Content Based Image Retrieval

II

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Tutorial outline

- Lecture 1
  - Introduction
  - Applications
- Lecture 2
  - Performance measurement
  - Visual perception
  - Color features
- Lecture 3
  - Texture features
  - Shape features
  - Fusion methods
- Lecture 4
  - Segmentation
  - Key points detection
- Lecture 5
  - Multidimensional indexing
  - Survey of existing systems

Lecture 2
Performance measurement
Visual perception
Color features

Lecture 2: Outline

- Performance measurement
  - Retrieval effectiveness
- Some facts about human visual perception
- Color features
  - Color fundamentals
  - Color spaces
  - Color features: histograms and moments
  - Comparison

Performance measurement

Performance concerns

- Efficiency
  - Important due to the large data size
- Retrieval effectiveness
  - No similarity metric which exactly conforms to human perception

Effectiveness measurement

- “You can see, that our results are better”

Effectiveness measurement

- "You can see, that our results are better"
- User comparison
- Numerical-valued measures
  - Rank of the best image
  - Average rank of relevant images
  - Percentage of weighted hits
  - Percentage of similarity ranking

$$P = \frac{\sum_{i=1}^{n} w_i}{\sum_{i=1}^{N} w_i}$$

$$S(i) = \sum_{k=K_1}^{K_2} Q(i,k), \quad K_1 = P(i) - \sigma(i), \quad K_2 = P(i) + \sigma(i)$$

Effectiveness measurement (2)

- Numerical-valued measures
  - Recall and precision

$$precision = \frac{\text{No. relevant documents retrieved}}{\text{Total No. documents retrieved}},$$

$$recall = \frac{\text{No. relevant documents retrieved}}{\text{Total No. relevant documents in the collection}}$$

    - Average recall/precision
    - Recall at N, Precision at N
    - F-measure

Effectiveness measurement (3)

- Numerical-valued measures
  - Target testing
  - Error rate

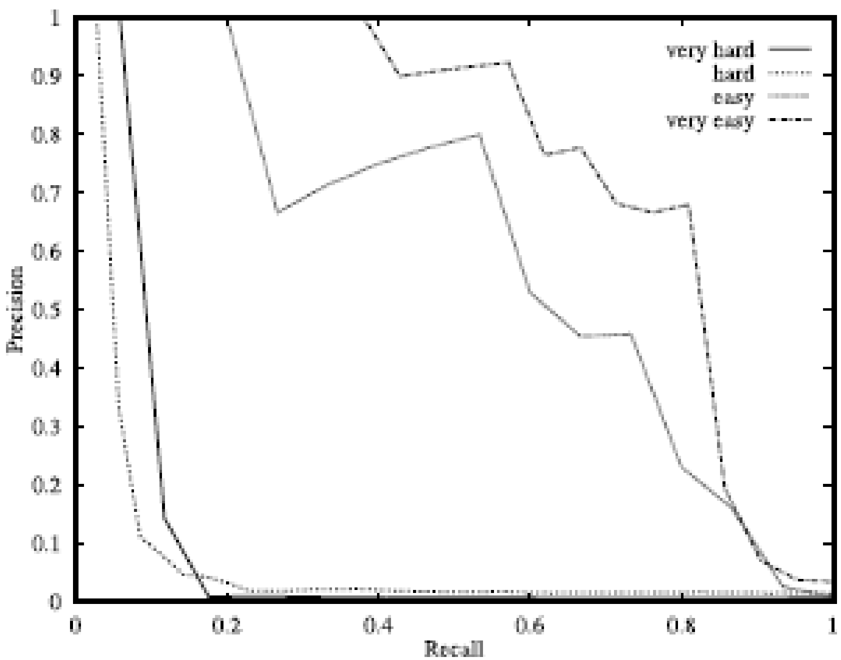
$$\text{Error rate} = \frac{\text{No. non-relevant images retrieved}}{\text{Total No. images retrieved}}$$

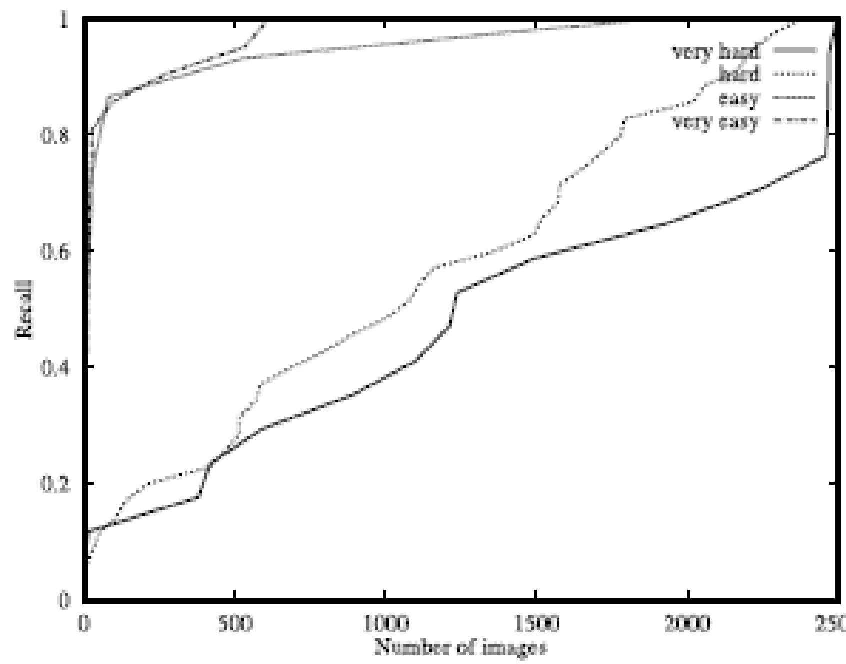
  - Retrieval efficiency

$$\text{Retrieval efficiency} = \begin{cases} \dfrac{\text{No. relevant images retrieved}}{\text{Total No. images retrieved}} & \\ \quad \text{if No. retrieved} > \text{No. relevant,} & \\ \dfrac{\text{No. relevant images retrieved}}{\text{Total No. relevant images}} & \text{otherwise.} \end{cases}$$

Effectiveness measurement (3)

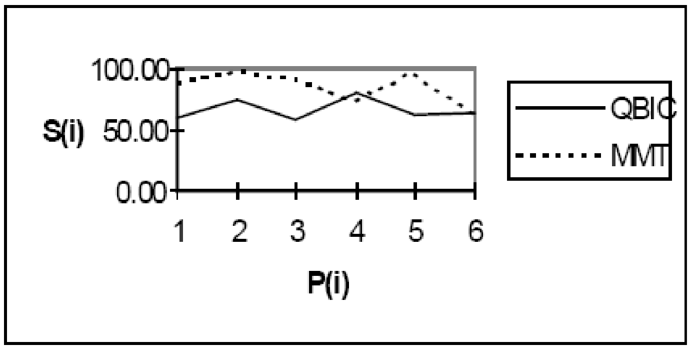
- Graphical representations
  - Precision versus Recall graphs
  - Precision at N versus N, Recall at N versus N
  - Retrieval accuracy versus noise graph



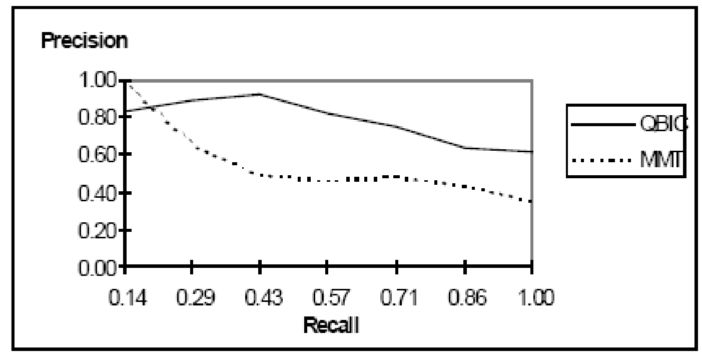


Effectiveness measurement (4)

- Different measurement (QBIC versus MMT)



(a)



(b)

Average performance measured using (a) the percentage of similarity ranking method (b) recall and precision pair

Lecture 2: Outline

- Performance measurement
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- Some facts about human visual perception
- Color features
  - Color fundamentals
  - Color spaces
  - Color features: histograms and moments
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Some facts about our visual perception

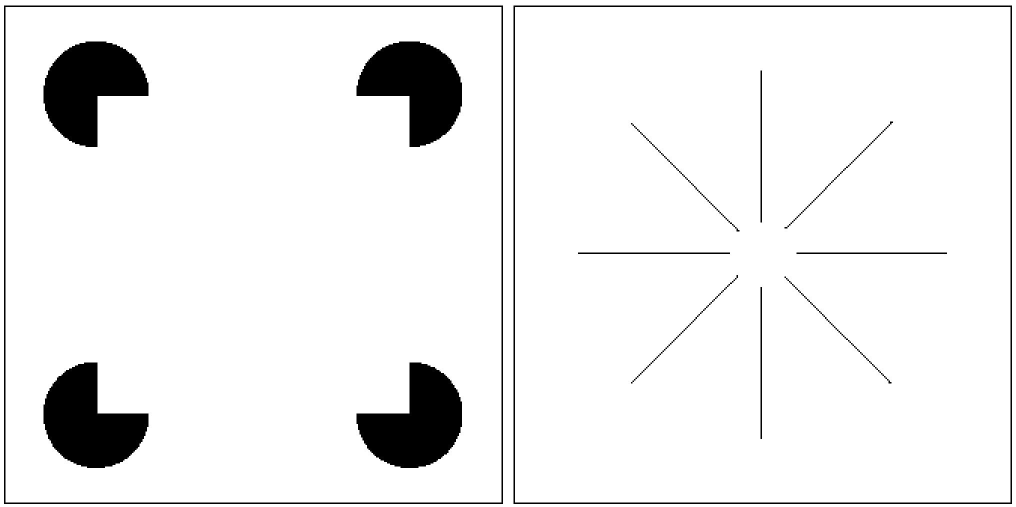
- We are driven by a desire to make meanings

  (We all seem to 'see things' in inkblots, flames, stains, clouds and so on.)

