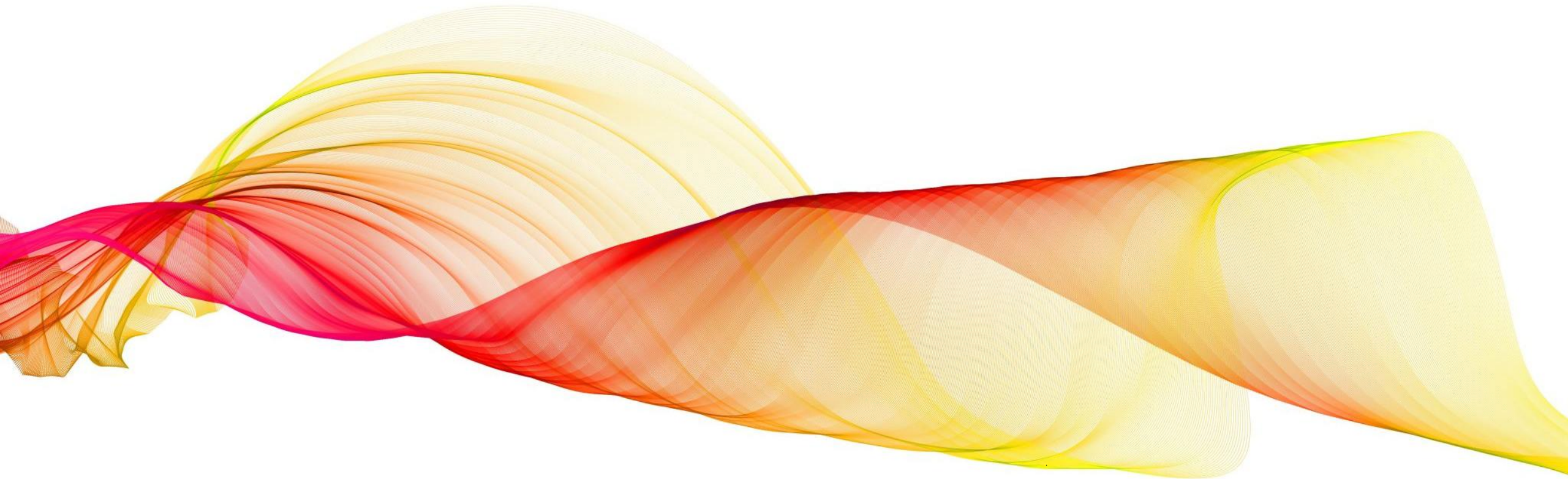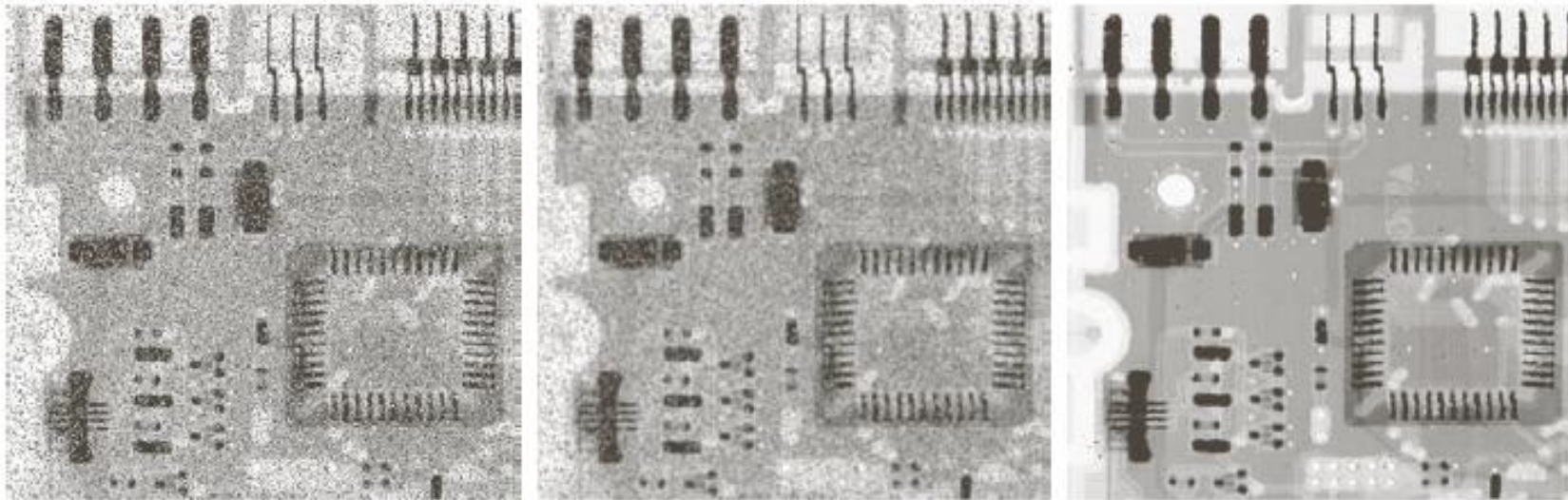# Spatial Filtering

