Features

Global feature and local feature

- Global feature

Related to information less dependent on local location such as Color, HOG, Code,…

- Local feature

Related to region detectors such as Blob, Corner,…and local descriptor where locations are quantized into small patches such as SIFT, SURF,…

Global Features

Color Histogram vs Correlogram

- Color Histogram
  - Histogram is a distribution of the number of pixels on color
  - No spatial information
- Color Correlogram
  - A color correlogram expresses how the correlation of a pair of colors changes with distance
  - Both color and spatial information are considered

Color histogram

- Histogram of a given image I:

  For one color C_i in image, $\mathcal{H}_{ci}(I)$ is the number of pixels of color C_i in image I . If $\mathcal{H}_{ci}(I)$ is normalized into [0, 1], then we have a statement:

  "For any pixel in image I, $\mathcal{H}_{ci}(I)$ represents the possibility of that pixel is in color C_i"
- Histogram of color C_i is a mapping from an order set of colors C_i into [0, 1]. Total number of pixels in the color histogram is equal to the total number of pixels in image.
- Color histogram is independent to direction and location of objects in image.

Distance of histogram

$$\text{histint}(h_i, h_j) = 1 - \sum_{m=1}^{K} \min\left(h_i(m), h_j(m)\right)$$

Histogram intersection (Cond: normalized histograms)

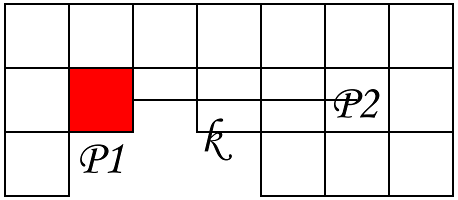
$$\chi^2(h_i, h_j) = \frac{1}{2} \sum_{m=1}^{K} \frac{[h_i(m) - h_j(m)]^2}{h_i(m) + h_j(m)}$$

Chi-square distance of two histograms

Cars found by color histogram matching using chi-squared

Color Correlogram

- For each pixel p_1 with color C_i, at distance k away from p_1 pick another pixel p_2, what is the probability that p_2 is also of color C_i

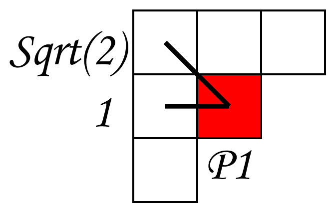


$\Pr(|p_2 - p_1| = k, \mathrm{Color}(p_2) = \mathrm{Red} \mid \mathrm{Color}(p_1) = \mathrm{Red})$

- Given distance k, how can we find the position of pixel p_2 from p_1 ?
- How can we calculate the probability of pixel p_2 correponding to color C_i?

Color Correlogram

- Distance *k* is selected such that the position of p_2 is found simply

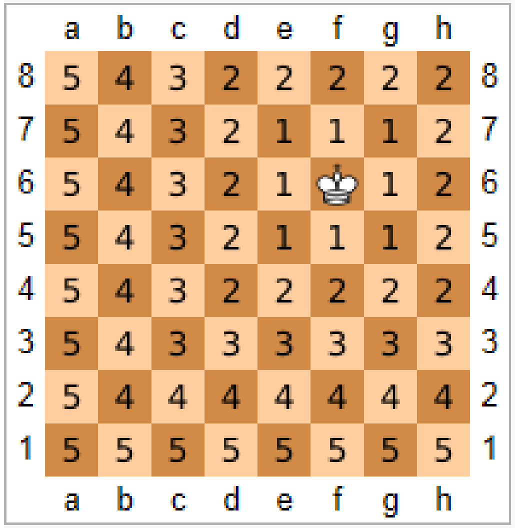


- Distance *k* is usually a natural number and the position of p_2 is found in the neighbour of p_1 by the radius of *k*

