Assignment: Image Restoration Using Noise Models, Filters, and Blur Functions

Objective:

To understand and implement different **noise models, blur functions, and restoration techniques** using spatial and frequency domain filters. This assignment will also focus on **quantifying restoration quality** using evaluation metrics and comparative analysis.

Part 1: Image Degradation (Noise and Blur)

1. **Load a grayscale image** (e.g., Any real-world image of your choice).
2. Apply the following **noise models** to the image and visualize their effects:
   a) **Gaussian noise** (zero mean, different variances)
   b) **Salt & Pepper noise** (varying densities)
   c) **Speckle noise**
   d) **Poisson noise**
3. Apply the following **blur functions** and analyze their effects:
   a) **Motion blur** (varying lengths and angles)
   b) **Gaussian blur** (varying standard deviations)
   c) **Defocus blur** (circular blur)

Expected Output:

- **Noisy & blurred images** for each degradation type.
- **Histogram analysis** of noise distributions.

Part 2: Noise and Blur Estimation

4. **Estimate the noise parameters** (mean, variance) for each noise model using:
   a) **Histogram analysis**
   b) **Variance estimation**
5. **Estimate the degradation function (blur kernel)** using:

a) **Visual observation**
b) **Experimental modeling** (using edge detection techniques)
c) **Mathematical modeling** (Gaussian/Motion blur kernel approximation)

Expected Output:

- **Estimated noise statistics** for each noise model.
- **Mathematical formulation of degradation functions.**

Part 3: Image Restoration Using Filtering Techniques

6. **Implement the following spatial domain filters** for noise removal:
   a) **Mean filter**
   b) **Median filter**
   c) **Adaptive median filter**
   d) **Local adaptive noise filter**
7. **Implement frequency domain filtering techniques** for deblurring:
   a) **Wiener filtering**
   b) **Inverse filtering**
   c) **Constrained Least Squares filtering**
8. **Compare the restoration results** for different filters and blur functions.

Expected Output:

- **Restored images using different techniques.**
- **Quantitative analysis using PSNR, SSIM, and MSE.**

Part 4: Comparative Analysis and Real-World Applications

9. **Perform a comparative study** to answer the following:
   - Which filter works best for each noise model? Explain why.
   - Compare Wiener filtering with **median and adaptive filters**.
   - Which method restores **motion blur and defocus blur** most effectively?

- Analyze **the trade-off between noise suppression and image sharpness.**

10. **Research and report** on real-world applications of image restoration in **medical imaging, satellite image processing, or forensic analysis.**

Submission Requirements:

- Submit your **Python code** with comments.
- Include **before and after images** for each restoration technique.
- Provide **histograms of noise distributions** before and after filtering.
- Submit a **short report (4-5 pages)** with:
  - Analysis of different filters and noise models.
  - **PSNR, SSIM, and MSE calculations** for each restoration method.
  - A **brief research summary** on real-world applications of image restoration.