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

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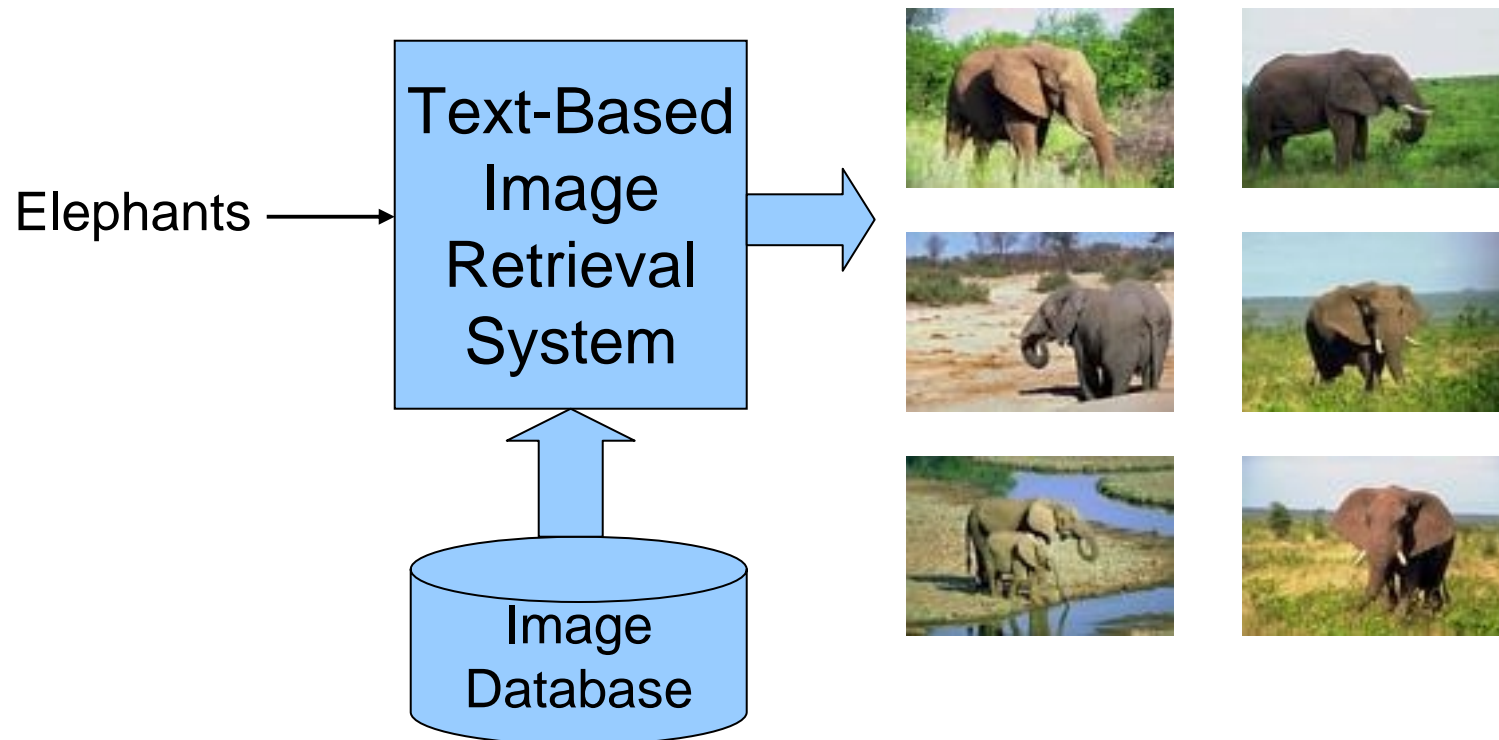http://www.cse.psu.edu/~yixchen