Color Correlogram

- Chessboard distance: Given two points p = (p_x ,p_y) and q =(q_x , q_y)

$$D(p,q) = \max(|\, p_x - q_x \,|, |\, p_y - q_y \,|)$$



k = 1, 2, 3, 4, 5

Color Correlogram

- The probability of pixel p_2 with color C_i

Given image *Img n x n,* the histogram of color C_i is defined as follows

$$h_{C_i}(\mathrm{Img}) = n^2 \times \Pr(p \in \mathrm{Img}_{C_i})$$

where Img_{Ci} is all pixels of image *Img* with color C_i

$$\gamma_{C_i}^{(k)}(I) \equiv \Pr[|p_1 - p_2| = k, p_2 \in \mathrm{Img}_{C_i} \mid p_1 \in \mathrm{Img}_{C_i}]$$

$$\equiv \frac{\sum_{p_1 \in \mathrm{Img}_{C_i}} |\{p_2 \in \mathrm{Img}_{C_i} \text{ with } |p_1 - p_2| = k\}|}{h_{C_i}(\mathrm{Img}) \times 8k}$$

Measurement

- We have some other measurements for histogram matching

Matching color histogram of two images *I* and *I′*:

$$|I - I'|_h \equiv \sum_{i \in [m]} \frac{|h_{C_i}(I) - h_{C_i}(I')|}{1 + h_{C_i}(I) + h_{C_i}(I')}$$

Matching correlogram of two images *I* and *I′* :

$$|I - I'|_\gamma \equiv \sum_{i \in [m]} \sum_{k \in [d]} \frac{|\gamma_{C_i}^{(k)}(I) - \gamma_{C_i}^{(k)}(I')|}{1 + \gamma_{C_i}^{(k)}(I) + \gamma_{C_i}^{(k)}(I')}$$

Examples

- Test and sampling images are similar (300 sampling images)

Xiaoguang Feng 2002

Examples

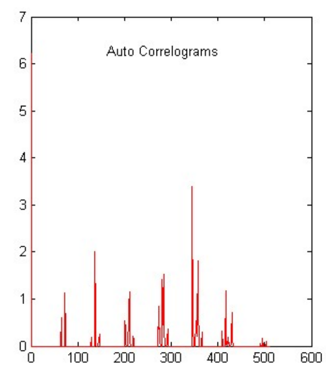
- Background of test image is different from that of sampling image

