A generalized distance between hierarchically partitioned images*

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2. *CCPD - Universidad Central de Venezuela - Caracas*

Outline

- **Background**
  - **Content-Based Image Retrieval**
  - **Recursive image partition**
  - **Multi-Level Feature Vector**
- **Δ-distance**
  - **Multi-level filtering for global image retrieval**
  - **Pattern and sub-image searches**
  - **Particular cases**
- **Conclusion and future work**

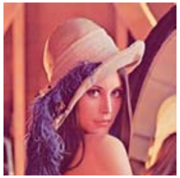
Background (1/4)

Content-Based Image Retrieval

- Image visual features extracted and represented as vectors
- Representation of each image by a point in a multidimensional space
- Image similarity defined as distance between points
- Use of index structure to speed up image searches

Background (1/4)

Content-Based Image Retrieval



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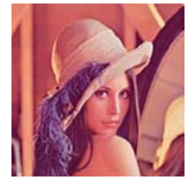

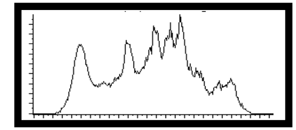

Color histogram

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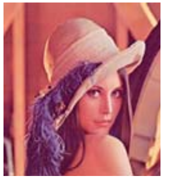

(180, 98, 105)

Vector on average color

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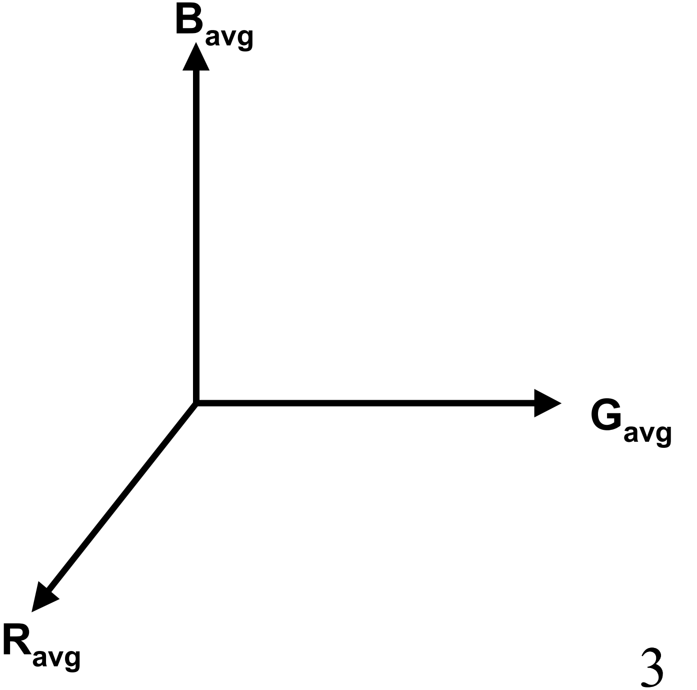

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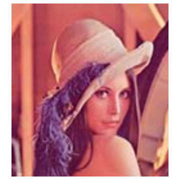

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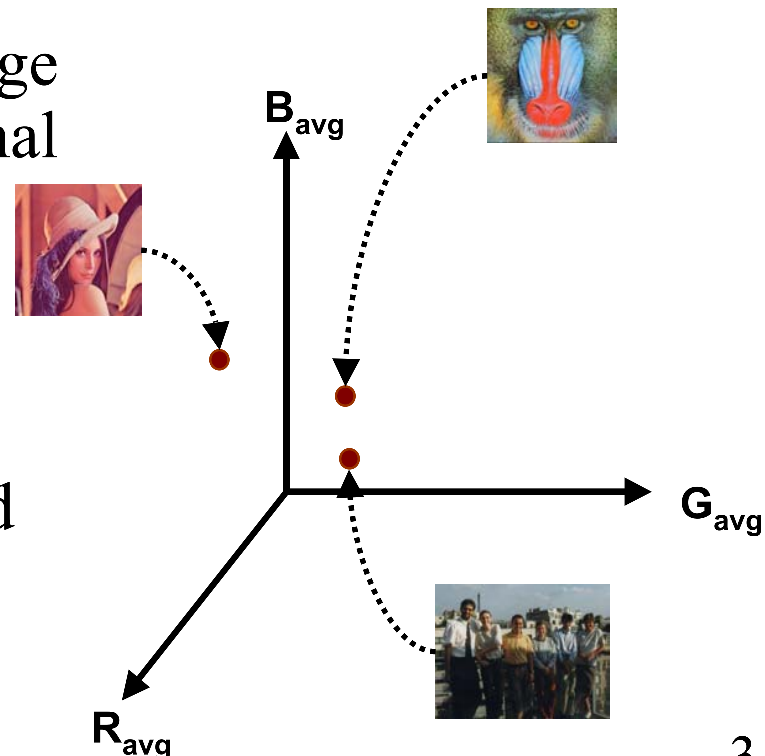

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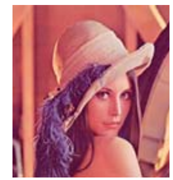

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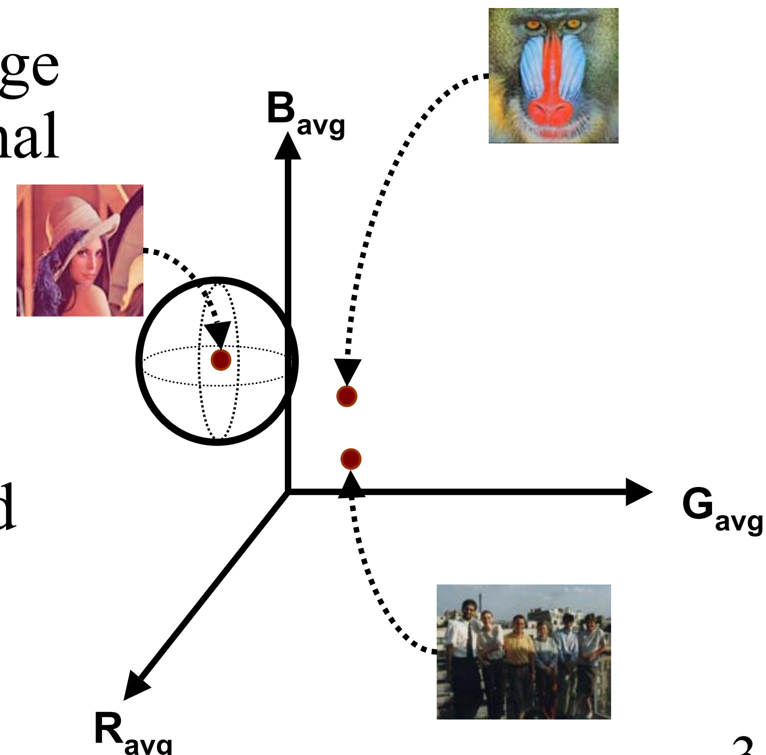

Background (1/4)

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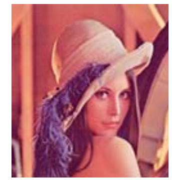