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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
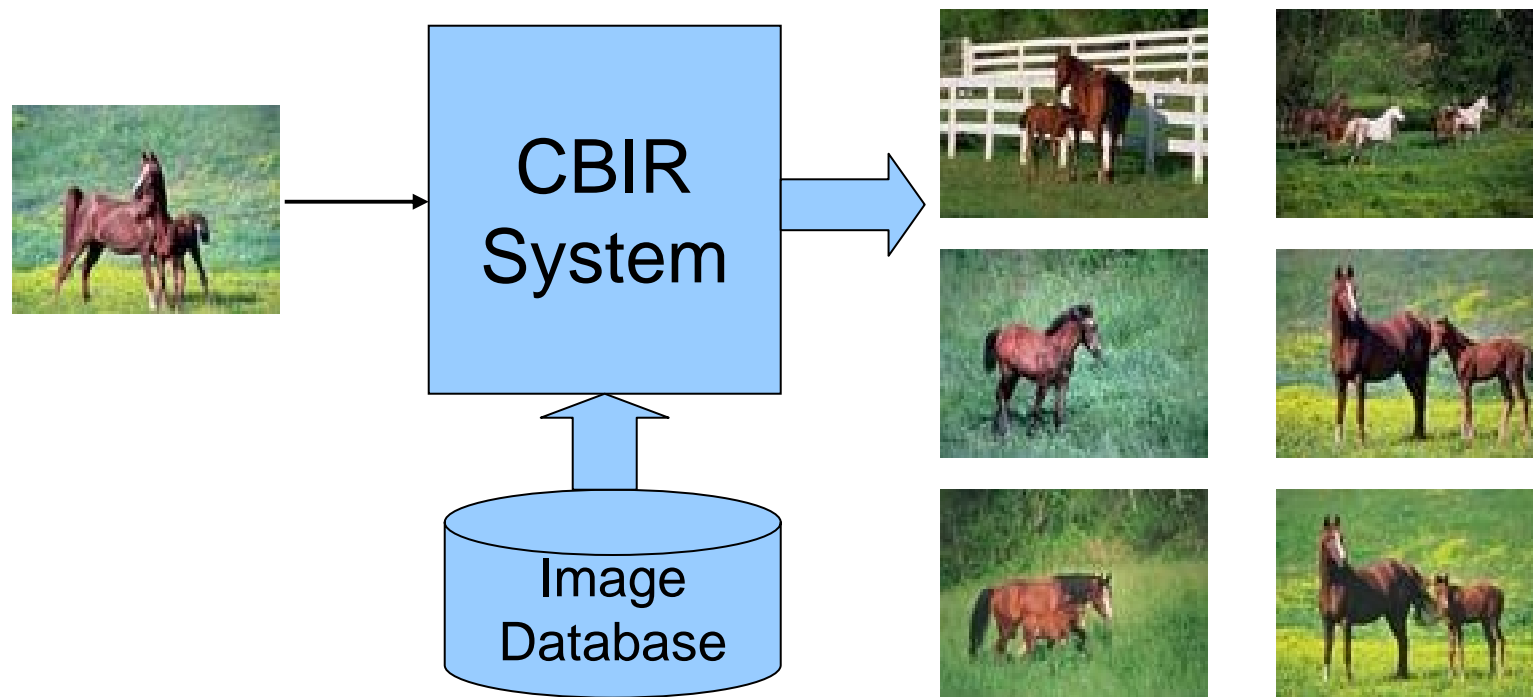
- Input keywords descriptions