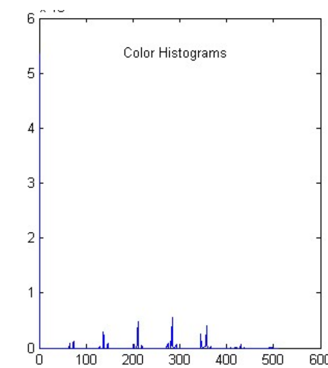
Test

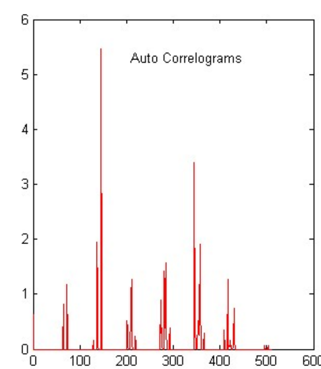
Correlogram : 1st

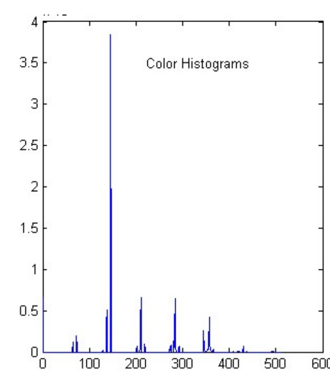
Histogram : 48th

Sampling









Xiaoguang Feng 2002

Examples

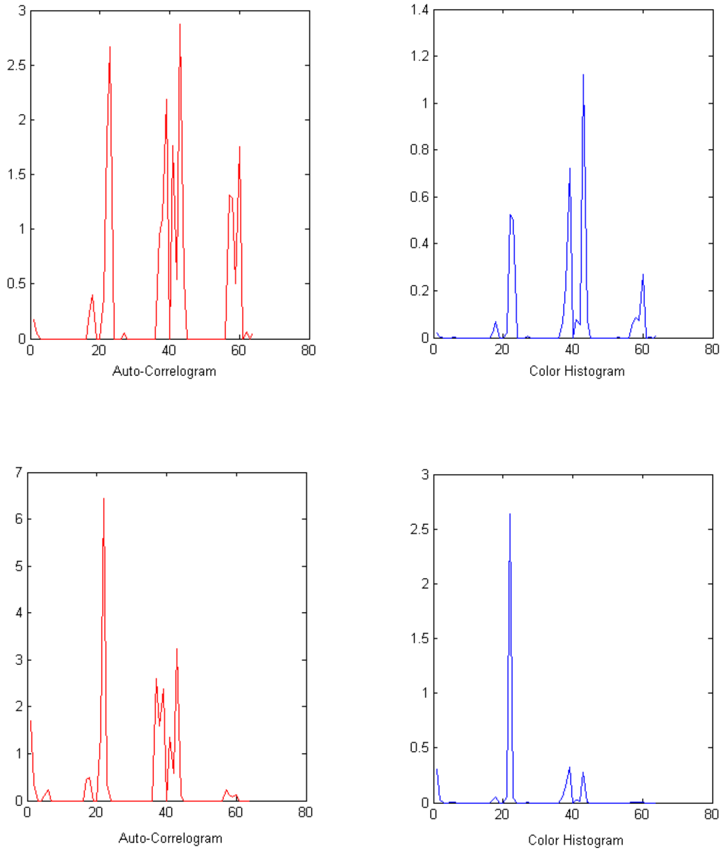
- Object size is different

Test

Correlogram : 1st

Histogram : 31th

Sampling



Xiaoguang Feng 2002

Discussions

- Correlogram needs more computation cost than color histogram
- Correlogram is more robust than color histogram
- Correlogram describes the global distribution of spatial information corresponding to color

Color moment

- There are 3 channels in color digital image (RGB, HSV, YCbCr, …), where RGB is the most popular.
- Each feature of “color moment” is a statistical value of mean, standard deviation, skewness in each channel of color.

Color moment

- Mean (Moment #1)

$$E_C = \frac{1}{N}\sum_{j=1}^{N} p_j^C,\ p_j^C$$: intensity value of the j^th pixel in image

- Standard deviation (Moment #2)

$$\sigma_C = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}\left(p_j^C - E_C\right)^2}$$

Color moment

- Skewness (Moment #3)

$$s_C = \sqrt[3]{\frac{1}{N-1}\sum_{j=1}^{N}\left(p_j^C - E_C\right)^3}$$

- Feature vector of “color moment”

E_R	σ_R	s_R	E_G	σ_G	s_G	E_B	σ_B	s_B

Color moment

- Distance of "color moment"

$$d(I,T)=\sum_{i=1}^{C} w_{i1}\,|\,E_{Ii}-E_{Ti}\,|+w_{i2}\,|\,\sigma_{Ii}-\sigma_{Ti}\,|+w_{i3}\,|\,s_{Ii}-s_{Ti}\,|$$

- Based on the color system, the value of w_{ij} will be changed to get more stable results
- $d(I,T)$ is small when the correlation of I and T is large

Color moment

- RGB system: RGB is the most popular. Analog-Digital converter is simple, but RGB space is not continuous in changes of color system

- HSV system: H channel is a continuous space and it is usually used to color detection. S and V channels are sensitive to changes of brightness and shadow.

- YCbCr system: Y channel is an gray image. Cb and Cr channels contribute as blue and red channels in RGB, but the texture of Y channel is better than that of Cb and Cr channel. The color range of YCbCr system is also larger than that of RGB. YCbCr is not sensitive to brightness and contrast.

