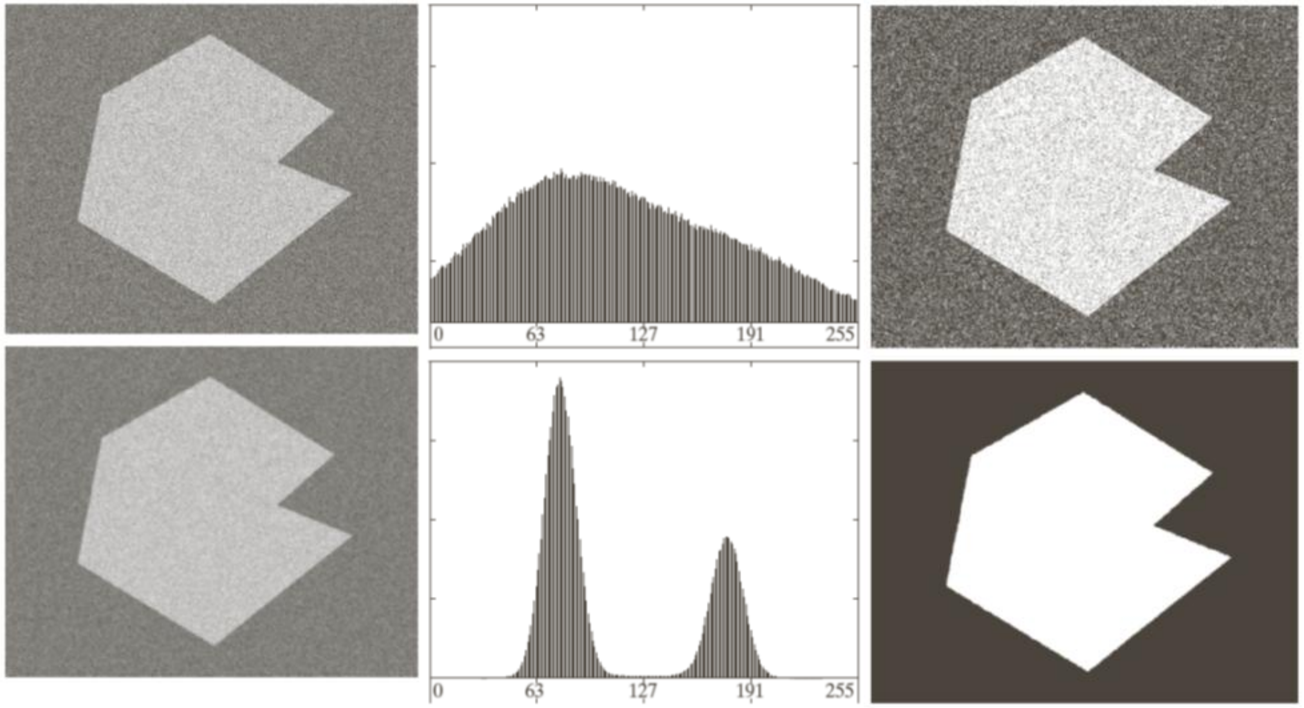
Spatial Filtering

Noise removal

Effect of Noise



Filter mask

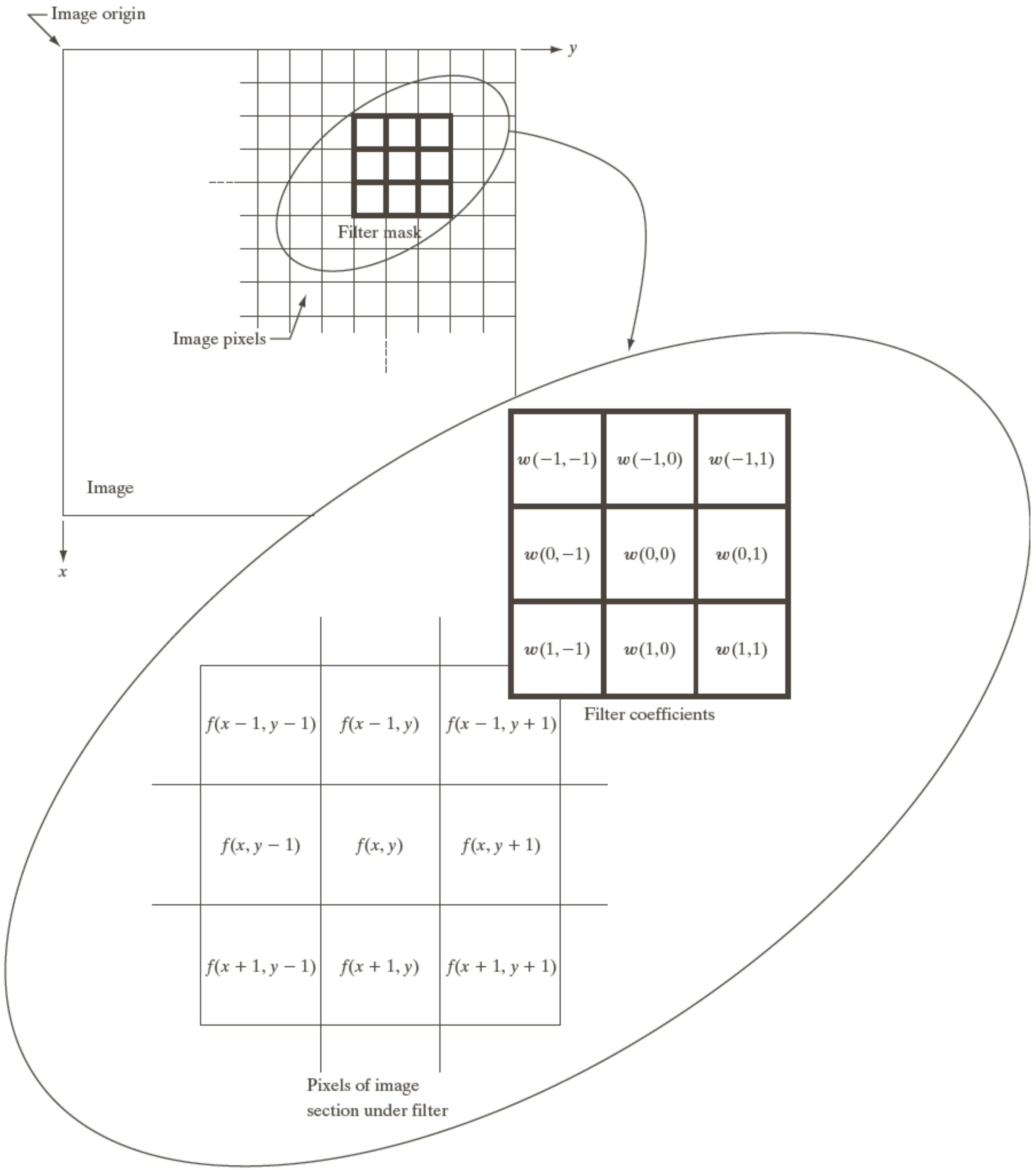


Image origin
y
Filter mask
Image pixels
Image
x
w(−1,−1)
w(−1,0)
w(−1,1)
w(0,−1)
w(0,0)
w(0,1)
w(1,−1)
w(1,0)
w(1,1)
Filter coefficients
f(x − 1, y − 1)
f(x − 1, y)
f(x − 1, y + 1)
f(x, y − 1)
f(x, y)
f(x, y + 1)
f(x + 1, y − 1)
f(x + 1, y)
f(x + 1, y + 1)
Pixels of image
section under filter

Correlation and Convolution (1D)

