Edge-preserving decompositions for multi-scale tone and detail manipulation

N8EN11D Projet Traitement d'image / Image Processing project

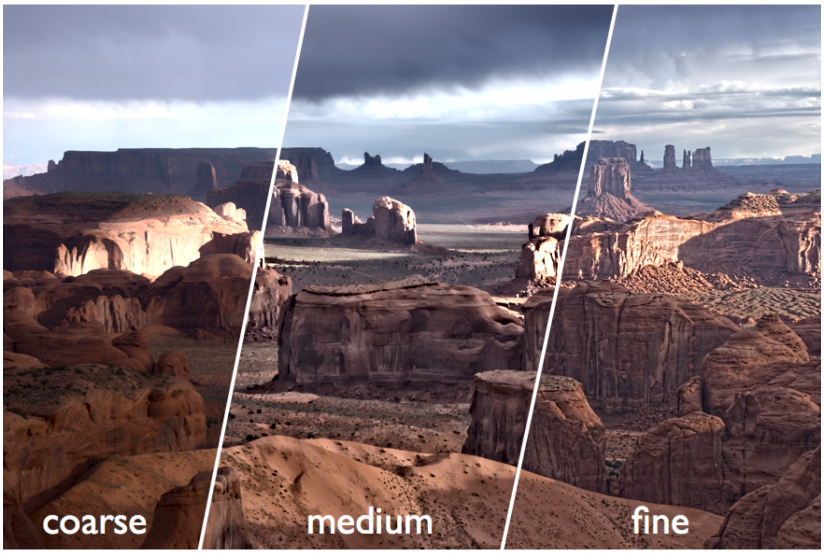

Figure 1: From left to right the multi-scale decomposition of an image with different levels of detail: coarse, medium, and fine details.

1 Introduction

Image processing often involves filtering techniques to enhance details, remove noise, or extract important features. Traditional linear low-pass filters, such as Gaussian smoothing, are commonly used to reduce noise by averaging pixel values. However, these filters tend to blur important structures, especially at edges where abrupt intensity changes occur, leading to loss of detail and sharpness (*c.f.* Chapter 1.3 of the course or [7, Chapter 3]).

This project explores a nonlinear edge-preserving filter introduced in [1]. Unlike standard smoothing filters, which uniformly blur all regions of an image, this operator selectively smooths homogeneous areas while preserving edges and important structures. By reducing noise without erasing fine details, it improves the quality of processed images in various applications.

A key feature of this filter is its ability to generate a multi-scale decomposition of an image. This means that by adjusting smoothing parameters, we can separate different levels of detail, making it possible to enhance or suppress specific image features (*c.f.* Figure 1). Such an approach has many practical applications, including:

- Enhancing fine details at a specific scale
- Reducing noise while maintaining important textures
- Producing High Dynamic Range (HDR) images with better contrast
- Stylizing images for artistic or graphical effects

2 Project Description

The first step will be to understand the paper and implement the filter using a sparse matrix inversion function.

- Implement the algorithm in a programming language of your choice (C++/Python or Matlab).
- Ensure the code is **well-structured and modular**, with proper decomposition into functions.
- Understand the role of the different parameters and their influence on the results.
- **Evaluation & Comparison**
  Explore one (or more) of the following applications and evaluate the results.
  - Detail manipulation for photographic rendering.
  - Comparison with the bilateral filter [8] for which implementations in different frameworks exist (*e.g.* [5] in OpenCV.
  - HDR image rendering.
- To assess the effectiveness of the implemented filter, select appropriate evaluation metrics based on the chosen application. Below is a list of commonly used image quality metrics for which common implementations exist, along with their references and relevant applications:
  - **Peak Signal-to-Noise Ratio** (PSNR) (*c.f.* [7, eq. 2.119]): Measures the overall difference between the processed image and a reference image. It is useful for evaluating denoising performance.
  - **Structural Similarity Index** (SSIM) [9]: Compares the structure, luminance, and contrast of two images, making it useful for assessing noise reduction and detail preservation.
  - **Laplacian Variance** [4]: Estimates image sharpness by computing the variance of the Laplacian operator. It is particularly useful for evaluating detail enhancement.
  - **Edge Preservation Index** (EPI) [6]: Measures how well a filter preserves edges by comparing gradient magnitudes before and after processing.
  - **Blind/Referenceless Image Spatial Quality Evaluator** (BRISQUE) [3]: A no-reference image quality metric that assesses the perceptual distortion of an image without requiring a reference.
  - **Tone-Mapped Image Quality Index** (TMQI) [10]: Evaluates the perceptual quality of HDR images after tone mapping, considering both structural fidelity and naturalness.

  For testing and benchmarking, the HDR+ dataset [2], which contains multi-exposure real-world images, is recommended for HDR-related experiments.

References

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