- Human visual perception is self-learning
  - If you are an European, it is hard to recognize Japanese and Chinese faces
  - We are looking for the known objects in the picture

Some facts about our visual perception

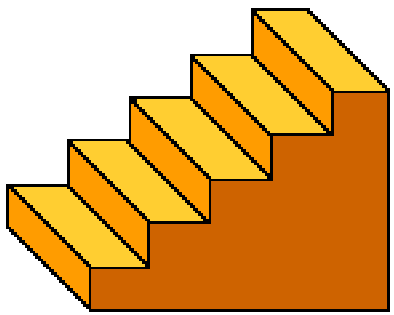
- We are looking for the known objects in the picture



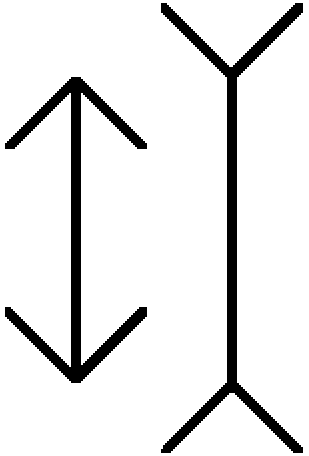
Some well known optical illusions

Some facts about our visual perception

- Cultural and environmental factors affects the way we see things



Are these stairs goes up or down?
- Arabs would read this (right to left) as a set of stairs going down

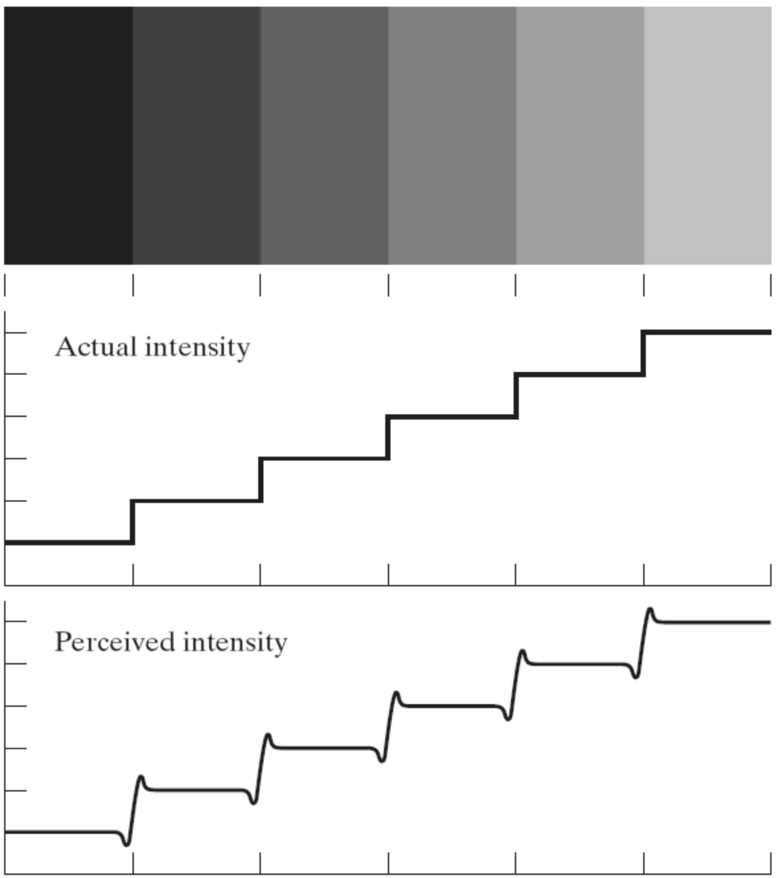


Is left line shorter than the right one?
- Left: *outside* corner of a building
- Right: *inside* corner of a room

Inside corner may appear to be nearer (and therefore larger)

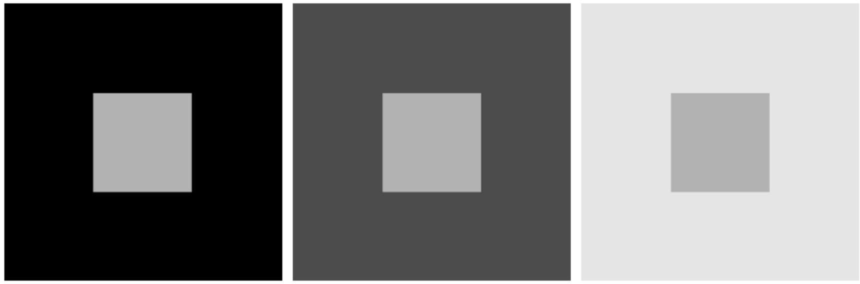
Some facts about our visual perception

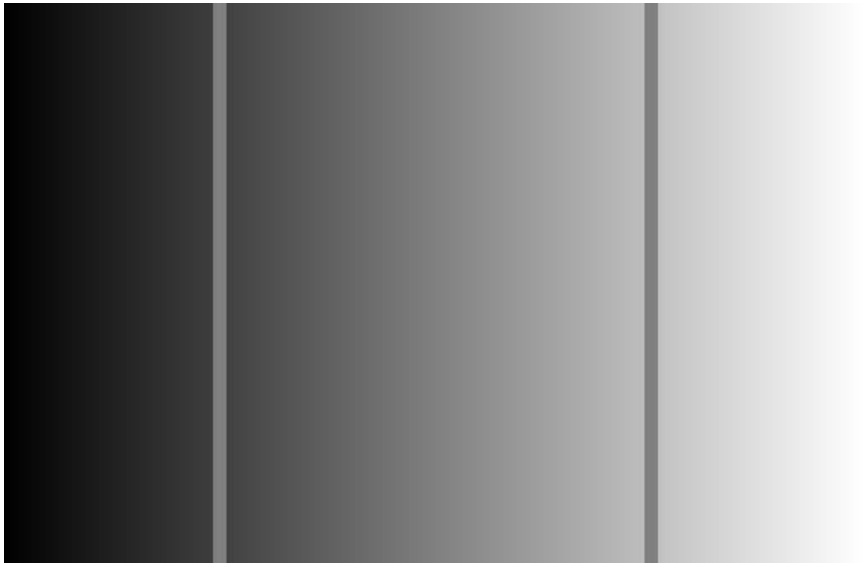
- Perceived brightness is not a simple function of intensity
  - Mach band effect (Scalloped effect)



Some facts about our visual perception

- Perceived brightness is not a simple function of intensity





  - Simultaneous contrast

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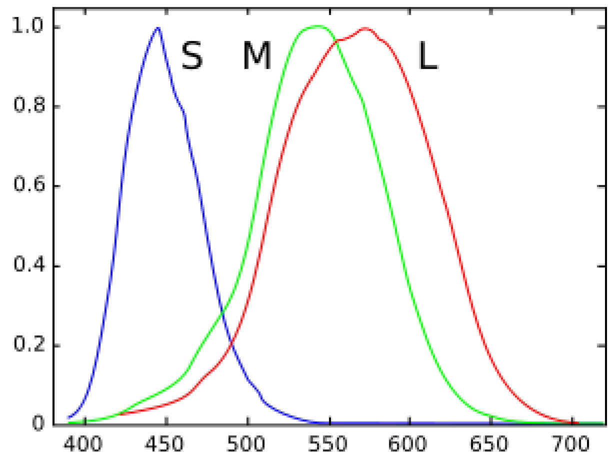
Color fundamentals

- Color in the eye



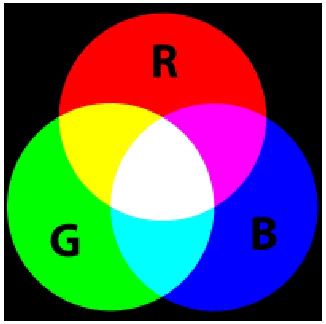
Normalized typical human cone cell responses (S, M, and L types) to monochromatic spectral stimuli

– Varying sensitivity of different cells in the retina (cones) to light of different wavelengths:
  - S-cones: short-wavelength (blue);
  - M-cones: middle-wavelength (green);
  - L-cones: long-wavelength (red).

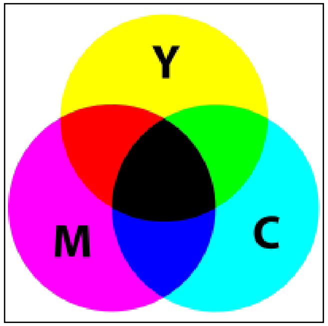
Cone type	Name	Range	Peak wavelength
S	β	400–500 nm	420–440 nm
M	γ	450–630 nm	534–545 nm
L	ρ	500–700 nm	564–580 nm

Color fundamentals

- Primary and secondary colors



Mixture of lights
(Additive primaries)



Mixture of pigments
(Subtractive primaries)

  - Due to different absorption curves of the cones, colors are seen as variable combinations of the so-called primary colors: red, green and blue.
  - The primary colors can be added to produce the secondary colors of light: magenta (R+B), cyan (G+B), and yellow (R+G).
  - For pigments and colorants, a primary color is the one that subtracts (absorbs) a primary color of light and reflects the other two.

