Web-Scale Image Databases and Their Applications

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Web-Scale Visual Data and Novel Applications

- Visual data are widely used for various communication and, and are more widely consumed at Web and mobile devices
  - YouTube, Facebook, Flickr, etc.
- Processing them requires scalable algorithms
- Web-scale visual data can enable new applications
- Examples
  - Photo tourism
  - Scene completion
  - Image-retrieval based image watermarking
  - Interactive content-aware zooming

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Outline

- **Image Retrieval based Image Watermarking for Large-Scale Image Databases**
- **Scene Completion using Millions of Photographs**
- **Photo Tourism**
- **Conclusions**

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Image Retrieval

- **At pre-processing, build an database for efficient retrieval at runtime**

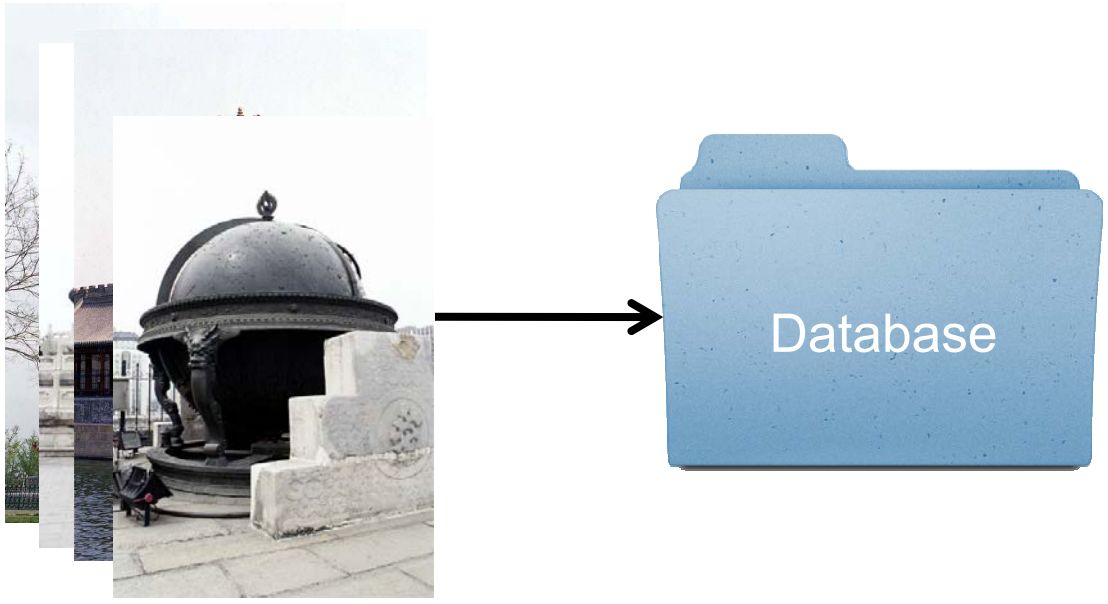
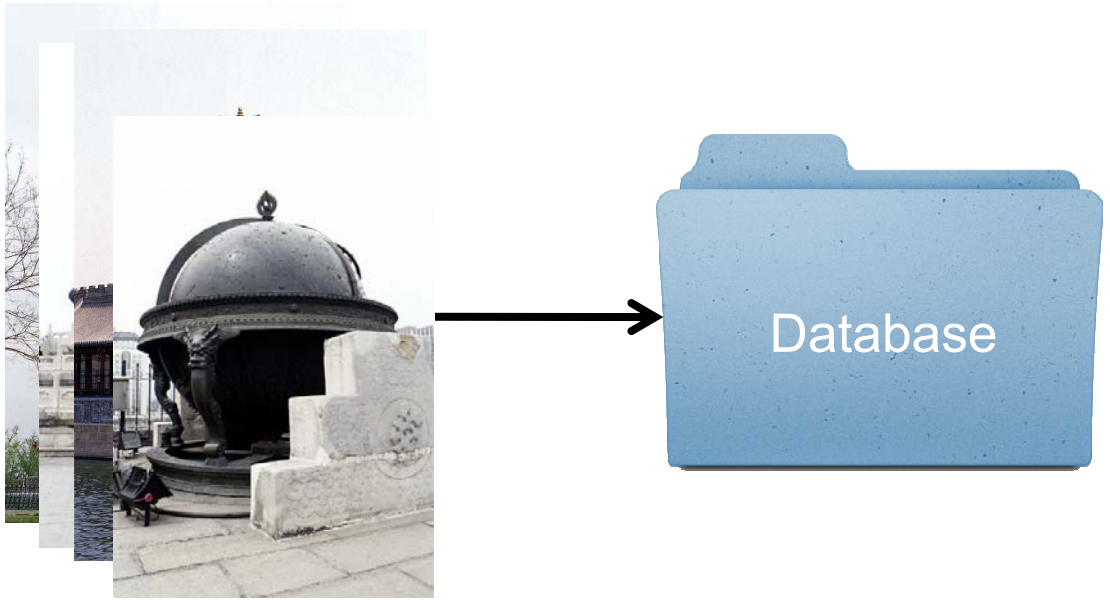