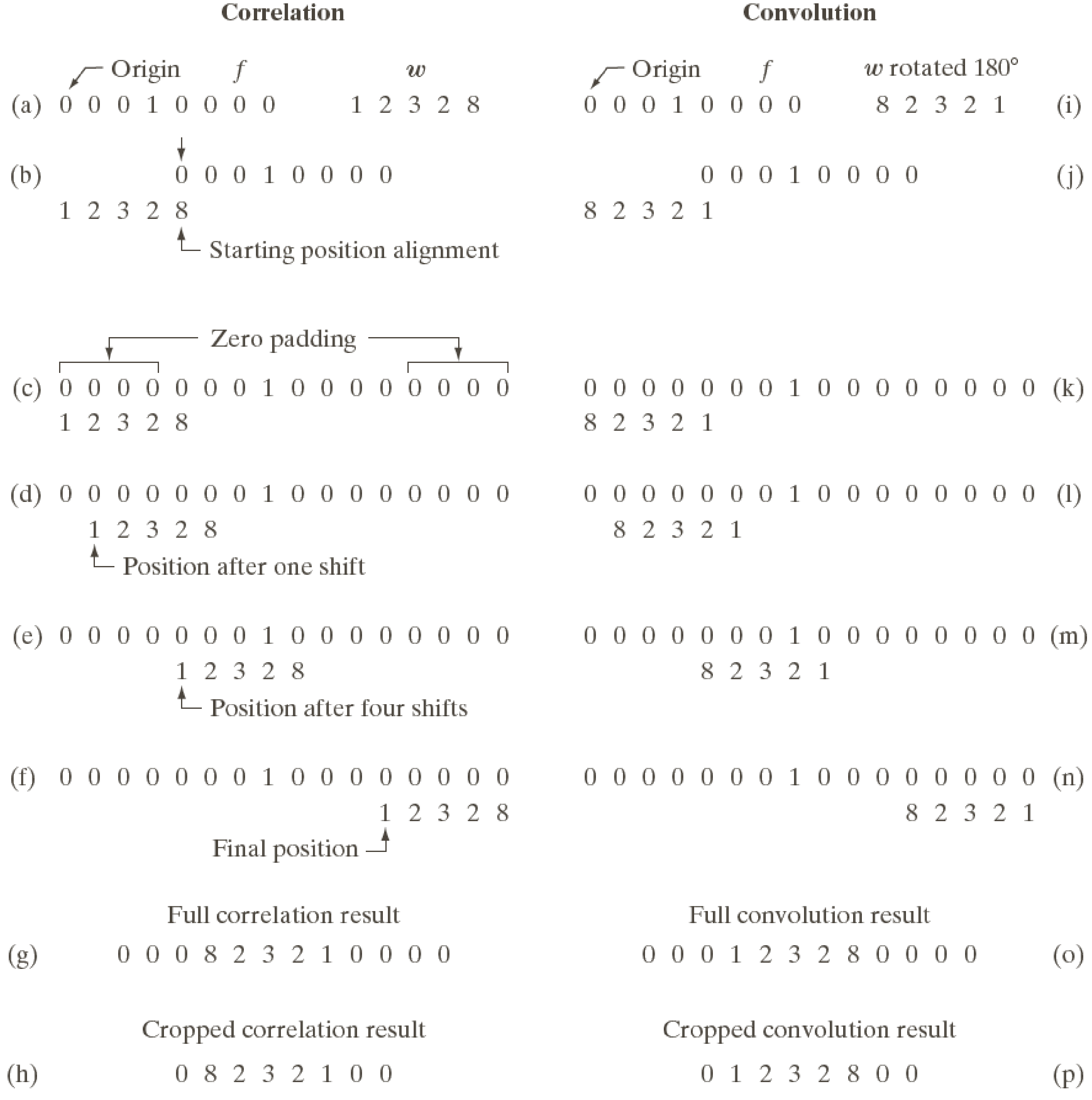


FIGURE 3.29 Illustration of 1-D correlation and convolution of a filter with a discrete unit impulse. Note that correlation and convolution are functions of *displacement*.