Color fundamentals

- Brightness, hue, and saturation
  - Brightness is a synonym of intensity
  - Hue represents the impression related to the dominant wavelength of the color stimulus
  - Saturation expresses the relative color purity (amount of white light in the color)
  - Hue and Saturation taken together are called the chromaticity coordinates (polar system)

Color fundamentals

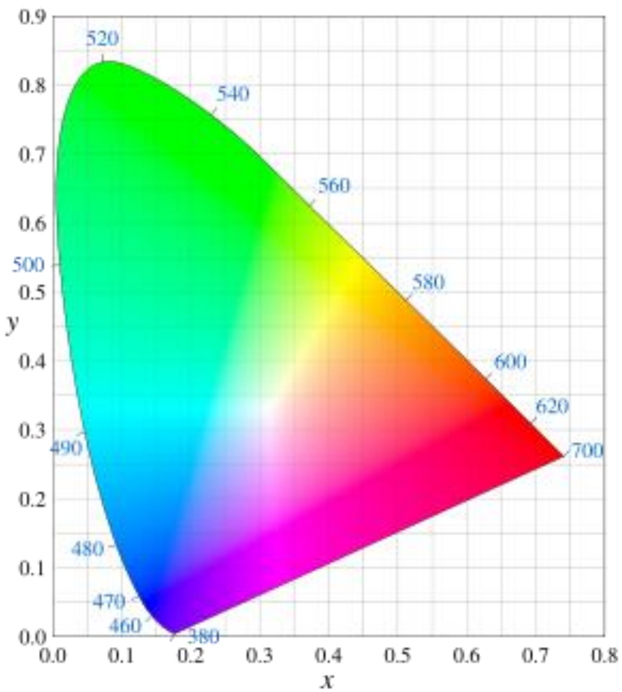
- From tristimulus values to chromaticity coordinates
  - The amounts of red, green, and blue needed to form any particular color are called the tristimulus values and denoted by X, Y, and Z
  - The chromaticity coordinates x and y (Cartesian system) are obtained as:

$$x = \frac{X}{X+Y+Z}, \quad y = \frac{Y}{X+Y+Z}, \quad z = \frac{Z}{X+Y+Z}$$

$$x + y + z = 1$$

Color fundamentals

- CIE xy Chromaticity Diagram

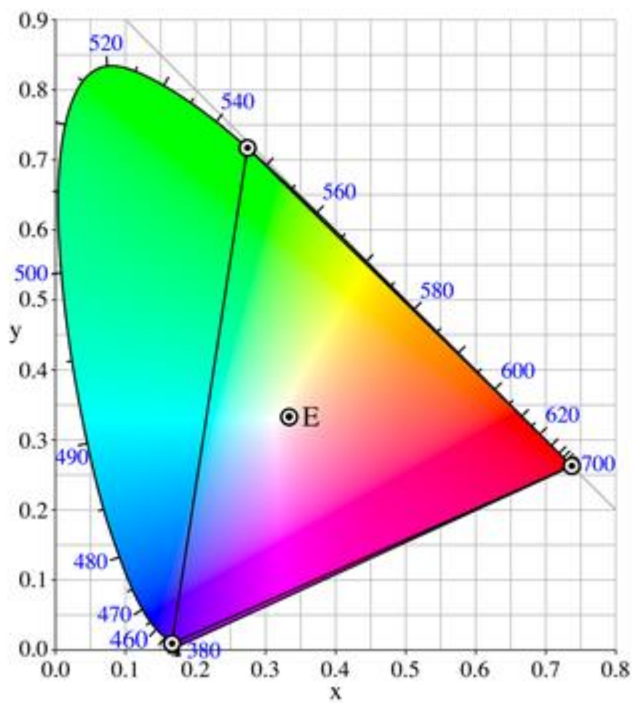


The CIE 1931 chromaticity diagram.

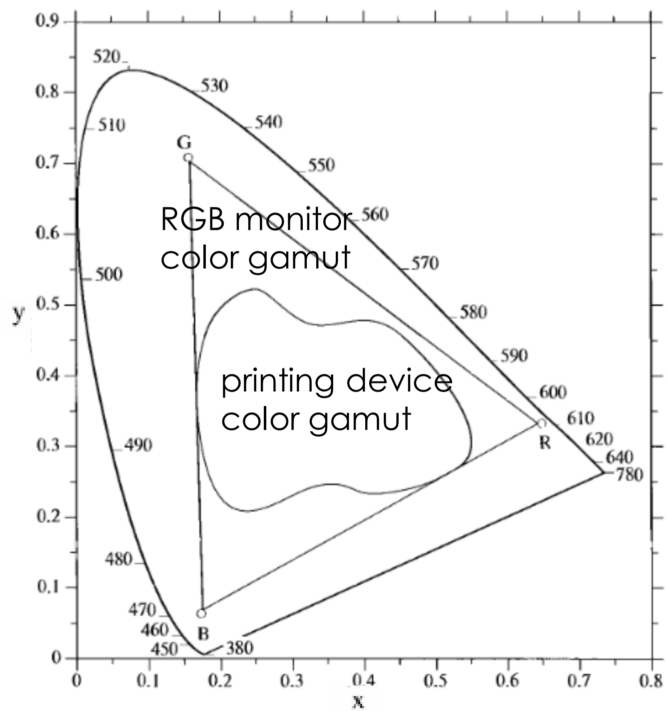
  - Created by the International Commission on Illumination (CIE) in 1931.
  - Function of x (red) and y (green) : z = 1 – (x + y).
  - The outer boundary is the spectral (monochromatic) locus, wavelengths shown in nm.
  - (x,y) = (1/3,1/3) is a flat energy spectrum point (point of equal energy).
  - Any point on the boundary is completely saturated.
  - Boundary → point of equal energy : saturation → 0

Color fundamentals

- Color Gamut



Gamut of the CIE RGB primaries and location of primaries on the CIE 1931 xy chromaticity diagram.



Typical gamuts of a monitor and of a printing device.

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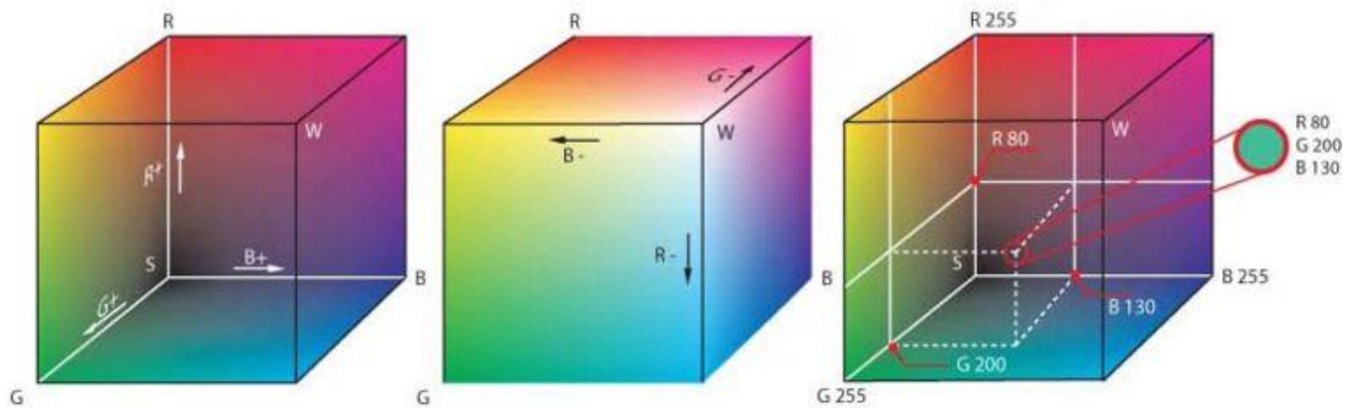
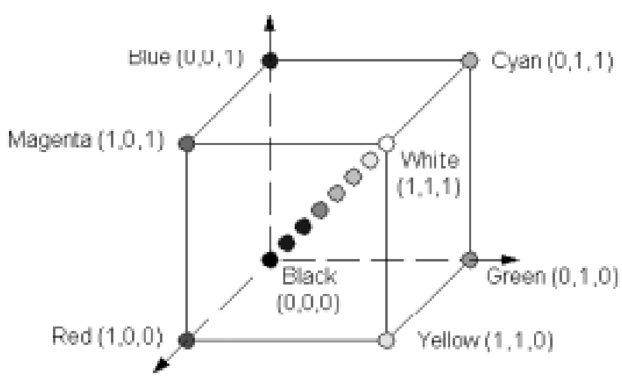
Color spaces

- The purpose of a *color space* (or *color model* or *color system*) is to facilitate the specification of colors in some standard way.
- A color model provides a *coordinate system* and a *subspace* in it where each color is represented by a single point.
- Common color spaces:
  - RGB (monitors, video cameras),
  - CMY/CMYK (printers),
  - HSI/HSV/HSL/HSB (image processing),
  - CIE Lab (image processing).

Color spaces

- RGB color space

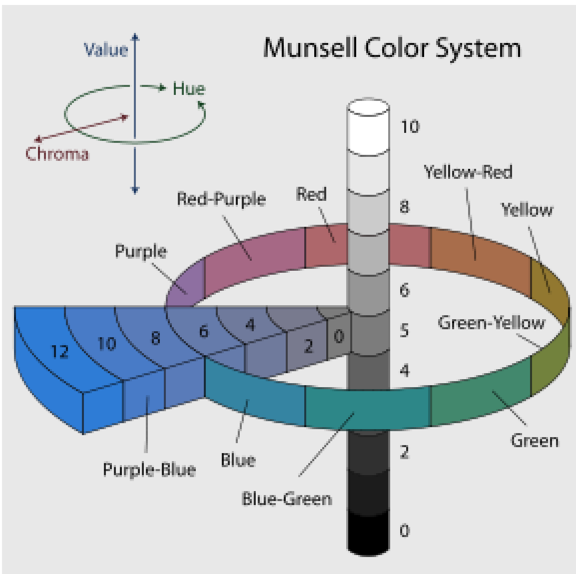




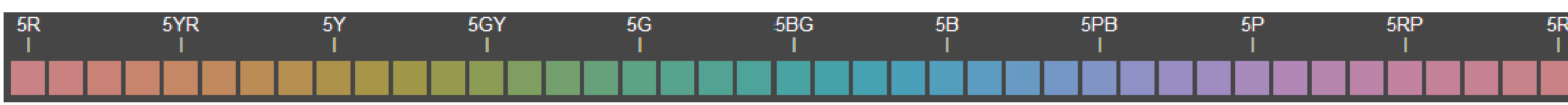
If R,G, and B are represented with 8 bits (24-bit RGB image), the total number of colors is $(2^8)^3$=16,777,216

Color spaces

- Munsell color system



  - By Professor Albert H. Munsell in the beginning of the 20th century.
  - Specifies colors based on 3 color dimensions, hue, value (lightness), and chroma (color purity or colorfulness).



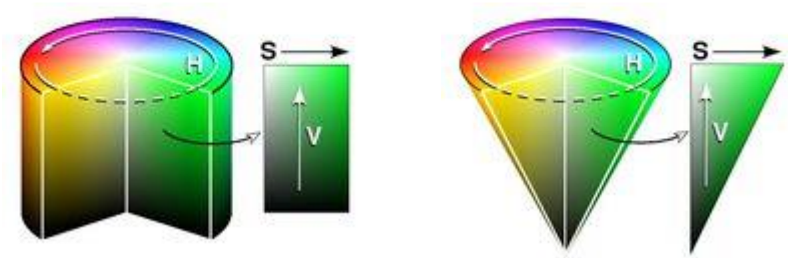
Munsell hues; value 6 / chroma 6

Color spaces

- HSI/HSL/HSV/HSB color spaces
  - RGB, CMY/CMYK are hardware oriented color spaces (suited for image acquisition and display).
  - The HSI/… (Hue, Saturation, Intensity/Lightness/ Value/Brightness) are perceptive color spaces (suited for image description and interpretation).
  - Allow the decoupling of chromatic signals (H+S) from the intensity signal (I).