Image Retrieval

- **At pre-processing, build an database for efficient retrieval at runtime**



kd-trees or
Hashing

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Image Retrieval: Runtime Procedure

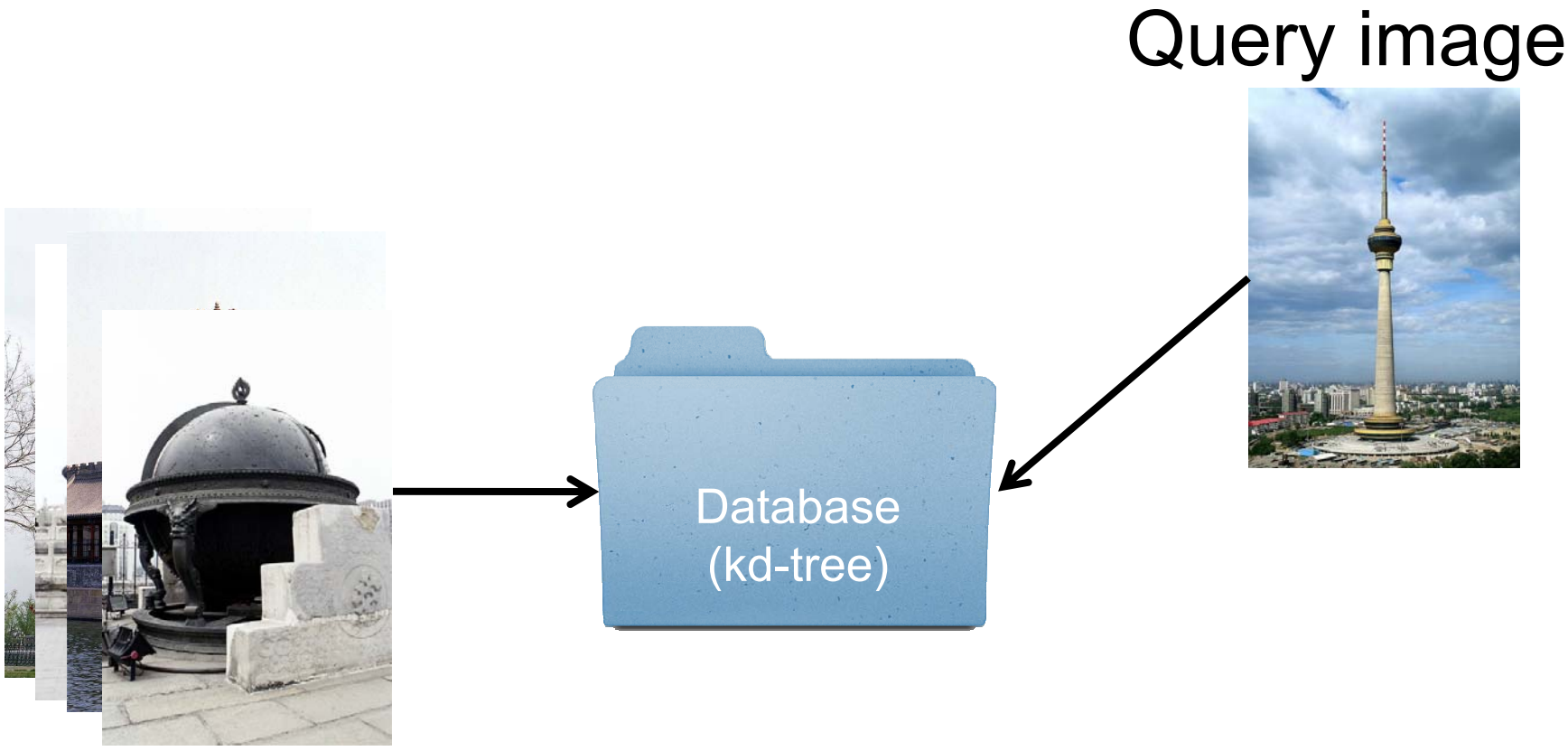
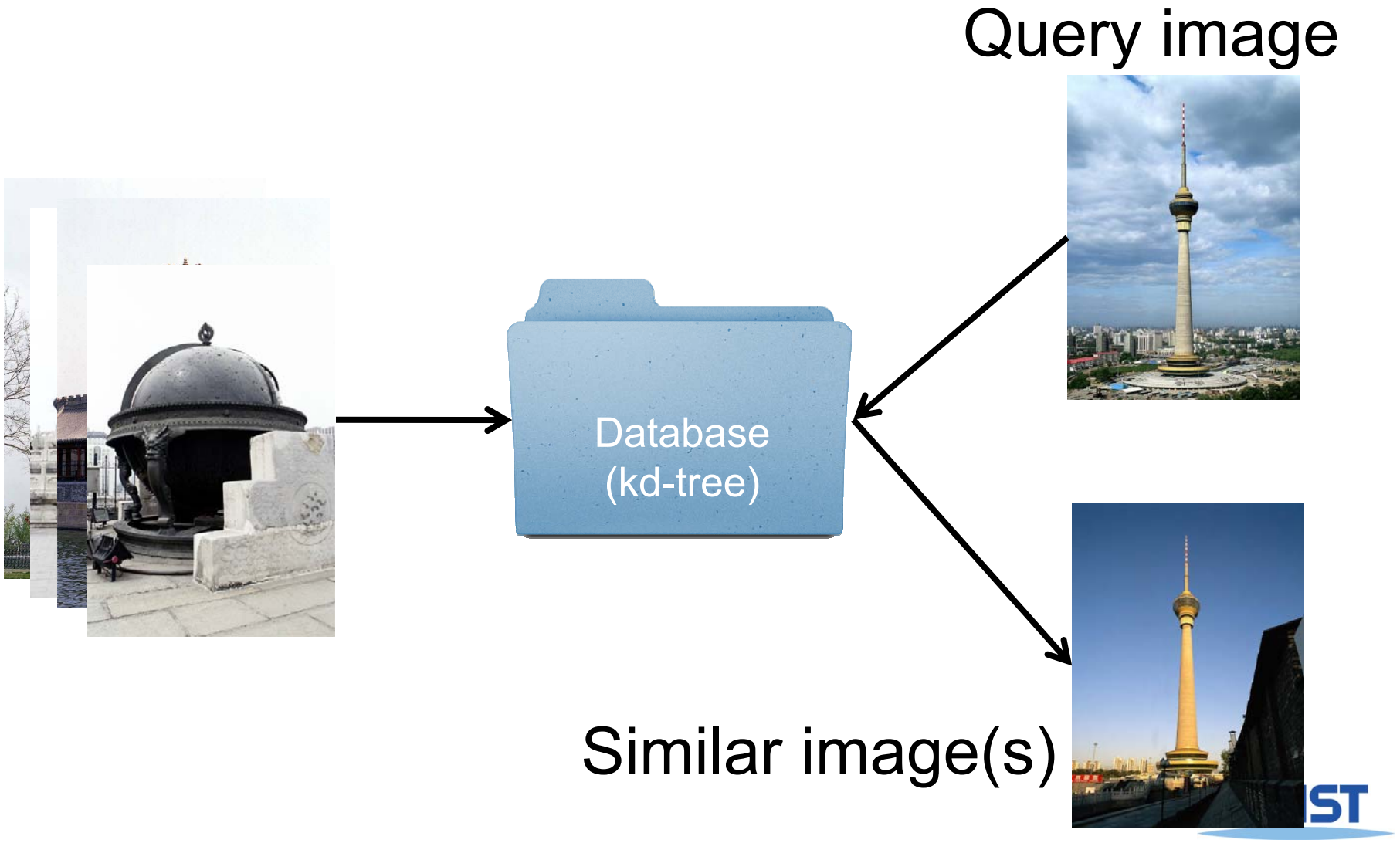


