

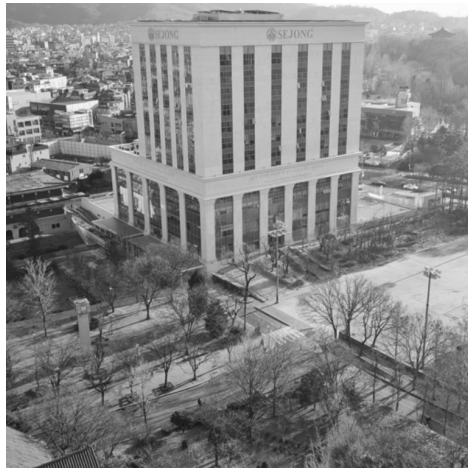
# Rotation

이진영

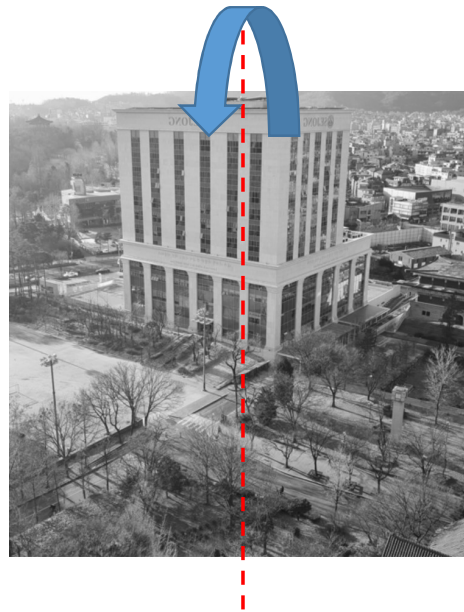


# Flip

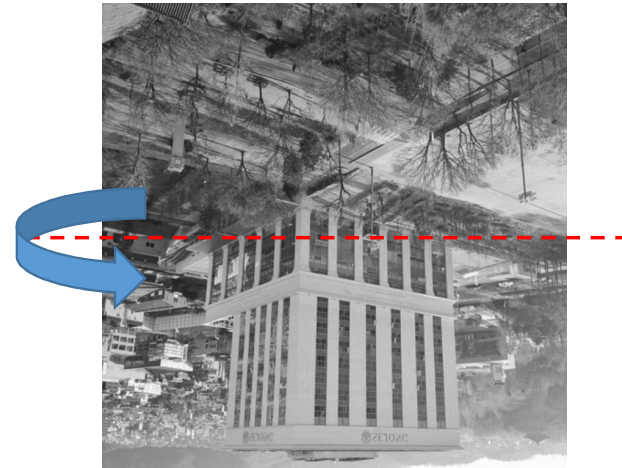
- Mirror reversal of an image across a horizontal or vertical axis