Color spaces

- HSI/HSL/HSV/HSB color spaces

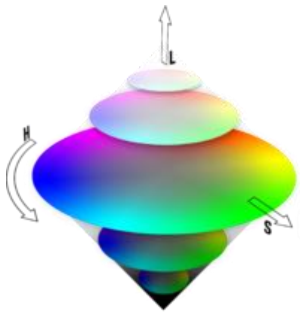


Graphical depiction of HSV (cylinder and cone)

$$I = \frac{R+G+B}{3}$$

$$L = \frac{\max(R,G,B)+\min(R,G,B)}{2}$$

$$V = \max(R,G,B)$$



Graphical depiction of HSL

http://www.easyrgb.com/index.php?X=MATH

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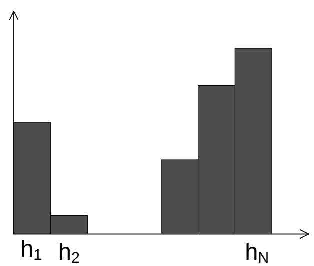
Color features

Color features

Color histograms

Color moments



$F(I) = (h_1^I, h_2^I, \ldots, h_N^I)$

Metrics: L_1, L_2, L_∞

Statistical moments for every color channel

$$F(I) = (E_1^I, E_2^I, E_3^I, \sigma_1^I, \sigma_2^I, \sigma_3^I, s_1^I, s_2^I, s_3^I)$$

Metrics: $\sim L_1$

Stricker M., Orengo M. Similarity of Color Images. Proceedings of the SPIE Conference, vol. 2420, p. 381-392, 1995

Intensity Histogram

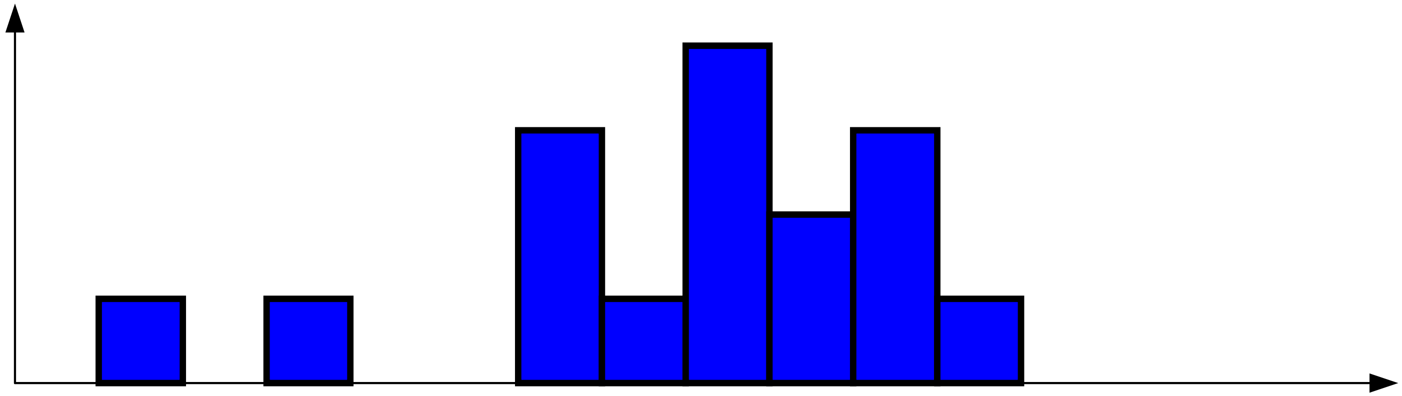
Intensity Histogram

- **Example**

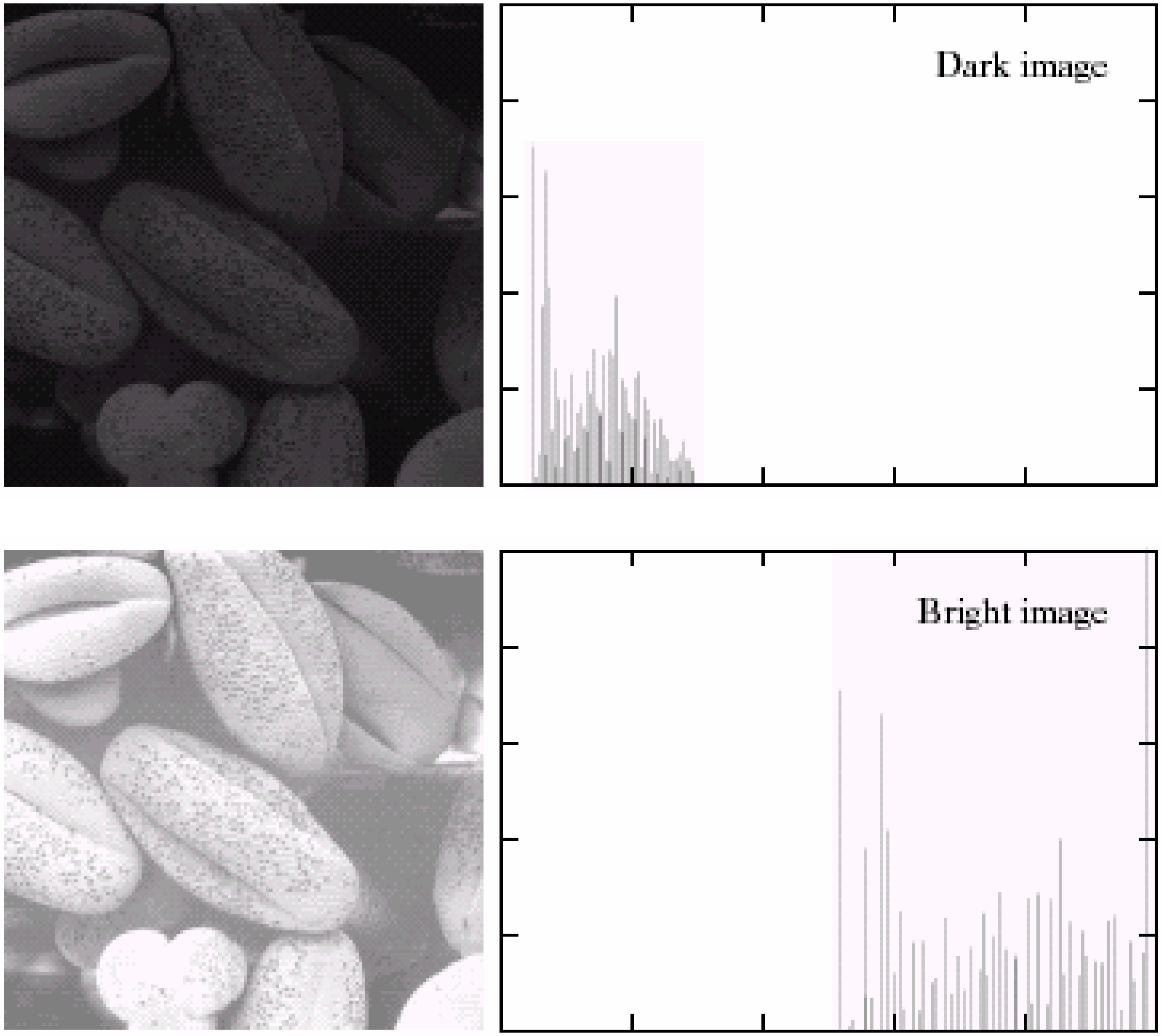
  a 4x4, 4bits/pixel image →

1	8	6	6
6	3	11	8
8	8	9	10
9	10	10	7

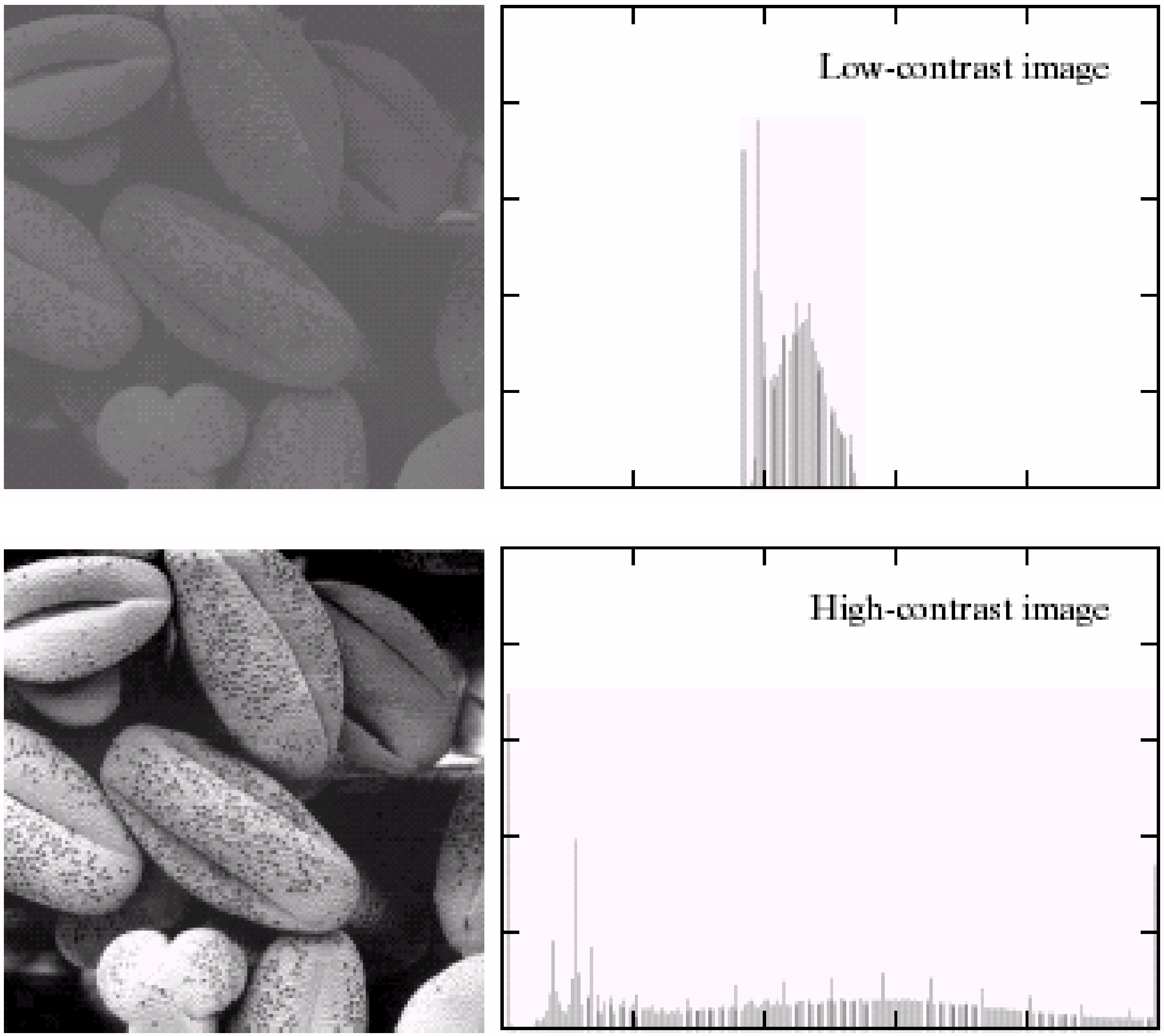
k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H(k)	0	1	0	1	0	0	3	1	4	2	3	1	0	0	0	0