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
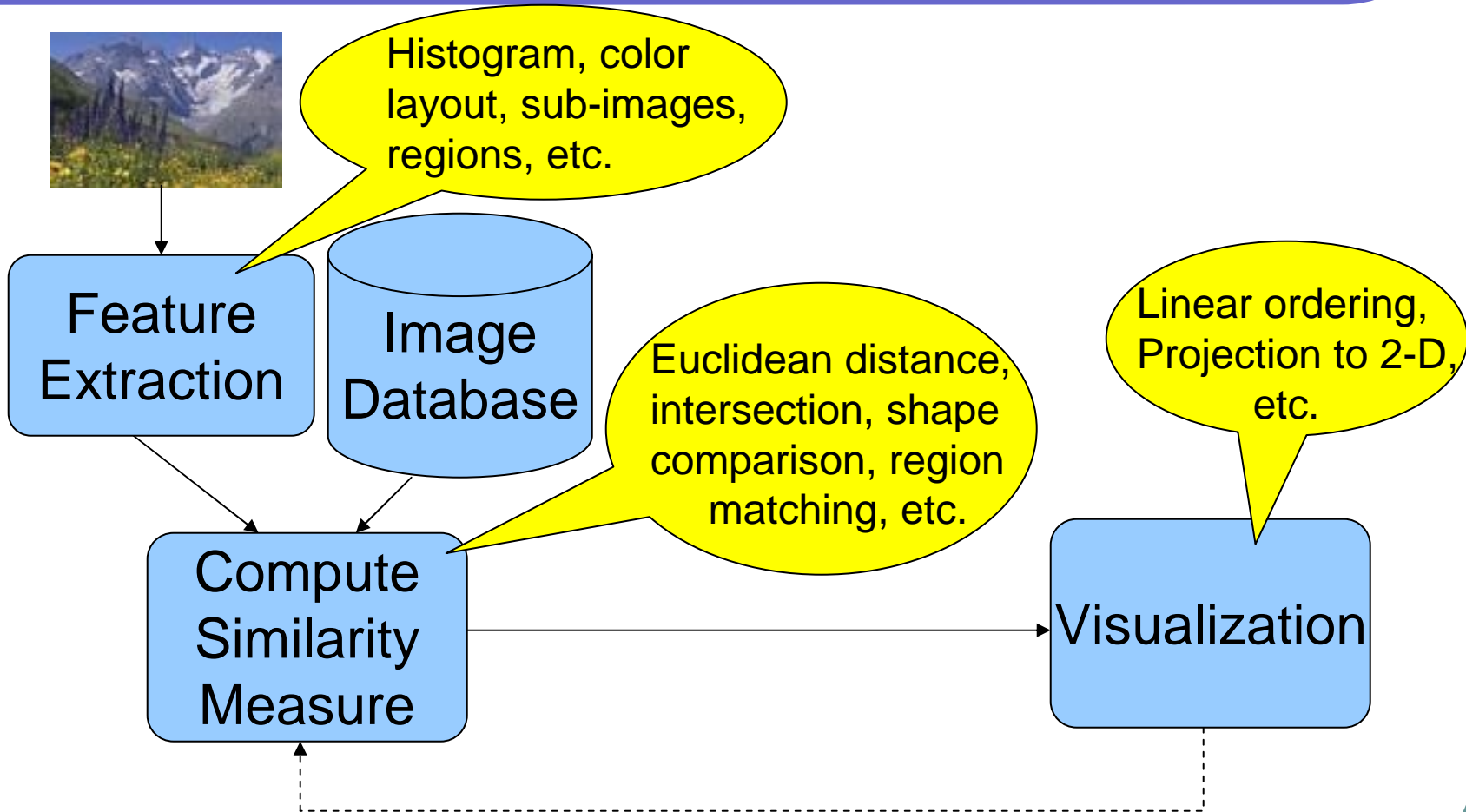 - Surrounding text may not describe the image

Content-Based Approach

- ## Index images using low-level features

Content-based image retrieval (CBIR): search pictures as pictures

A Data-Flow Diagram

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

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UFM: Unified Feature Matching

- ## 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
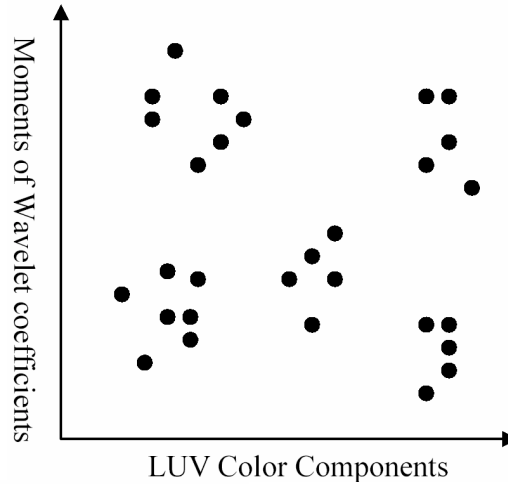
UFM: Unified Feature Matching

