Arithmetic/Logic Operations

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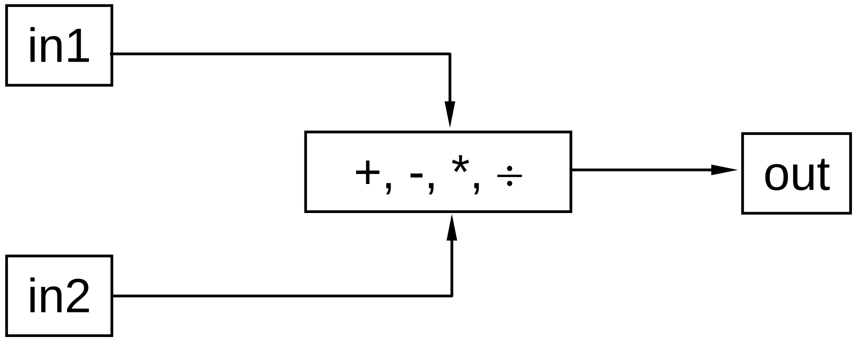
Objectives

- In this lecture we describe arithmetic and logic operations commonly used in image processing.
- Arithmetic ops:
  - Addition, subtraction, multiplication, division
  - Hybrid: cross-dissolves
- Logic ops:
  - AND, OR, XOR, BIC, …

Arithmetic/Logic Operations

- Arithmetic/Logic operations are performed on a pixel-by-pixel basis between two images.
- Logic NOT operation performs only on a single image.
  - It is equivalent to a negative transformation.
- Logic operations treat pixels as binary numbers:
  - 158 & 235 = 10011110 & 11101011 = 10001010
- Use of LUTs requires 16-bit rather than 8-bit indices:
  - Concatenate two 8-bit input pixels to form a 16-bit index into a 64K-entry LUT. Not commonly done.

Addition / Subtraction



Addition:

```
for(i=0; i<total; i++)
      out[i] = MIN(((int)in1[i]+in2[i]), 255);
```

Avoid overflow: clip result

Subtraction:

```
for(i=0; i<total; i++)
      out[i] = MAX(((int)in1[i]-in2[i]), 0);
```

Avoid underflow: clip result

Overflow / Underflow

- Default datatype for pixel is `unsigned char.`
- It is 1 byte that accounts for nonnegative range [0,255].
- Addition of two such quantities may exceed 255 (overflow).
- This will cause wrap-around effect:
  - 254:   11111110
  - 255:   11111111
  - 256: 100000000
  - 257: 100000001
- Notice that low-order byte reverts to 0, 1, … when we exceed 255.
- Clipping is performed to prevent wrap-around.
- Same comments apply to underflow (result < 0).

Implementation Issues

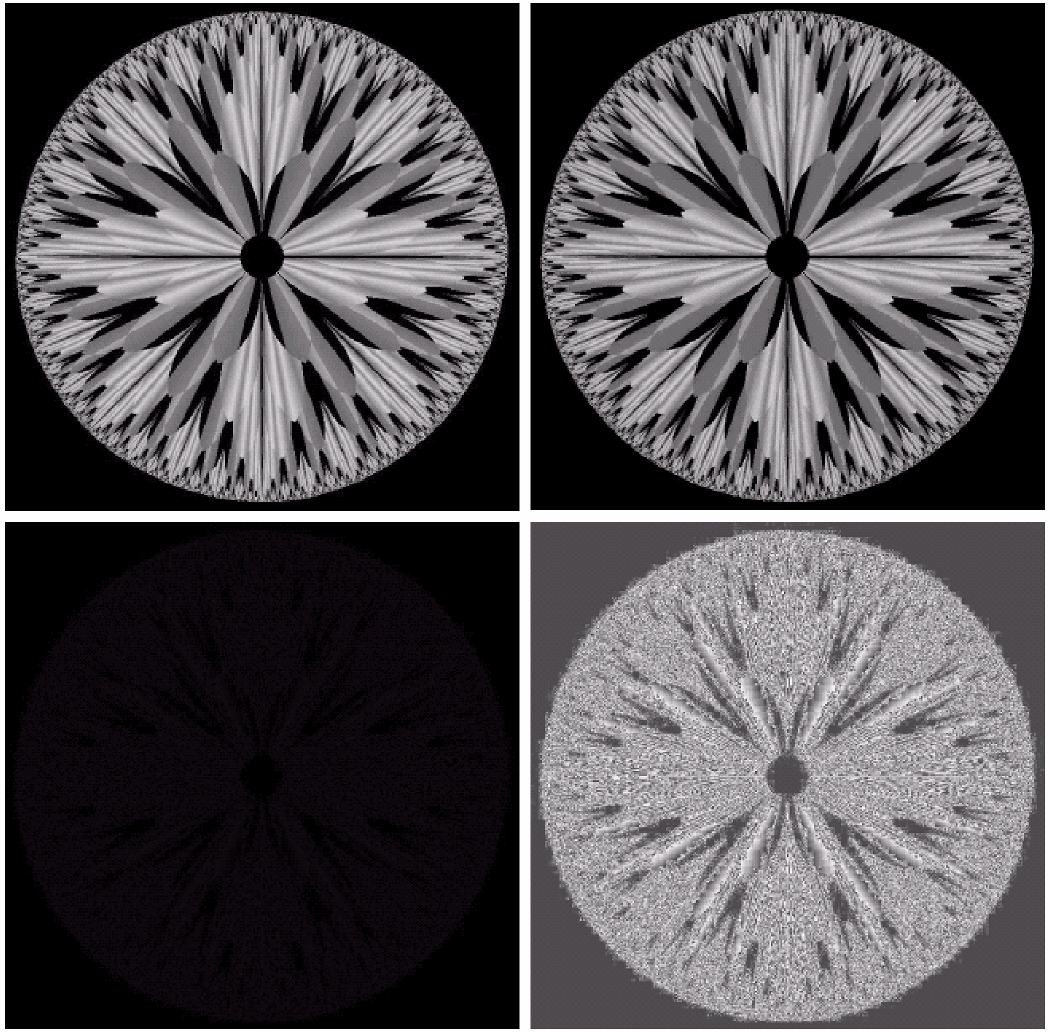
- The values of a subtraction operation may lie between -255 and 255. Addition: [0,510].
- Clipping prevents over/underflow.
- Alternative: scale results in one of two ways:

1. Add 255 to every pixel and then divide by 2.
   - Values may not cover full [0,255] range
   - Requires **`short`** intermediate image
   - Fast and simple to implement
2. Add negative of min difference (shift min to 0). Then, multiply all pixels by 255/(max difference) to scale range to [0,255] interval.
   - Full utilization of [0,255] range
   - Requires **`short`** intermediate image
   - More complex and difficult to implement

Example of Subtraction Operation

a b
c d

FIGURE 3.28
(a) Original fractal image.
(b) Result of setting the four lower-order bit planes to zero.
(c) Difference between (a) and (b).
(d) Histogram-equalized difference image.
(Original image courtesy of Ms. Melissa D. Binde, Swarthmore College, Swarthmore, PA).

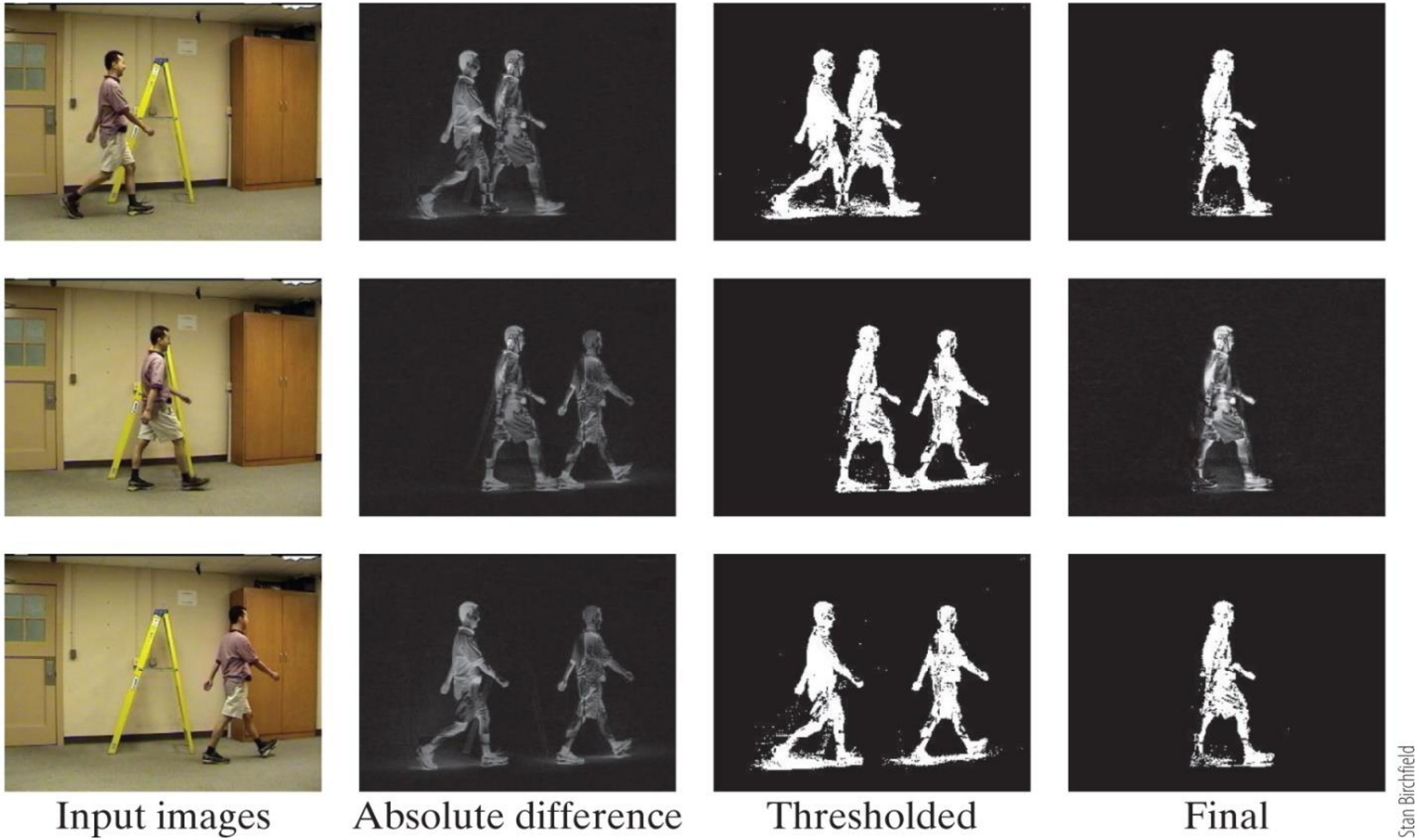


Example: Motion Detection

- Use **frame differencing** to compare successive video frames
- Insight: since camera is stationary, the background will not change much
- The moving foreground will change considerably
- Basic approach: use two successive frames to compute a **difference image**
- This produces a binary image from the threshold of | I1-I2 |
- Unfortunately this two-frame approach suffers from the double-image problem, which will display foreground pixels in both current and adjacent frame
- Solution: use double difference image (or three-frame difference)

Frame Differencing

