Sec.10.3.2 - End of Sec. 10

McLean seminar
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10.3.2 Image enhancement

1. Image Display Methods

- Pseudo 3D Representation
  - Images appear three-dimensional.
- Contours or Isophotes
  - Displays brightness as contour lines.
- 1D Cross-Sections
  - Slices or profiles of the image.

2. Image Filtering Techniques

- Low-Pass Filter
  - Purpose: Smooths the image by removing fine details.
  - Effect: Reduces noise, creates a soft or blurred appearance.

- High-Pass Filter
  - Purpose: Enhances fine details by emphasizing edges.
  - Effect: Increases sharpness but amplifies noise.

- Block Smoothing
  - Averages pixel values within an n×n block.

- Gaussian Smoothing
  - Uses a Gaussian curve for weighted averaging.

- Median Filtering
  - Removes outliers (extreme pixel values).
  - Replaces with the median of neighboring pixels.

10.3.2 Image enhancement

3. Unsharp Masking

- Process:
  - Smooth image with a low-pass filter.
  - Subtract the blurred version to enhance sharpness.
- Effect: Highlights fine details while removing low-frequency features.

4. Image Restoration

- Deconvolution
  - Corrects blur caused by the instrument's point spread function.
- Pixel Shifting
  - Moves pixels with interpolation for non-integer shifts.
- Bad Pixel Correction
  - Replaces defective pixels using neighboring data.

5. Advanced Filters

- Edge-Enhancing Filters
  - Sobel, Laplacian filters emphasize boundaries.
- Bas-Relief Effect
  - Produces 3D-like effects by highlighting brightness gradients.

10.4 Image restoration

1. What is Image Restoration?

- Restoration: Corrects distortions in raw images (e.g., blurring, noise).
- Reconstruction: Creates an image from complex, encoded data (e.g., interferometric data)
- Widely used in astronomy (UV-visible-IR images, Hubble Space Telescope).

2. Key Restoration Methods

2-1. Richardson-Lucy Deconvolution

1. Iterative algorithm to enhance sharpness.
2. Suitable for photon-counting detectors (e.g., CCDs).

2-2. Maximum Entropy (ME)

1. Balances noise reduction and sharpness.
2. Prevents overfitting by assuming flat regions.

2-3. Pixon-Based Technique

1. Adaptive restoration using variable-sized “pixons.”
2. Reduces artifacts and improves clarity.

3. Bayesian Approach

- Bayes’ Theorem: Combines data, prior knowledge, and noise models.
- Key Terms:
  - Likelihood: How well the data fits the model.
  - Image Prior: Assumptions about the image before data analysis.

10.4 Image restoration

4. Challenges in Image Restoration

4-1. Noise Amplification

- Overfitting creates artificial speckles.

4-2. Ringing Effect

- Bright and dark rings appear near sharp edges.

4-3. Sensitivity to PSF Errors

- Minor inaccuracies in the PSF can affect results.

5. Practical Tools and Applications

- Richardson-Lucy Algorithm
  - Available in STSDAS/IRAF for Hubble data processing.
- Tiny Tim Software
  - Simulates PSF for the Hubble Space Telescope.
  - Applications:
    - Revealing faint objects
    - Improving observational data

10.5 Summary

1. Use of Computers in Astronomy

- Wide Applications for Astronomers:
  - Controlling telescopes and instruments: Utilizing fast hardware and Digital Signal Processors (DSPs).
  - Processing and displaying data with powerful workstations or PCs.

2. Key Software Tools

- Programs developed for image analysis and data processing:
  - IRAF, AIPS, STSDAS, STARLINK, MIDAS (community-developed).
  - IDL, a popular commercial software.

3. Standard File Format: FITS

- FITS (Flexible Image Transport System) is the standard format for astronomical images.
- FITS Liberator: A tool enabling Adobe Photoshop to open FITS images.

4. Image Processing and Restoration

- Enhancing images for better visualization:
  - Stretching: Adjusting brightness to highlight faint details.
  - Filtering: Removing noise or emphasizing specific features.
  - False Coloring: Adding colors to emphasize structures.
- Image Restoration Techniques:
  - Deconvolution: Mathematically correcting image blurring.
  - Bayesian-based methods: Recovering images with known optical limitations like diffraction.