An Efficient and Effective Region-based Image Retrieval Framework

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Outline

- Content-based image retrieval
- Region-based image retrieval
- Overview of our framework
- Technologies
  - Image representation;
  - Indexing techniques;
  - Learning techniques
- Experiments

Content-based Image Retrieval

- Motivation
  - Text-based image retrieval
    - Manual annotation is a tedious task.
    - “An image is worth a thousand words”
    - Some visual contents are difficult to describe
- Goal
  - Retrieve images based on their *content*
  - What is content:
    - Automatically extracted visual features.
    - Color, texture, shape and so on.
  - Query by an example image or sketch

Content-based Image Retrieval

- Challenges
  - High dimensionality of features
    - Dimension of color histogram > 100;
    - Storage and indexing.
  - Gap between features and semantics.
    - Similar features might represent different semantic concepts;
    - Images of similar semantics might have very different features.



Content-based Image Retrieval

Content-based Image Retrieval

- To shorten or bridge the gap
  - Relevance feedback
    - Originally developed for text retrieval
    - Supervised active learning technique.

  - Better representation
    - Region-based representation.

Region-based Image Retrieval (RBIR)

- Motivation
  - Global representation vs. region representation;
  - Represent and retrieve images at the granularity of region (Object in ideal case);
  - Perception of human visual system.
- Typical RBIR systems
  - Netra (UCSB)
  - Blobworld (Berkeley)
  - Walrus (Bell-lab)
  - SIMPLIcity (Stanford)

Key Issues

- Image similarity measure
  - Region-to-region (Blobworld, Netra)
    - Sensitive to image segmentation;
  - Image-to-image (SIMPLIcity, Walrus)
    - All the regions;
    - Importance of regions is area percentage.
  - Our solution
    - Earth Mover's Distance (EMD);
    - The importance of regions is learned from user's feedback.

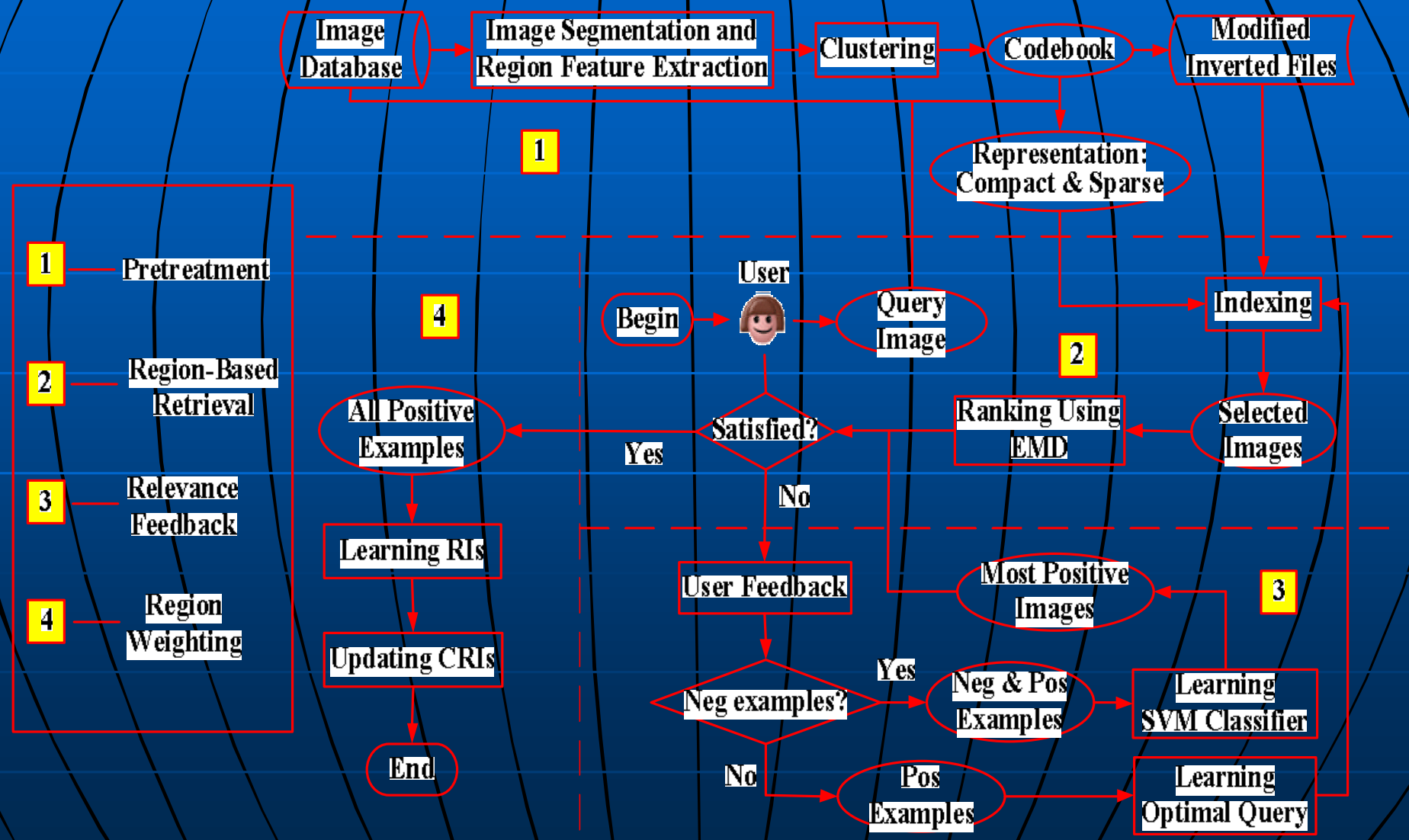
Key Issues (Cont.)

- Efficiency issues
  - Storage
  - Indexing
    - Tree structure: R*-tree (Walrus);
    - Clustering techniques: SIMPLIcity & Netra.
  - Our solution
    - Region codebook (storage);
    - Inverted files (Indexing).

Key Issues (Cont.)

