A generalized distance between hierarchically partitioned images*

Maude Manouvrier¹
Marta Rukoz²
Geneviève Jomier¹

* Supported in part by CDCH in Venezuela

1. LAMSADÉ - Paris-Dauphine University - France
2. CCPD - Universidad Central de Venezuela - Caracas
Outline

- Background
  - Content-Based Image Retrieval
  - Recursive image partition
  - Multi-Level Feature Vector

- $\Delta$-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)

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Content-Based Image Retrieval

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Vector on average color

Color histogram

R_{avg}  G_{avg}  B_{avg}
Background (1/4)

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Vector on average color (180, 98, 105)

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Background (2/4)

- Global similarity ≠ Local similarity
Background (2/4)

- Global similarity \not\Rightarrow Local similarity
Background (2/4)

- Global similarity ≠ Local similarity

- Recursive image partition
  - Quadtree decomposition
Background (2/4)

- Global similarity  $\Rightarrow$ Local similarity

- Recursive image partition
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Background (2/4)

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<table>
<thead>
<tr>
<th>Original image</th>
<th>00</th>
<th>01</th>
</tr>
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<tbody>
<tr>
<td>02</td>
<td>03</td>
<td></td>
</tr>
</tbody>
</table>

Level 1
Background (2/4)

- Global similarity ⇒ Local similarity

- Recursive image partition
  - Quadtree decomposition

Original image

Level 1

Level 2

00 01
02 03

00 01
02 03

002 003

000 001

...
Background (2/4)

- Global similarity \(\not\Rightarrow\) Local similarity

- Recursive image partition
  - Nona-tree decomposition

```
Original image
00 01
02 03

04

05 06

07 08
```

Level 1
Background (3/4)

Multi-Level Feature Vector

- Representation of each quadrant by a visual descriptor
- Storage of the descriptors in tree nodes
Background (3/4)

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Background (3/4)

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Multi-Level Feature Vector

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## Background (4/4)

### Related works based on multi-level feature vector

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

A generalized distance between multi-level feature vectors

\[\Delta(i, j) = \sum_{n} w_k \delta(i, j, n) \]

\[\frac{\sum_{n} w_k \delta(i, j, n)}{\sum_{n} w_n} \]
$$\Delta\text{-distance}$$

A generalized distance between multi-level feature vectors

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

- For all nodes $n$ of both multi-level feature vectors
\( \Delta\)-distance

A generalized distance between multi-level feature vectors

\[
\Delta (i,j) = \frac{\sum_n w_k \delta(i,j,n)}{\sum_n w_n}
\]

- For all nodes \( n \) of both multi-level feature vectors
- \( \delta(i,j,n) = \) metric distance between feature vectors stored in homologous node \( n \) of multi-level feature vectors of images \( i \) and \( j \)
**Δ-distance**

A generalized distance between multi-level feature vectors

\[
Δ(i, j) = \frac{\sum_n w_n \delta(i, j, n)}{\sum_n w_n}
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- For all nodes \( n \) of both multi-level feature vectors
- \( \delta(i, j, n) \) = metric distance between feature vectors stored in homologous node \( n \) of multi-level feature vectors of images \( i \) and \( j \)
- \( \delta \)-distances weighted by \( w_n, w_n ≥ 0 \)
\[ \Delta \text{-distance} \]

A generalized distance between multi-level feature vectors

\[ \Delta(i,j) = \frac{\sum_{n} w_n \delta(i,j,n)}{\sum_{n} W_n} \]

- For all nodes \( n \) of both multi-level feature vectors
- \( \delta(i,j,n) = \) metric distance between feature vectors stored in homologous node \( n \) of multi-level feature vectors of images \( i \) and \( j \)
- \( \delta \)-distances weighted by \( w_n, w_n \geq 0 \)
- \( \Delta \)-distance normalized by \( W = \sum w_n \)

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Global search using $\Delta$-distance

Query image

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 \( \Delta \)-distance

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

\[
\Delta^{(l-1)}(i,j) \leq \Delta^{(l)}(i,j) \leq \Delta^{(l+1)}(i,j)
\]

- Filtering process: Computing \( \Delta \)-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 $i$
If $\Delta^{(0)}(i,j) \leq \alpha$ then proceed to the next level.
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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 $i$