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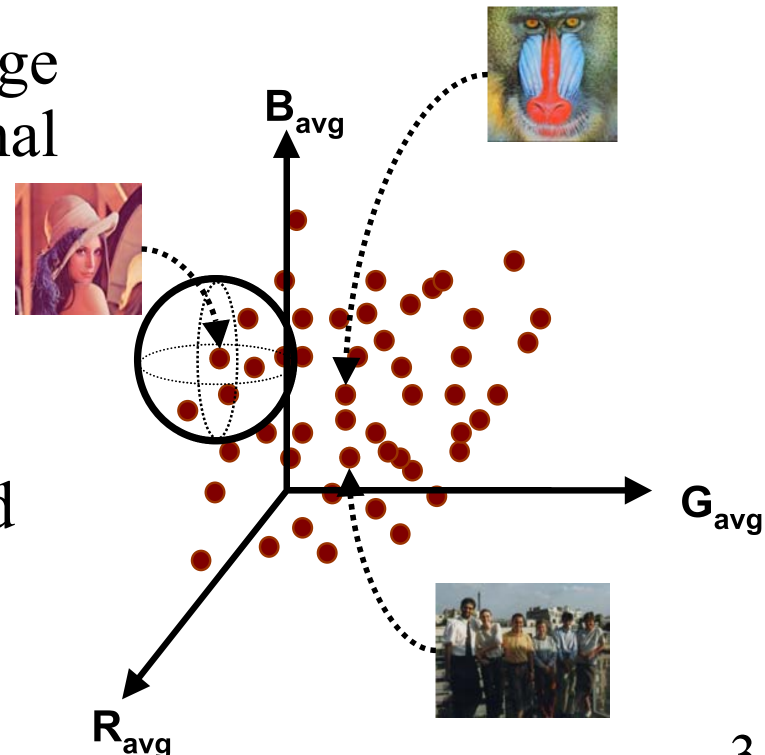
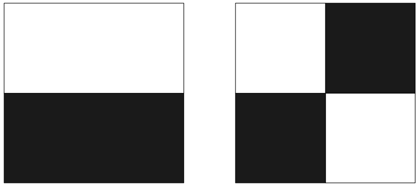


Background (2/4)

- Global similarity $\not\Rightarrow$ Local similarity



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  - Quadtree decomposition

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Original image

0

Background (2/4)

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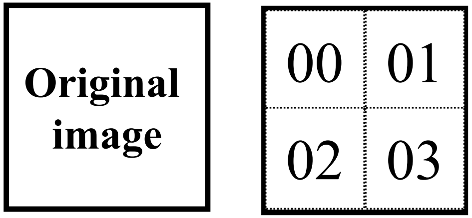

Level 1

Background (2/4)

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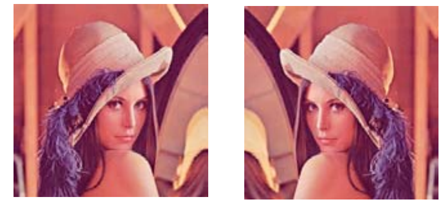

- **Recursive image partition**
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Background (2/4)

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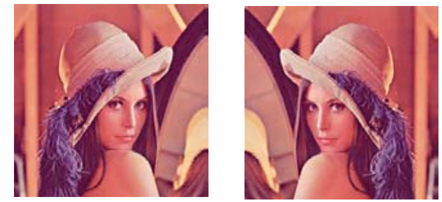

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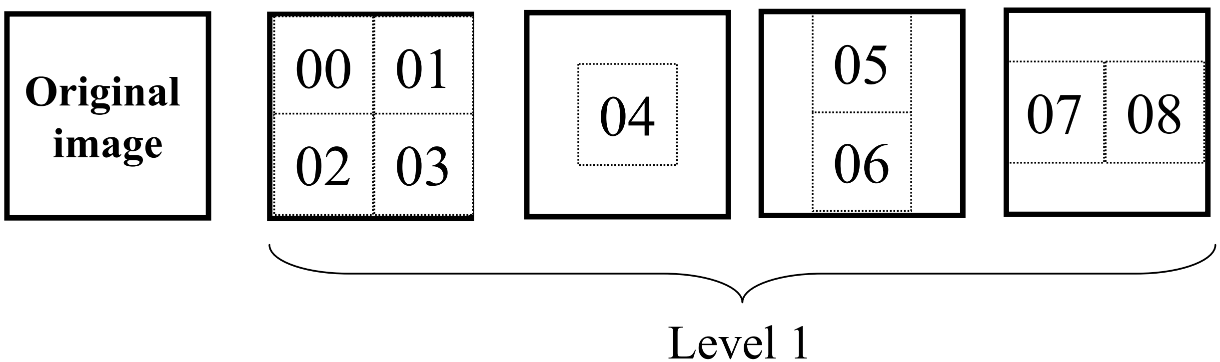

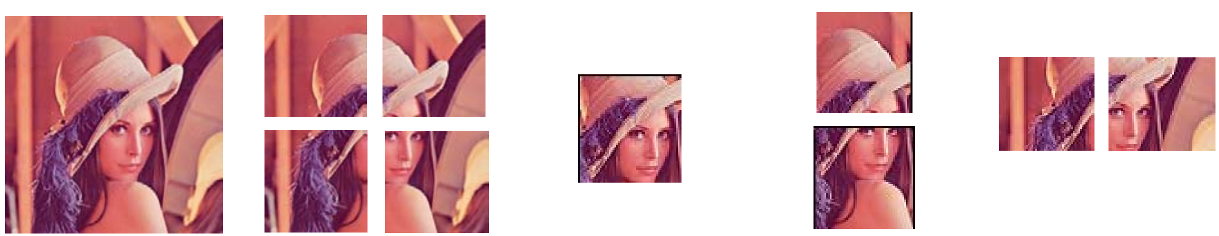

Background (3/4)

Multi-Level Feature Vector

- Representation of each quadrant by a visual descriptor
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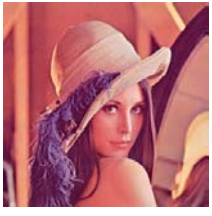

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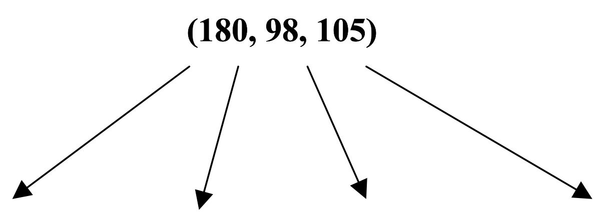

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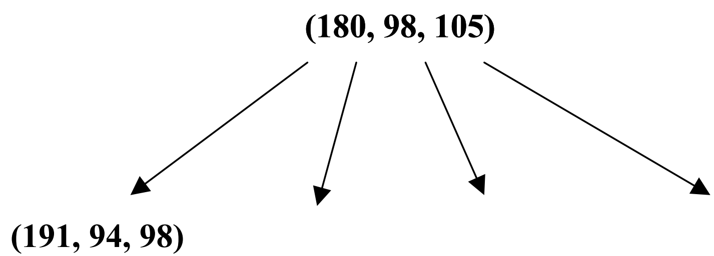

