Looking Beyond Region Boundaries: A Robust Image Similarity Measure Using Fuzzified Region Features

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Outline

- Introduction
- A robust image similarity measure
- Experimental results
- Conclusions and future work
Introduction

- The driving force
  - Internet
  - Storage devices
  - Computing power

- Two approaches
  - Text-based approach
  - Content-based approach
Text-Based Approach

- Input keywords descriptions

Elephants

Text-Based Image Retrieval System

Image Database
Text-Based Approach

- Index images using keywords (Google, Lycos, etc.)
  - Easy to implement
  - Fast retrieval
  - Web image search (surrounding text)
  - Manual annotation is not always available
  - A picture is worth a thousand words
  - Surrounding text may not describe the image
Content-Based Approach

- Index images using low-level features

Content-based image retrieval (CBIR): search pictures as pictures
A Data-Flow Diagram

- Feature Extraction
- Image Database
- Compute Similarity Measure
- Visualization

**Feature Extraction**
- Histogram, color layout, sub-images, regions, etc.

**Image Database**
- Euclidean distance, intersection, shape comparison, region matching, etc.

**Compute Similarity Measure**
- Linear ordering, Projection to 2-D, etc.

**Visualization**
Region-Based Approach

- An image is viewed as a collection of regions
  - Regions → Objects → Semantics
- Difficulties
  - Image segmentation
  - Region matching
- Our goal
  - Robust to image segmentation
Motivation

- Human can identify complex objects in a collection of points even when those points cannot always be assigned unambiguously to objects

Hypothesis

- Allowing for blurry boundaries between regions may increase the robustness
UFM: Unified Feature Matching

- UFM
  - Fuzzified region features
  - Region matching $\leftrightarrow$ fuzzy logic operation
  - Integrate region-level similarities
Image Segmentation

Original Image

Wavelet, RGB→LUV

K-means

Moments of Wavelet coefficients

Moments of Wavelet coefficients

LUV Color Components

LUV Color Components

(Centroid, Inertia)=region features

Segmentation Result
Image Segmentation

Segmentation examples

Original Image  3 regions  5 regions  7 regions  10 regions  13 regions
Original Image  3 regions  5 regions  7 regions  10 regions  13 regions
A segmented image
- regions \( \{R_1, \ldots, R_C\} \leftrightarrow \text{feature sets} \ \{F_1, \ldots, F_C\} \).

Region \( R_j \) is represented by a fuzzy feature with membership function of the form

\[
\mu_{\overline{F}_j}(\bar{f}) = \frac{1}{1 + \left( \frac{\|\bar{f} - \bar{f}_j\|}{d_f} \right)^\alpha}
\]
Region Matching

- Two regions
  - “AND” or intersection of two fuzzy sets
- A region and an image
  - An image → “Union” of all its regions
- Two images
  - A vector of similarities
- UFM measure
  - A convex combination of region level similarities
Experimental Results

- Query Examples from 60,000-image COREL Database
  - Natural Out-Door Scene
  - Horses
  - People
  - Vehicle
  - Flag
Natural Outdoor Scene
15 matches out of 19

People
15 matches out of 19

Horses
19 matches out of 19

Flag
19 matches out of 19

Vehicle
17 matches out of 19
Experimental Results

Robustness to Image Alterations

- Intensity Variation
- Sharpness Variation
- Color Distortion
- Cropping
- Shifting
- Rotation
Clockwise rotation by 45 degrees

Horizontal shifting right by 120 pixels

30% cropping

15% less saturated

Sharpen with 5×3 filter

Darken 30%

Random spread in 10×10 neighborhood

50% more saturated

Blur with a 10×10, σ = 5 Gaussian filter

Brighten 40%
Experimental Results

- Performance on Image Categorization
  - Subset of the COREL database formed by 10 image categories, each containing 100 images
    - Africa, Beach, Buildings, Buses, Dinosaurs, Elephants, Flowers, Horses, Mountains, and Food
  - Comparison with EMD-based color histogram approaches
Experimental Results

Average Precision for the UFM and the EMD-based color histogram approaches

Average Precision

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

0 1 2 3 4 5 6 7 8 9 10 11

Category ID

Color Histogram 1  
Color Histogram 2  
UFM
Experimental Results

- Robustness to Image Segmentation

Performance with respect to Segmentation-related Uncertainties:

- Overall Average Entropy $E$
- Overall Average Precision $P$
- Overall Average Rank $R$
- Overall Average Standard Deviation $SD$
Conclusions

- A robust image similarity measure
  - Fuzzified region features
  - Region matching
- Good retrieval performance
- Robust to image segmentation
- Robust to image alterations
Future Work

- Improving image segmentation
- Generating fuzzy features directly from segmentation
- Utilizing location information