Color-Based Retrieval of Facial Images

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Overview

- Content-Based Retrieval
- A Working Scenario
- Color Segmentation
- Skin-Tone Color Distribution
- Shape Processing
- Retrieval Result Ranking
- Experimental Results

Content-Based Retrieval

- New tools for summarization, content-based query, browsing, indexing and retrieval required for the emerging multimedia applications
- Existing systems use color, motion, texture, shape information as well as spatial and temporal relation between objects
- Extraction of *semantic* information requires *a priori* knowledge and can only be achieved in the context of specific applications
- Growing interest in retrieval of images containing *human faces*: face detection and segmentation required

Face Detection for Multimedia Applications

- In many cases it is enough to detect the presence of a face in a picture / video sequence
  - i.e. detect the anchorperson
- Fast Implementations (real-time performance is desirable)
  - example: news summarization
- Color should be exploited
  - convenience with dedicated content-based indexing /retrieval algorithms

The Proposed Technique

- Combine color segmentation and color based face detection for facial image retrieving
- M-RSST segmentation algorithm employed; average color components, size, location, shape and texture extracted.
- Adaptive 2-D Gaussian density function used for modeling skin-tone color distribution; exploit shape characteristics to discriminate face from skin segments
- Query-by-example framework proposed for interactive, configurable and flexible content-based human face retrieval

A Working Scenario

- Images in database segmented and color chrominance components, size and shape information stored
- *Query-by-example* : User presents a facial image; system performs face detection and ranks existing images according to several criteria
- Retrieval based on *color similarity*, *facial scale* or *number of face segments* possible
- Retrieved images returned to user; further manual selection used to *adapt* skin-color probabilistic model

Color Segmentation: M-RSST

- *Multiresolution decomposition* and construction of a truncated image pyramid
- All 4-connected region pairs assigned a *link weight* equal to the distance measure

$$d(X,Y) = \| \mathbf{c}_X - \mathbf{c}_Y \| \frac{a_X a_Y}{a_X + a_Y}$$

- *Recursive merging* of adjacent regions and *boundary block splitting* in each resolution level
- Fast algorithm, employed directly on MPEG streams with minimal decoding

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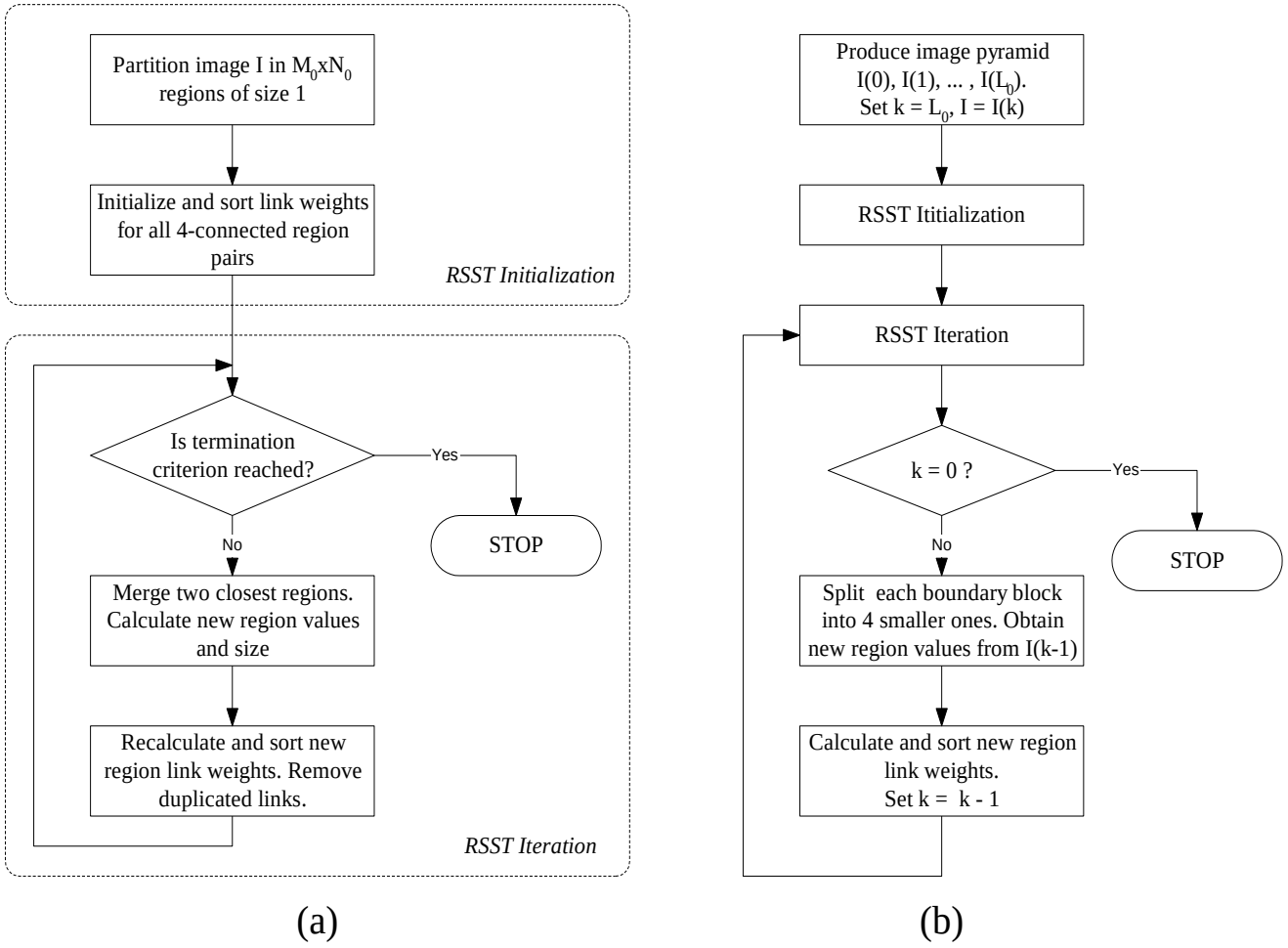
M-RSST Flowchart