Intensity Histogram

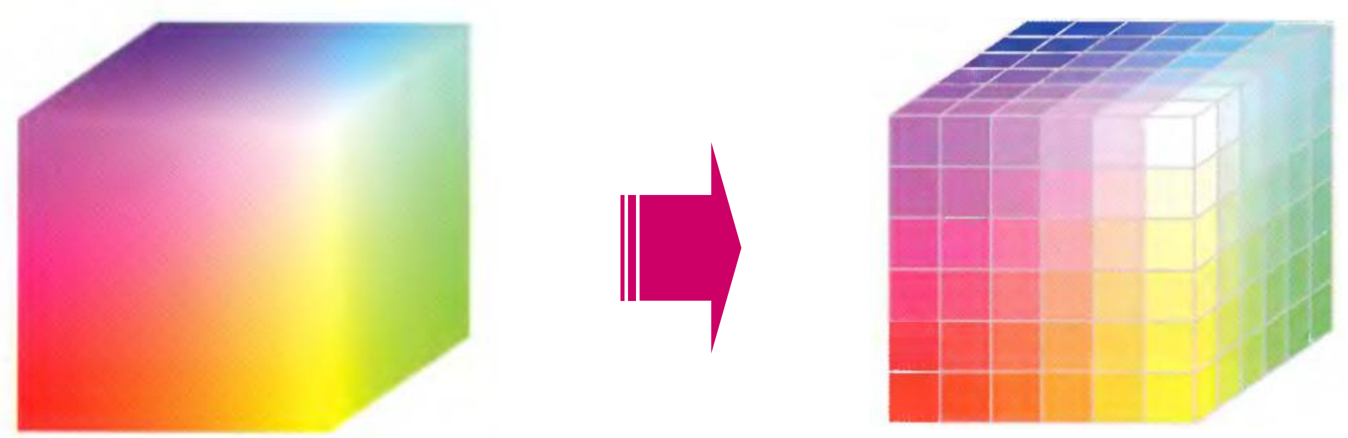


Intensity Histogram



Color histograms

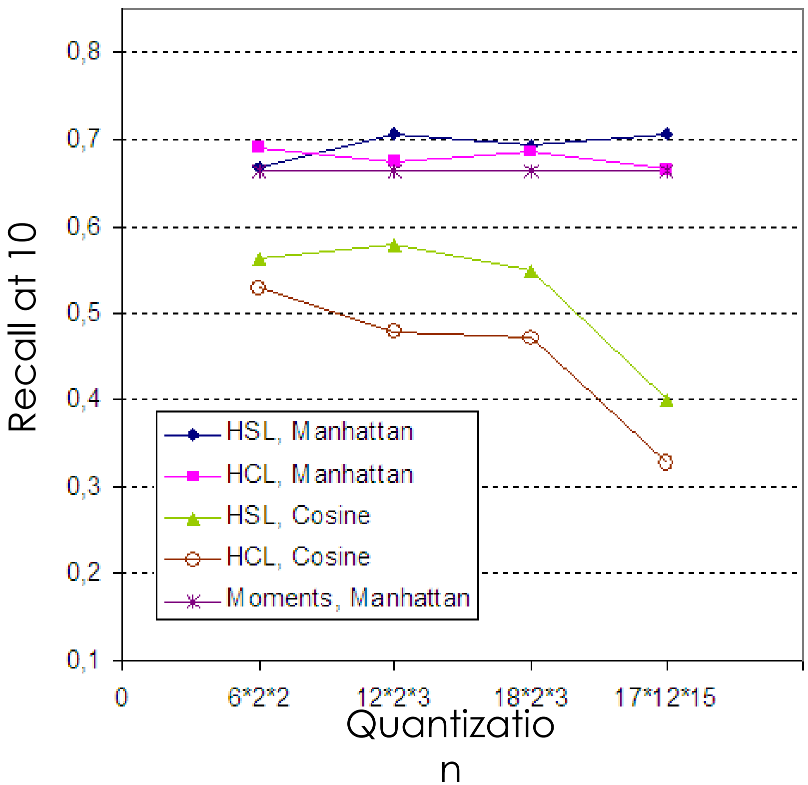
- Quantization of color space



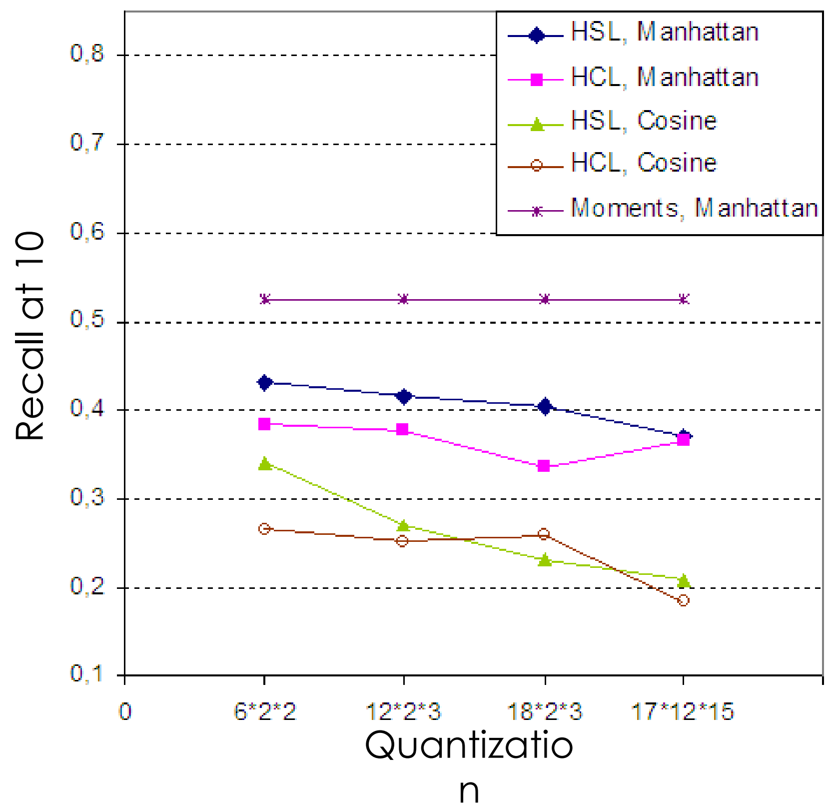
  - Quantization is important: size of the feature vector.
  - When no color similarity function used:
    - Too many bins – similar colors are treated as dissimilar.
    - Too little bins – dissimilar colors are treated as similar.