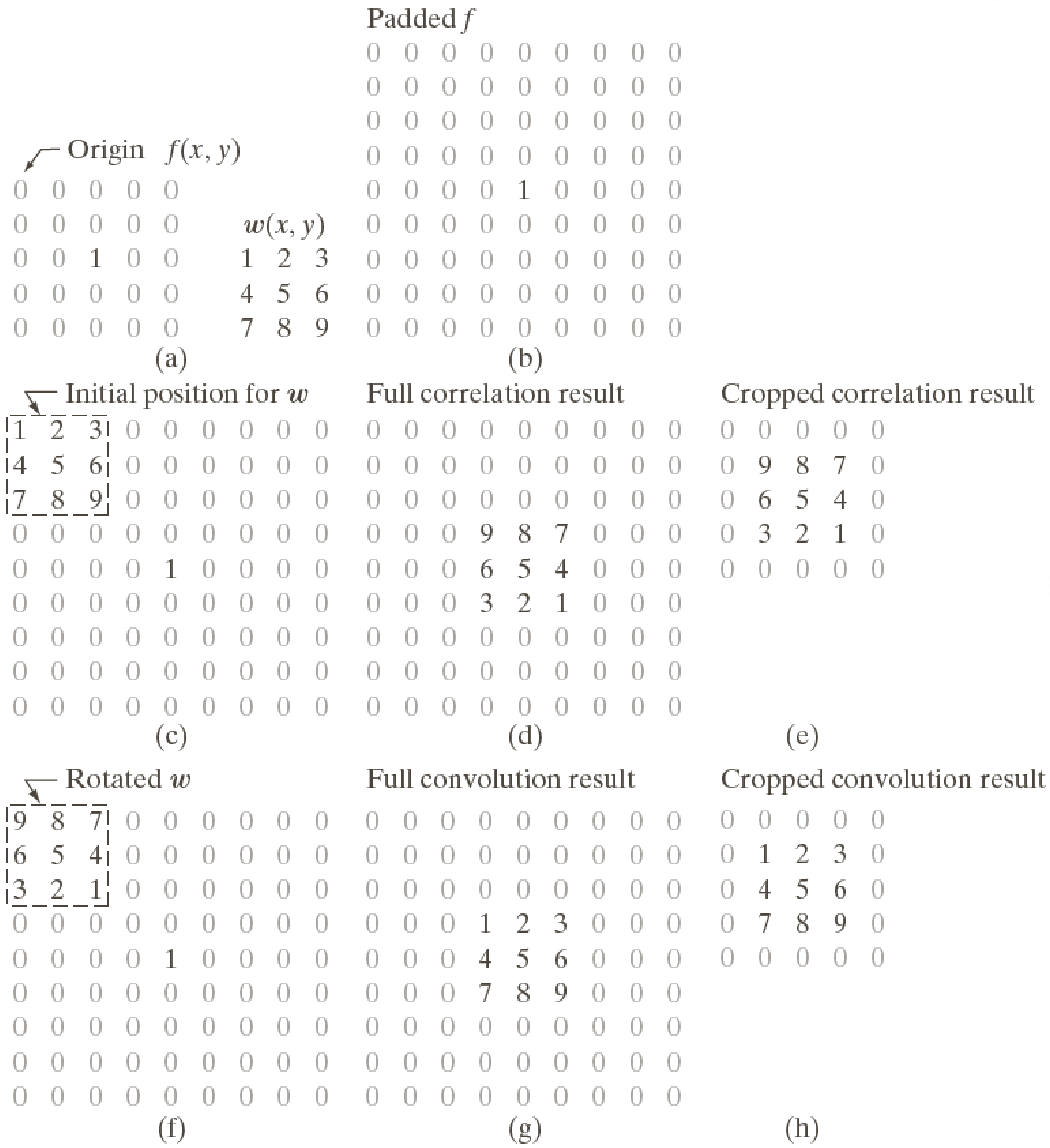
Correlation and Convolution

Correlation

$$w(x, y) \star f(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x + s, y + t)$$

Convolution

$$w(x, y) \bigstar f(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x - s, y - t)$$



Correlation and Convolution (2D)

Food for thought!

1. What is spatial filtering in digital image processing?
2. What is the primary purpose of spatial filters?
3. What is a filter mask (kernel)?
4. How does noise affect an image?
5. What is the key difference between correlation and convolution?

Programming assignment

- Implement spatial filtering techniques to reduce noise and enhance image quality using filter masks.
- **Concepts Used**
  - Spatial filtering
  - Filter mask (kernel)
  - Neighborhood processing
  - Correlation and convolution
  - Noise reduction
- **Tasks**
  - Read a grayscale image and optionally add salt-and-pepper or Gaussian noise.
  - Implement a mean (average) filter using a 3×3 mask to smooth the image.
  - Implement the filtering operation using both correlation and convolution, and observe any differences.
  - Apply the filter to the noisy image and generate the output.
  - Display the original, noisy, and filtered images.
  - Briefly comment on how spatial filtering improves image quality.

AI supported self-learning (Prompts compatible with ChatGPT)

Active Learners (Learning by Doing)

1. Provide a small 5×5 grayscale matrix and a 3×3 mean filter. Ask me to manually perform spatial filtering and verify my answer step by step.
2. Guide me through writing a NumPy program that adds salt-and-pepper noise to an image and removes it using a mean filter.

Reflective Learners (Learning by Thinking)

1. Explain why spatial filtering reduces noise and summarize the mathematical reasoning behind averaging operations.
2. Conceptually compare correlation and convolution and explain why flipping the kernel matters.

Sensing Learners (Concrete & Practical)

1. Use actual pixel values to demonstrate how a mean filter smooths an image.
2. Provide real-world examples where spatial filtering is critical, such as medical imaging or satellite imagery.

Intuitive Learners (Concepts & Patterns)

1. Explain spatial filtering as a neighborhood-based weighted averaging process and describe the pattern behind noise suppression.
2. Why does increasing kernel size increase smoothing but reduce detail? Explain the trade-off mathematically.

Visual Learners (Diagrams & Structure)

1. Visually demonstrate how a 3×3 kernel moves across an image during spatial filtering.
2. Show images before noise addition, after noise addition, and after filtering, and explain the differences visually.

Verbal Learners (Words & Explanation)

1. Explain spatial filtering using an analogy such as averaging opinions in a neighborhood.
2. Describe the difference between correlation and convolution in simple teaching language.

Sequential Learners (Step-by-Step Logic)

1. Explain the step-by-step algorithm for performing 2D convolution on an image.
2. Break down the procedure for applying a mean filter from padding to generating the final output.

Global Learners (Big Picture First)

1. Explain the overall purpose of spatial filtering in the image enhancement pipeline before discussing implementation.
2. Provide a big-picture comparison between spatial domain filtering and frequency domain filtering.