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YCrCb Color Space and Human Skin

- Skin color can be modeled via the chrominance components of the *YCrCb* color model
  - Skin color covers a small part of the *Cr-Cb* plane
  - Influence of *Y* channel small
- Skin color subspace restrictions:
  - cannot be modeled in a general way for all face images
  - 'relaxing' the model => increased number of False Alarms
  - a 'rigorous' model => increased number of Dismissals
- *False Alarm*: Detection of a face in a wrong position or in frames / pictures where no faces are contained
- *Dismissal*: A failure to detect an existing face

The Proposed Skin Color Model

- Approximation of skin-tone color distribution with a *2-D Gaussian density function* on the *Cr-Cb* chrominance plane:

$$P(\mathbf{x}\,|\,\boldsymbol{\mu}_0,\mathbf{C}) = \frac{\exp\{-\frac{1}{2}(\mathbf{x}-\boldsymbol{\mu}_0)^T\mathbf{C}^{-1}(\mathbf{x}-\boldsymbol{\mu}_0)\}}{(2\pi)^{\frac{k}{2}}\cdot|\mathbf{C}|^{\frac{1}{2}}}$$

- **x**: input pattern (mean chrominance components of an image segment)
- $\boldsymbol{\mu}_0$: mean vector, **C**: covariance matrix

Skin-Color Region Extraction

- *Re-estimation* of the mean vector based on current image / frame:

$$\boldsymbol{\mu}_0 = (1-m)\cdot\boldsymbol{\mu}_0 + m\cdot\boldsymbol{\mu}$$

μ: mean vector estimated from current image / frame

m : a memory tuning constant

- *Skin-color region merging* based on estimated skin-color probability:

$$d_C(X,Y) = [\max(1-p_X, 1-p_Y)]^2$$

- Adjacent face segments merged – remaining partition map not affected

Shape Processing

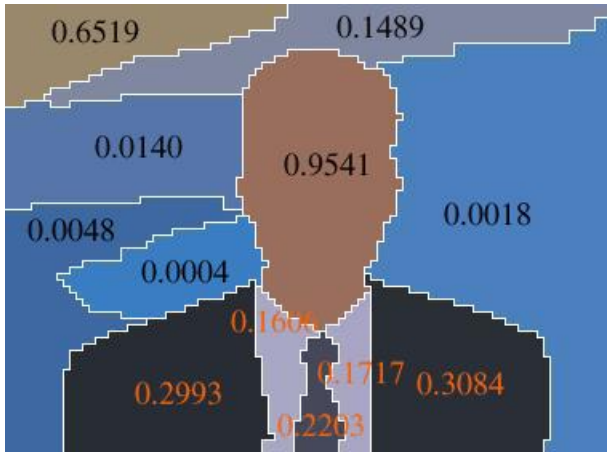
- *Global shape features* of segment contours
  - Shape *compactness* : $g_X = 4\pi\, a_X / r_X^2$
  - Shape *elongation* : $\ell_X = \sqrt{\lambda_2 / \lambda_1}$
- Both normalized in [0,1] and *invariant* to translation, scaling and rotation
- Combination with skin-color probability using non-linear functions – construction of an overall *face probability map*
- Segments with extremely irregular shape discarded

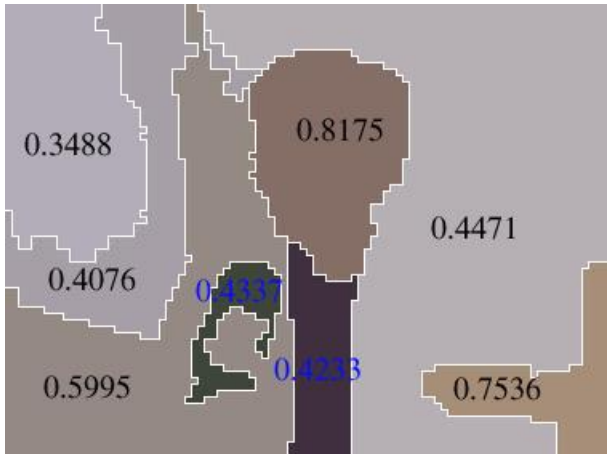
Retrieval Result Ranking

- *Query-by-example* : User presents a facial image; system performs face detection and ranks existing images according to several criteria
- *Similarity with the presented face segment* : *m* small, ranking w.r.t. segment probability
- *Facial scale* : *m* high, ranking w.r.t. percentage of image area
- *Number of face segments*: *m* high, ranking w.r.t. facial segments present in the image

Experimental Results

- Segmentation and probability assignment





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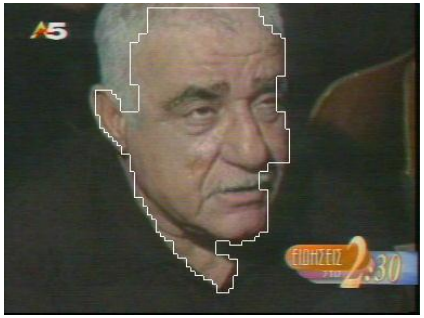
Skin Color based Retrieval

Image Presented to the system

mem: 0.3

Selected from the user segment

0.9992



0.9872

0.9735

0.9591

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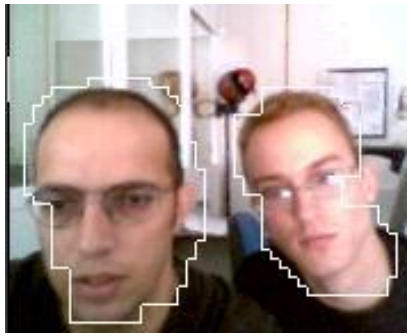
Retrieval based on number of Faces

Image Presented to the system

Segmented Faces

mem: 0.7

prob=0.6369



0.5525

0.1581

0.1224

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Retrieval based on Facial Scale

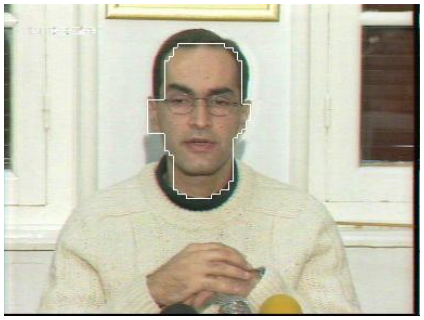
Image Presented to the system

mem: 0.8

Segmented Face

Facial area: 0.0867

0.0873



0.0883

0.0969

0.0985

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Conclusions

- *Color segmentation* : powerful tool for object extraction, especially for human faces
- *M-RSST algorithm* : eliminates facial details and provides a single object for each face
- *Chrominance components* with a *probabilistic model* used in an efficient way for retrieving facial images from image databases
- *Interactive retrieval framework* adapts the model to user needs and leads to meaningful retrieval results