Example

Index Image

Test Image 1

Test Image 2

Three values of color moments for each channel of HSV system:

$$\begin{array}{lc} & \begin{array}{ccc} \textbf{H} & \textbf{S} & \textbf{V} \end{array} \\ \begin{array}{l} \text{Moment \#1} \\ \text{Moment \#2} \\ \text{Moment \#3} \end{array} & \begin{bmatrix} 0.1016 & 0.1149 & 0.1779 \\ 0.8583 & 0.1139 & 0.0563 \\ 0.6416 & 0.2994 & 0.0974 \end{bmatrix} \end{array} \quad \begin{bmatrix} 0.1718 & 0.0986 & 0..1400 \\ 0.7619 & 0.1508 & 0.0455 \\ 0.7062 & 0.2242 & 0.0772 \end{bmatrix} \quad \begin{bmatrix} 0.1878 & 0.1671 & 0.2331 \\ 0.2462 & 0.2281 & 0.2492 \\ 0.6052 & 0.3532 & 0.1534 \end{bmatrix}$$

Index Image   Test Image 1   Test Image 2

Weight matrix W: $\mathbf{W} = \begin{bmatrix} 1 & 2 & 1 \\ 1 & 2 & 1 \\ 1 & 2 & 1 \end{bmatrix}$

Distance calculation: $d_{mom}(Index, Test1) = 0.5878$

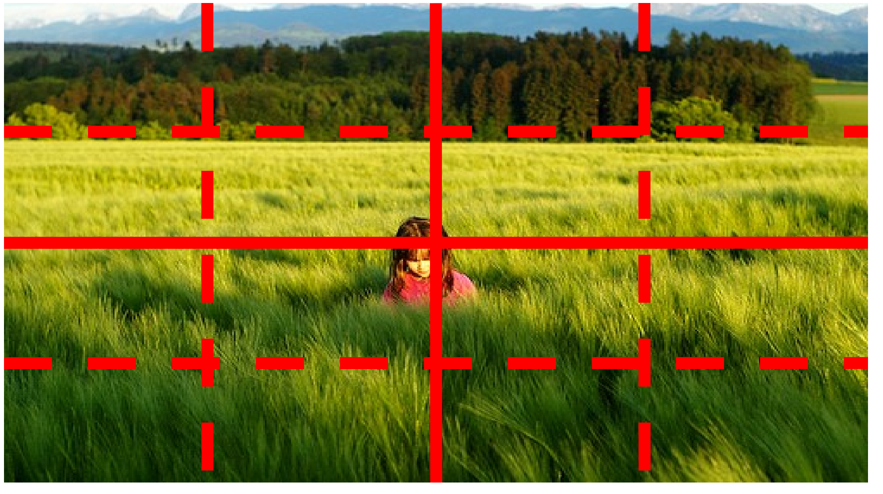
$d_{mom}(Index, Test2) = 1.5585$

"Test Image 1" is more correlated than "Test Image 2" to "Index image"

Noah Keen 2005

Color moment

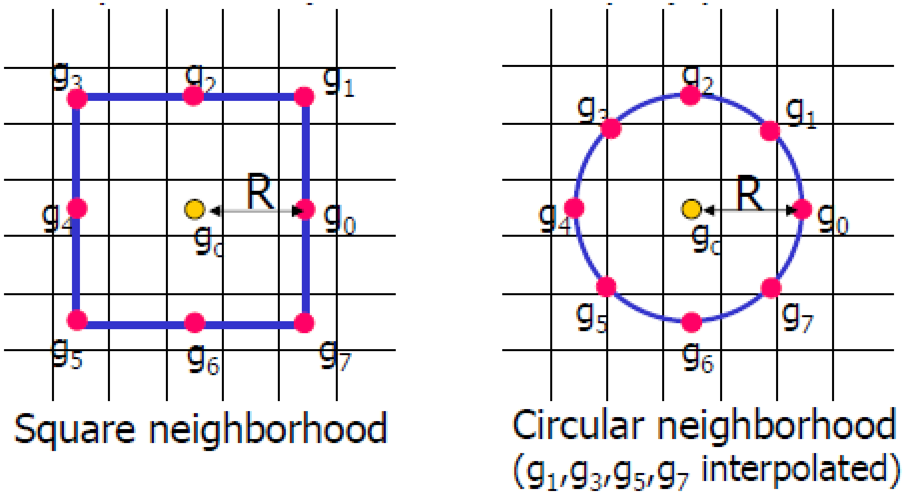
- In feature of “color moment”, the spatial information is not considered. We can add the spatial information by dividing image into many regions