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Horizontal Flip

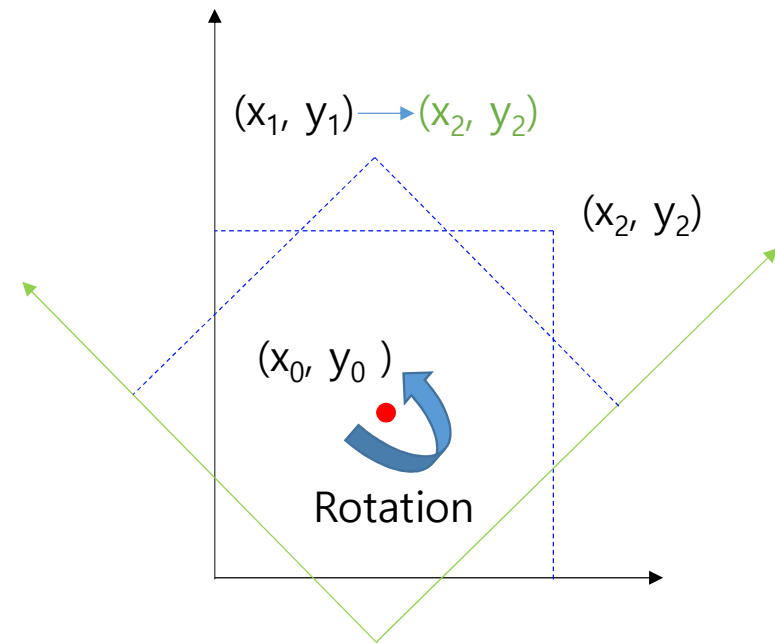
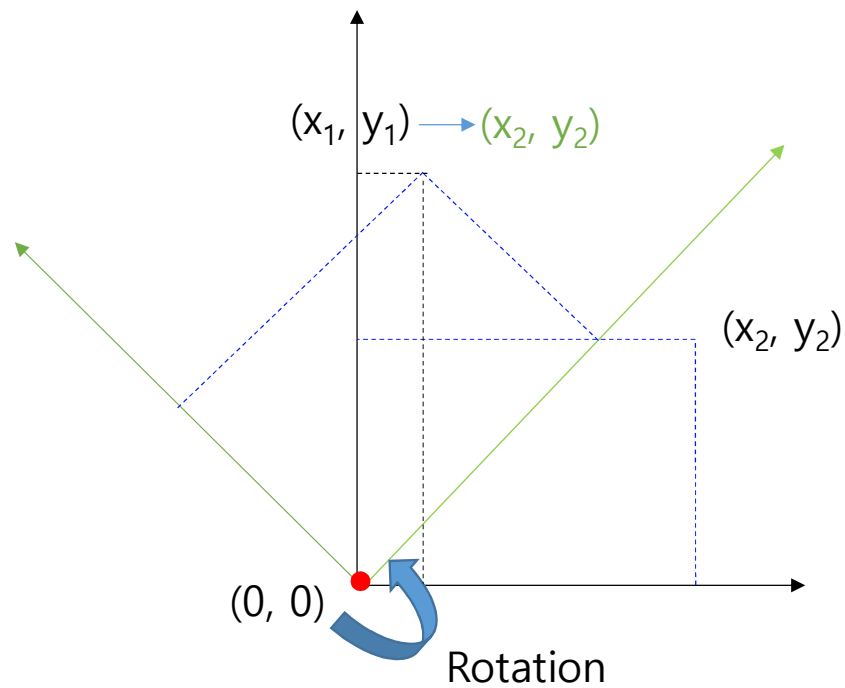


Vertical Flip



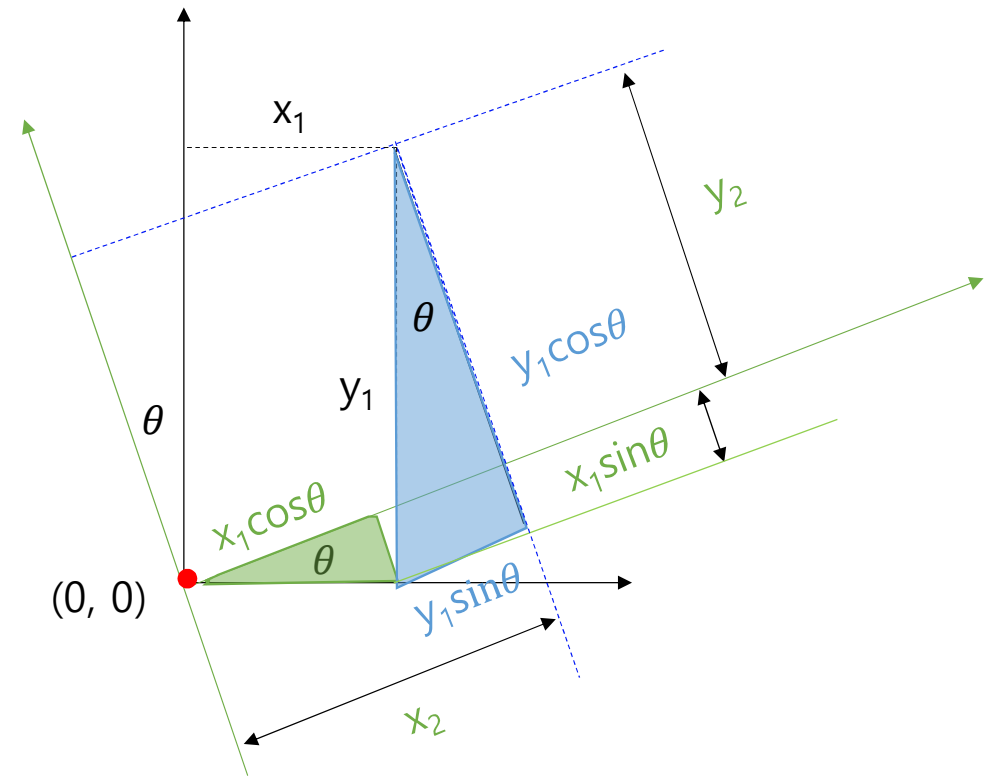
# Image Rotation

- Image processing of turning an image in a clockwise or counterclockwise direction
- Circular movement of an image around an origin of rotation