Image Retrieval: Runtime Procedure



Issues of Image-Retrieval for Web-Scale Image Databases

- Accuracy issues
- Memory issues
  - The state-of-the-art techniques can handle about 10M images in a commodity hardware
- Handling dynamic databases of images
  - Not much work on efficient handling data databases
- Copyright violations of images
  - IRIW: Image Retrieval based Image Watermarking for Large-Scale Image Databases, JongYun Jun, et al., KAIST Tech. Report

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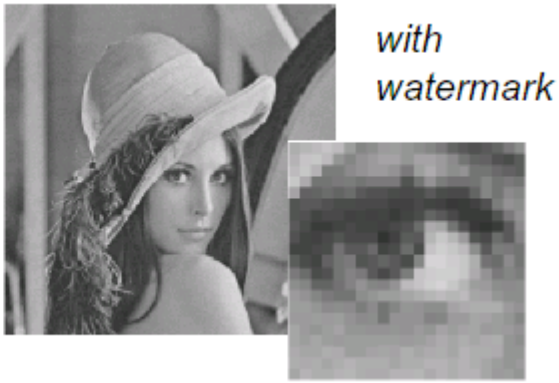
Introduction

Watermarking

- ***A process that embeds data, called watermark***
  - **Watermark is integrated into the content itself**
  - **Requires no additional file header**
  - **Resist on conversion of data format**



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Motivation

- **Problem**
  - **How to find unauthorized image usages?**

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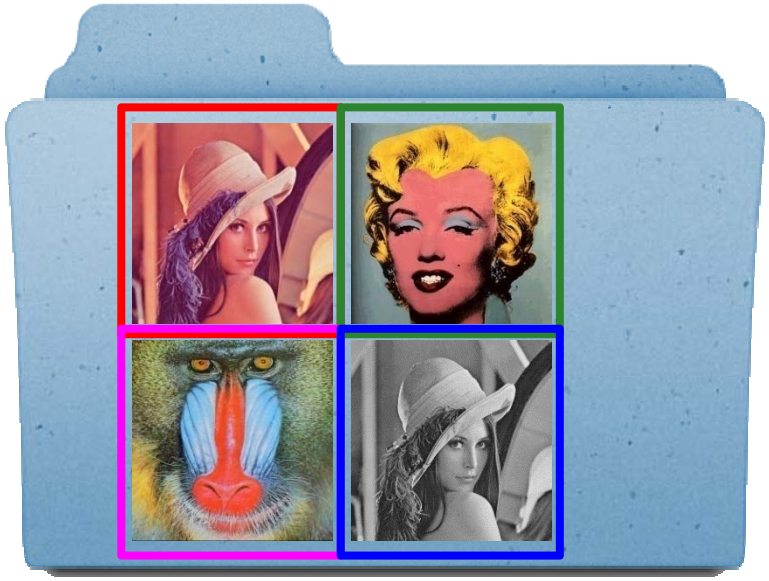
Possible Approach

- **Exhaustive watermark matching**
  - **Sequential one-to-one comparison**
  - **Time-consuming job**



WM similarity	
99%	detect
25%	
70%	fail
15%	fail

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Goal

- **Identify modified watermarked images in efficient and accurate manner by combining with image retrieval in large-scale database.**

- **Main assumption**
  - **Dissimilar images have less relevance**

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Related Work

- **Image Retrieval**
  - **D. Lowe. Distinctive image features from scale-invariant keypoints. Computer Vision 2004.**
  - **D. Nister and H. Stewenius. Scalable recognition with a vocabulary tree. CVPR 2006.**

- **Image Retrieval with Watermarking**
  - **Lu et al. Image retrieval based on a multipurpose watermarking scheme. KBIIES 2005.**
  - **Xu et al. A new scheme of image retrieval based upon digital watermarking. ISCSCT 2008**