Figure 3.27 Detecting a moving object by frame differencing. LEFT COLUMN: Three image frames from a video sequence. SECOND COLUMN: The absolute difference between pairs of frames. THIRD COLUMN: Thresholded absolute difference. RIGHT COLUMN: Final result using double difference (top), triple difference (middle), and thresholded triple difference (bottom) methods.



Pseudocode: Double Differencing

ALGORITHM 3.13 Compute the double difference between three consecutive image frames

FrameDifferenceDouble $(I_{t-1}, I_t, I_{t+1}, \tau)$

Input: successive images I_{t-1}, I_t, and I_{t+1}, and threshold τ
Output: binary image indicating the moving regions

for $(x, y) \in I_t$ **do**
 $d_1 \leftarrow |I_{t-1}(x, y) - I_t(x, y)|$
 $d_2 \leftarrow |I_{t+1}(x, y) - I_t(x, y)|$
 $I'(x, y) \leftarrow 1$ **if** $d_1 > \tau$ AND $d_2 > \tau$ **else** 0
return I'

Pseudocode: Triple Differencing

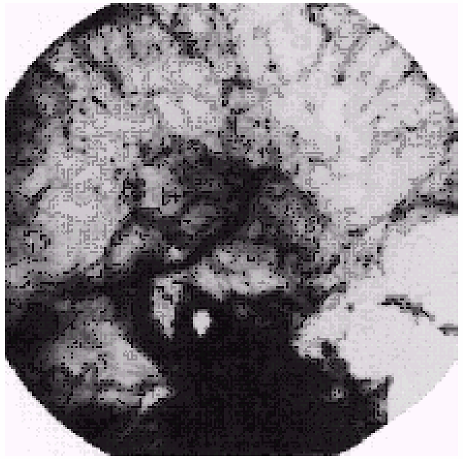
ALGORITHM 3.14 Compute the triple difference between three consecutive image frames

FrameDifferenceTriple $(I_{t-1}, I_t, I_{t+1}, \tau)$

Input: successive images I_{t-1}, I_t, and I_{t+1}, and threshold τ
Output: binary image indicating the moving regions

for $(x, y) \in I_t$ **do**
  $d_1 \leftarrow |I_{t-1}(x, y) - I_t(x, y)|$
  $d_2 \leftarrow |I_{t+1}(x, y) - I_t(x, y)|$
  $d_3 \leftarrow |I_{t+1}(x, y) - I_{t-1}(x, y)|$
  $I'(x, y) \leftarrow 1$ **if** $d_1 + d_2 - d_3 > \tau$ **else** 0
return I'

Example: Mask Mode Radiography



mask image h(x,y)

image f(x,y) taken after injection of a contrast medium (iodine) into the bloodstream, with mask subtracted out.

Note:

• the background is dark because it doesn’t change much in both images.