Color histograms

- Quantization of color space: recall



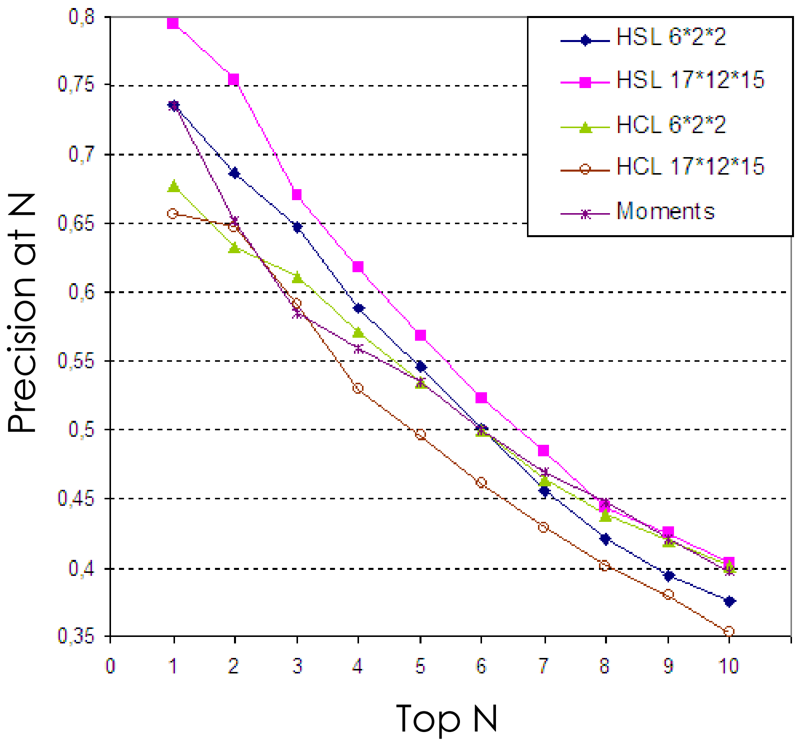
ImageDB-100



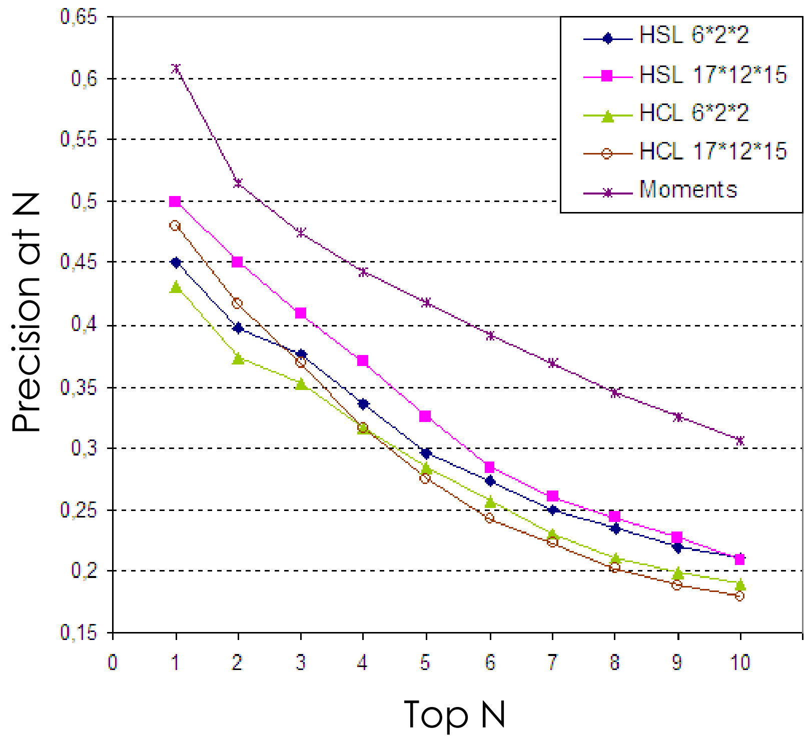
ImageDB-1000

Color histograms

- Quantization of color space: precision



ImageDB-100



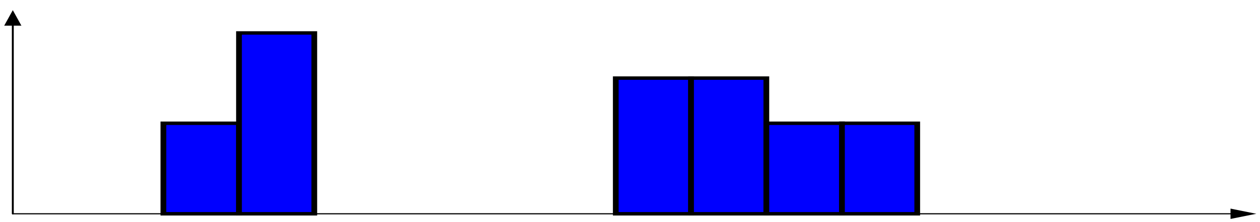
ImageDB-1000

Cumulative Histogram

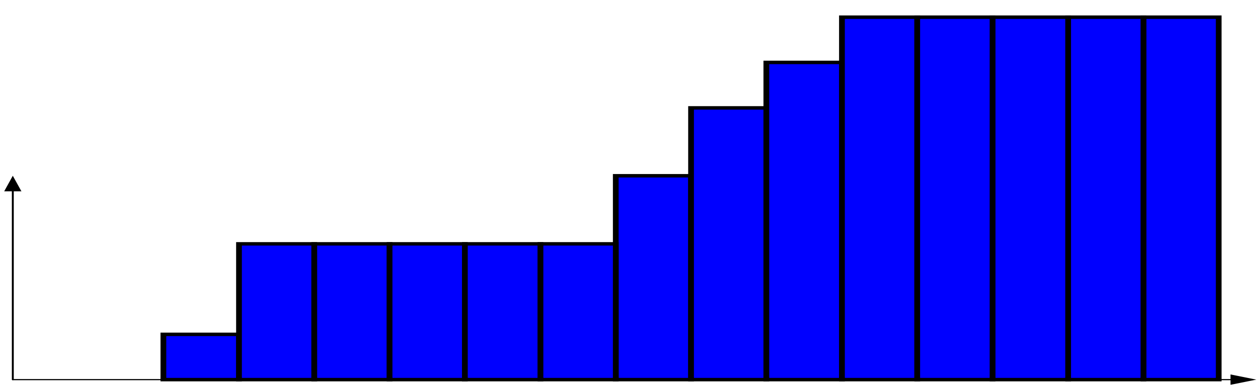
2	8	9	9
2	3	10	9
8	3	3	11
8	3	10	11

k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H(k)	0	0	2	4	0	0	0	0	3	3	2	2	0	0	0	0
Q(k)	0	0	2	6	6	6	6	6	9	12	14	16	16	16	16	16

H(k)

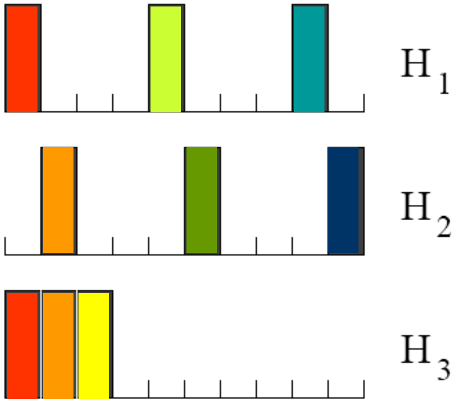


Q(k)



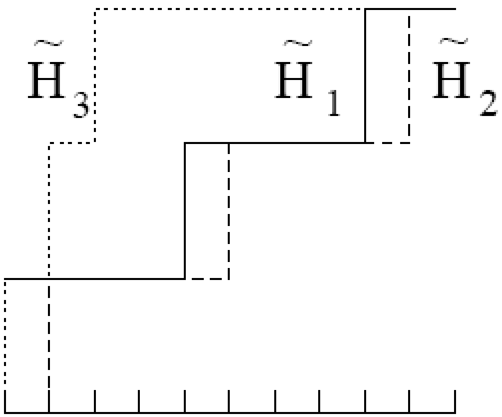
Color histograms: main disadvantages

1. Colors similarity across histo bins is not considered:



$d(H_1, H_2) > d(H_1, H_3)$

- Cumulative histograms



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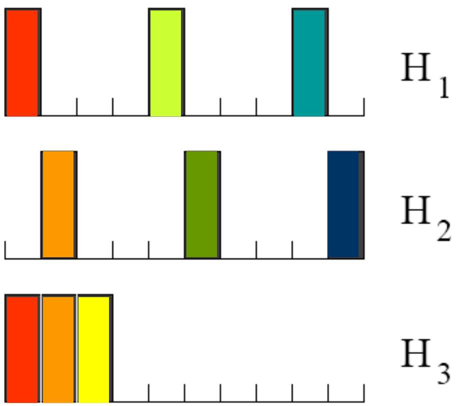

$d(H_1, H_2) > d(H_1, H_3)$

- Cumulative histograms
- $$d(H_1,H_2)=\sqrt{(H_1-H_2)\cdot A\cdot(H_1-H_2)^T}$$

  A – matrix with color similarity coefficients

Niblack W., Barber R., et al. The QBIC project: Querying images by content using color, texture and shape. In IS&T/SPIE International Symposium on Electronic Imaging: Science & Technology, Conference 1908, Storage and Retrieval for Image and Video Databases, Feb. 1993

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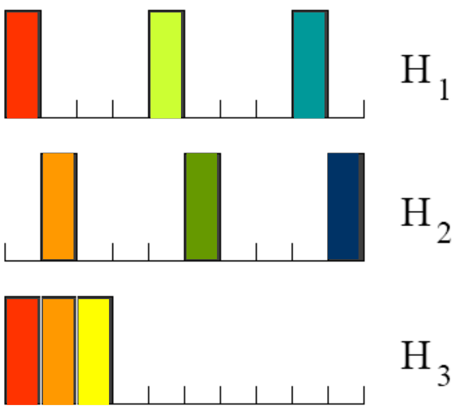
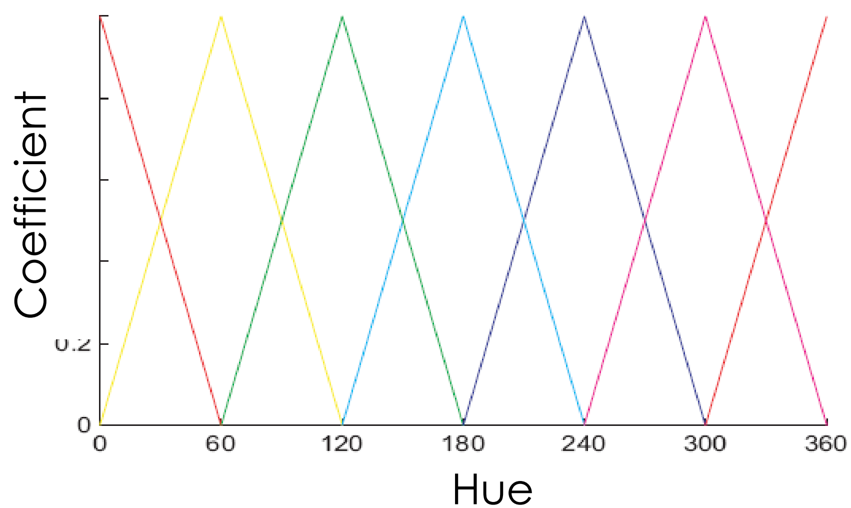


$d(H_1, H_2) > d(H_1, H_3)$

- Cumulative histograms
- $d(H_1, H_2) = \sqrt{(H_1 - H_2) \cdot A \cdot (H_1 - H_2)^T}$
- Fuzzy histo



Color histograms: main disadvantages

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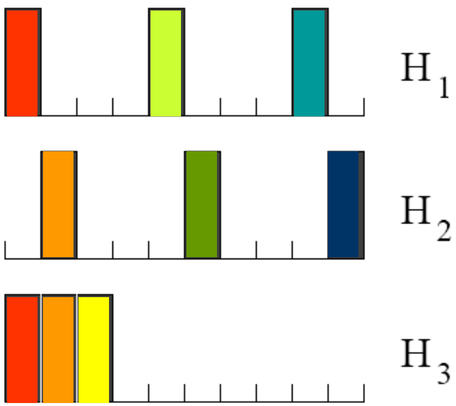


