EEE-6512: Image Processing and Computer Vision

August 30, 2017

Lecture #5: Point and Geometric Transformations

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Chapter Outline

- Different ways to transform an image into another image
- Simple Geometric Transformations
- Graylevel Transformations
- Graylevel Histograms
- Multispectral Transformations
- Multi-Image Transformations
- Change Detection
- Compositing
- Interpolation
- Warping

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Simple Geometric Transformations

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Flipping and Flopping

- The simplest geometric transformation is to reflect the image about a horizontal or vertical axis passing through the center of the image.
  - If the axis is horizontal, the transformation **flips** the image upside down.
  - If the axis is vertical, the transformation **flops** the image to produce a right-to-left mirror image.

$$\begin{bmatrix} 128 & 78 & 174 \\ 181 & 48 & 77 \\ 109 & 49 & 138 \end{bmatrix} \xrightarrow{\text{FLOP}} \begin{bmatrix} 174 & 78 & 128 \\ 77 & 48 & 181 \\ 138 & 49 & 109 \end{bmatrix}$$

$$\downarrow \text{FLIP}$$

$$\begin{bmatrix} 109 & 49 & 138 \\ 181 & 48 & 77 \\ 128 & 78 & 174 \end{bmatrix}$$

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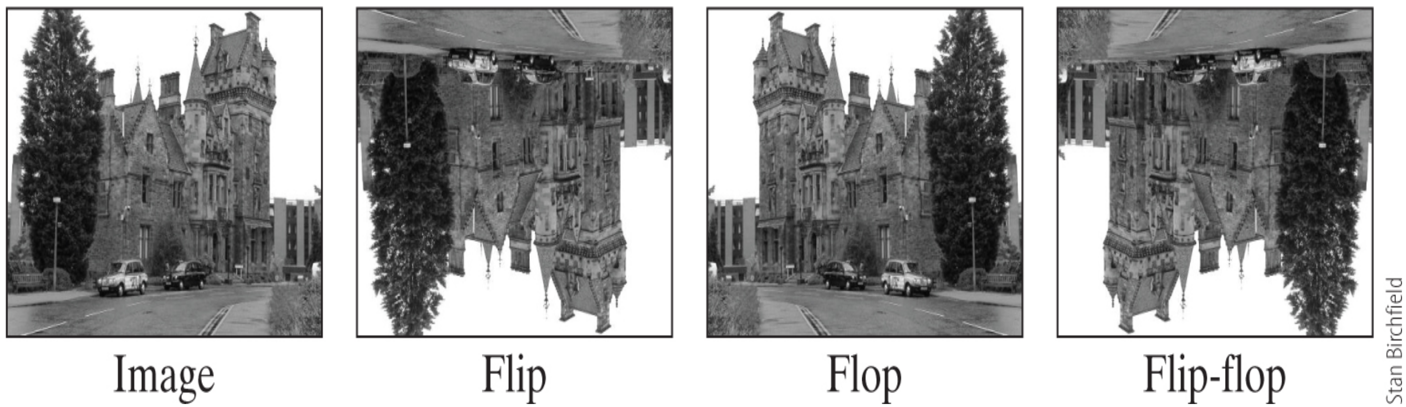
Flipping and Flopping (cont'd)

Figure 3.1 An image, and the result of flipping, flopping, and flip-flopping.



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Flipping and Flopping (cont’d)

ALGORITHM 3.1 Flip an image by reflecting about a horizontal axis

FlipImage (I)

Input: image I of size $width \times height$
Output: upside-down image I'

$I' \leftarrow$ AllocateImage($width$, $height$) ➤ Allocate memory for output image.
for $(x, y) \in I$ **do** ➤ For each pixel in input image,
    $I'(x, height - 1 - y) \leftarrow I(x, y)$ set corresponding pixel in output image.
return I' ➤ Return output image.

ALGORITHM 3.2 Flop an image by reflecting about a vertical axis

FlopImage (I)

Input: image I of size $width \times height$
Output: mirror-reversed image I'

$I' \leftarrow$ AllocateImage($width$, $height$) ➤ Allocate memory for output image.
for $(x, y) \in I$ **do** ➤ For each pixel in input image,
    $I'(width - 1 - x, y) \leftarrow I(x, y)$ set corresponding pixel in output image.
return I' ➤ Return output image.