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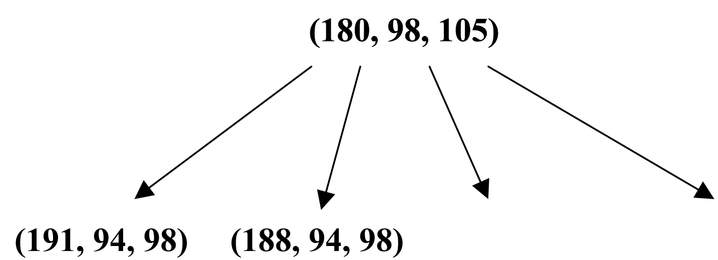

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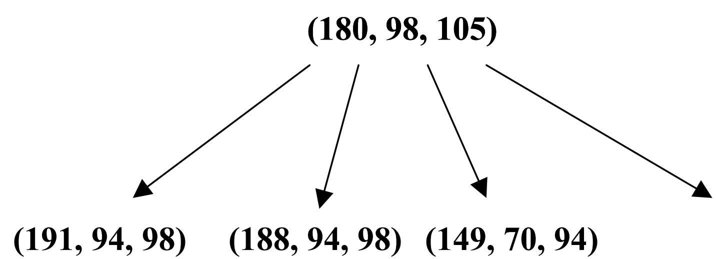

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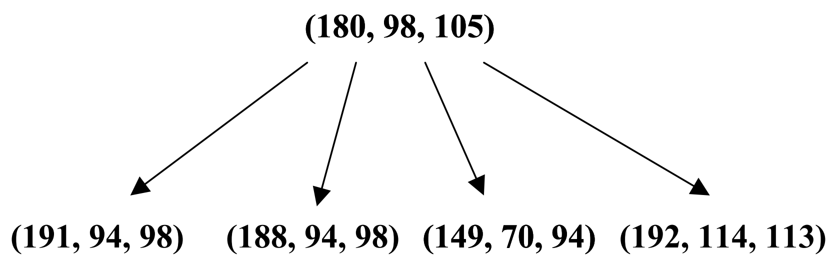

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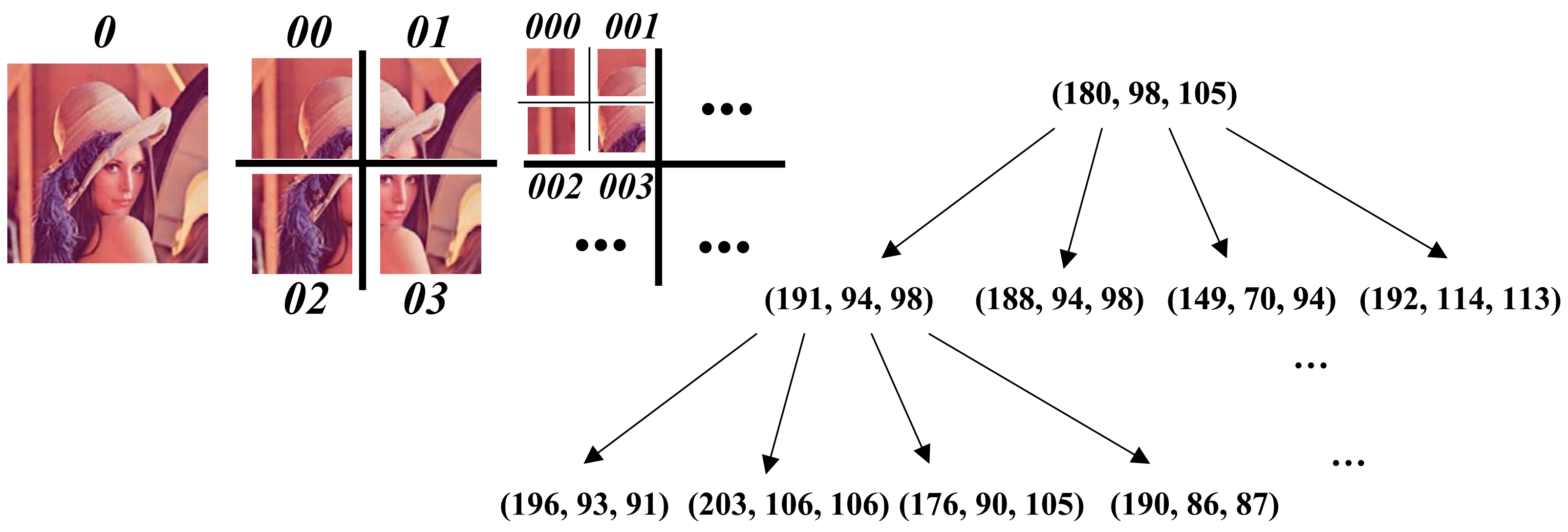

Background (4/4)

Related works based on multi-level feature vector

Reference	Tree	Feature vector
(Jomier et al., 2005)	quadtree	color moments
(Kim and Kim, 2000)	quadtree	shape feature
(Lin et al., 2001)	quadtree	average color vector in the root and color histograms in the other nodes
(Lu et al., 1994)	quadtree	color histograms
(Luo and Nascimento, 2003)	mixed between a nona and a quad trees	mean and covariance color
(Malki et al., 1999)	quadtree	color and texture histograms
(Remias et al., 1997)	nona-tree	texture vectors

Δ-distance

A generalized distance between multi-level feature vectors

$$\Delta(i,j) = \frac{\sum_{n} w_k \delta(i,j,n)}{\sum_{n} w_n}$$

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- δ-distances weighted by w_n, $w_n \geq 0$
- Δ-distance normalized by $W = \Sigma w_n$

Global search using Δ-distance

Rank 1

Query result using a global distance

Query image

Rank 4

Query result using Δ-distance

From the prototype of (Jomier et al., 2005)

Search criteria : values and location of the image features

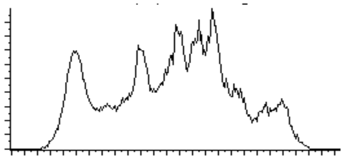
Multi-level filtering (1/3)

- $\Delta^{(l)}$ = approximation of Δ-distance

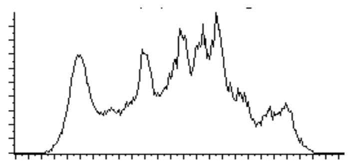
$$\Delta^{(l)}(i,j) = \frac{1}{W}\sum_{k=0}^{l}\left(w_n \delta(i,j,n)\right)$$

$$\Delta^{(l-1)}(i,j) \le \Delta^{(l)}(i,j) \le \Delta^{(l+1)}(i,j)$$

- Filtering process: Computing Δ-distance level by level



Feature vector of quadrant 0 of the query image *q*



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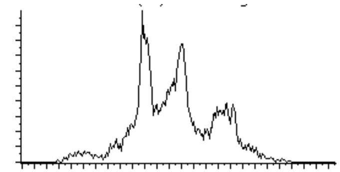
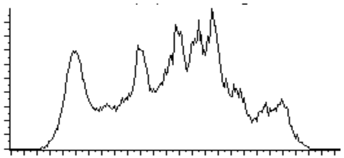
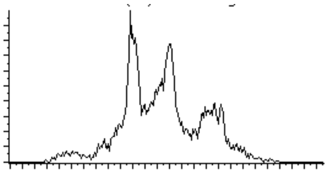