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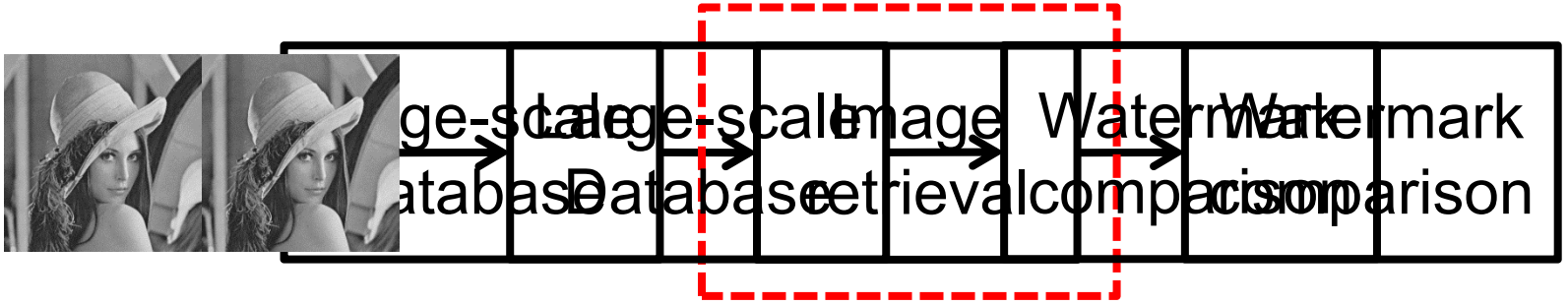
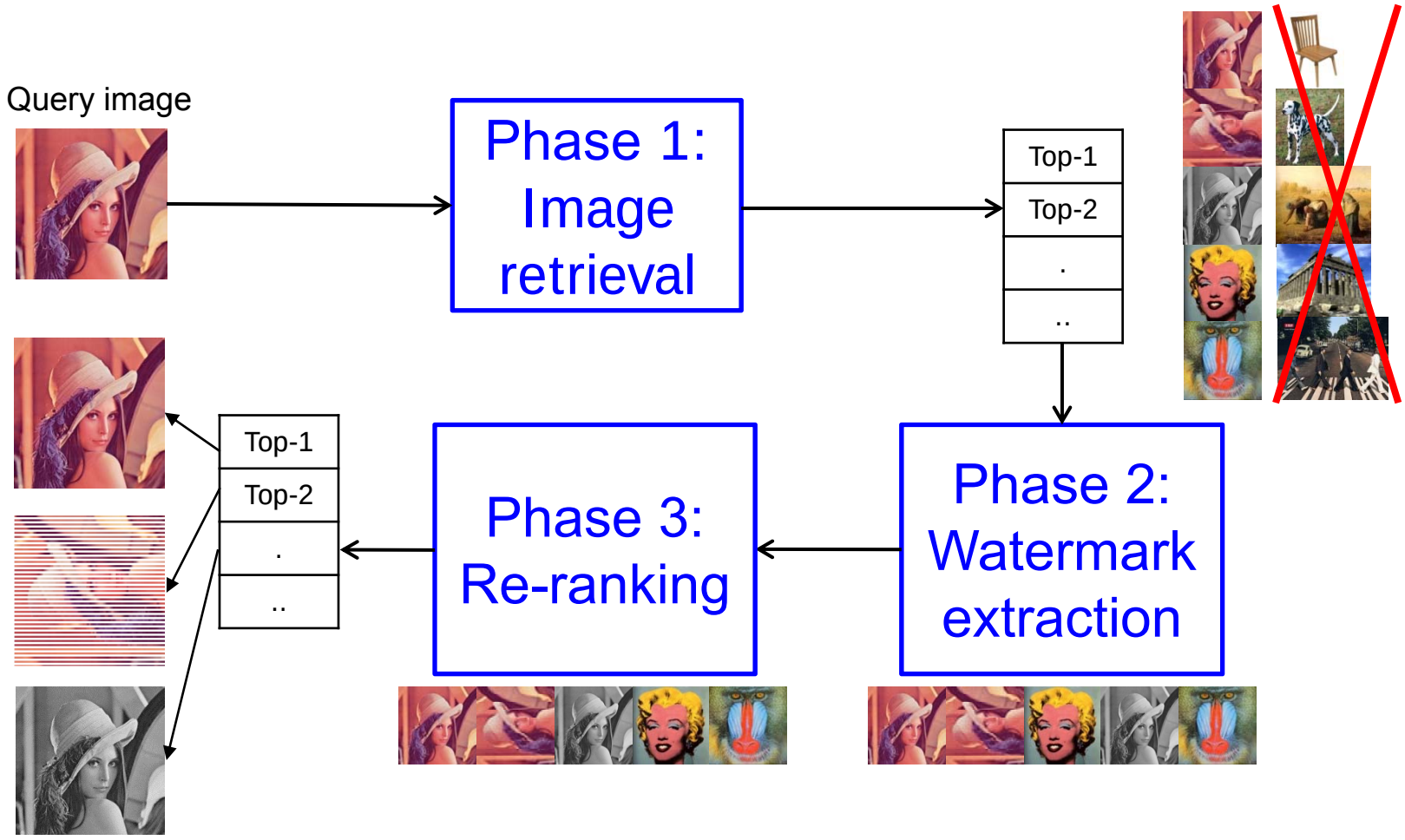
Our Approach