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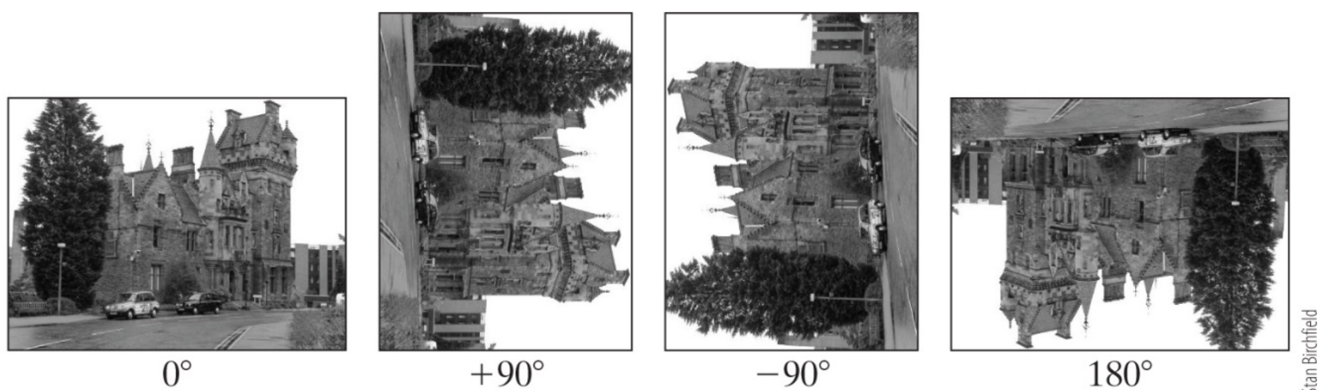
Rotating by a Multiple of 90 Degrees

- The transformations are expressed as functions that define the mapping between each input pixel $I(x, y)$ and its corresponding output pixel $I'(x', y')$:

$$I'(height - 1 - y, x) = I(x, y) \qquad I'(x', y') = I(y', height - 1 - x')$$

Figure 3.3 An image rotated by 0, +90, −90, and 180 degrees.



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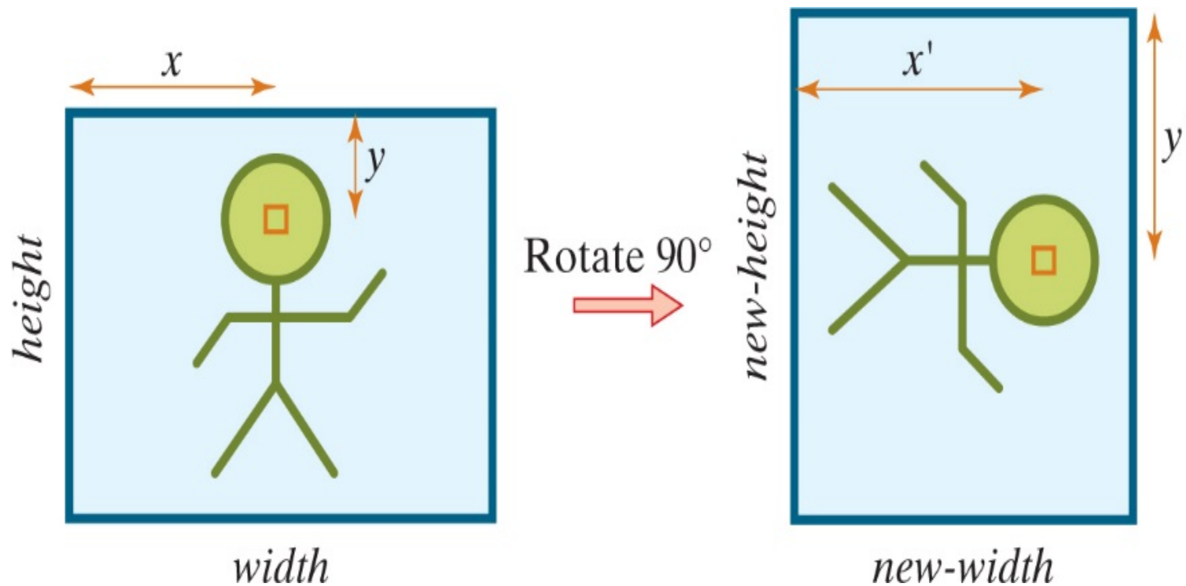
Rotating by a Multiple of 90 Degrees (cont'd)

Figure 3.4 To rotate an image clockwise by 90 degrees, the pixel (x, y) in the input image is mapped to (x', y') in the output image. From the drawing, it is easy to see that $x' = \textit{new-width} - 1 - y = \textit{height} - 1 - y$, and $y' = x$.



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Cropping an Image

Figure 3.5 An image and an automobile cropped out of the region of the image indicated by the red rectangle.

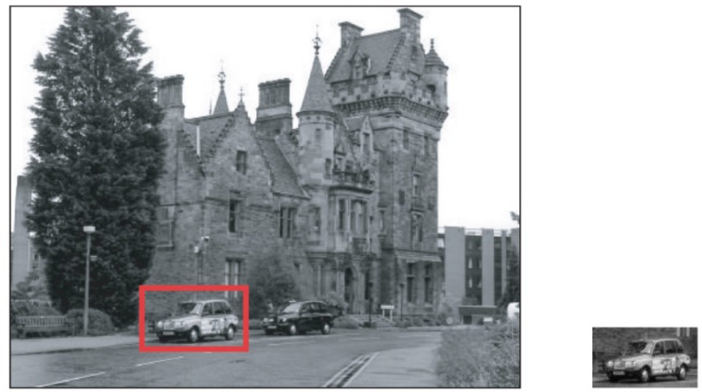

Image　　Cropped region

Stan Birchfield

ALGORITHM 3.4 Crop an image

CropImage(I, *left*, *top*, *right*, *bottom*)