- Relevance feedback
  - Global feature-based RF is fruitful.
  - Little attention for region-based RF;
  - Our solution
    - Query Point Movement;
    - Support Vector Machines;
    - Region importance learning.

Overview Of The Framework



Pretreatment

- Image segmentation
  - HSEG (region growing).
    - Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "Unsupervised Image Segmentation Using Local Homogeneity Analysis", Proc. IEEE International Symposium on Circuits and Systems, 2003.
- Region representation:
  - Low-level visual feature:
    - Color moments
      - CIE Luv color space
      - Three scales of moments (9)
    - Any other feature is available.
  - Importance (weight)
    - Constraint: sum be 1.

Pretreatment (Cont.)

- Region codebook design:
  - K-Means;
  - Regions of all the images in the database
  - The size of the codebook (K);
  - Codeword properties:
    - The center;
    - Indexing structure (modified inverted file).

Pretreatment (Cont.)

Examples of the Codewords

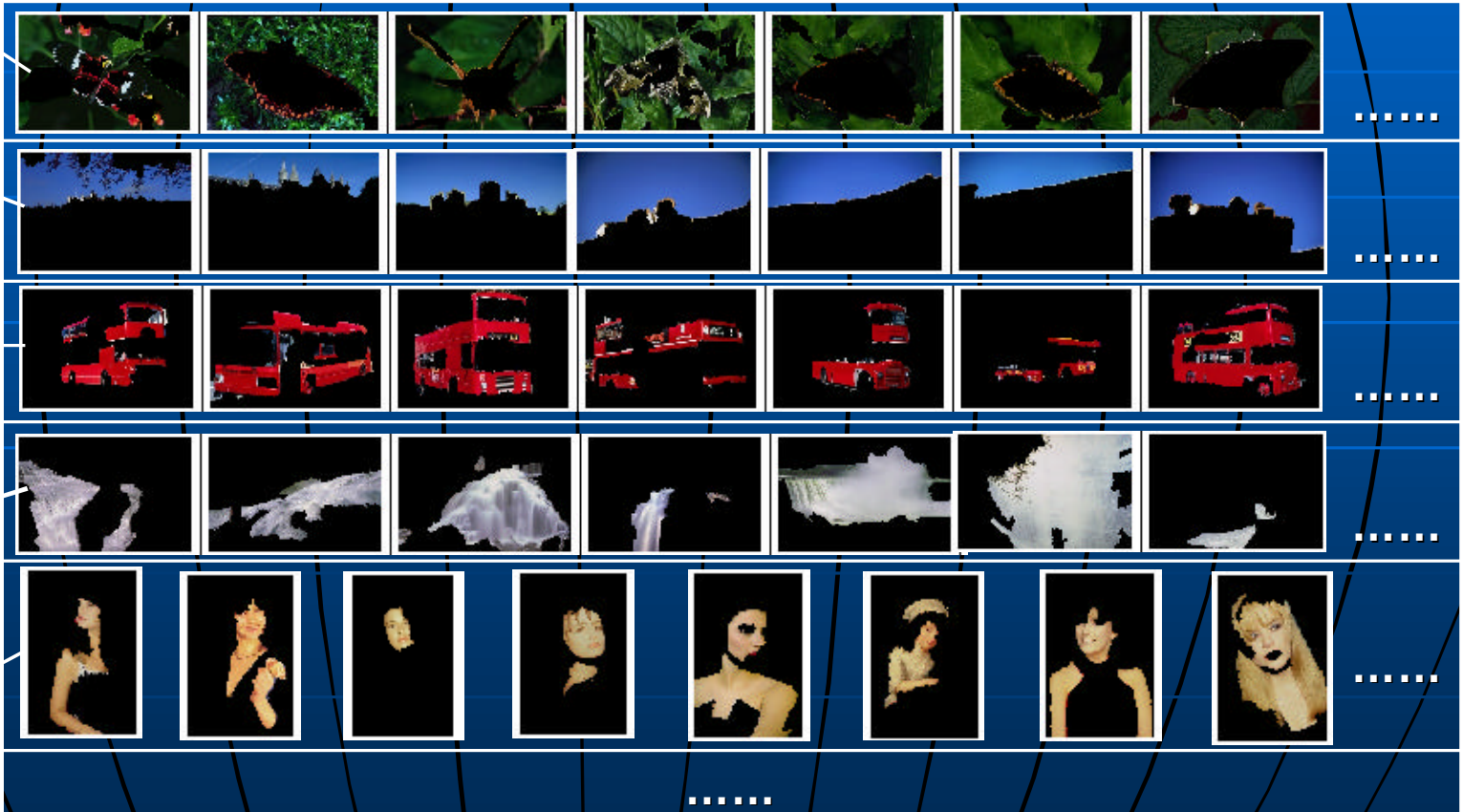


Image Representation

- Image encoding:
  - Low level feature ⟶ codeword index
- Compact Representation:
  - A region set;
- Sparse (Vector) Representation:
  - A N dimensional vector;
  - N is the number of the codewords;
  - Number of regions vs. number of codewords.