- UFM

  - Fuzzified region features

  - Region matching ← fuzzy logic operation

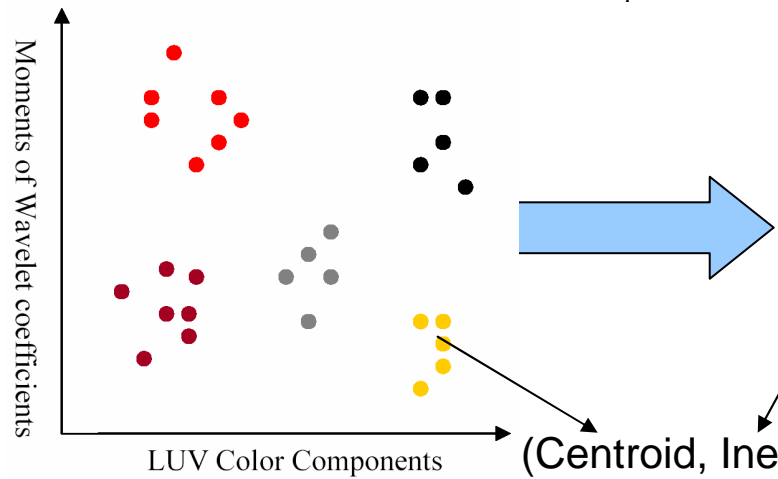 - Integrate region-level similarities
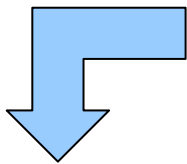
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Image Segmentation

Original Image

Wavelet, RGB→LUV

K-means

Moments of Wavelet coefficients

LUV Color Components

Moments of Wavelet coefficients

LUV Color Components

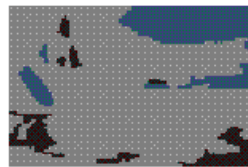Segmentation Result

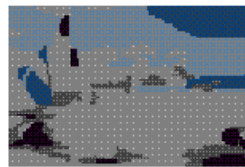(Centroid, Inertia)=region features
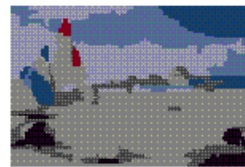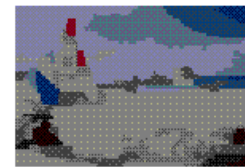
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Image Segmentation

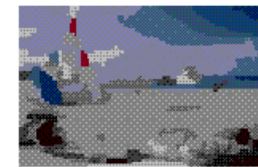- Segmentation examples

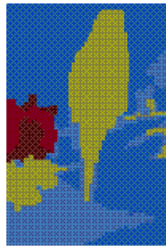| Original Image | 3 regions | 5 regions | 7 regions | 10 regions | 13 regions |

| Original Image | 3 regions | 5 regions | 7 regions | 10 regions | 13 regions |

Fuzzy Feature Representation

- A segmented image
  - regions $\{R_1,\ldots,R_C\} \Leftrightarrow$ feature sets $\{F_1,\ldots,F_C\}$.

- Region R_j is represented by a fuzzy feature with membership function of the form

$$\mu_{\widetilde{F}_j}(\vec{f}) = \frac{1}{1 + \left(\frac{\|\vec{f} - \widehat{\vec{f}}_j\|}{d_f}\right)^\alpha}$$

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
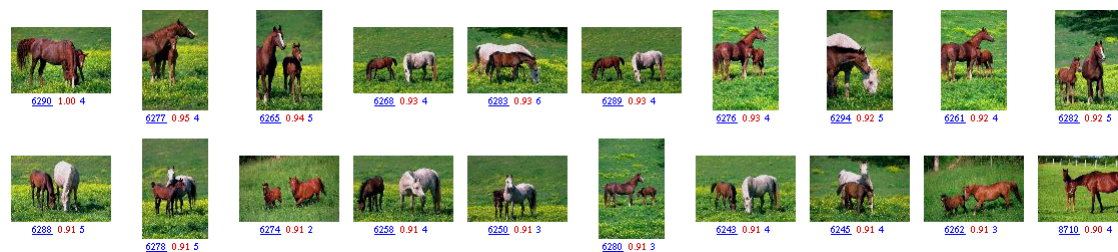 - Flag