Feature vector of quadrant 0 of the image *i*

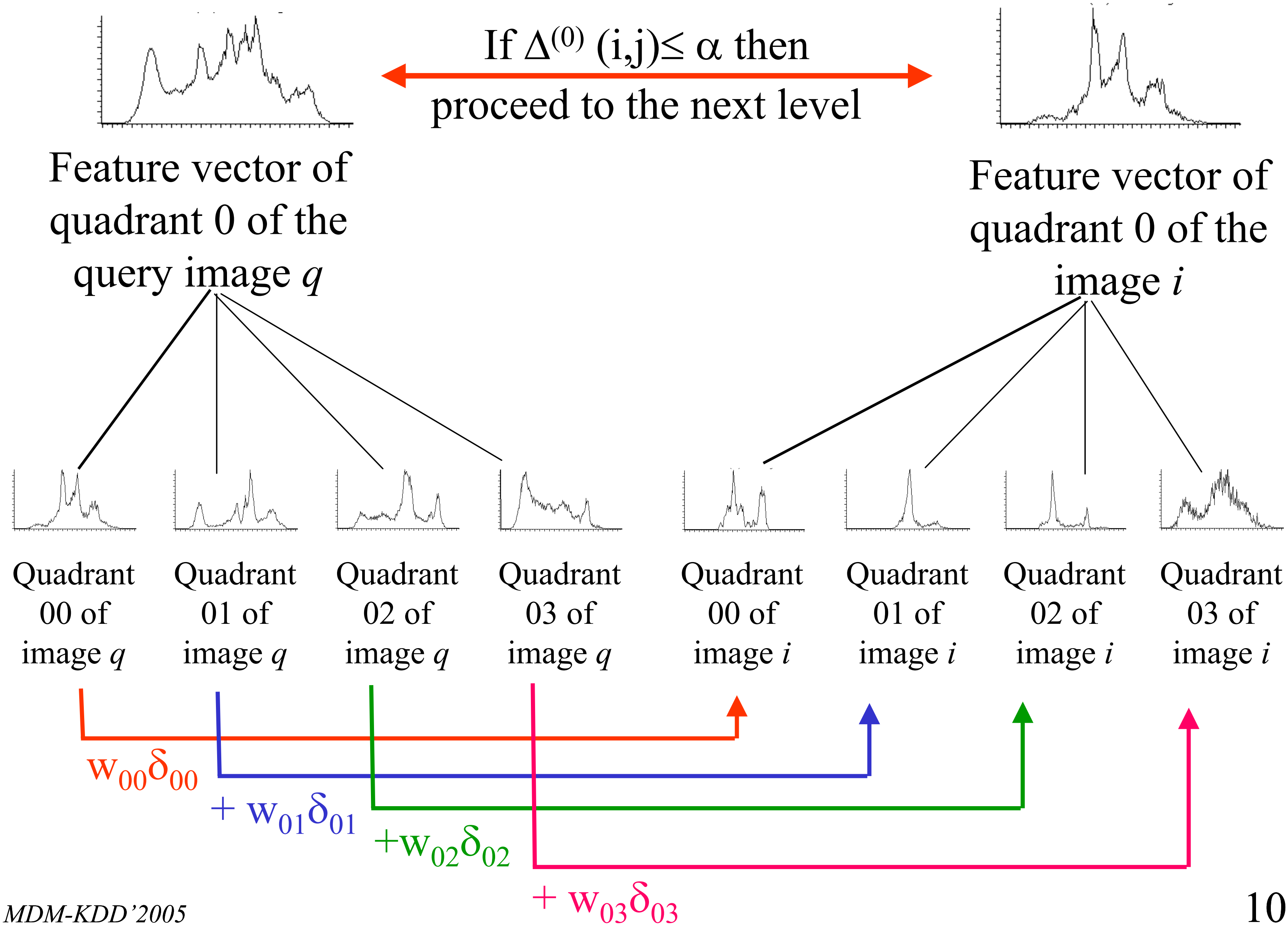


Feature vector of quadrant 0 of the query image *q*

If $\Delta^{(0)}$ (i,j) $\leq \alpha$ then proceed to the next level



Feature vector of quadrant 0 of the image *i*


If $\Delta^{(0)}$ (i,j)≤ α then
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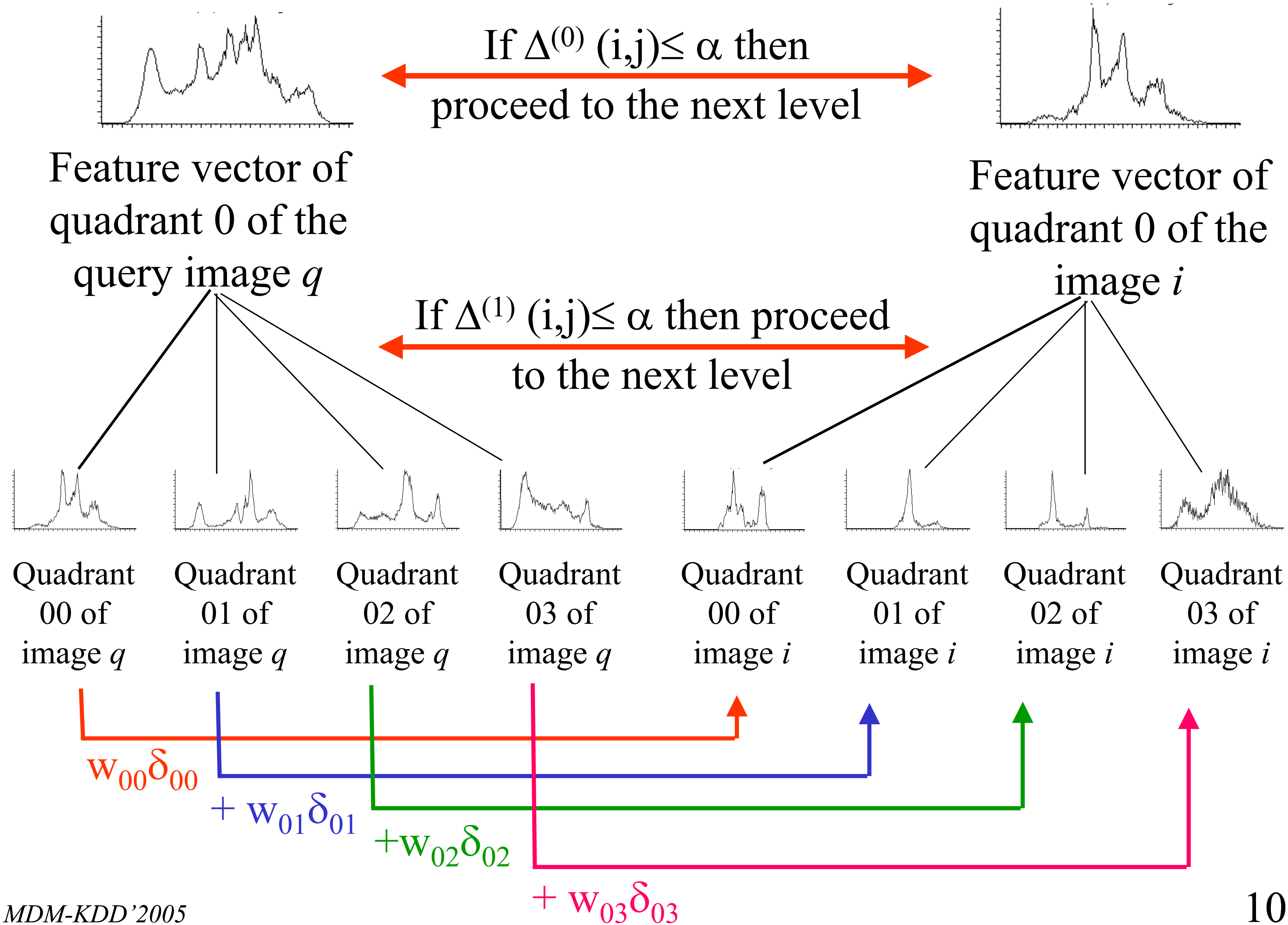
Feature vector of quadrant 0 of the query image *q*
Feature vector of quadrant 0 of the image *i*
Quadrant 00 of image *q*
Quadrant 01 of image *q*
Quadrant 02 of image *q*
Quadrant 03 of image *q*
Quadrant 00 of image *i*
Quadrant 01 of image *i*
Quadrant 02 of image *i*
Quadrant 03 of image *i*
$w_{00}\delta_{00}$
$+ w_{01}\delta_{01}$
$+w_{02}\delta_{02}$
$+ w_{03}\delta_{03}$