- Exhaustive watermark matching
  - Sequential one-to-one comparison
  - Time-consuming job
- **Image Retrieval based Image watermarking (IRIW)**
  - **Reduce search domain by image search**
  - **Achieve performance enhancement**



Overview


Query image
Phase 1: Image retrieval
Top-1
Top-2
.
..
Phase 2: Watermark extraction
Phase 3: Re-ranking
Top-1
Top-2
.
..

Phase 1 – Image Retrieval

- **Main assumption**
  - **Dissimilar images have less relevance**
- **Performance speed-up**
  - **Compute similar images and cull out others**
- **Accuracy**
  - **Detect severely attacked images even though watermark is removed (false negative)**
  - **Cull out dissimilar images (false positive)**

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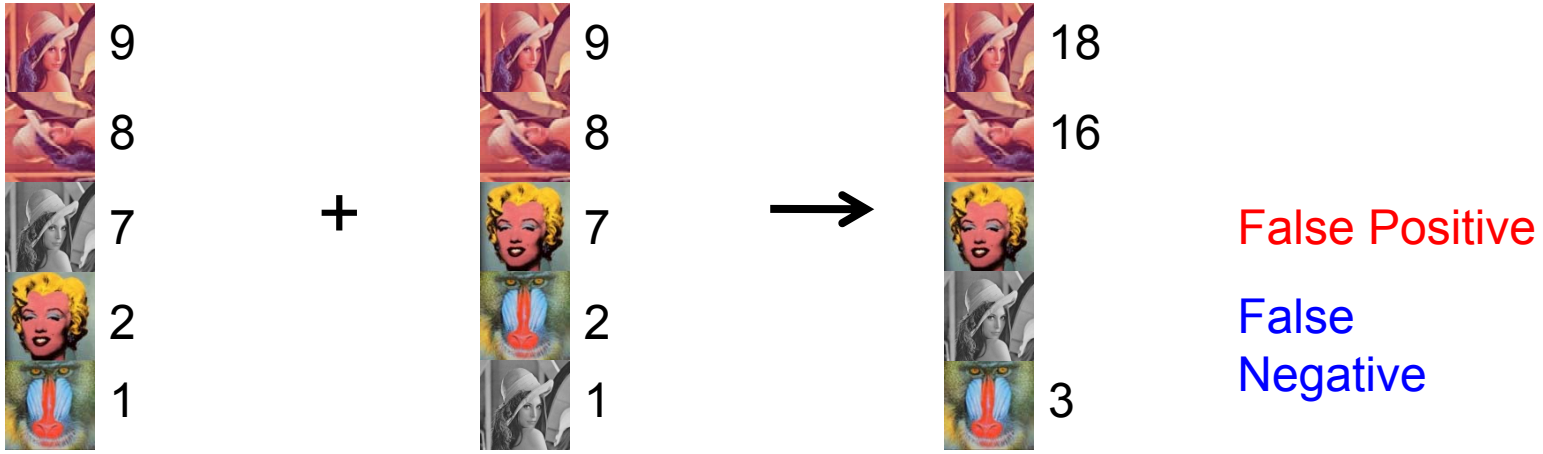
Phase 2 – Watermark Extraction