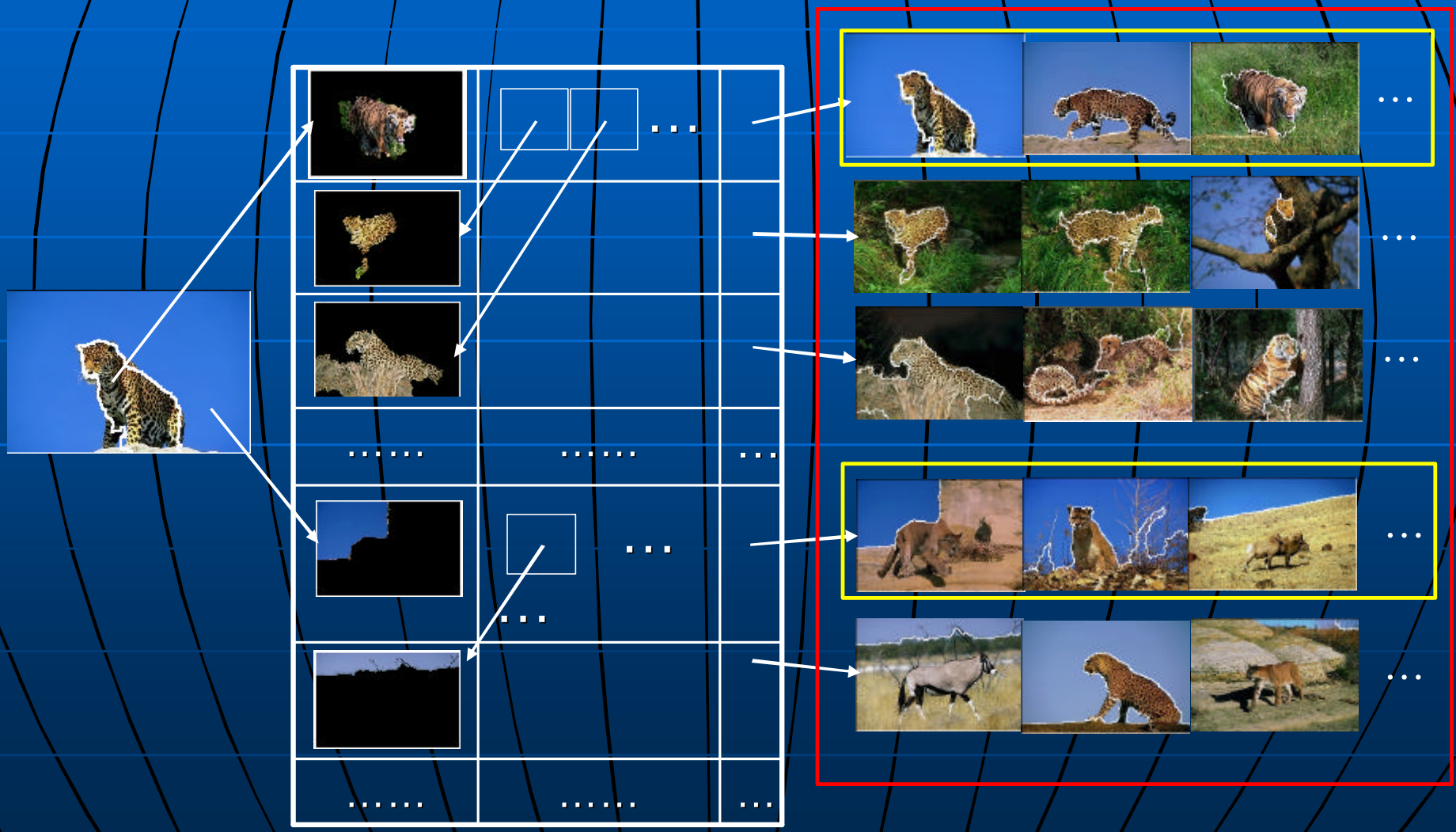
Image Similarity Measure

- Compact representation
- Earth Mover's Distance (EMD)
  - Originally introduced as a flexible similarity measure between multidimensional distributions;
  - Based on the minimal cost that must be paid to transform one distribution into another;
  - Matches perceptual similarity well;
  - Can operate on variable-length representations.
  - Rubner, Y., et.al "A Metric for Distributions with Applications to Image Databases." Proc. Of IEEE International Conference on Computer Vision, January 1998.

Indexing Using Modified Inverted Files

- Tree structures:
  - Curse of dimensionality;
  - The performance of R*-trees degrades by a factor of 12 as the number of dimensions increases from 5 to 10.
- Inverted Files (IF):
  - Widely used in text retrieval community;
  - The IF of a codeword are the IDs of the images contain it.
  - Indexing using IF
    - Find out the images within at least one of the IF of the query's codewords;
    - Only sort these images with other images neglected

Indexing Using Modified Inverted Files (Cont.)



Indexing Using Modified Inverted Files (Cont.)

- Modified Inverted Files:
  - Expand codewords according to importance.
  - Expand $\lfloor w \cdot k \rfloor$ codewords to a region with importance *w.*
  - The upper bound *k* is 10 currently.

Relevance Feedback

- Query Point Movement (QPM):
  - Only positive examples.
  - Vector representation;
  - Optimal query:

$$\vec{I}_{opt} = \sum_{k=1}^{n} \vec{I}_k \Big/ n$$

  - Indexing using modified IFs.

Relevance Feedback

- Support Vector Machine (SVM)
  - Both negative and positive examples;
  - Classification problem;
  - A classifier that separates positive examples from negative ones.
  - Compact representation;
  - Why SVM
    - strong theoretical foundations
    - excellent empirical successes

Relevance Feedback (Cont.)

- New Kernel
  - Motivation:
    - Common kernels (Gaussian) depend on L_p norm or inner product in the input space.
  - Generalized Gaussian kernel:

$$k_{GGaussian}(x, y) = \exp(-d(x, y)/2s^2)$$

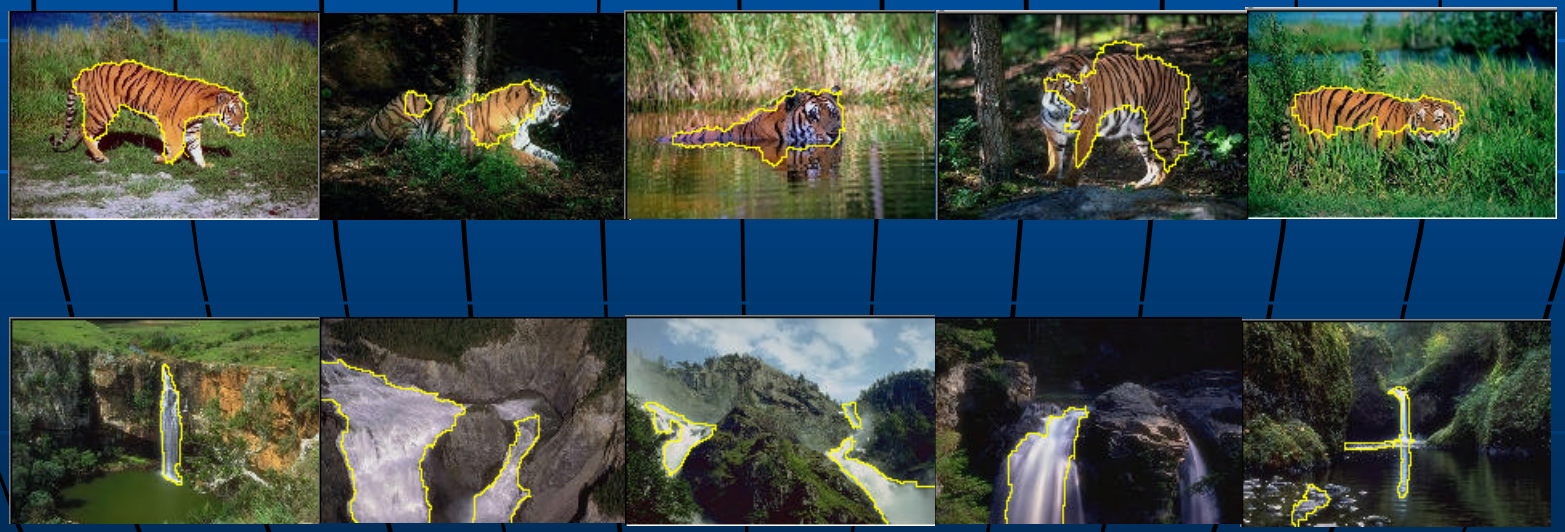
d is a distance measure in the input space

  - EMD-based kernel:

$$k_{GEMD}(x, y) = \exp(-EMD(x, y)/2s^2)$$

Region Importance Learning

- Basic assumption: Important regions should appear more times in the positive images.



Region Importance Learning (Cont.)

- Some definitions:
  - Region R_i is similar to region R_j, if $d(R_i, R_j) < e$,
  - $s(R, I) = \begin{cases} 1, \text{if one region of image } I \text{ is similar to } R \\ 0, \text{otherwise} \end{cases}$
  - Region Frequency (RF): $RF_i = \sum_{j=1}^{n^+} s(R_i, I_j^+)$
  - Inverse Image Frequency (IIF):

$$IIF_i = \log(N / \sum_{j=1}^{N} s(R_i, I_j))$$

Region Importance Learning (Cont.)

- Region Importance (*RI*):

$$RI_i = \frac{RF_i * IIF_i}{\sum_{j=1}^{n} (RF_j * IIF_j)}$$

the *RI* of all the positive images can be learned.

Cumulate Region Importance

- Why to cumulate?
  - The region importance (*RI*) is similar to common users.
  - The feedback information from users is often incomplete.
  - The accumulation can make the *RI* more robust and meaningful.

Cumulate Region Importance (Cont.)

- How to cumulate?
  - The cumulated importance of region after *l* (>0) updates is:

$$CRI_i(l) = \frac{CRI_i(l-1)\cdot(l-1) + RI_i}{l}$$

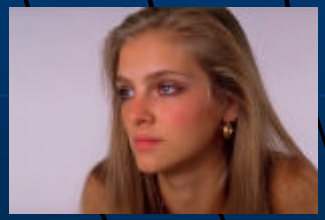
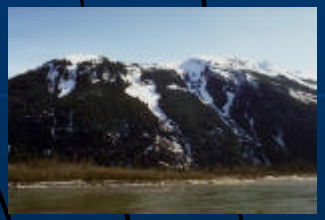
  - RI_i is the latest *RI*.
  - $CRI_i(0)$ is initialized to be area percentage .
  - Once updated, area percentage is ignored.

Experimental setup

- Image DB size: 10,000 (from Corel)
- Query number: 200 (10 categories with each 20 queries)
- Test categories:



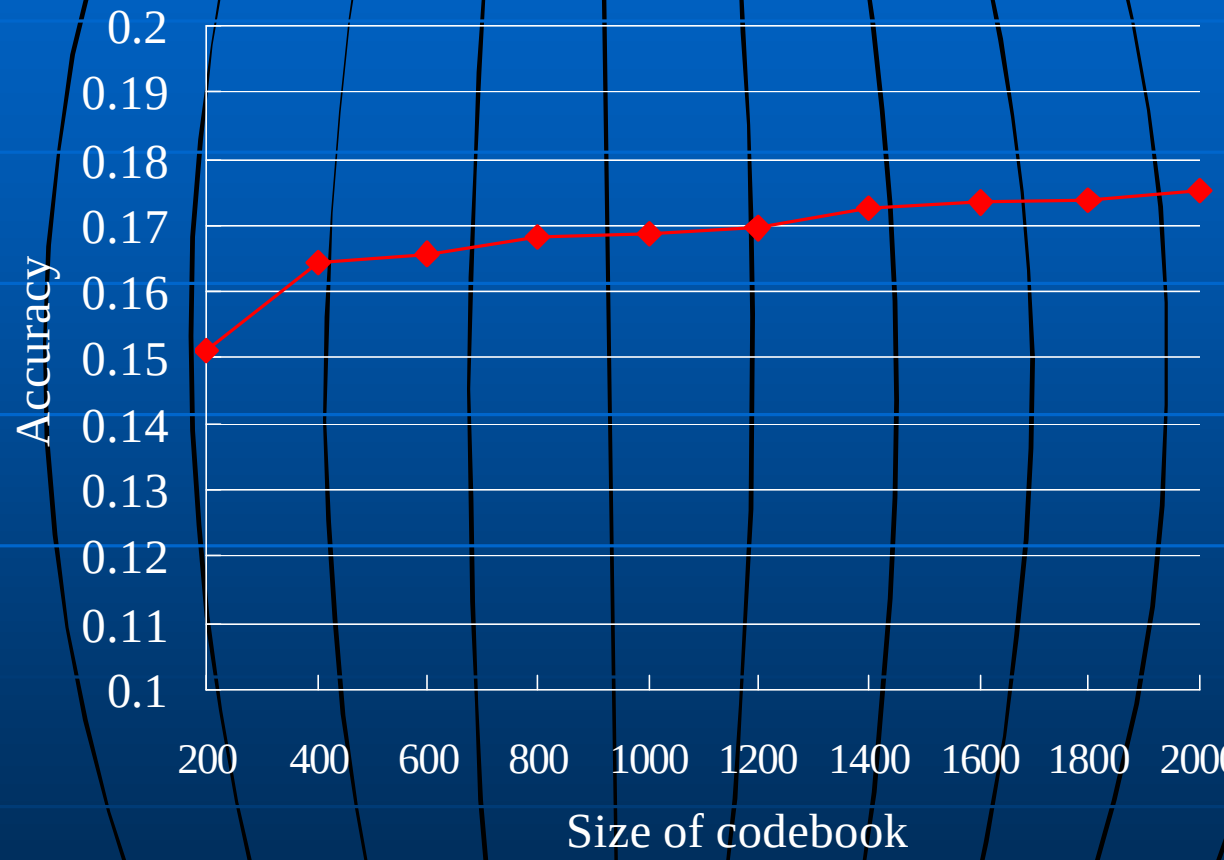



Experimental setup

- For each of the query images, 5 iterations of user-and-system interaction were carried out.
- At each round of feedback, the system examined the top 30 images.
- When the top *N* images are considered and there are *R* relevant images, the precision within top *N* images is defined to be $P(N) = R / N$.
- Accuracy = the average precision within top 50 images, i.e. average P(50).

