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
- Interactive Content-Aware Zooming
- Photo Tourism
- Conclusions

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- **Image Retrieval based Image Watermarking for Large-Scale Image Databases**

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Image Retrieval

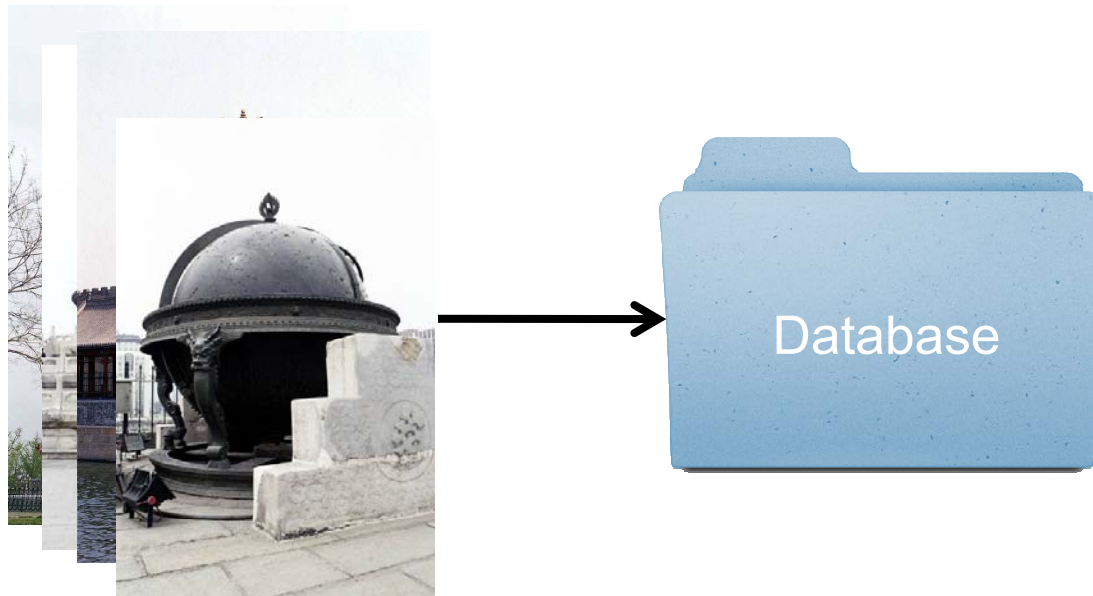- At pre-processing, build an database for efficient retrieval at runtime

