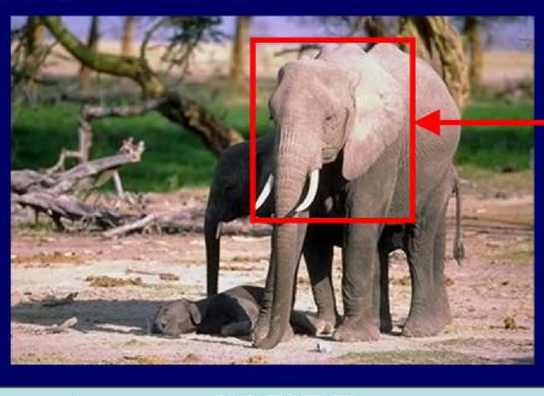
Acceleration of similarity-based partial image retrieval using multistage vector quantization

Akisato Kimura, Takahito Kawanishi, and Kunio Kashino
NTT Communication Science Laboratories, NTT Corporation, Japan
Contact address: akisato@eye.brl.ntt.co.jp

SUMMARY

As an important component of region-based image retrieval, we propose a new method for similarity-based partial image retrieval called **SPIRE**.



Query image

Database image

Advantages of SPIRE

Basic concept (Presented at ICME2004 [4])

- Reduce storage space for indexes to as little as 1/250 by extracting image portions sparsely
- Theoretically guarantee to provide the same search results as exhaustive matching by setting margins appropriately

Acceleration techniques (Current proposal)

- Reduce the amount of calculation by introducing multistage vector quantization (VQ)

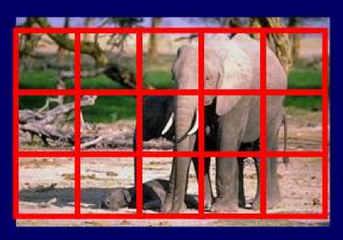
BACKGROUND

CBIR (Content-Based Image Retrieval)

- **Object-based approach**
  - Most commonly used approach
  - Attempt to decompose an image into individual objects
  - Provide the decomposed objects with indexes or keywords

Problem
Needs domain-specific constraints to improve accuracy when decomposing objects

- **Region-based approach**
  - Divide images into partial images without finding individual objects or considering their positions
  - Determine similarities between whole images based on partial similarities between images



Problem
Requires a huge amount of calculation and storage space to maintain retrieval accuracy

WHAT'S THE SPIRE?

Basic Concept

- Extend the indexing algorithm of the fast matching methods to time-series signals [1] [2]
- Greatly reduce the size of indexes while theoretically guaranteeing that it provides the same search results as exhaustive matching

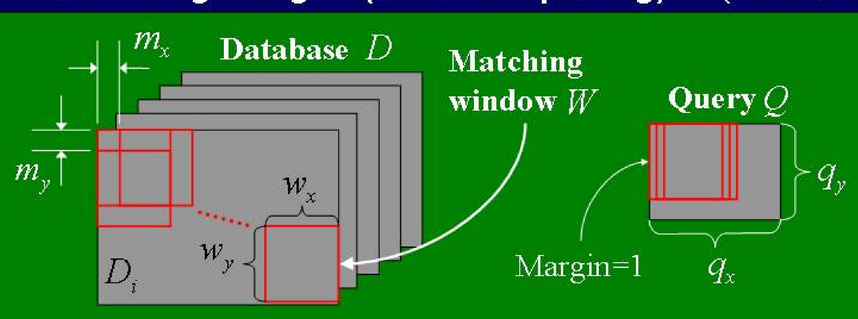
- Extract image portions **sparsely** for each image of a **database**
- Extract image portions from a **query** by using a **sliding** window

Acceleration Techniques (Proposed method)

- Multistage VQ = **block VQ** (quantization) + **feature VQ** (classification)
- Reduce the computational cost while maintaining search accuracy
- Search results not always the same as those obtained without multistage VQ

- **Block feature quantization** accelerates matching calculation
- **Global feature clustering** reduces the number of matching calculation

Determining margin (window spacing) (See also [4])

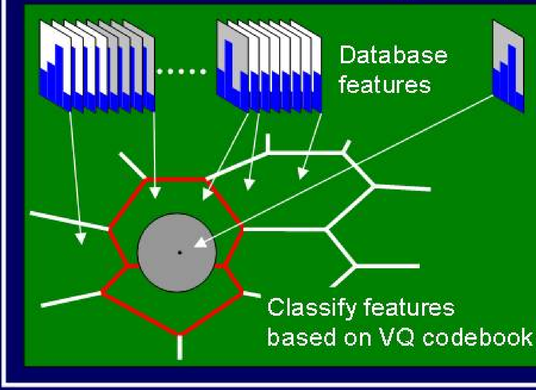


Required constraints to avoid false dismissals

$$q_x \geq w_x + m_x, \quad q_y \geq w_y + m_y$$

m_x, m_y : larger → w_x, w_y : small → false alarm : increasing
w_x, w_y : larger → m_x, m_y : small → index size : increasing

Feature VQ : indexing and pruning (See also [3])