$d(H_1, H_2) > d(H_1, H_3)$

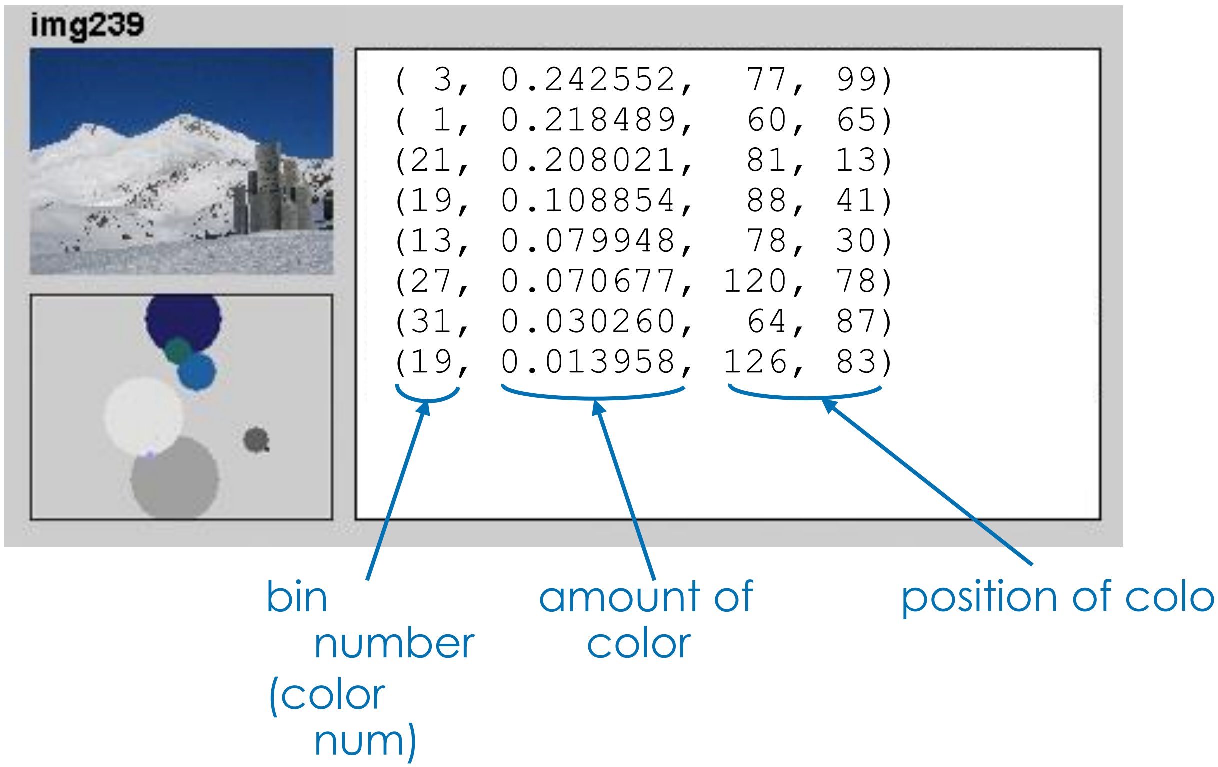
- Cumulative histograms
- $d(H_1, H_2) = \sqrt{(H_1 - H_2) \cdot A \cdot (H_1 - H_2)^T}$
- Fuzzy histo
- Color similarity measure

$$\triangle E_{RGB} = \sqrt{\triangle R^2 + \triangle G^2 + \triangle B^2}$$

$$D_{cyl} = \sqrt{\triangle L*^2 + C*_1{}^2 + C*_2{}^2 - 2C*_1 C*_2 \cos(\triangle H)}$$

Color histograms: main disadvantages

2. Spatial color layout is not considered:



$$dist(Q,I)=\sum_{i=1}^{N}\begin{cases}\alpha\,|h_i^Q-h_i^I|\sqrt{(x_i^Q-x_i^I)^2+(y_i^Q-y_i^I)^2}, & h_i^Q\neq 0,\ h_i^I\neq 0;\\ \beta h_i^Q, & h_i^Q\neq 0,\ h_i^I=0;\\ \beta h_i^I, & h_i^I\neq 0,\ h_i^Q=0.\end{cases}$$

Color moments

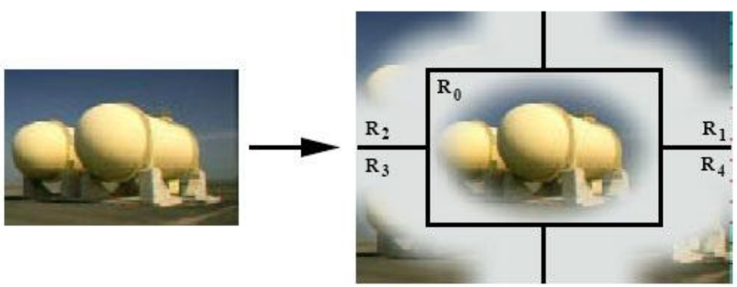
- Average, standard deviation, skewness

$$E_i = \frac{1}{N}\sum_{j=1}^{N} p_{ij} \quad , \quad \sigma_i = \left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij} - E_i)^2\right)^{\frac{1}{2}} \quad \text{and} \quad s_i = \left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij} - E_i)^3\right)^{\frac{1}{3}}$$

$$d_{\text{mom}}(H, I) = \sum_{i=1}^{r} w_{i1}|E_i - F_i| + w_{i2}|\sigma_i - \varsigma_i| + w_{i3}|s_i - t_i|$$

- Average, covariance matrix of the color channels

- Consider spatial layout: fuzzy regions



Stricker M., Dimai A. Spectral Covariance and Fuzzy Regions for Image Indexing. Machine Vision and Applications, vol. 10., p. 66-73, 1997

Lecture 2: Outline

- Performance measurement
  - Retrieval effectiveness
- Some facts about human visual perception
- Color features
  - Color fundamentals
  - Color spaces
  - Color features: histograms and moments
  - Comparison

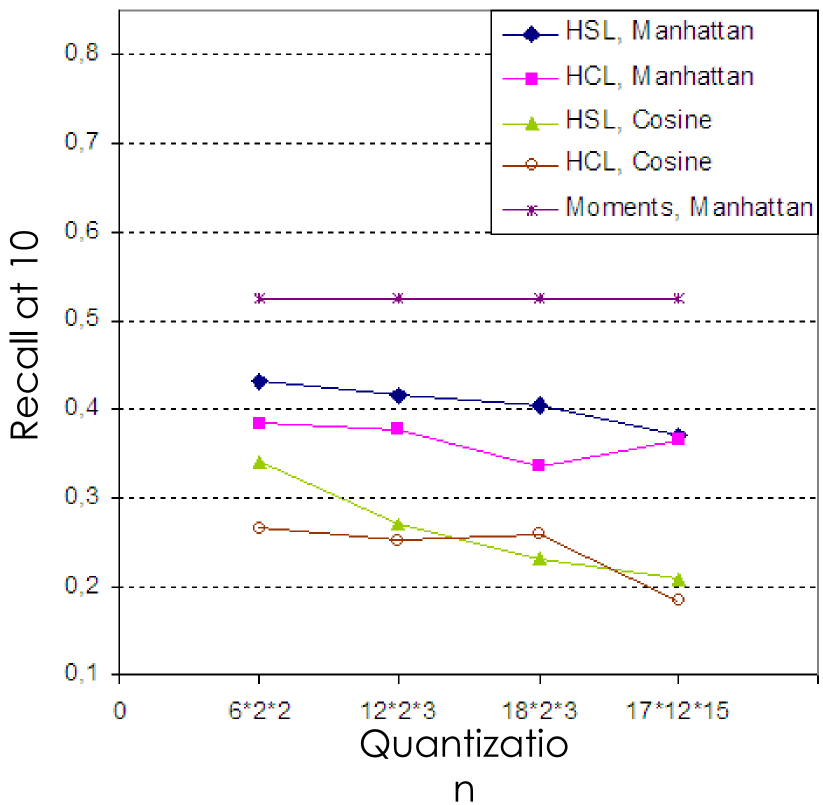
Histograms or color moments? (1)

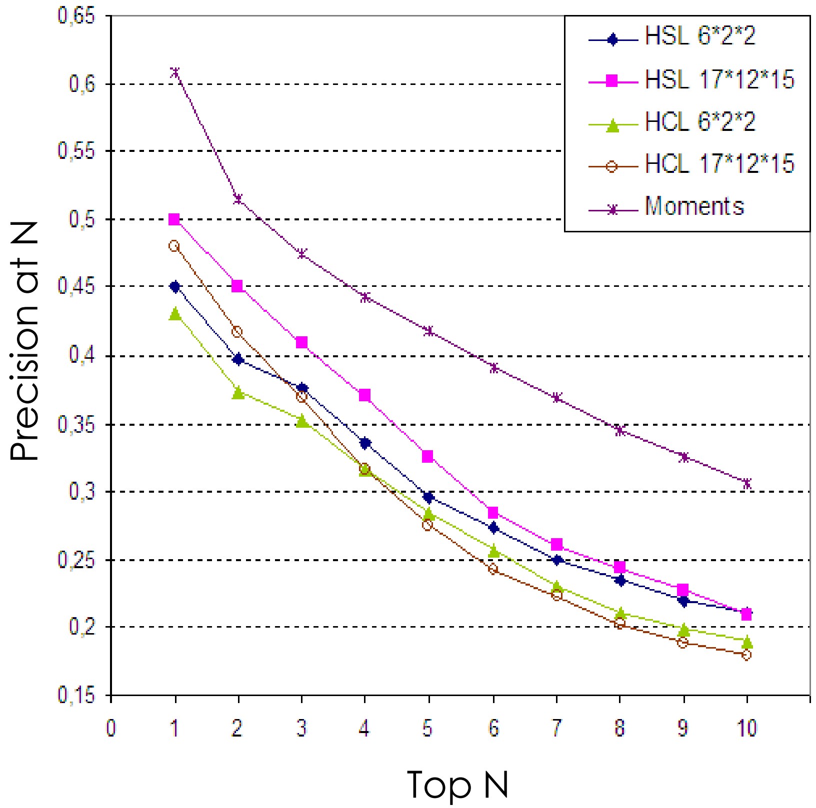
Stricker M., Orengo M. Similarity of Color Images. ... (3000 images)

index	sim. measure	rank of the image 			max. rank
9 moments	W_1	4	5	8	8
	W_2	2	8	6	8
	W_3	4	6	9	9
cum. hist. 8/2/2	L_∞	34	98	79	98
16/4/4	L_∞	3	57	42	57
8/2/2	L_1	53	162	30	162
16/4/4	L_1	33	354	8	354
8/2/2	L_2	65	158	34	158
16/4/4	L_2	15	306	11	306
histogram 8/2/2	L_1	138	394	48	394
16/4/4	L_1	4	132	6	132
8/2/2	L_2	71	541	102	541
16/4/4	L_2	10	1358	75	1358