Database

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Image Retrieval

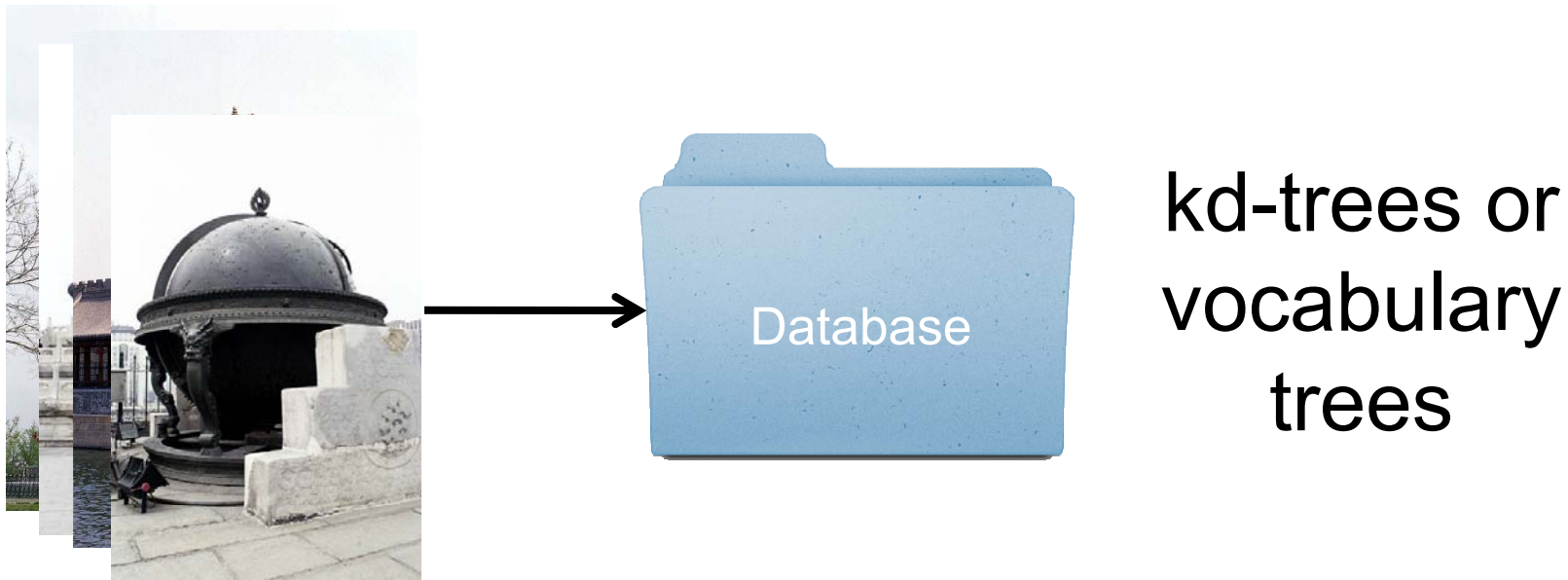- **At pre-processing, build an database for efficient retrieval at runtime**

Database

kd-trees or vocabulary trees

Image Retrieval: Runtime Procedure

Query image

Database
(kd-tree)

Image Retrieval: Runtime Procedure

Query image

Database (kd-tree)