Input: image I, rectangle with corners (*left*, *top*) and $(right-1, bottom-1)$
Output: cropped image I' of size *new-width* $\times$ *new-height*

$new\text{-}width \leftarrow right - left$
$new\text{-}height \leftarrow bottom - top$
$I' \leftarrow$ AllocateImage(*new-width*, *new-height*)
for $(x', y') \in I'$ **do**
　$I'(x', y') \leftarrow I(x' + left, y' + top)$
return I'

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Downsampling and Upsampling

- **Downsample** an image to produce a smaller image than the original:

$$I'(x, y) = I(2x, 2y) \qquad \text{(downsample by two)}$$

- **Upsample** an image to produce a larger image than the original:

$$I'(x, y) = I\left(\left\lfloor \frac{x}{2} \right\rfloor, \left\lfloor \frac{y}{2} \right\rfloor\right) \qquad \text{(upsample by two)}$$

Figure 3.6 LEFT: An image and the result of downsampling by a factor of 2 and 4, respectively, in each direction. RIGHT: A cropped region and the result of upsampling by a factor of 2 and 4, respectively, in each direction.

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Point Transformations

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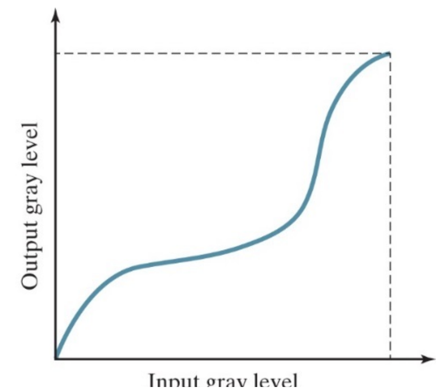
Graylevel Transformations

- **Point transformation**: changes a pixel's value without changing its location.

$$I'(x, y) = f(I(x, y))$$

Figure 3.7 A graylevel transformation maps input gray levels to output gray levels. Based on http://www.unit.eu/cours/videocommunication/Point_Transformation_histogram.pdf



ALGORITHM 3.5 Transform gray levels of an image

TransformGrayLevels(I, f)

Input: grayscale image I, graylevel mapping f
Output: transformed image I'

for $(x, y) \in I$ **do**
    $I'(x, y) \leftarrow f(I(x, y))$
return I'

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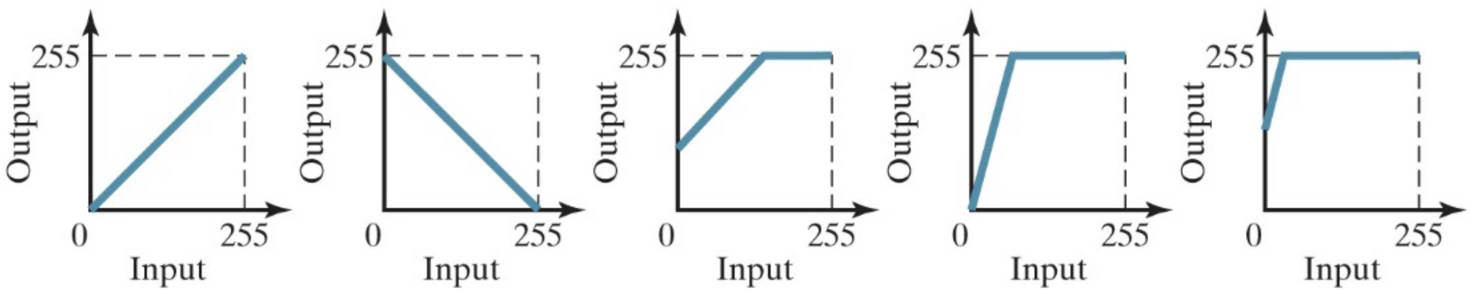
Arithmetic Operations

- A useful class of gray level transformations is the set of arithmetic operations, depicted in graphical form in the following figure:

Figure 3.8 Arithmetic graylevel transformations. From left to right: identity, inversion, addition (bias), multiplication (gain), and gain-bias transformation, where saturation arithmetic prevents the output from exceeding the valid range. Note that the slope remains 1 under addition, while the mapping passes through the origin under multiplication.



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Linear Contrast Stretching

- **Linear contrast stretch:** A transformation that specifies a line segment that maps gray levels between g_{min} and g_{max} in the input image to the gray levels g'_{min} and g'_{max} in the output image according to a linear function:

actual values

desired values/ output

$$I'(x, y) = \frac{g'_{max} - g'_{min}}{g_{max} - g_{min}}(I(x, y) - g_{min}) + g'_{min}$$

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