Noise removal

Order-Statistic (Non-linear) filter (median)

a b c

FIGURE 3.35 (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3×3 averaging mask. (c) Noise reduction with a 3×3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

Median filter Algo

1. Define the size of the filter mask

2. Image Padding depending on the size of filter mask

3. Apply the filter mask on input image

4. Arrange the values in the ascending/descending order

5. Pick the median value and assign to pixel location under observation

6. Crop the output image to make it of same size as input image

Median Filtering in OpenCV

```
medianBlur(image, smoothed_image, 5);
```

Inserting Gaussian Noise

```python
import cv2

import numpy as np

# Load the image

img = cv2.imread('test_image.jpg')

# Generate random Gaussian noise

mean = 0

stddev = 180

noise = np.zeros(img.shape, np.uint8)

cv2.randn(noise, mean, stddev)

# Add noise to image

noisy_img = cv2.add(img, noise)

# Save noisy image

cv2.imwrite('noisy_img.jpg', noisy_img)
```

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Gaussian Noise profile

5	-1	-3	4	0
-10	-1	4	7	-9
-2	0	-6	9	-6
2	5	-10	5	10
6	1	1	1	10

Noisy Image

156	150	150	156	151
143	149	157	159	142
148	153	146	160	148
155	160	140	159	164
157	152	154	153	162

Padded Image

156	156	150	150	156	151	151
156	156	150	150	156	151	151
143	143	149	157	159	142	142
148	148	153	146	160	148	148
155	155	160	140	159	164	164
157	157	152	154	153	162	162
157	157	152	154	153	162	162

Padded Image

156	156	150	150	156	151	151
156	156	150	150	156	151	151
143	143	149	157	159	142	142
148	148	153	146	160	148	148
155	155	160	140	159	164	164
157	157	152	154	153	162	162
157	157	152	154	153	162	162

Average filter mask

1	1	1
1	1	1
1	1	1

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Filtered Image

151	151	153	152	151
149	150	153	152	150
150	150	153	152	154
153	151	153	154	157
155	153	153	155	160

Padded Image

156	156	150	150	156	151	151
156	156	150	150	156	151	151
143	143	149	157	159	142	142
148	148	153	146	160	148	148
155	155	160	140	159	164	164
157	157	152	154	153	162	162
157	157	152	154	153	162	162

Average filter mask

1	2	1
2	4	2
1	2	1

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Filtered Image

152	151	152	153	150
148	150	153	153	148
149	150	151	154	152
154	152	151	155	159
155	153	152	155	160

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Impulse Noise profile

		1		
	0	0		1
0	1		0	1
1	1			
0	1		1	

Noisy Image

151	151	255	152	151
153	0	0	152	255
0	255	152	0	255
255	255	150	154	154
0	255	153	255	152

Padded Image

151	151	151	255	152	151	151
151	151	151	255	152	151	151
153	153	0	0	152	255	255
0	0	255	152	0	255	255
255	255	255	150	154	154	154
0	0	255	153	255	152	152
0	0	255	153	255	152	152