Natural Outdoor Scene

15 matches out of 19

People

15 matches out of 19
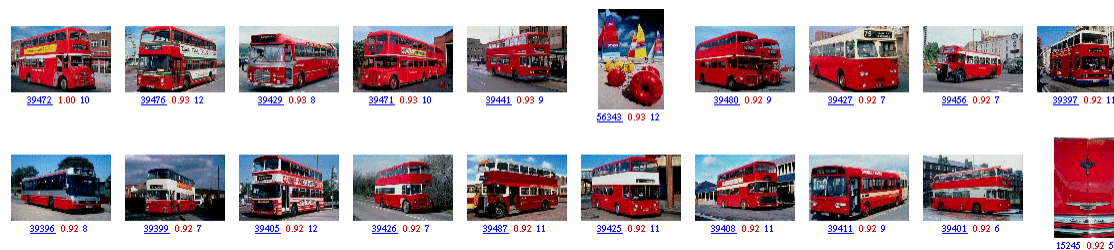
Horses

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
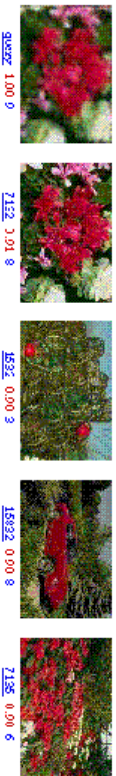 - Color Distortion
  - Cropping
  - Shifting
  - Rotation

Brighten 40%

Blur with a 10×10, $\sigma = 5$ Gaussian filter

55% more saturated

Random spread in 10×10 neighborhood

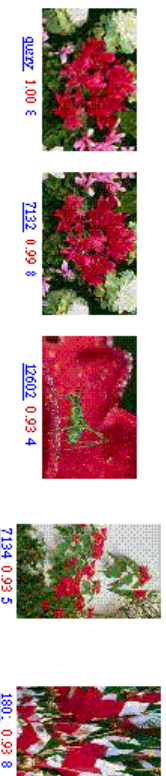Horizontal shifting right by 120 pixels

Darken 30%

Sharpen with 5×5 filter

15% less saturated

30% cropping

Clockwise rotating by 45 degrees
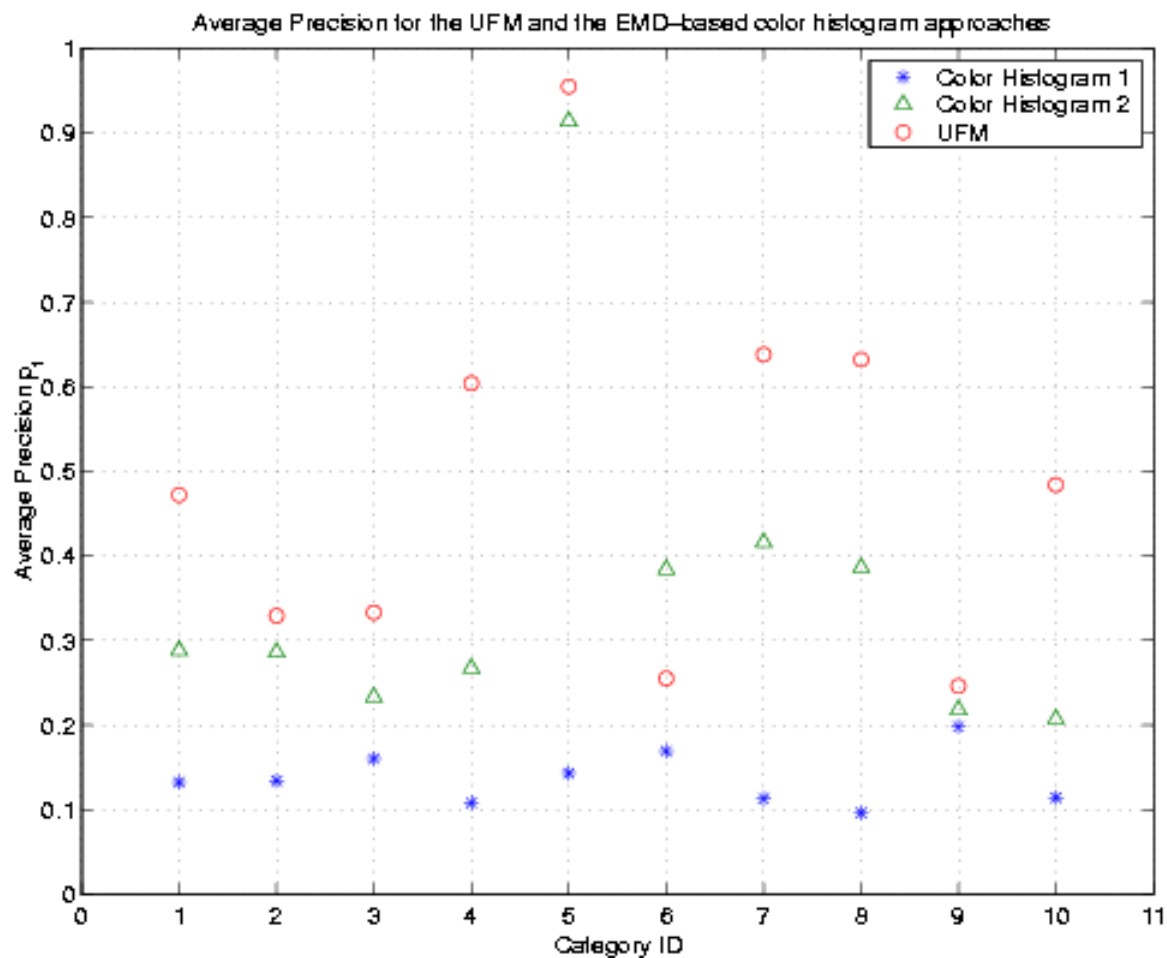
Experimental Results

