebra concepts are applied in real-world AI systems. It is an excellent beginner-to-intermediate level project for students preparing for careers in Generative AI, Machine Learning, or Data Science.