Padded Image

151	151	151	255	152	151	151
151	151	151	255	152	151	151
153	153	0	0	152	255	255
0	0	255	152	0	255	255
255	255	255	150	154	154	154
0	0	255	153	255	152	152
0	0	255	153	255	152	152

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Filtered Image

151	151	152	152	152
151	151	152	152	152
153	152	152	152	154
255	153	154	154	154
255	153	255	153	154

Padded Image

151	151	151	255	152	151	151
151	151	151	255	152	151	151
153	153	0	0	152	255	255
0	0	255	152	0	255	255
255	255	255	150	154	154	154
0	0	255	153	255	152	152
0	0	255	153	255	152	152

Average filter mask

1	1	1
1	1	1
1	1	1

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Filtered Image

134	140	140	169	174
112	124	124	152	180
147	135	124	141	181
141	163	181	158	170
141	164	209	175	175

Padded Image

151	151	151	255	152	151	151
151	151	151	255	152	151	151
153	153	0	0	152	255	255
0	0	255	152	0	255	255
255	255	255	150	154	154	154
0	0	255	153	255	152	152
0	0	255	153	255	152	152

Average filter mask

1	2	1
2	4	2
1	2	1

Input Image

151	151	153	152	151
153	150	153	152	151
150	153	152	151	154
153	155	150	154	154
151	151	153	152	152

Filtered Image

141	142	161	168	170
111	104	104	139	200
124	149	123	124	191
159	197	174	152	169
111	181	197	191	171

Food for thought!

1. What is a non-linear smoothing filter?

2. What is a median filter and how does it work?

3. Which type of noise is best removed using a median filter?

4. Why does the median filter preserve edges better than average filters?

5. What are the main steps involved in the median filtering algorithm?

Programming assignment

- Implement a median filter to remove impulse noise from an image and compare its performance with a linear smoothing filter.
- **Concepts Used**
  - Non-linear spatial filtering
  - Median filter
  - Impulse (salt-and-pepper) noise
  - Image padding
  - Linear vs non-linear filtering
- **Tasks**
  - Read a grayscale image.
  - Add salt-and-pepper noise to the image.
  - Implement a median filter (e.g., 3×3 mask) to remove the noise.
  - Apply an average filter to the same noisy image for comparison.
  - Display the original, noisy, and filtered images.
  - Compare the outputs and briefly comment on which filter better preserves edges and removes noise.

AI supported self-learning (Prompts compatible with ChatGPT)

Active Learners (Learning by Doing)

1. Provide a small grayscale matrix with salt-and-pepper noise and ask me to manually apply a 3×3 median filter. Let me solve it first, then explain the correct process.

2. Guide me in writing a Python/OpenCV program to add impulse noise to an image and remove it using a median filter, then compare it with an average filter.

Reflective Learners (Learning by Thinking)

1. Explain why median filtering is considered a non-linear operation and summarize how it differs conceptually from linear smoothing.

2. Why does the median filter preserve edges better than averaging filters? Provide a reasoning-based explanation.

Sensing Learners (Concrete & Practical)

1. Use actual pixel values to demonstrate how a median filter removes impulse noise.

2. Provide a real-world example where median filtering is preferred for noise removal.

Intuitive Learners (Concepts & Patterns)

1. Explain the underlying pattern behind order-statistic filters and why selecting the median improves robustness to outliers.

2. How does replacing the mean with the median change the statistical behavior of the filter?

Visual Learners (Diagrams & Structure)

1. Show an original image, an impulse-noisy image, and outputs after median and average filtering, and visually explain the differences.

2. Illustrate step by step how pixel values inside a filter window are sorted before selecting the median.

Verbal Learners (Words & Explanation)

1. Explain the median filter using an analogy such as choosing the middle value to avoid extreme disturbances.

2. Describe the difference between linear and non-linear smoothing filters in simple teaching language.

Sequential Learners (Step-by-Step Logic)

1. Break down the median filtering algorithm into ordered steps including padding, sorting, median selection, and output generation.

2. Explain step by step how to implement a 3×3 median filter algorithm.

Global Learners (Big Picture First)

1. Explain the overall role of non-linear filters in image enhancement before discussing the median filter.

2. Provide a big-picture comparison between linear and non-linear filtering and when each should be used.