- **Extract watermarks only from image retrieval list and compare the similarity**

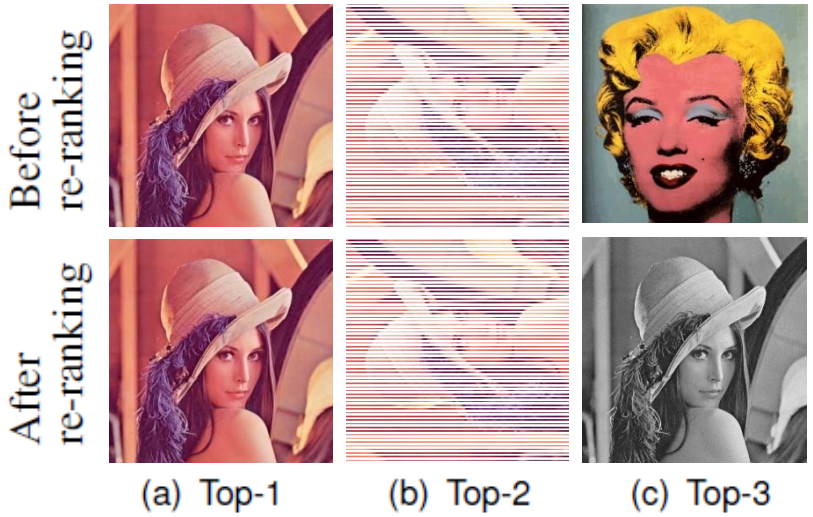
- **Sort output list based on watermark and image similarity**



Phase 3 – Re-ranking

- **High ranked images**
  - **Have high image similarity**
  - **Have high watermark similarity**

- **By utilizing high ranked images, re-rank output list based on image similarity**



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Result

- **Runtime performance (10K images)**
  - **Exhaustive search : 19 min**
  - **Our approach : Average 5.9 sec**
    - **SIFT extraction : 0.34 sec**
    - **Image retrieval : 0.71 sec**
    - **WM comparison (30 images) : 4.9 sec**
- **200x performance enhancement**