If Δ^(0) (i,j)≤ α then
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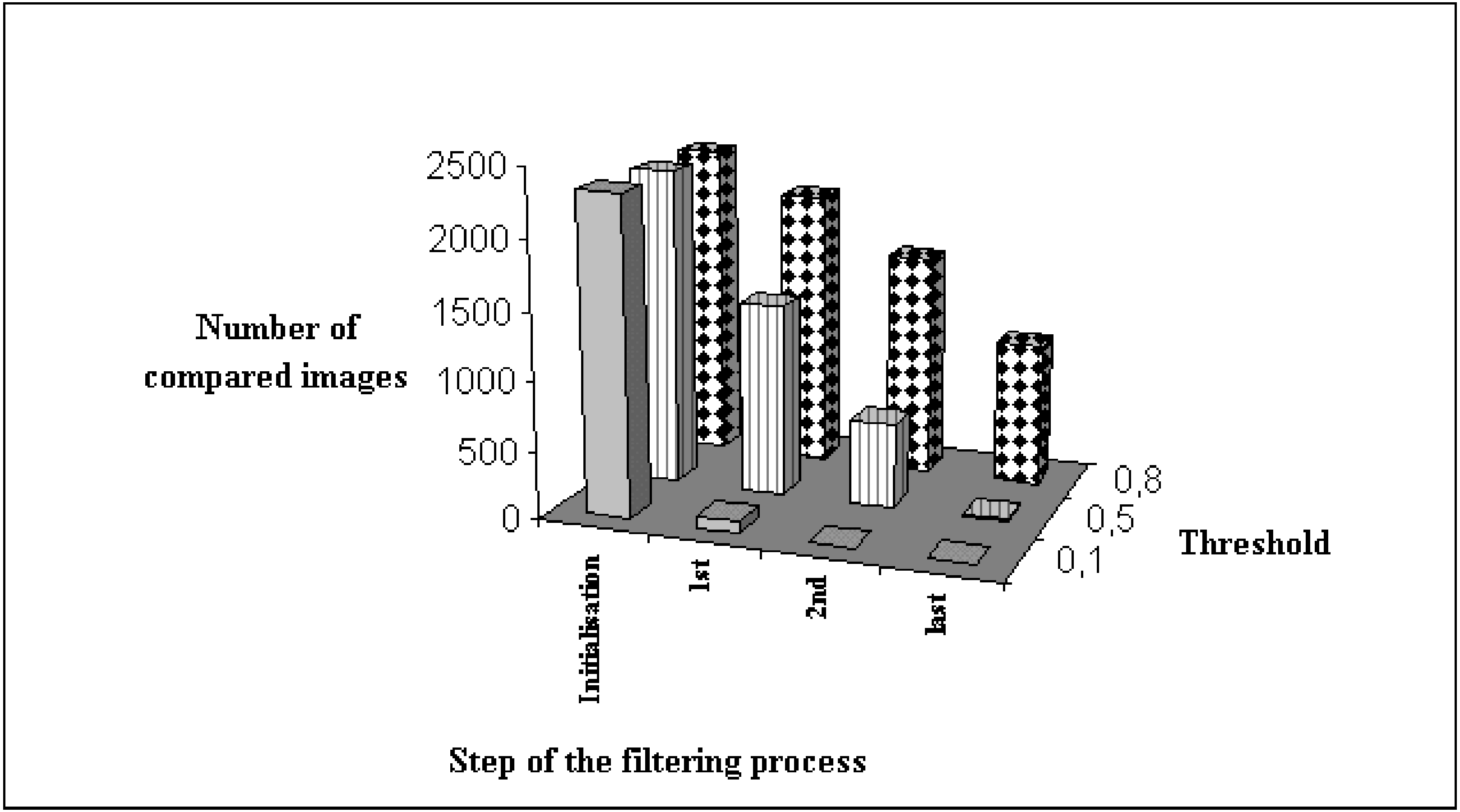
Feature vector of quadrant 0 of the query image q
Feature vector of quadrant 0 of the image i
If Δ^(1) (i,j)≤ α then proceed
to the next level
Quadrant 00 of image q
Quadrant 01 of image q
Quadrant 02 of image q
Quadrant 03 of image q
Quadrant 00 of image i
Quadrant 01 of image i
Quadrant 02 of image i
Quadrant 03 of image i
w00δ00
+ w01δ01
+w02δ02
+ w03δ03

Multi-level filtering (3/3)



Pattern search (1/2)

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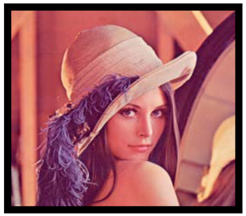
(a) Query image



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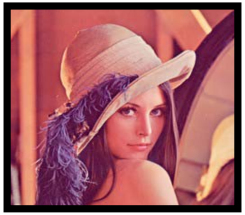

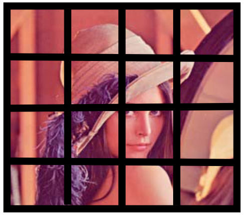

(b) 3 level quadtree image representation

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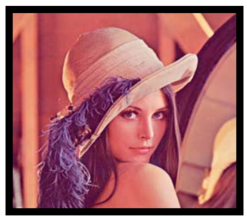

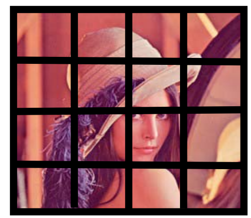

(b) 3 level quadtree image representation

(c) Quadrants selected by the user

Pattern search (1/2)