Pruning condition

$$d_\theta = \frac{d_{Q2}^2 - d_{Q1}^2}{d_{12}} \leq \hat{\theta}$$

d_{Q1} Distance between query and initial cluster
d_{Q2} Distance between query and another cluster
d_{12} Distance between clusters

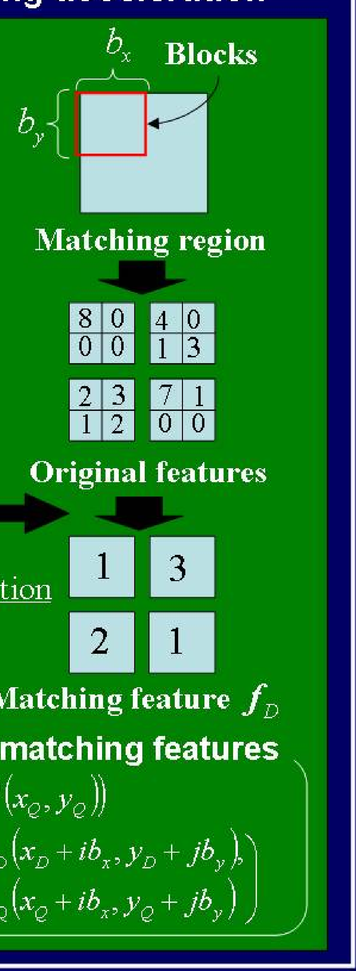
Preprocessing

Extract block features from each image of a database
→ Extract matching features from a matching database window
→ Index and store matching features

Retrieving

Extract matching features from a query
→ Extract matching features from a matching window of a query
→ Find sets of candidate image portions
→ Verify candidate image portions

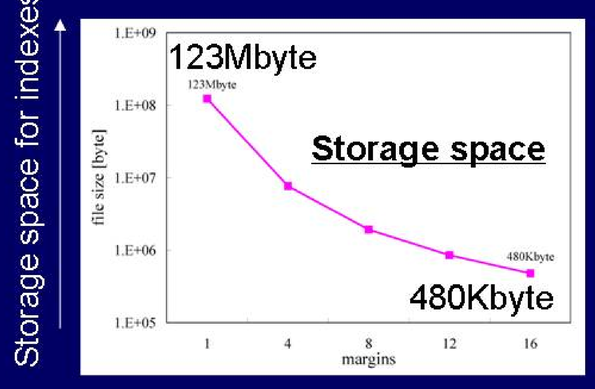
Block VQ : matching acceleration

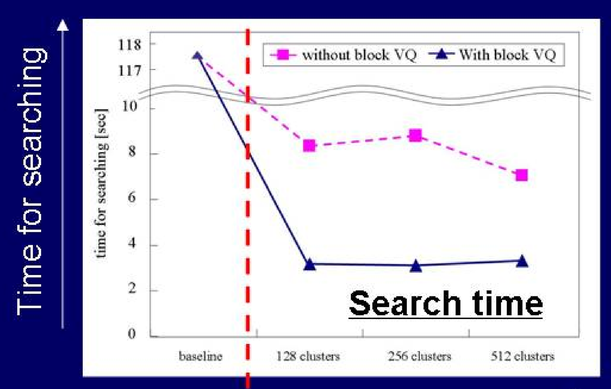


Distances between matching features

$$d\left(f_D^{(W)}(x_D, y_D), f_Q^{(W)}(x_Q, y_Q)\right) \overset{\text{def}}{=} \sum_{i=0}^{w_x/b_x-1} \sum_{j=0}^{w_y/b_y-1} d\left(\begin{matrix}\text{idx}_D(x_D + ib_x, y_D + jb_y), \\ \text{idx}_Q(x_Q + ib_x, y_Q + jb_y)\end{matrix}\right)$$

EXPERIMENTS





Conditions of experiments

- PC : CPU = Intel Pentium4 2.8GHz, RAM = 2.0Gbyte, OS=RedHat9.0
- Database : real-life image data set from Pennsylvania State Univ. [5,6] (1000 images, 384x256 pixels)
- Query : extracted from database (10 images, 80x80 pixels)
- Size of matching window : 64x64 pixels
- Features : DCT coefficients

References

[1] Y.Moon et al. "Duality-based subsequence matching in time-series signals", Proc. of ICDE, 2001
[2] Y.Moon et al. "GeneralMatch: A subsequence matching method in time-series signals based on generalized windows", Proc. of ACM SIGMOD, 2002
[3] A.Kimura et al. "A quick search method for multimedia signals using global pruning", Systems and Computers in Japan, Vol.34, No.13, 2003.
[4] A.Kimura et al. "Similarity-based partial image retrieval guaranteeing same accuracy as exhaustive matching", Proc. of ICME, 2004
[5] "Test image database used in SIMPLIcity paper", *http://wang/ist.psu.edu/IMAGE/*
[6] J.Z.Wang et al. "SIMPLIcity: Semantics-sensitive integrated matching for picture libraries", IEEE Trans. PAMI, Vol.23, No.9, pp.947-963, 2001