The features of “color moment” is calculated for each region and we combine the color moment of each region to make one feature vector.

Local Binary Pattern

- Given a center point g_c , the neighbours of g_c are presented by a radius R:



- g_c and its neighbour g_p (p=0,…,P-1) is coded by T

  $T = t(g_c , g_0 ,…, g_{P-1})$

Local Binary Pattern

- Reduce the number of varible in t(), we subtract its parameters from g_c

$$\mathbf{T \sim t(0,\ g_0 - g_c\ ,\ldots,\ g_{P-1} - g_c)}$$

- After that, T can be transformed as follows:

$$\mathbf{T \sim t(\ g_0 - g_c\ ,\ldots,\ g_{P-1} - g_c)}$$

The above equation gives us the difference of color between the center point and its neighbours.

LBP: Local Binary Pattern

- Normalize the value of function t(), we apply function s() :

$$T \sim t(\ s(g_0\text{-}g_c),\ldots,\ s(g_{P\text{-}1}\text{-}g_c))$$

where

$$s(x) = \begin{cases} 1, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

- We convert a sequence of P bits in T to an interger number

$$LBP_{P,R} = \sum_{p=0}^{P\text{-}1} s\ (g_p\text{-}g_c)\ 2^p$$

Example

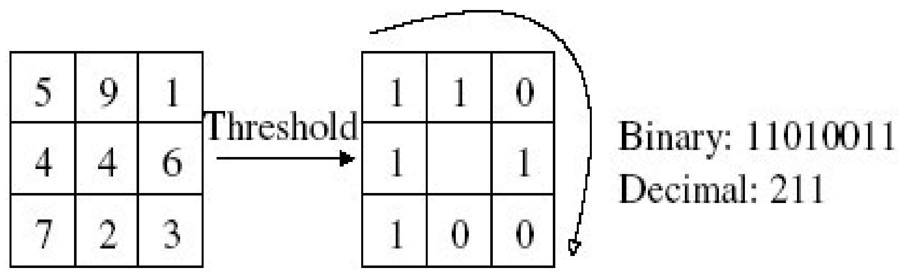


Fig. 1. The basic LBP operator.