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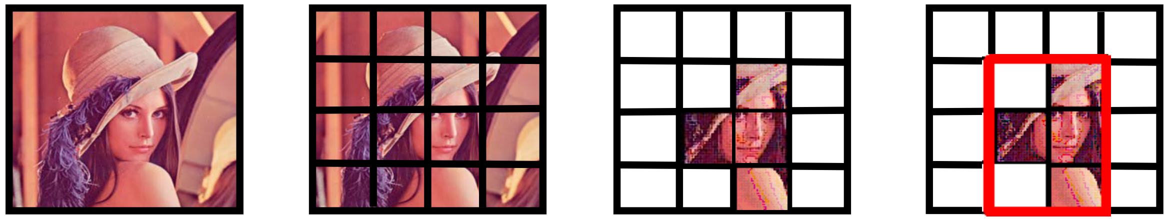

(b) 3 level quadtree image representation

(c) Quadrants selected by the user

(d) Minimum bounding rectangle minimum containing the selected quadrants

Adapted from (Malki et al., 1999)

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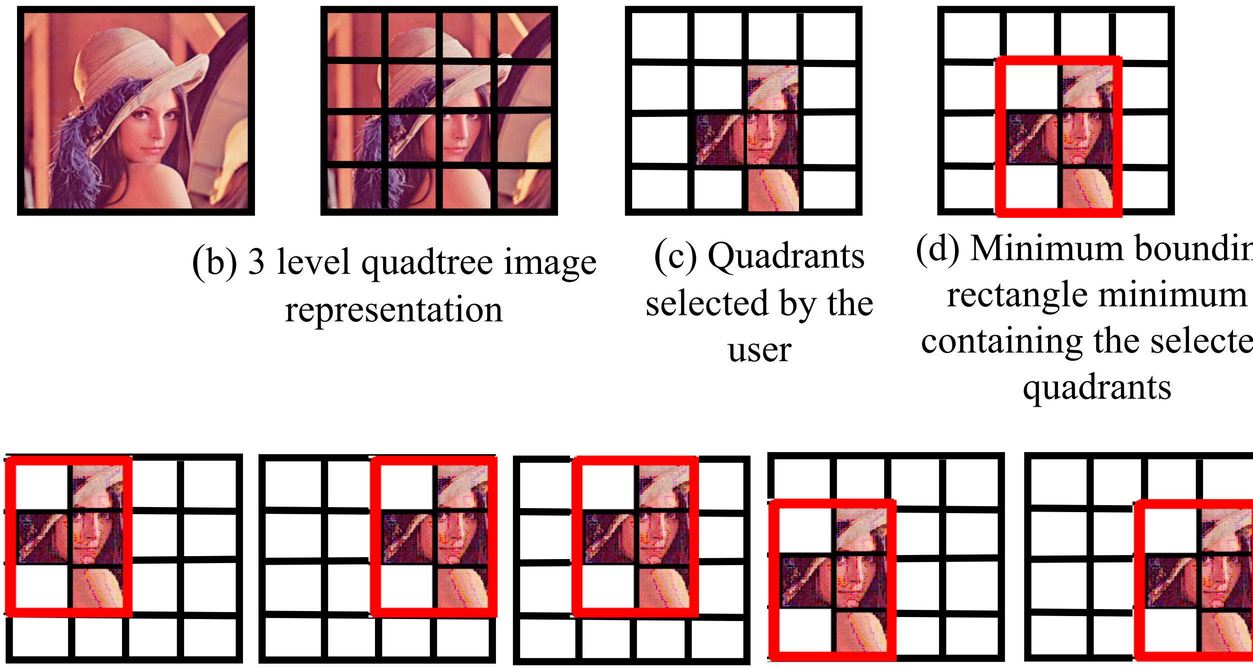

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(e) Translation of the minimum bounding rectangle

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Pattern search (1/2)

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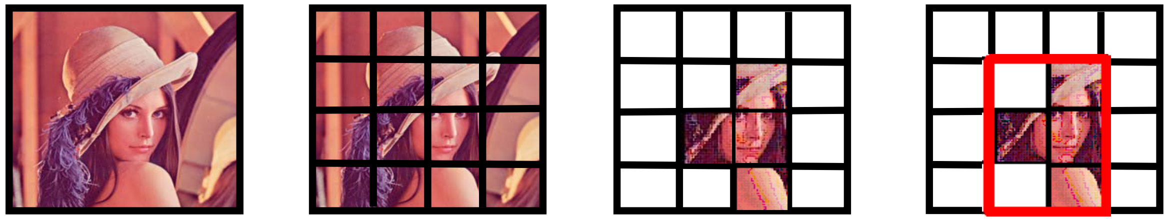

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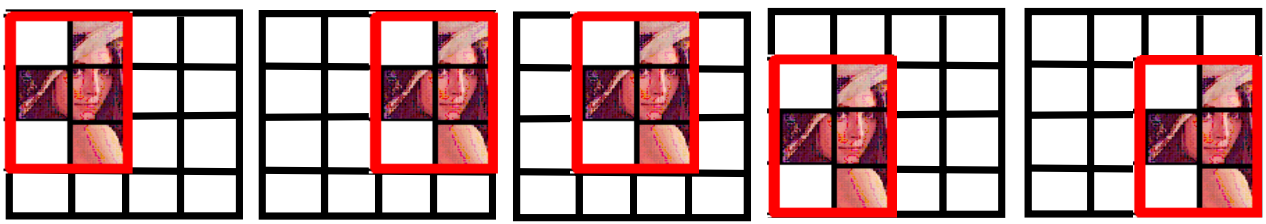
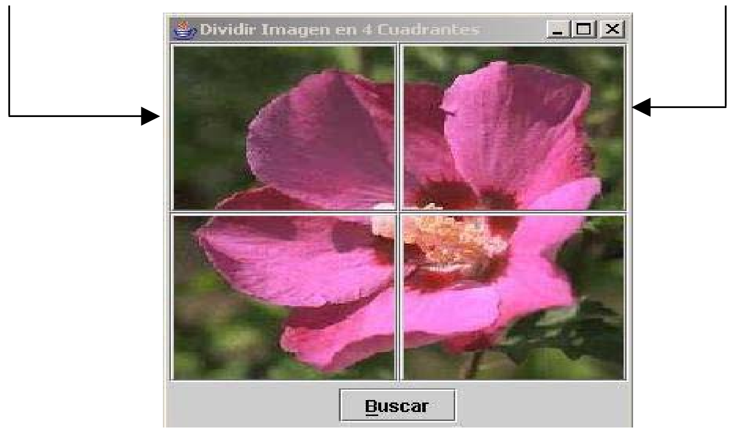


(e) Translation of the minimum bounding rectangle

Using $\Delta_p(i,q)$ where $w_n>0$ for all selected image quadrants and $w_n=0$ for the other quadrants