# Basic Principle

- Geometric transformation from a source coordinate  $(x_1, y_1)$  to a target coordinate  $(x_2, y_2)$
- Rotation of a coordinate by an angle  $\theta$
- Integer coordinate, but floating operation with  $\cos\theta$  and  $\sin\theta$
- Ignored, if  $(x_2, y_2)$  is located out of image boundaries



$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$



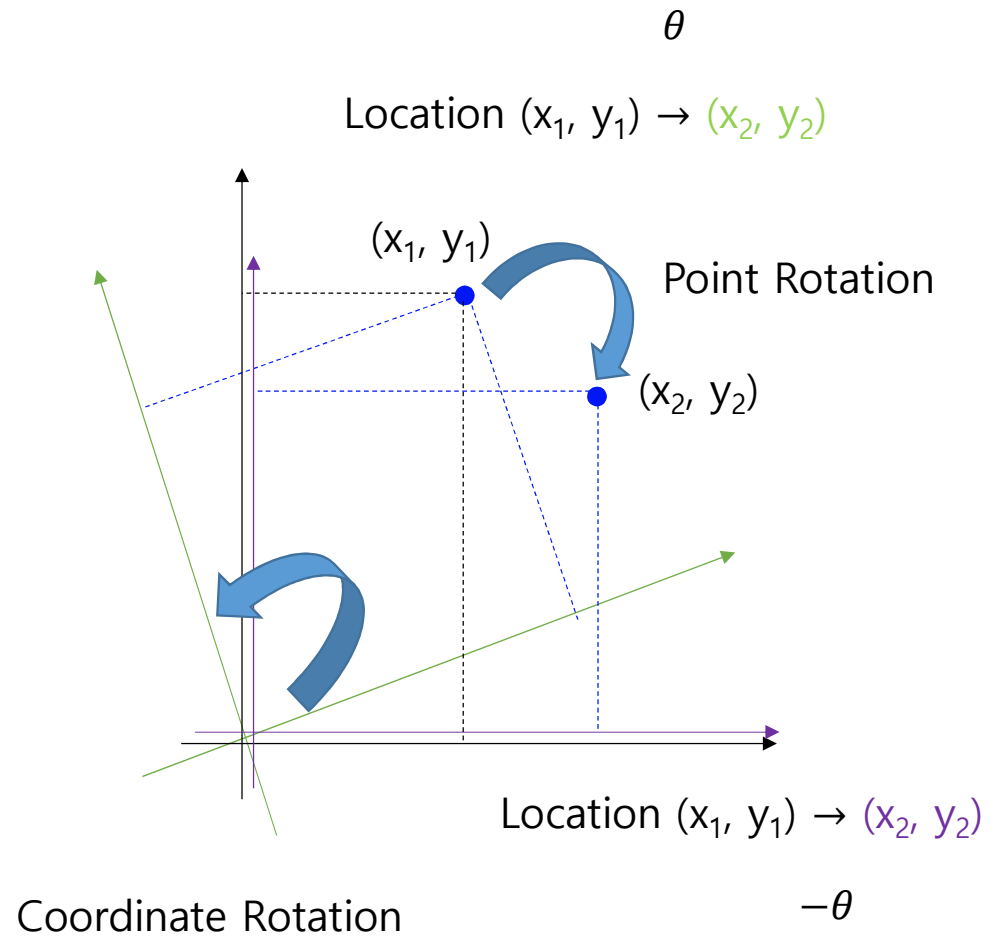
# Rotation Matrix

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$




$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos(-\theta) & \sin(-\theta) \\ -\sin(-\theta) & \cos(-\theta) \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$