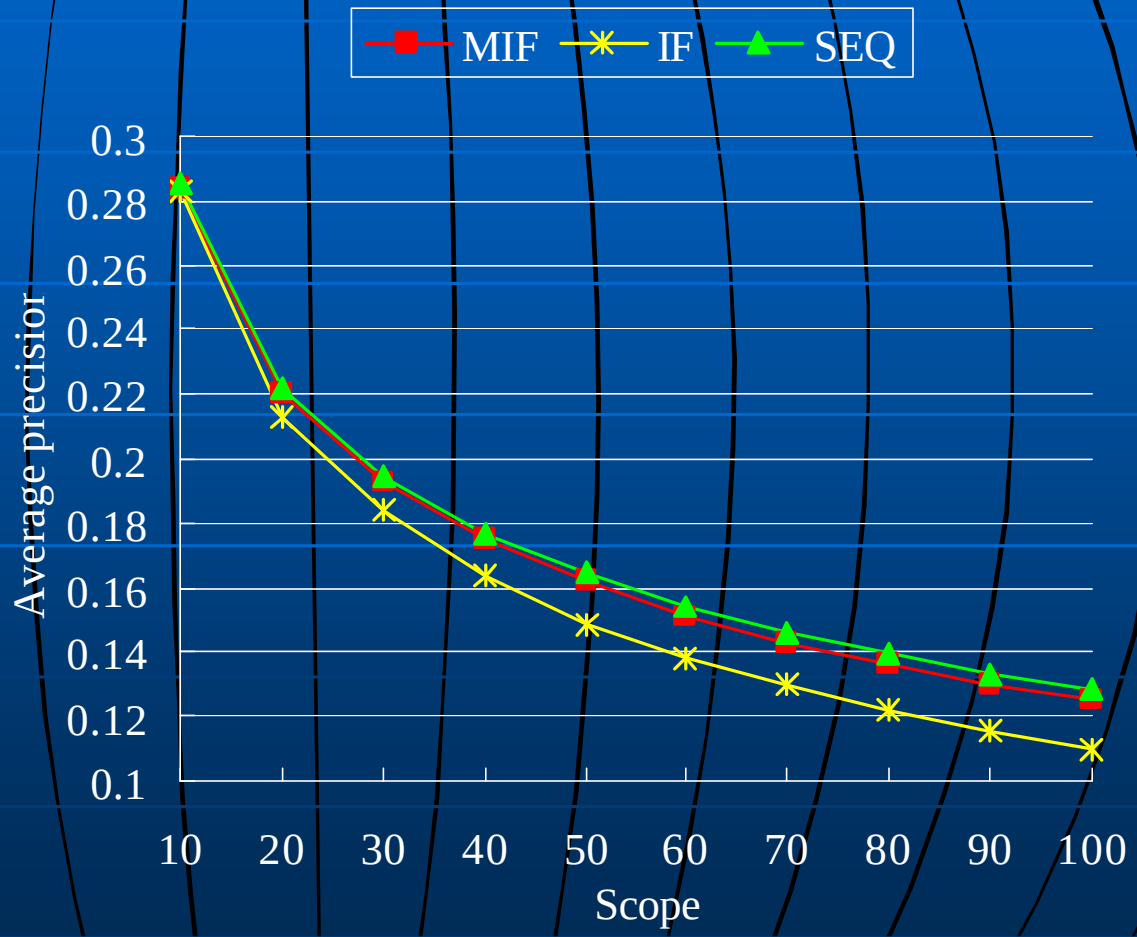
Size of the codebook



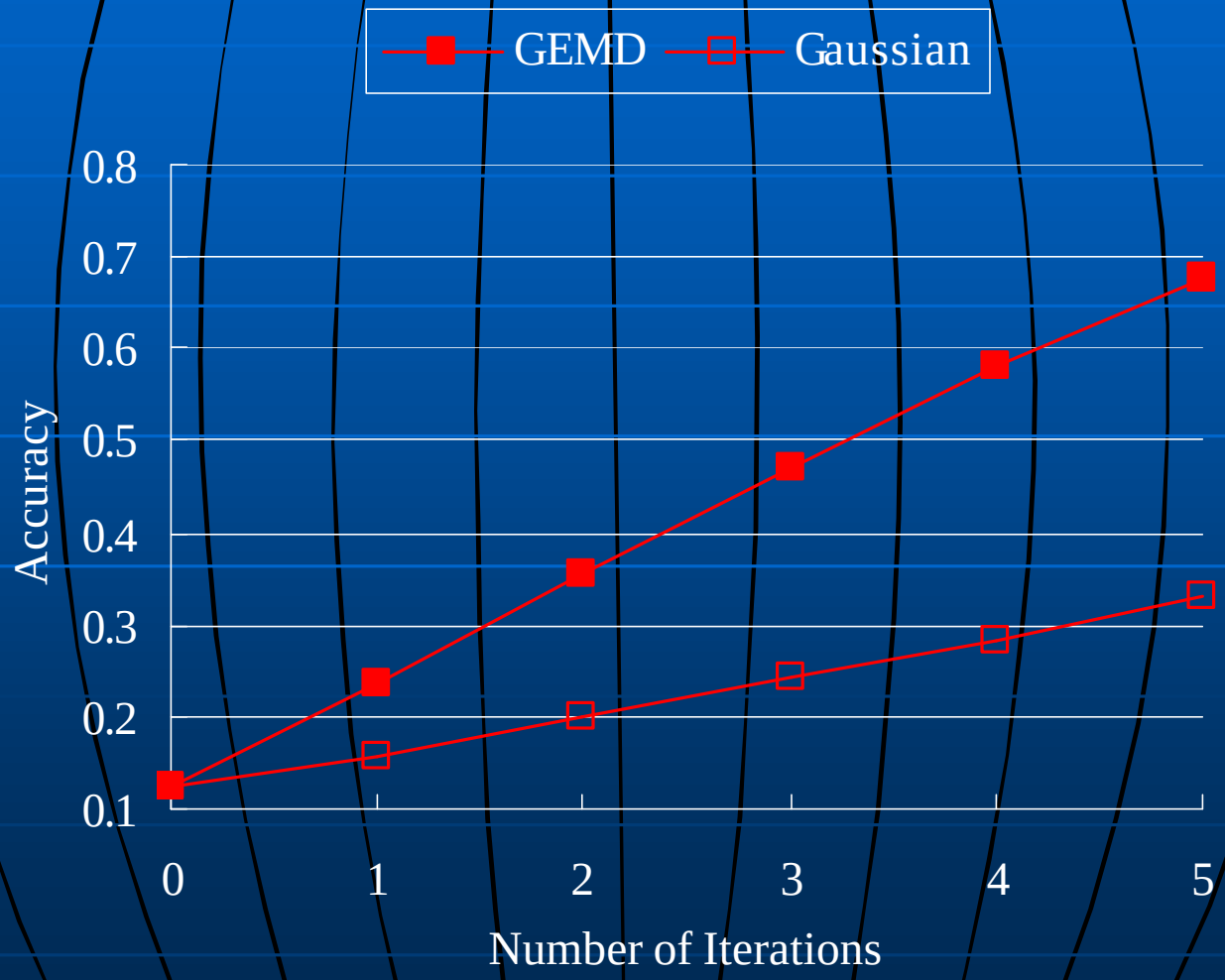
We use 400 (the first turning point) as the size of the codebook