- **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

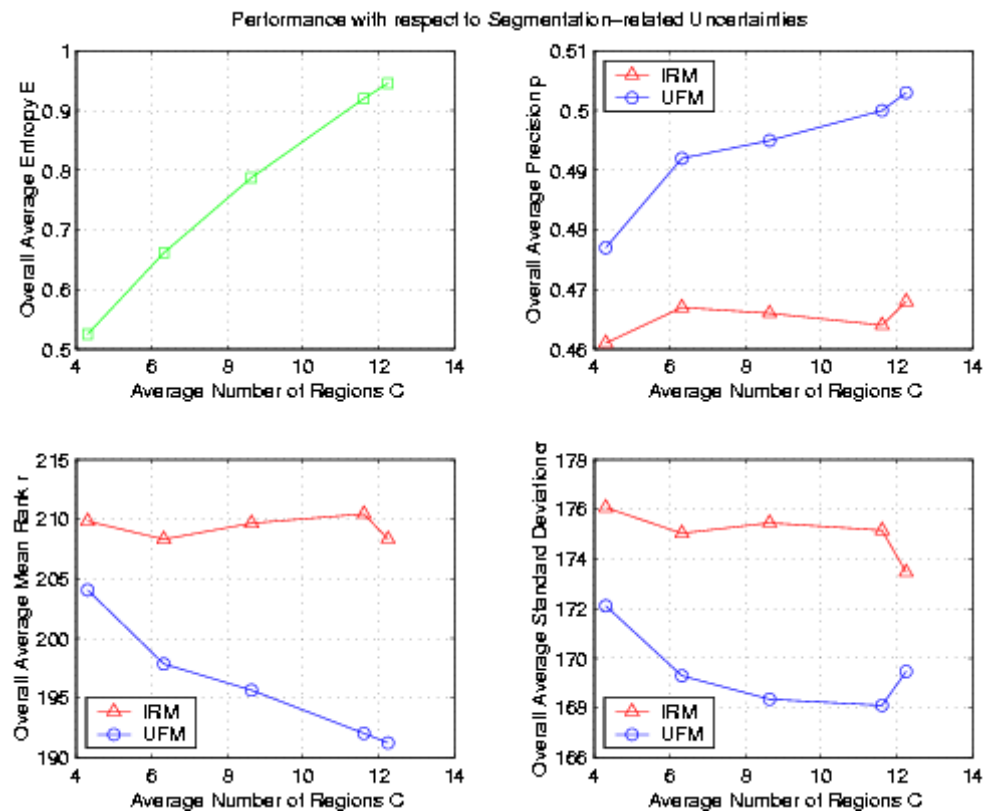 - Comparison with EMD-based color histogram approaches

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Experimental Results

Average Precision

Experimental Results

- ## Robustness to Image Segmentation

Performance with respect to Segmentation–related Uncertainties

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 form segmentation

- Utilizing location information

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