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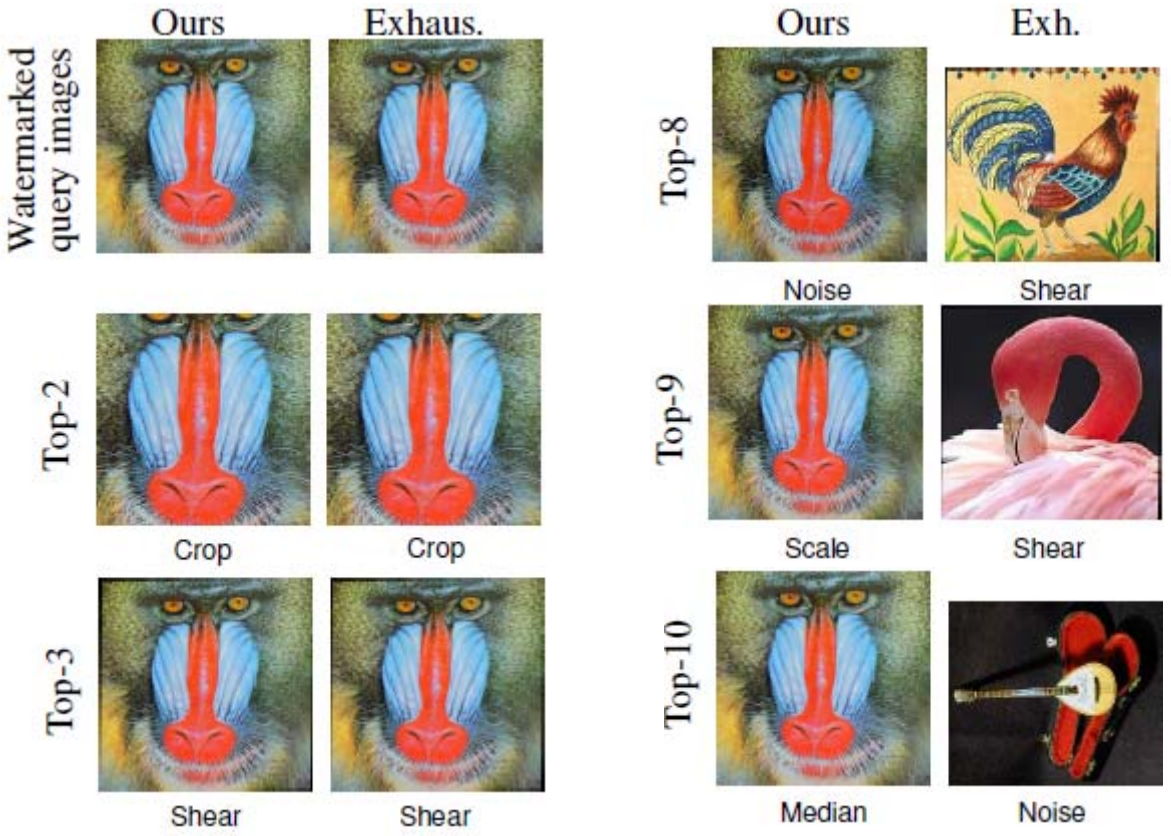
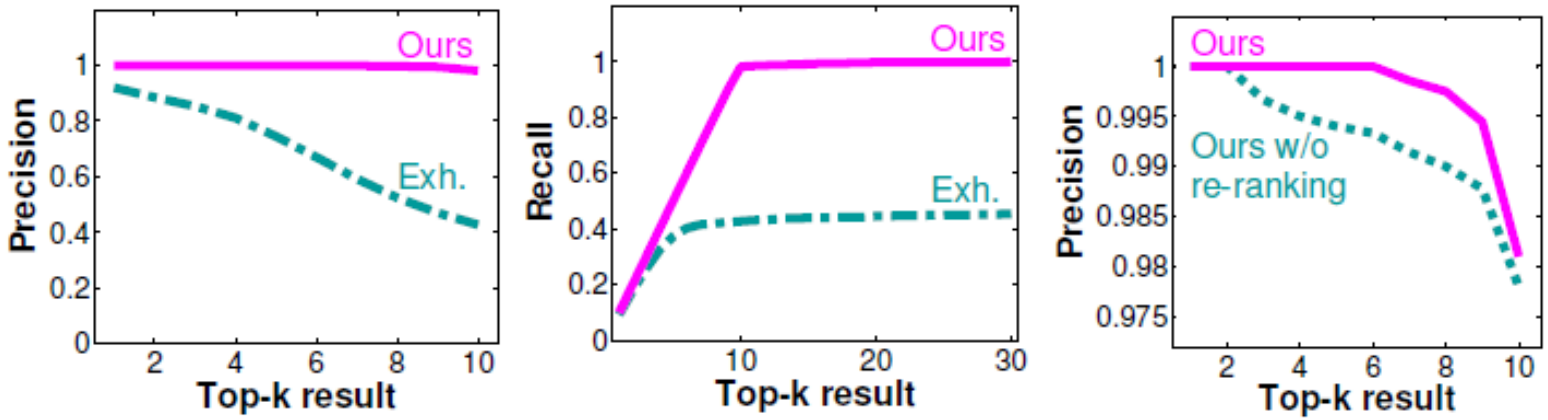
Result

- **Accuracy**
  - **Crop**
  - **Scale**
  - **Shear**
  - **Rotate**
  - **Noise**
  - **Median**
  - **JPEG**



Result

- **Accuracy (100 tests)**



$$\text{Precision} = \frac{\#\text{of}\,(I \cap R)}{\#\text{of}\,(R)} \qquad I : \text{ground truth set}$$

$$R : \text{result set}$$

$$\text{Recall} = \frac{\#\text{of}\,(I \cap R)}{\#\text{of}\,(I)}$$

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Conclusion

- **Image retrieval based image watermarking**
  - **Cull out irrelevant images in terms of image similarity**
  - **Can be used with other watermark algorithms**
- **Two order of magnitude speed-up**
- **Higher accuracy (small number of FP & FN)**
  - **Cull out irrelevant images (FP)**
  - **Detect severely attacked images (FN)**
  - **Re-ranking phase (FP & FN)**

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Conclusions

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- Processing them requires scalable algorithms
- Web-scale visual data can enable new applications
- Examples
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  - Scene completion
  - Image-retrieval based image watermarking

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