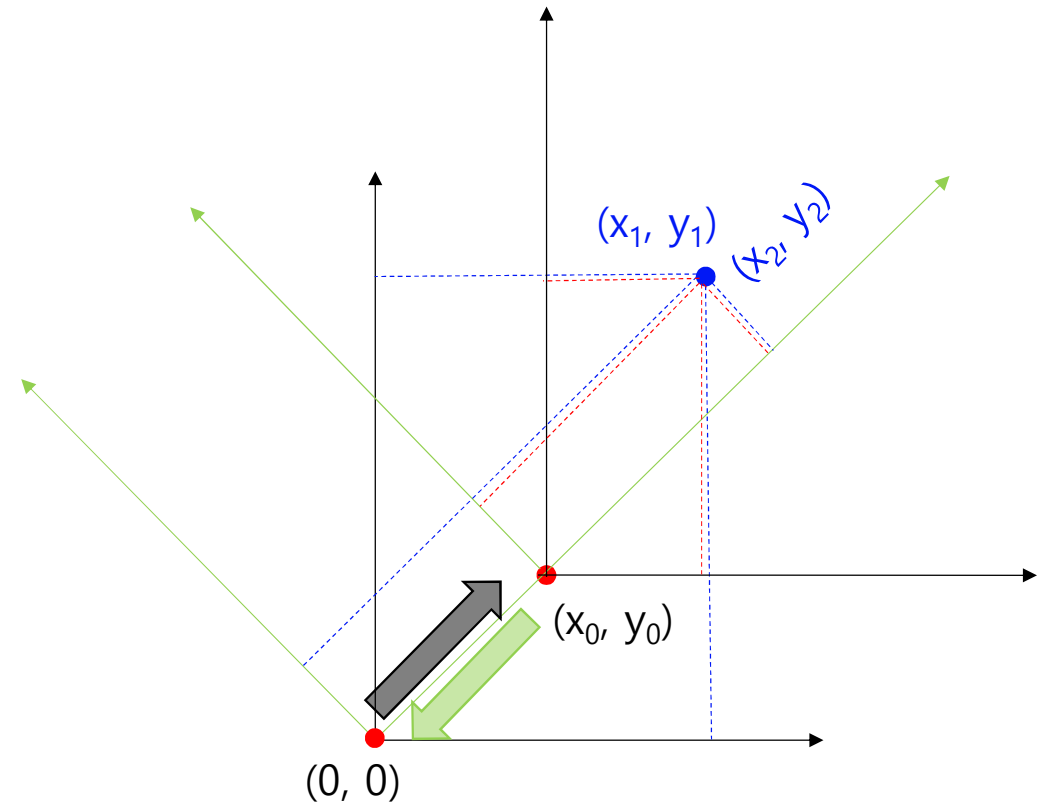
# Rotation Equation

- Rotation from  $(x_1, y_1)$  into  $(x_2, y_2)$  around an origin of  $(x_0, y_0)$


$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 - x_0 \\ y_1 - y_0 \end{bmatrix} + \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}$$

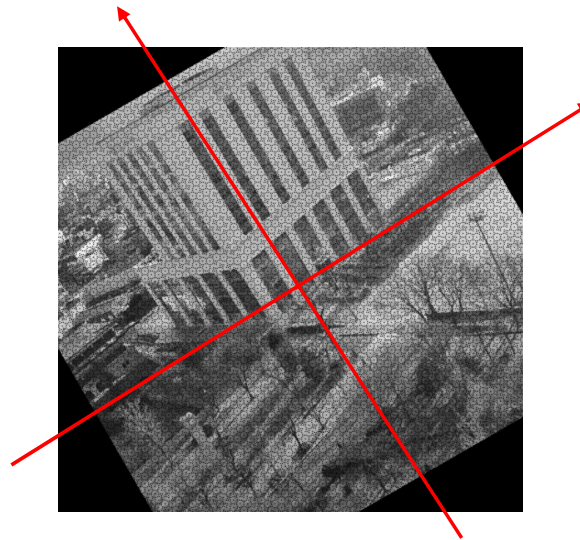
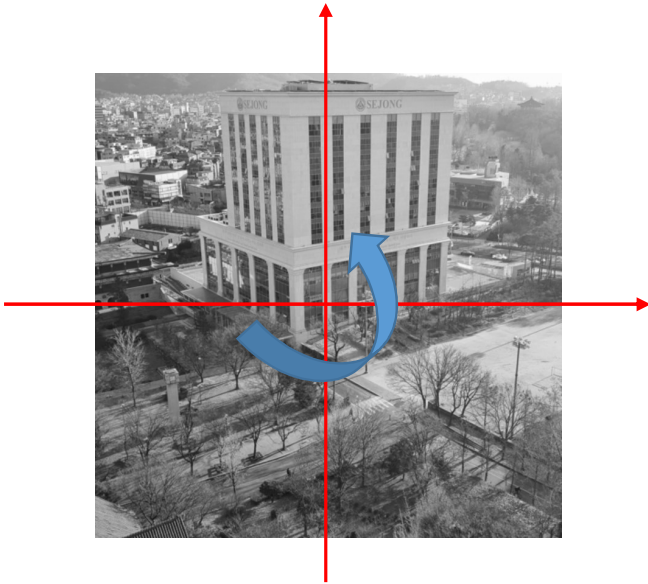
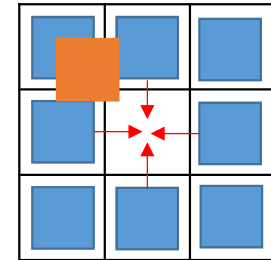
$$x_2 = \cos\theta \cdot (x_1 - x_0) - \sin\theta \cdot (y_1 - y_0) + x_0$$