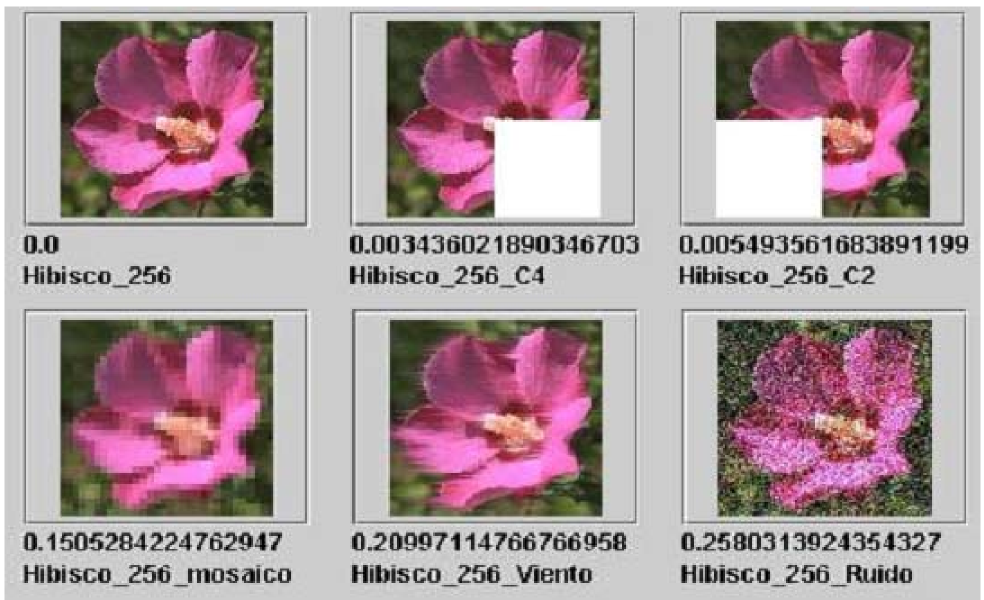
Pattern search (2/2)

$w_{00}=0.9$ $w_{01}=0.1$



(a) Query image : $w_{00}=0.9$ and $w_{01}=0.1$ and other weights $w_n=0$

From the prototype of (Jomier et al., 2005)



(b) Query result

Sub-image search (1/2)

Comparing the query image with all image quadrants

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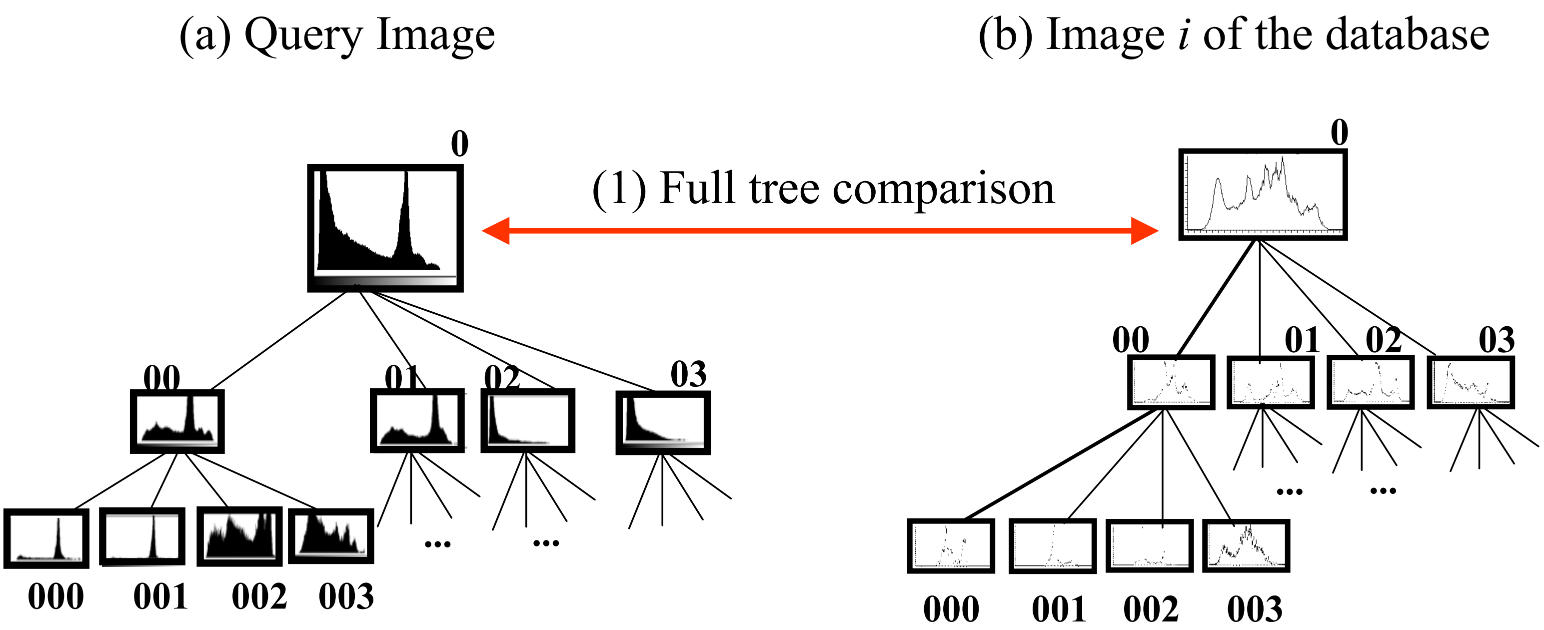
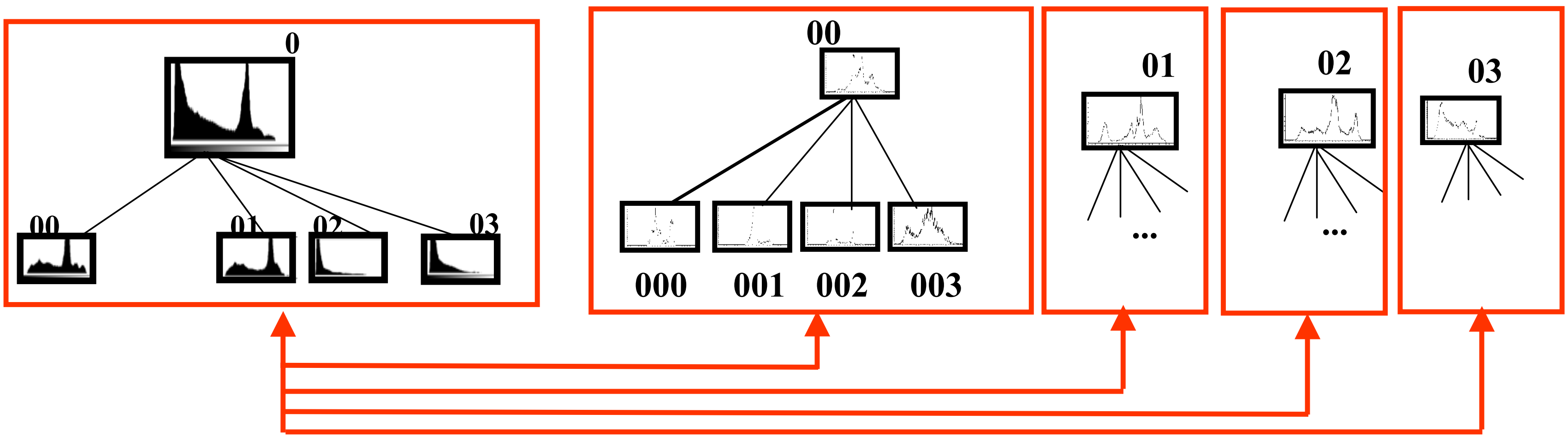