$w_{00} \delta_{00} + w_{01} \delta_{01} + w_{02} \delta_{02} + w_{03} \delta_{03}$
Feature vector of quadrant 0 of the query image $q$

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

$w_{00}\delta_{00} + w_{01}\delta_{01} + w_{02}\delta_{02} + w_{03}\delta_{03}$

Feature vector of quadrant 0 of the image $i$

If $\Delta^{(1)} (i,j) \leq \alpha$ then proceed to the next level
Multi-level filtering (3/3)
Pattern search (1/2)
Pattern search (1/2)

(a) Query image
Pattern search (1/2)

(a) Query image

(b) 3 level quadtree image representation
Pattern search (1/2)

(a) Query image

(b) 3 level quadtree image representation

(c) Quadrants selected by the user
Pattern search (1/2)

(a) Query image

(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)
Pattern search (1/2)

(a) Query image
(b) 3 level quadtree image representation
(c) Quadrants selected by the user
(d) Minimum bounding rectangle minimum containing the selected quadrants
(e) Translation of the minimum bounding rectangle

Adapted from (Malki et al., 1999)
Pattern search (1/2)

(a) Query image

(b) 3 level quadtree image representation

(c) Quadrants selected by the user

(d) Minimum bounding rectangle minimum containing the selected quadrants

(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

Adapted from (Malki et al., 1999)
Pattern search (2/2)

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

(b) Query result

From the prototype of (Jomier et al., 2005)
Sub-image search (1/2)

Comparing the query image with all image quadrants
Sub-image search (1/2)

Comparing the query image with all image quadrants

(a) Query Image

(b) Image $i$ of the database

(1) Full tree comparison
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

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

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## Particular cases of Δ-distance

<table>
<thead>
<tr>
<th>Reference</th>
<th>Δ-distance</th>
<th>δ</th>
<th>weights $w_n$</th>
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<tbody>
<tr>
<td>(Jomier et al., 2005)</td>
<td>$\Delta^{(\ell)}$ and $\Delta_p$</td>
<td>$L_2$</td>
<td>$4^{-\ell}$ for all nodes $n$ at level $\ell$</td>
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<tr>
<td>(Kim and Kim, 2000)</td>
<td>$\Delta$</td>
<td>$L_1$</td>
<td>1 for all nodes $n$</td>
</tr>
<tr>
<td>(Lin et al., 2001)</td>
<td>$\Delta^{(\ell)}$ and $\Delta_p$</td>
<td>$L_2$</td>
<td>$4^{-\ell}$ for all nodes $n$ at level $\ell$</td>
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</tr>
<tr>
<td>(Luo and Nascimento, 2003)</td>
<td>$\Delta$</td>
<td>$L_1$</td>
<td>$w_n = 0$ for all internal nodes $n$ and $w_n = 1$ for leaf nodes $n$</td>
</tr>
<tr>
<td>(Malki et al., 1999)</td>
<td>$\Delta_p$</td>
<td>$d$</td>
<td>$w_n = 0$ for all quadrants $n$ not selected by the user</td>
</tr>
<tr>
<td>(Remias et al., 1997)</td>
<td>$\Delta_p$</td>
<td>$L_2$</td>
<td>$w_n = 1$ for each compared quadrants $n$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$w_n = 0$ otherwise</td>
</tr>
</tbody>
</table>
Conclusion and future work

- **Done**: $\Delta$-distance presentation
  - Definition of a metric distance between images represented by multi-level feature vectors
  - Global image retrieval, computed by multi-level filtering
  - Pattern and sub-image searches
  - Generalization of existing distances, based on weights $w_n$ and on $\delta$-distance between image quadrants

- **To do**: Develop a $\Delta$-distance based prototype
  - To compare existing works
  - To help the user to choose weights $w_n$ and $\delta$-distances
  - Including full-balanced multi-level feature vectors and those based on image segmentation
References


- S. Lin, M. Tamer Özsu, V. Oria, and R. Ng. An Extendible Hash for Multi-Precision Similarity Querying of Image Databases. In Proc. of the 27th Int. Conf. on Very Large DataBases (VLDB’2001), Roma (Italy), pages 221-230, Sept. 2001


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