$$y_2 = \sin\theta \cdot (x_1 - x_0) + \cos\theta \cdot (y_1 - y_0) + y_0$$

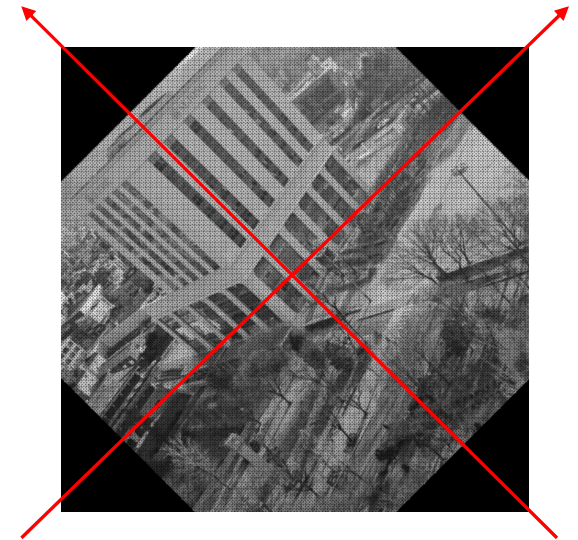


# Hole

- Unmapped pixels in a rotated image
- Rounding error for an integer coordinate, after floating transformation
- Hole filling, for example, interpolation with neighboring pixels surrounding unmapped pixels



Rotation by 30°



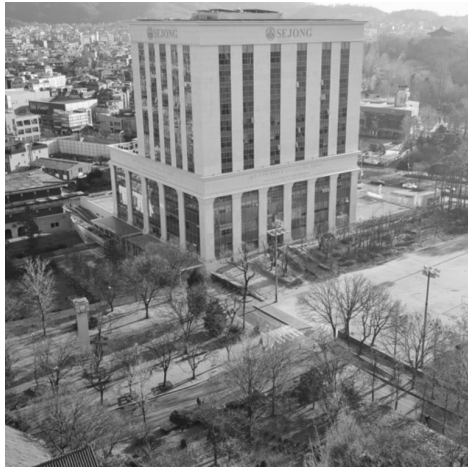
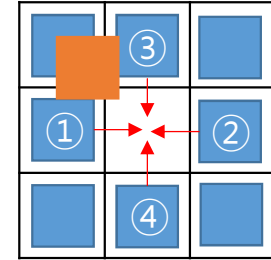
Rotation by 45°



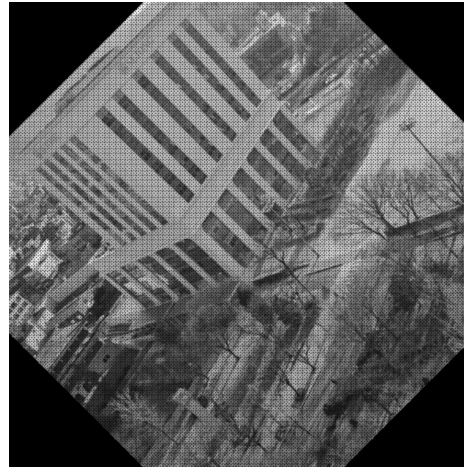


# Experiment

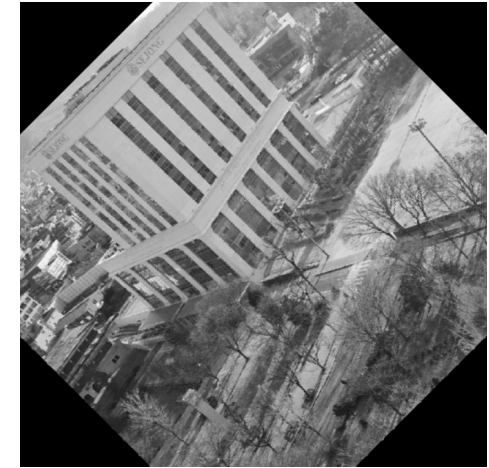
- Rotation by  $45^\circ$  ( $\pi/4$ ,  $\pi=3.1415926535$ )
- Nearest neighbor interpolation in left, right, top, and bottom order



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Rotation without hole filling



Rotation with hole filling