Similar image(s)
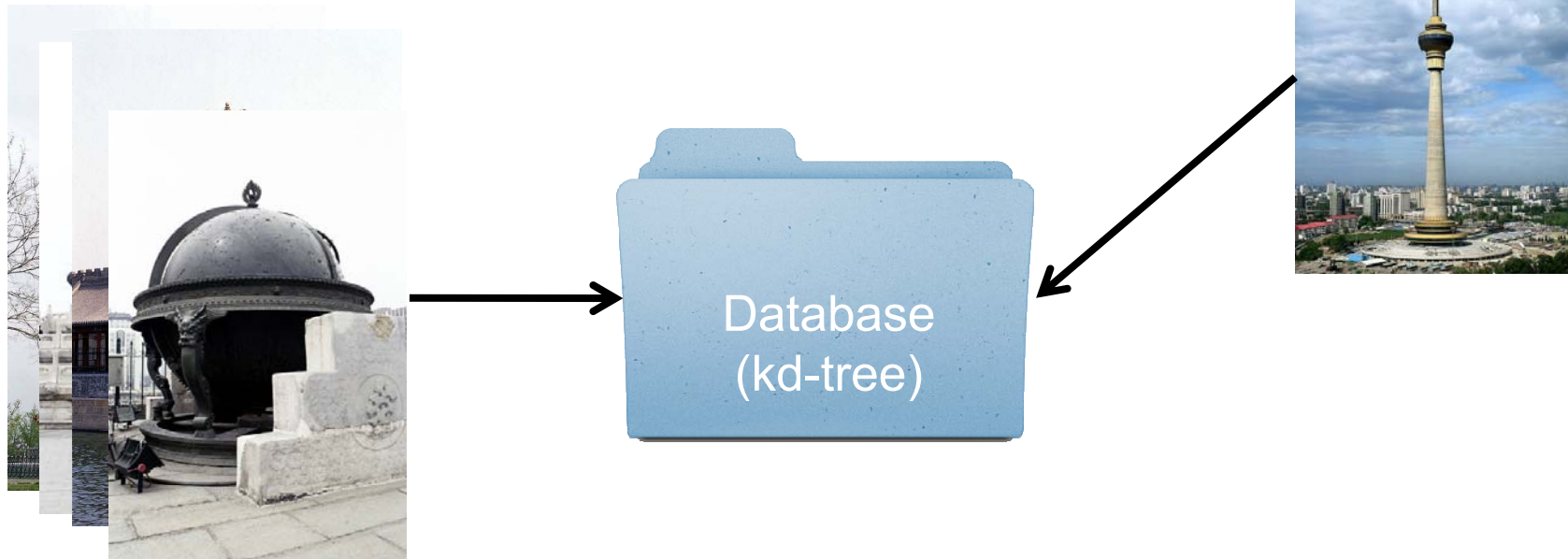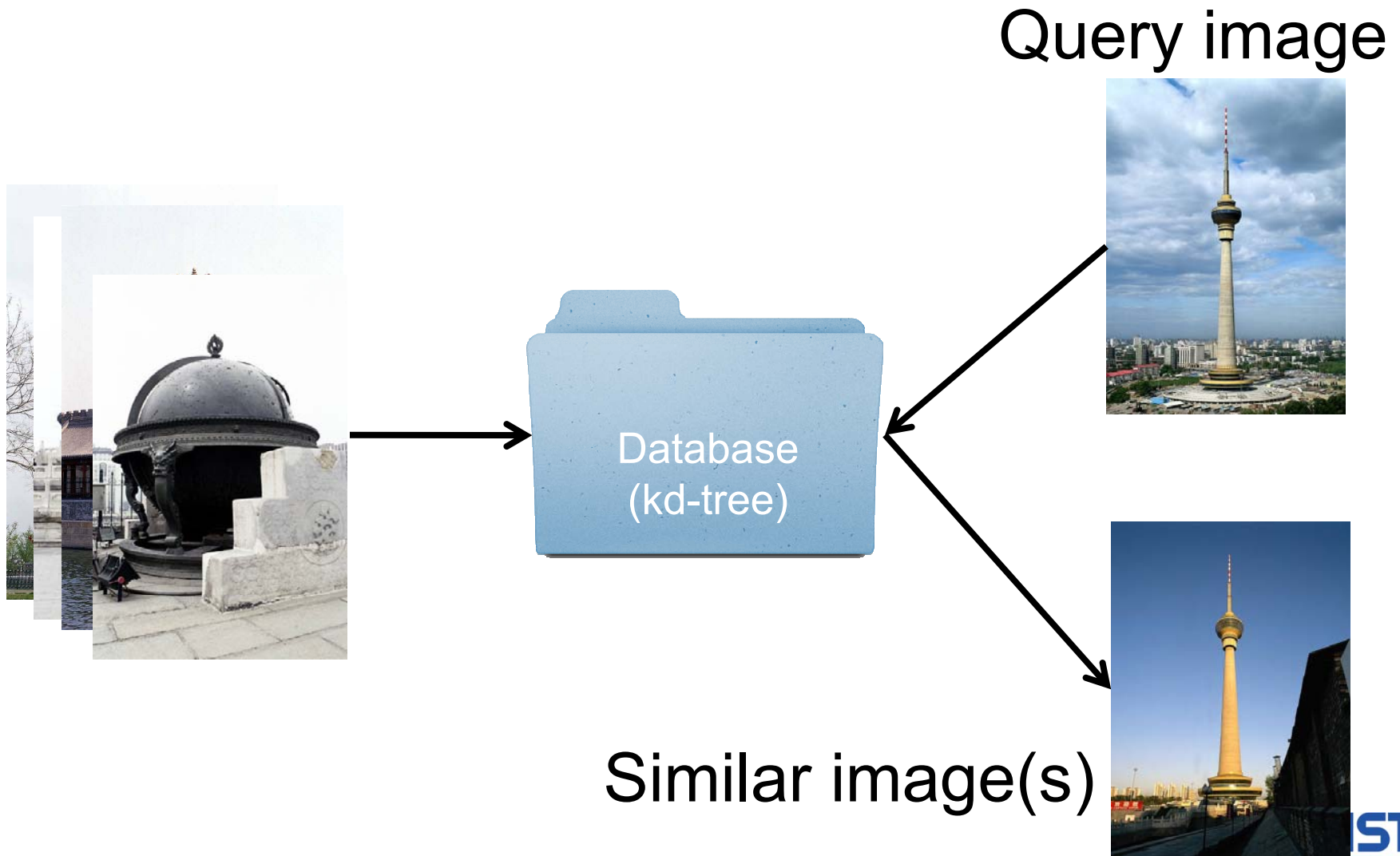
Issues of Image-Retrieval for Web-Scale Image Databases