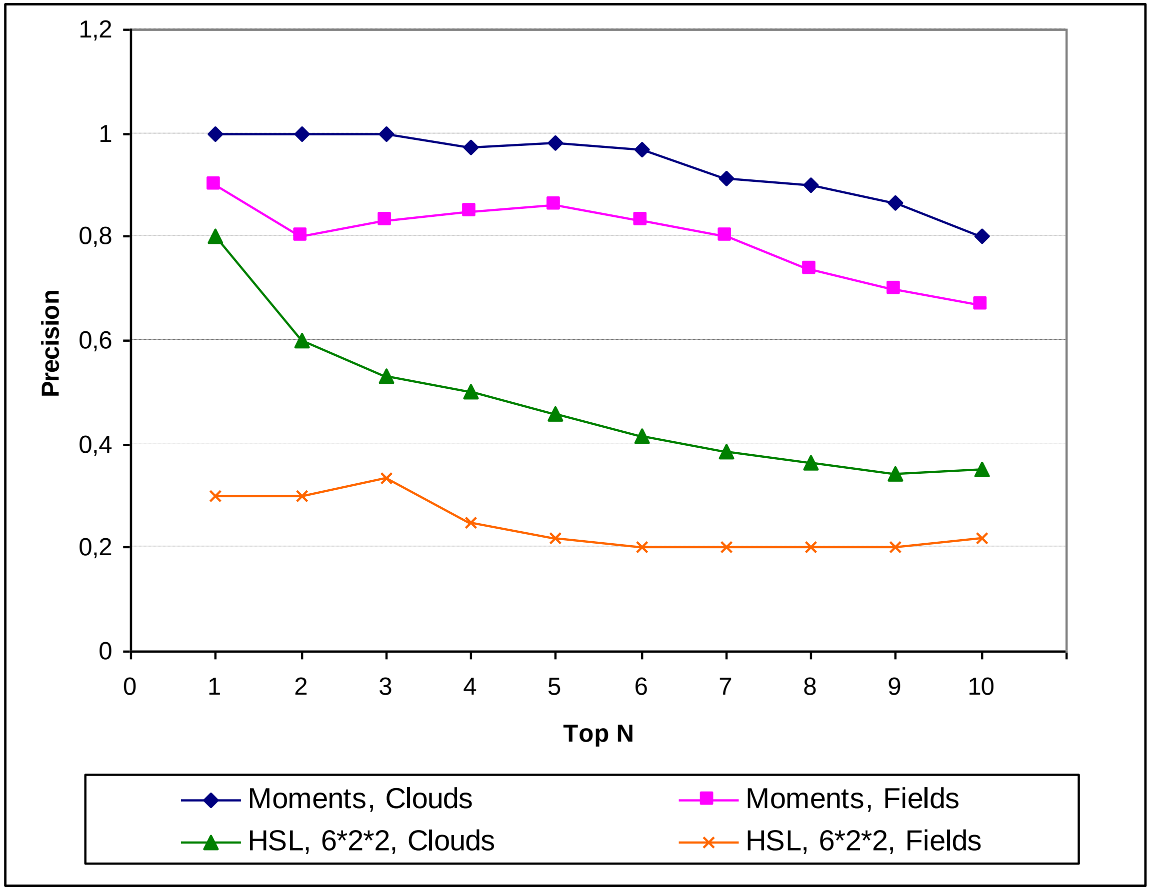
Histograms or color moments? (2)

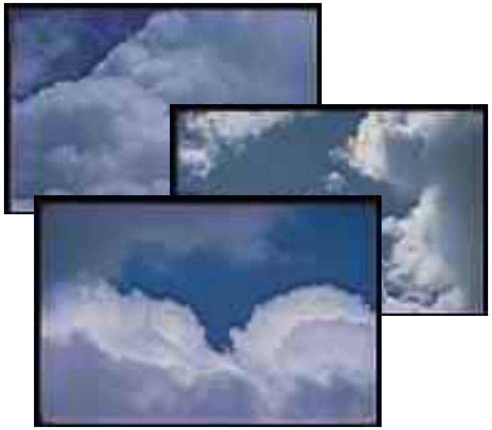
ImageDB-1000



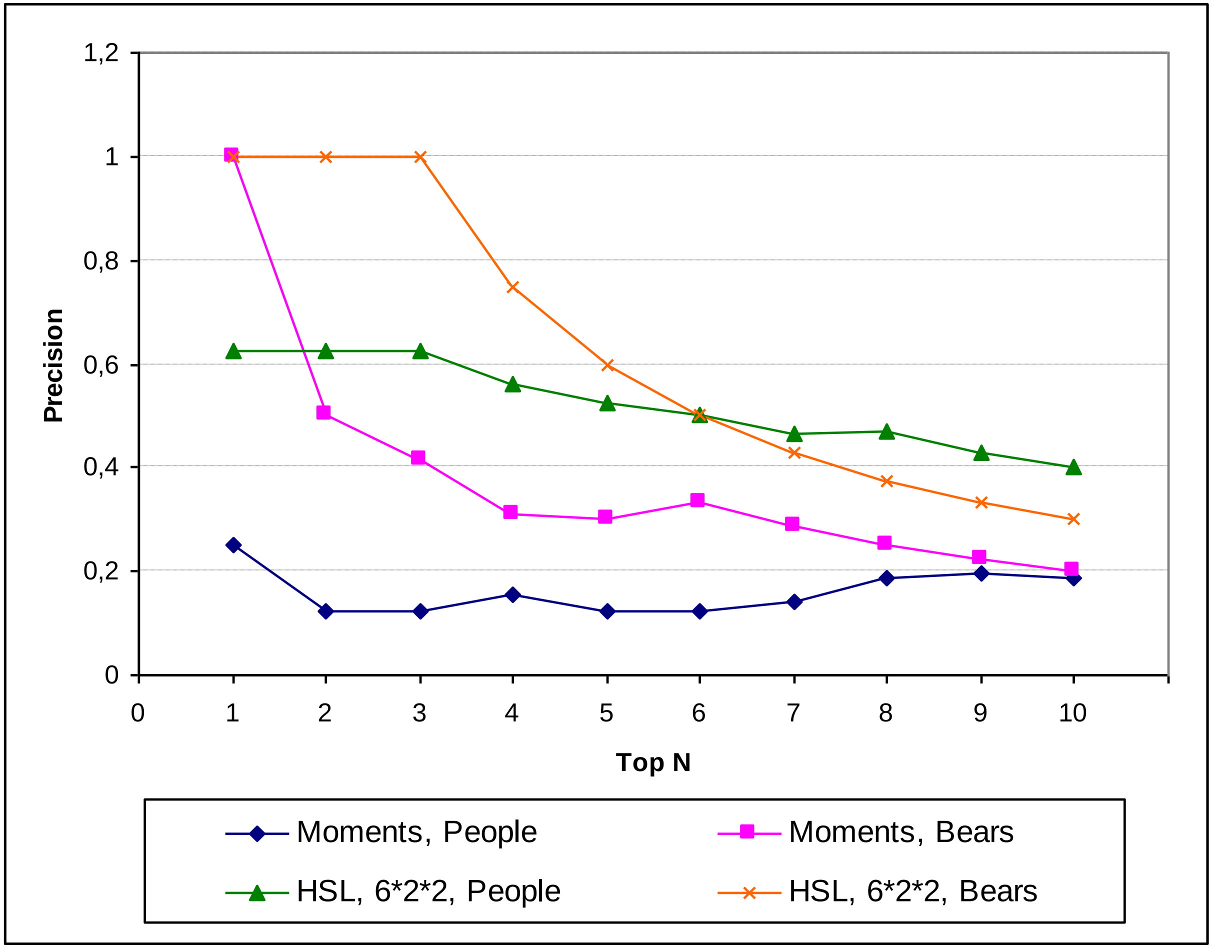


Histograms or color moments? (3)





Histograms or color moments? (4)



Lecture 2: Resume

- Performance: efficiency and effectiveness
  - Lack of the common benchmark collections and retrieval effectiveness measurement

- Human visual perception is very complex
  - Have to take into account known facts about our perception to reduce the semantic gap

- Color features: histograms and moments
  - On heterogeneous collections moments are slightly better
  - Fusion of histograms and moments can give better results

Lecture 2: Bibliography

- Muller H., Muller W., McG. Squire D., Marchand-Maillet S., Pun T. Performance evaluation in content-based image retrieval: overview and proposals. In Pattern Recognition Letters, vol. 22, pp. 593-601, 2001.
- Lu G. , Sajjanhar A. On performance measurement of multimedia information retrieval systems. In Proc of the International Conference on Computational Intelligence and Multimedia Applications, pp.781-787, 1998.
- Swain M. J., Ballard D. H. Color indexing. In International Journal of Computer Vision, vol. 7, no. 1, pp. 1132, 1991.
- Stricker M., Orengo M. Similarity of Color Images. In Proc. of the SPIE Conference, vol. 2420, pp. 381 – 392, 1995.
- Stricker M., Dimai A. Spectral Covariance and Fuzzy Regions for Image Indexing. In Machine Vision and Applications, vol. 10, pp. 66 – 73, 1997.
- Sarifuddin M., Missaoui R. A new perceptually uniform color space with associated color similarity measure for content based image and video retrieval. In Proc. of the ACM SIGIR Workshop on Multimedia Information Retrieval, 2005.
- Sural S., Qian G., Pramanik S. A histogram with perceptually smooth color transition for image retrieval. In Proc. of the Fourth International Conference on Computer Vision, Pattern Recognition and Image Processing, 2002.