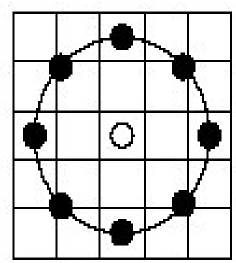
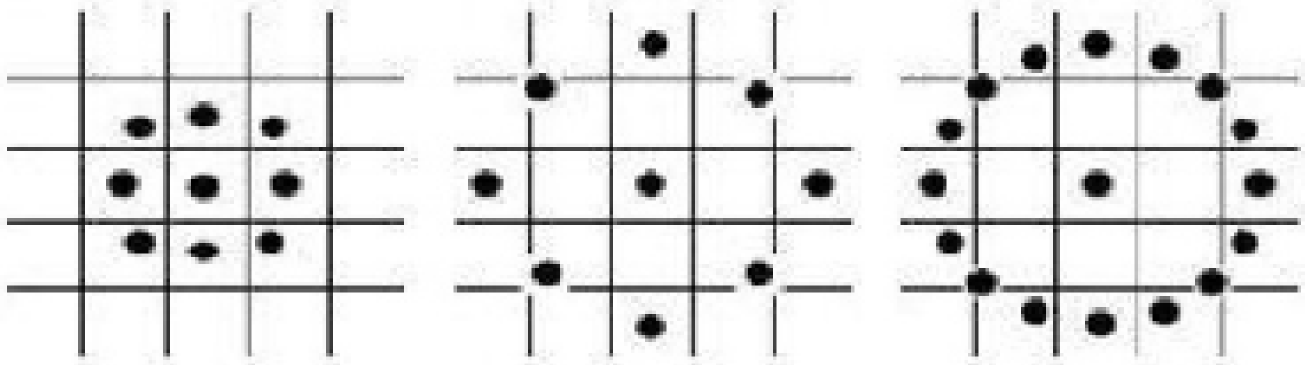
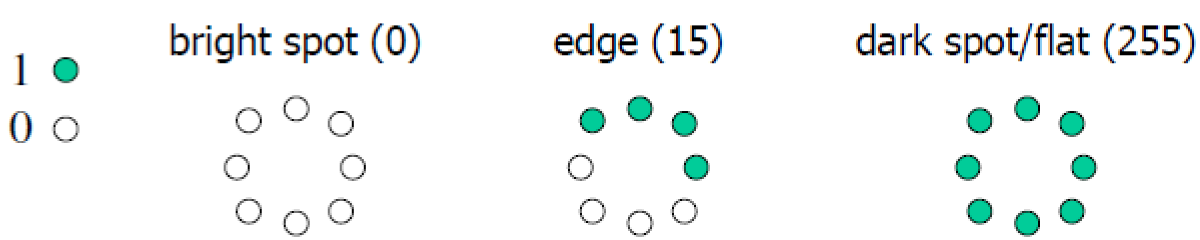


Fig. 2. The circular (8,2) neigbourhood. The pixel values are bilinearly interpolated whenever the sampling point is not in the center of a pixel.