- 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

<= 2009
Google

Watermarking

- *A process that embeds data, called watermark*
  - Watermark is integrated into the content itself

  - Requires no additional file header
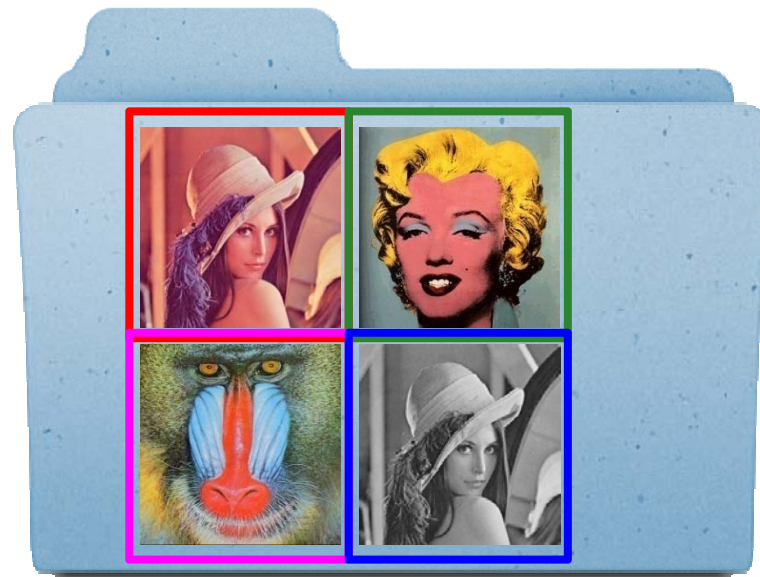 - Resist on conversion of data format
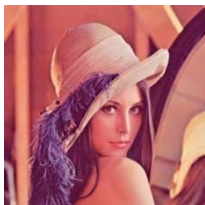