Indexing Evaluation

	Search Time
SEQ	351 ms
IF	70 ms
MIF	91 ms

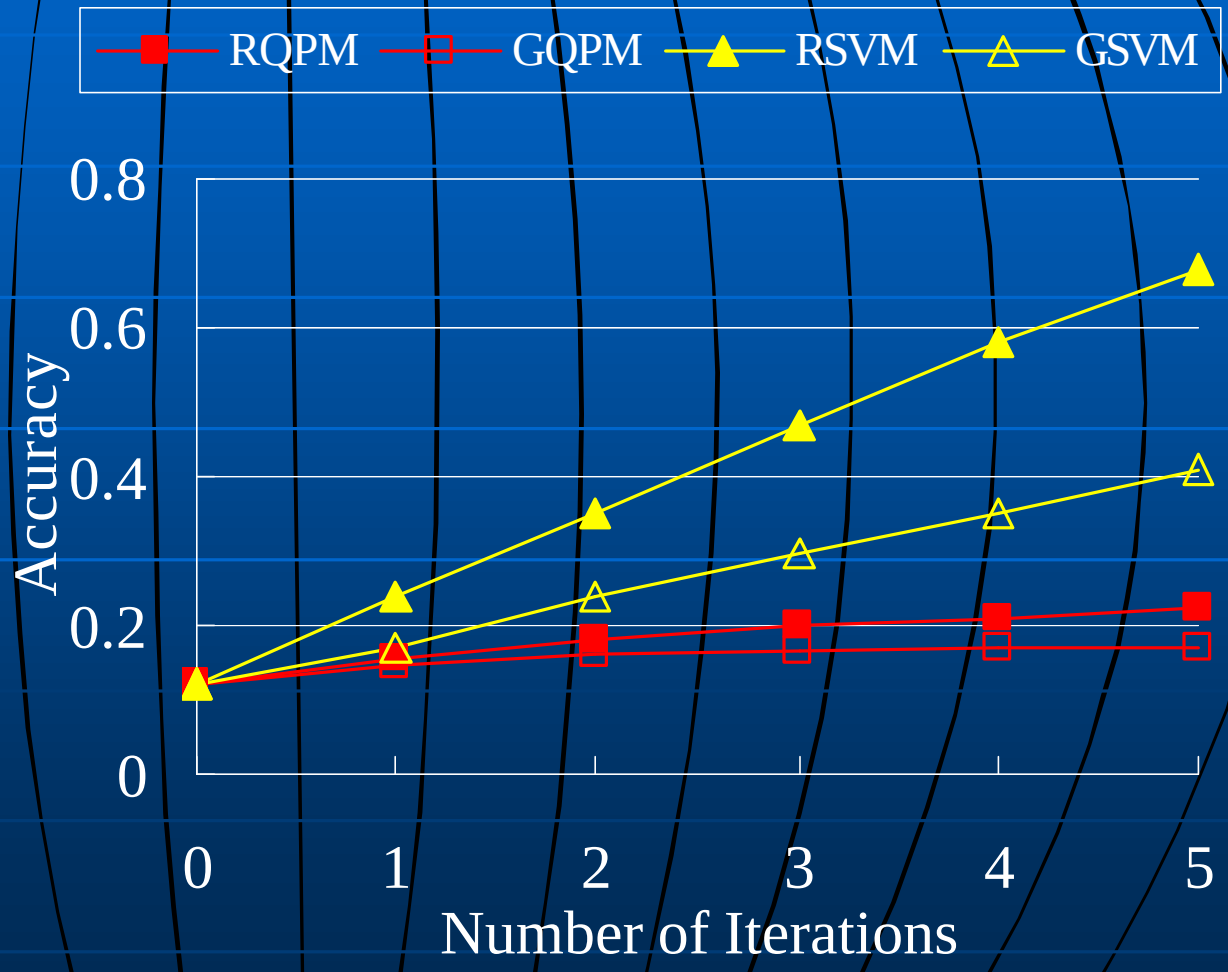


Kernel Evaluation



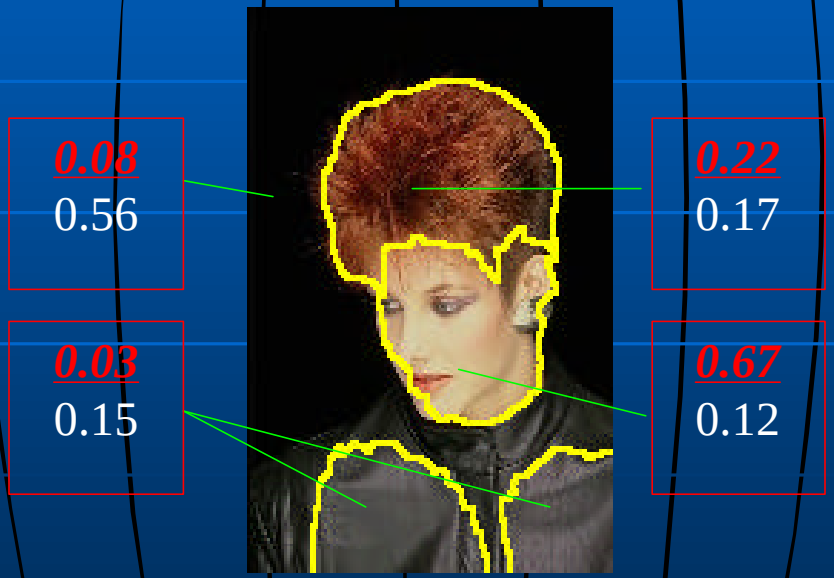
Relevance Feedback Evaluation

- No RF in most of the existing RBIR systems
- Same color moment feature
- Performance of SVM is better
- The speed of QPM is fast



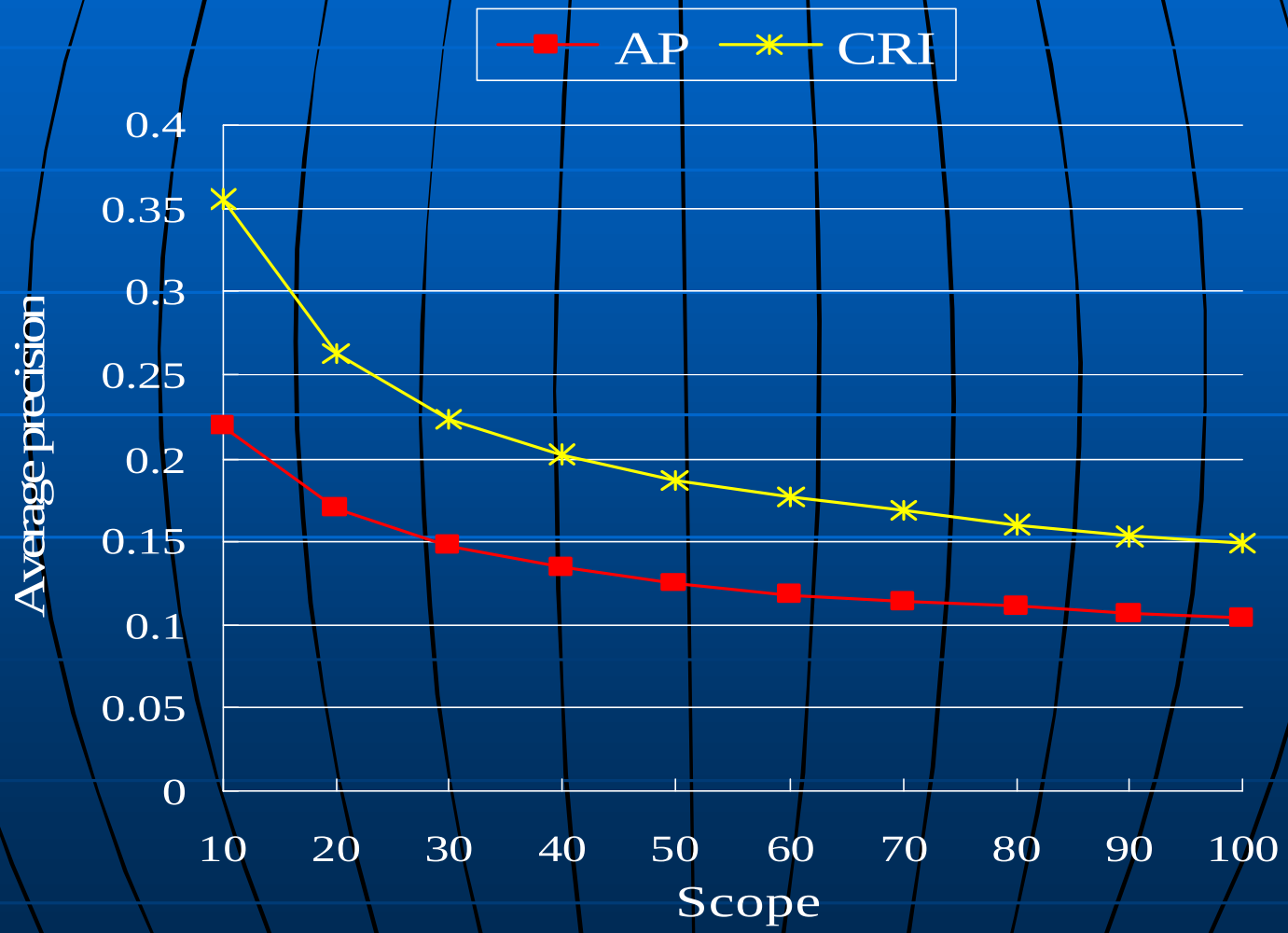
Region Weighting Evaluation

- To learn the CRIs, 10,000 random query and feedback sessions were carried out.
- An example:

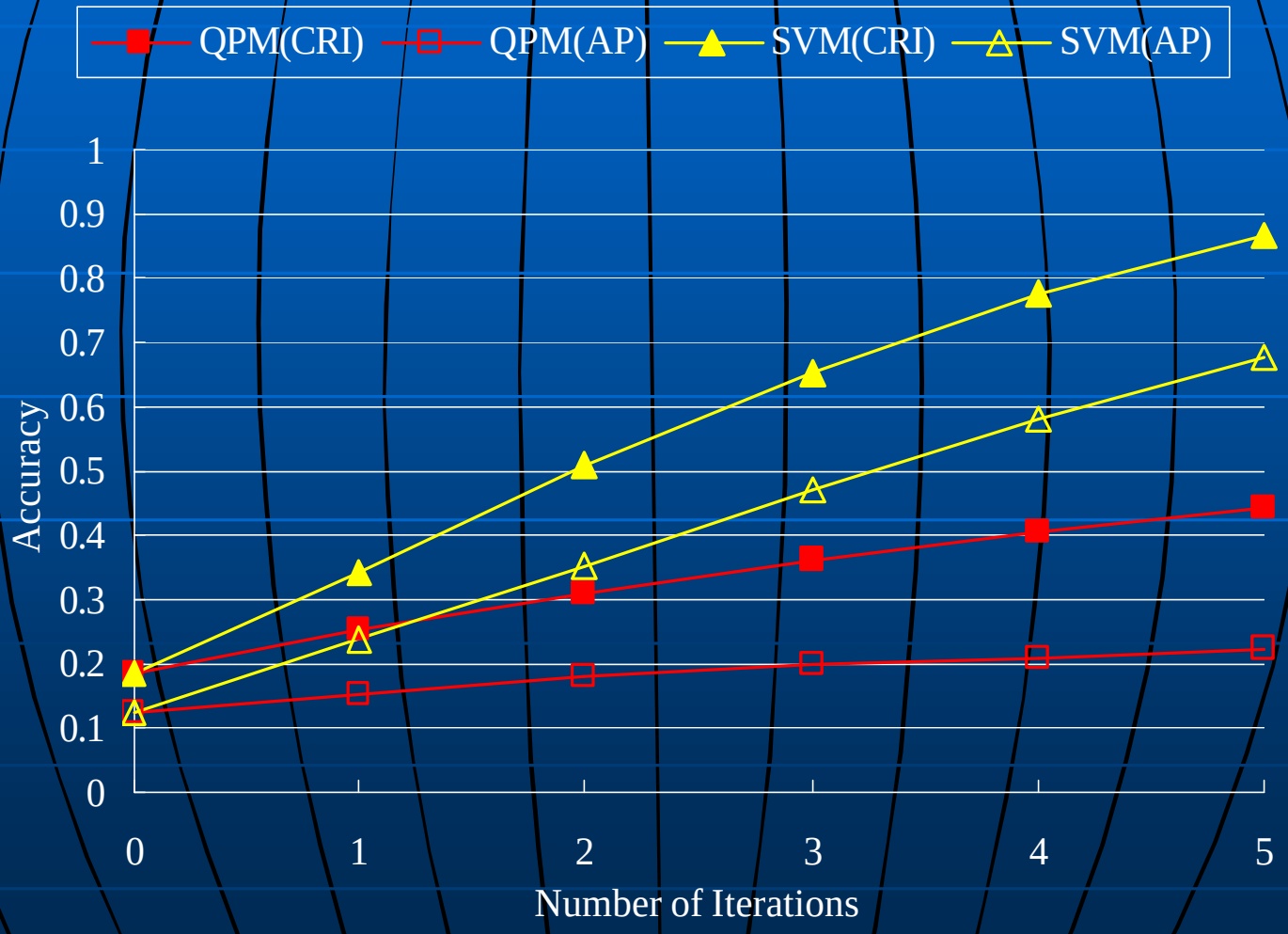


Cumulated region importance (red and italic) and area percentage of the regions of an image.

Region Weighting Evaluation



Region Weighting Evaluation



Conclusions

- Region codebook
  - Save storage;
  - Facilitate indexing and relevance feedback.
- Modified inverted files
  - Save retrieval time.
- Relevance feedback
  - Query point movement;
  - Support Vector Machines.
- Region importance learning
  - Reasonable, reflects semantic importance;
  - Cumulated for future use.

Related Publications

- Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "An Efficient and Effective Region-based Image Retrieval Framework", to appear in IEEE Transaction on Image Processing.
- Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "Support Vector Machines for Region-Based Image Retrieval", Proc. IEEE International Conference on Multimedia & Expo, 2003.
- Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "An Effective Region-based Image Retrieval Framework", Proc. ACM Multimedia, 2002.
- Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "Learning Region Weighting from Relevance Feedback in Image Retrieval", Proc. IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2002.
- Feng Jing, Mingjing Li, Hong-Jiang Zhang, Bo Zhang, "Region-based relevance feedback in image retrieval", Proc. IEEE International Symposium on Circuits and Systems, 2002.

Q&A

http://scenery.nease.net

Thanks !