Local Binary Pattern

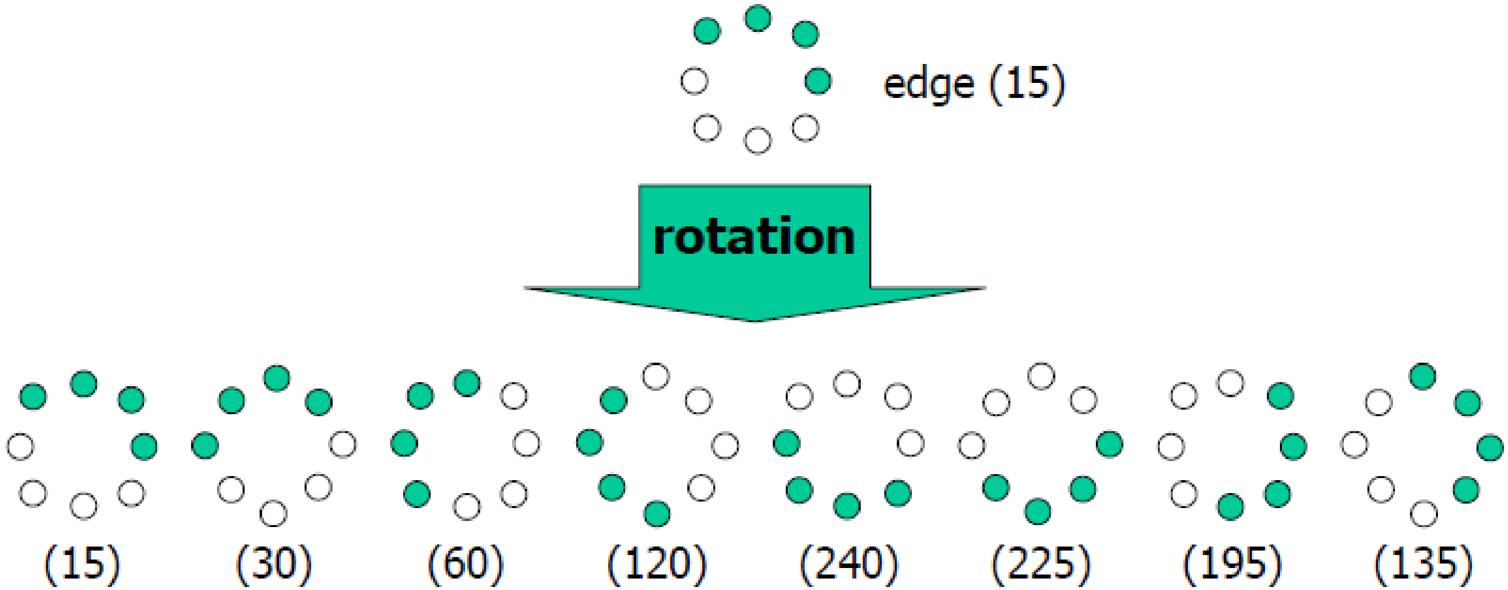


a) P=8, R=1 b) P=8, R=2 c) P=16, R=2



Select descriptor of LBP

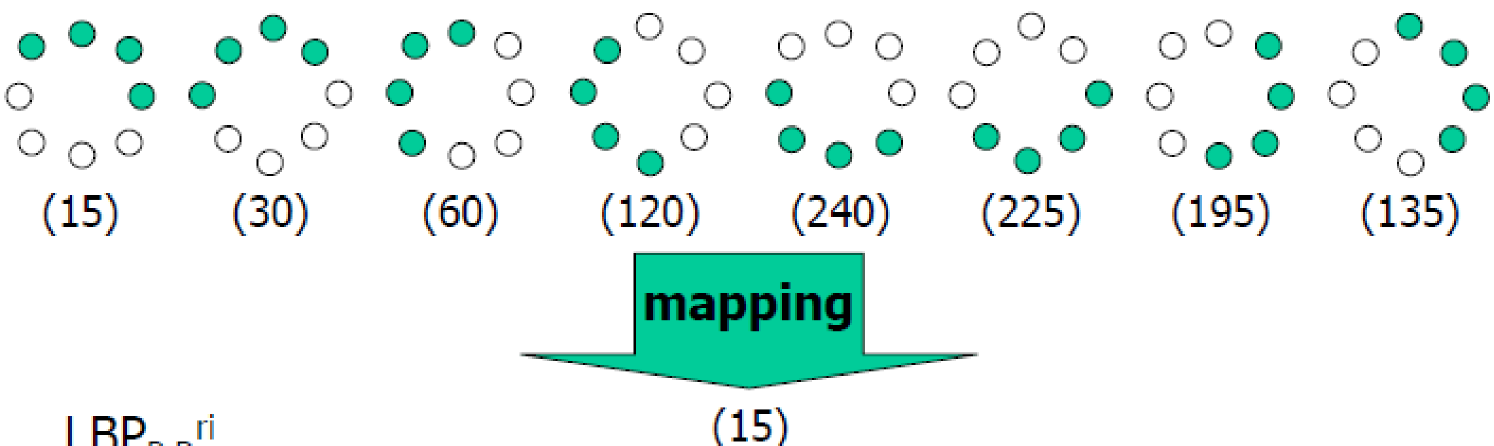
Spatial rotation of the binary pattern changes the LBP code:



LBP: Rotation invariance

Formally, rotation invariance can be achieved by defining:

$$LBP_{P,R}^{ri} = \min\{ROR(LBP_{P,R}, i) \mid i=0, \ldots, P-1\}$$



$LBP_{P,R}^{ri}$

- Brightness invariance
- Rotation invariance

Example

- LBP is one of useful features for face recognition problem