Sub-image search (1/2)

Comparing the query image with all image quadrants

(a) Query Image

(b) Image *i* of the database



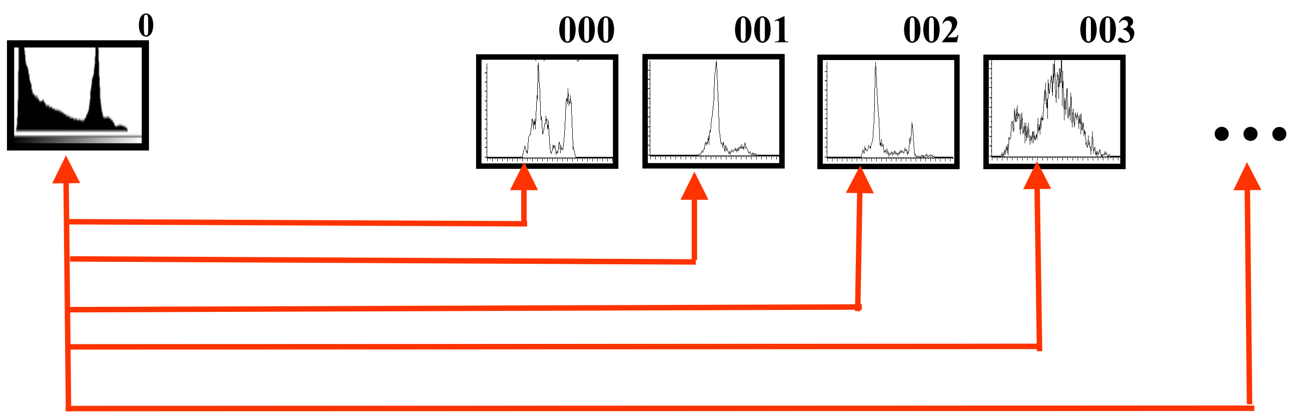
(2) Comparing the query image with the first level quadrants

Sub-image search (1/2)

Comparing the query image with all image quadrants

(a) Query Image

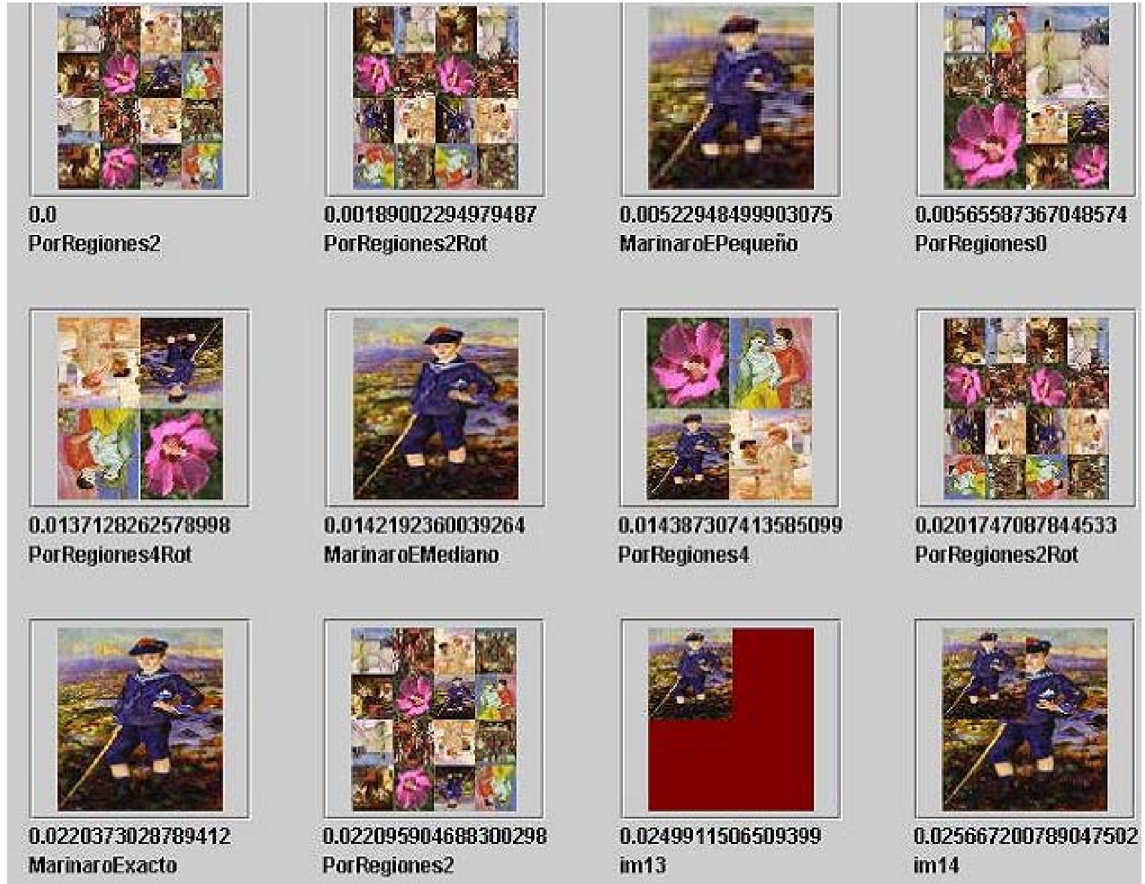
(b) Image *i* of the database



(3) Comparing the query image with the second level quadrants

Sub-image search (2/2)

(a) Query image



(b) Query result

From the prototype of (Jomier et al., 2005)

Particular cases of Δ-distance

Reference	Δ-distance	δ	weights w_n
(Jomier et al., 2005)	$\widetilde{\Delta^{(\ell)}}$ and Δ_p	L_2	$4^{-\ell}$ for all nodes n at level ℓ
(Kim and Kim, 2000)	Δ	L_1	1 for all nodes n
(Lin et al., 2001)	$\widetilde{\Delta^{(\ell)}}$ and Δ_p	L_2	$4^{-\ell}$ for all nodes n at level ℓ
(Lu et al., 1994)	$\widetilde{\Delta^{(\ell)}}$	L_2	$4^{-\ell}$ for all nodes n at level ℓ
(Luo and Nascimento, 2003)	Δ	L_1	$w_n = 0$ for all internal nodes n and $w_n = 1$ for leaf nodes n
(Malki et al., 1999)	Δ_p	d	$w_n = 0$ for all quadrants n not selected by the user
(Remias et al., 1997)	Δ_p	L_2	$w_n = 1$ for each compared quadrants n $w_n = 0$ otherwise

Conclusion and future work

- **Done :** Δ-distance presentation
  - o Definition of a metric distance between images represented by multi-level feature vectors
  - o Global image retrieval, computed by multi-level filtering
  - o Pattern and sub-image searches
  - o Generalization of existing distances, based on weights w_n and on δ-distance between image quadrants
- **To do :** Develop a Δ-distance based prototype
  - o To compare existing works
  - o To help the user to choose weights w_n and δ-distances
  - o Including full-balanced multi-level feature vectors and those based on image segmentation

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