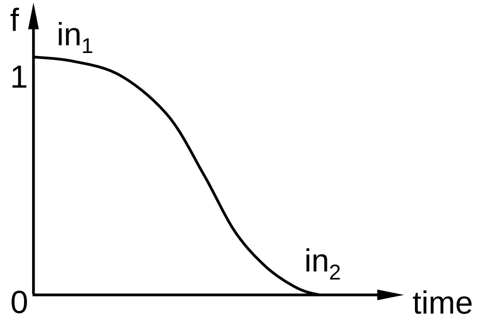
• the difference area is bright because it has a big change

- h(x,y) is the mask, an X-ray image of a region of a patient’s body captured by an intensified TV camera (instead of traditional X-ray film) located opposite an X-ray source
- f(x,y) is an X-ray image taken after injection a contrast medium into the patient’s bloodstream
- images are captured at TV rates, so the doctor can see how the medium propagates through the various arteries in an animation of f(x,y)-h(x,y).

Arithmetic Operations: Cross-Dissolve

- Linearly interpolate between two images.
- Used to perform a fade from one image to another.
- Morphing can improve upon the results shown below.

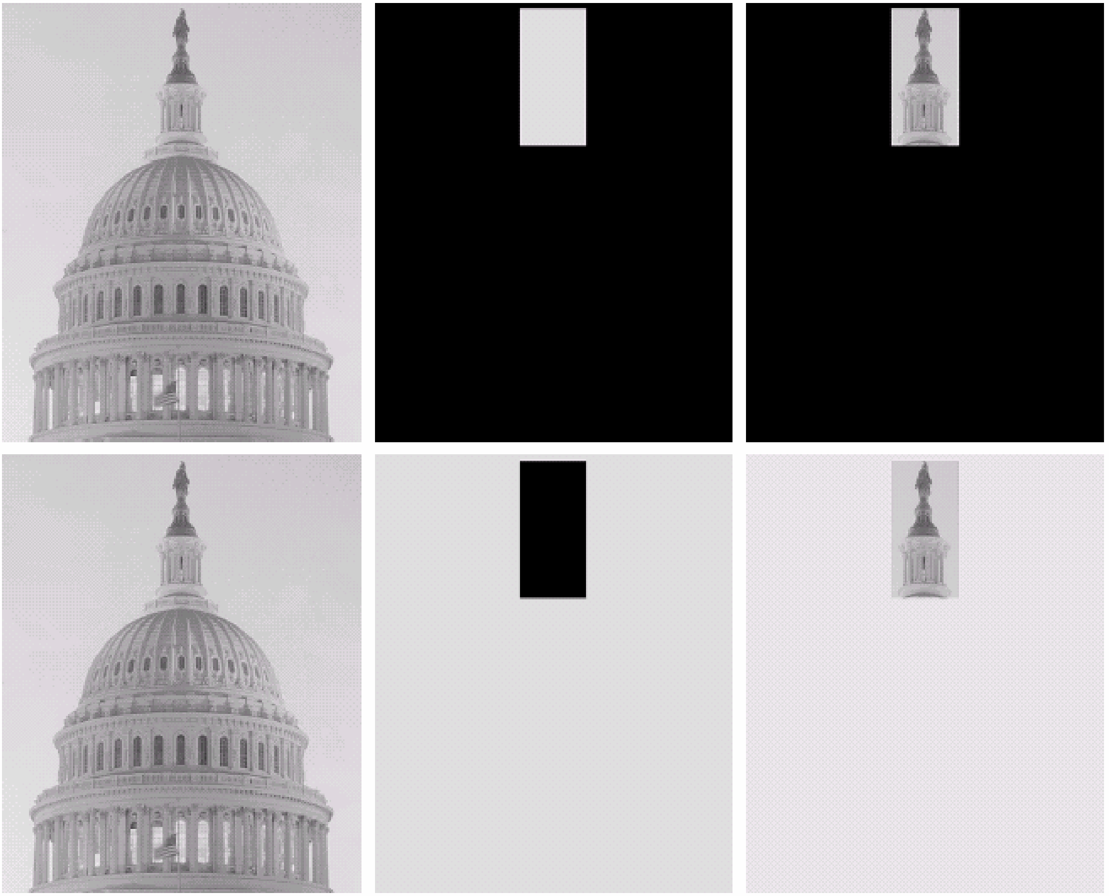
```
for(i=0; i<total; i++)
        out[i] = in1[i]*f + in2[i]*(1-f);
```



Masking

- Used for selecting subimages.
- Also referred to as region of interest (ROI) processing.
- In enhancement, masking is used primarily to isolate an area for processing.
- AND and OR operations are used for masking.

Example of AND/OR Operation



a	b	c
d	e	f

FIGURE 3.27 (a) Original image. (b) AND image mask. (c) Result of the AND operation on images (a) and (b). (d) Original image. (e) OR image mask. (f) Result of operation OR on images (d) and (e).