without watermark

with watermark

Motivation

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

Possible Approach

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

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

Terminology
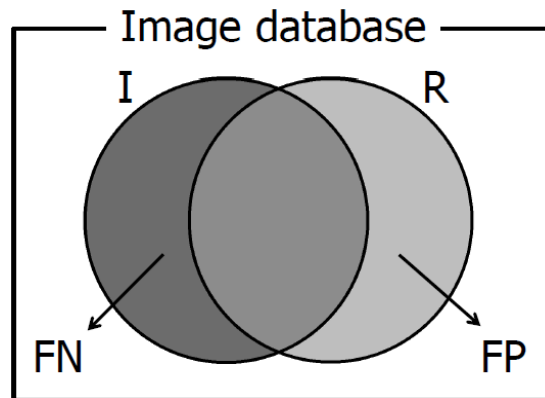
I : ground truth set

R : result set

FN : false negative

FP : false positive

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

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

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
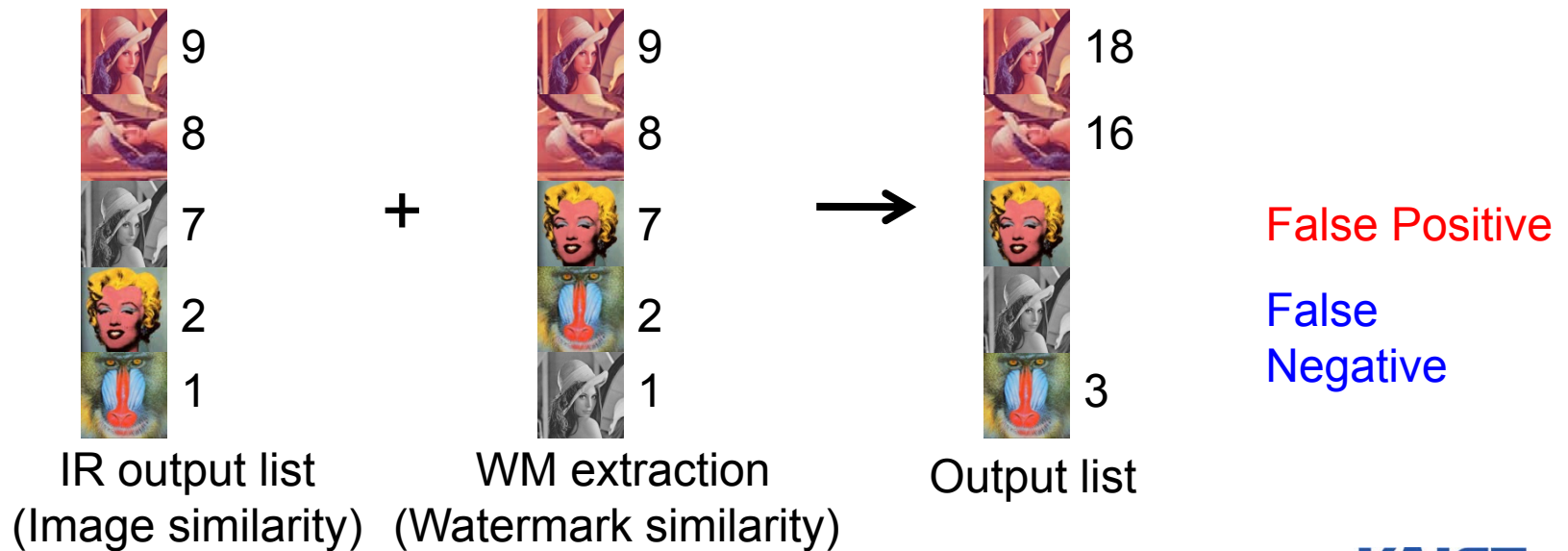 - Achieve performance enhancement
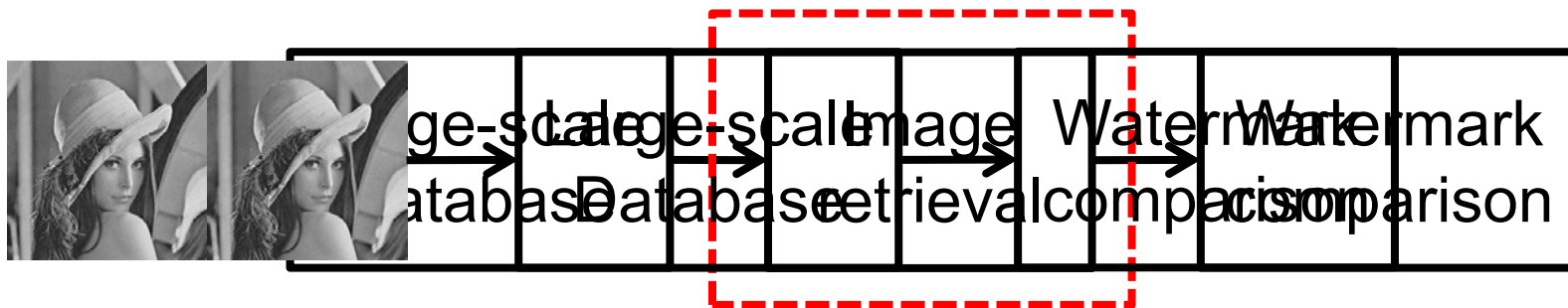
Overview
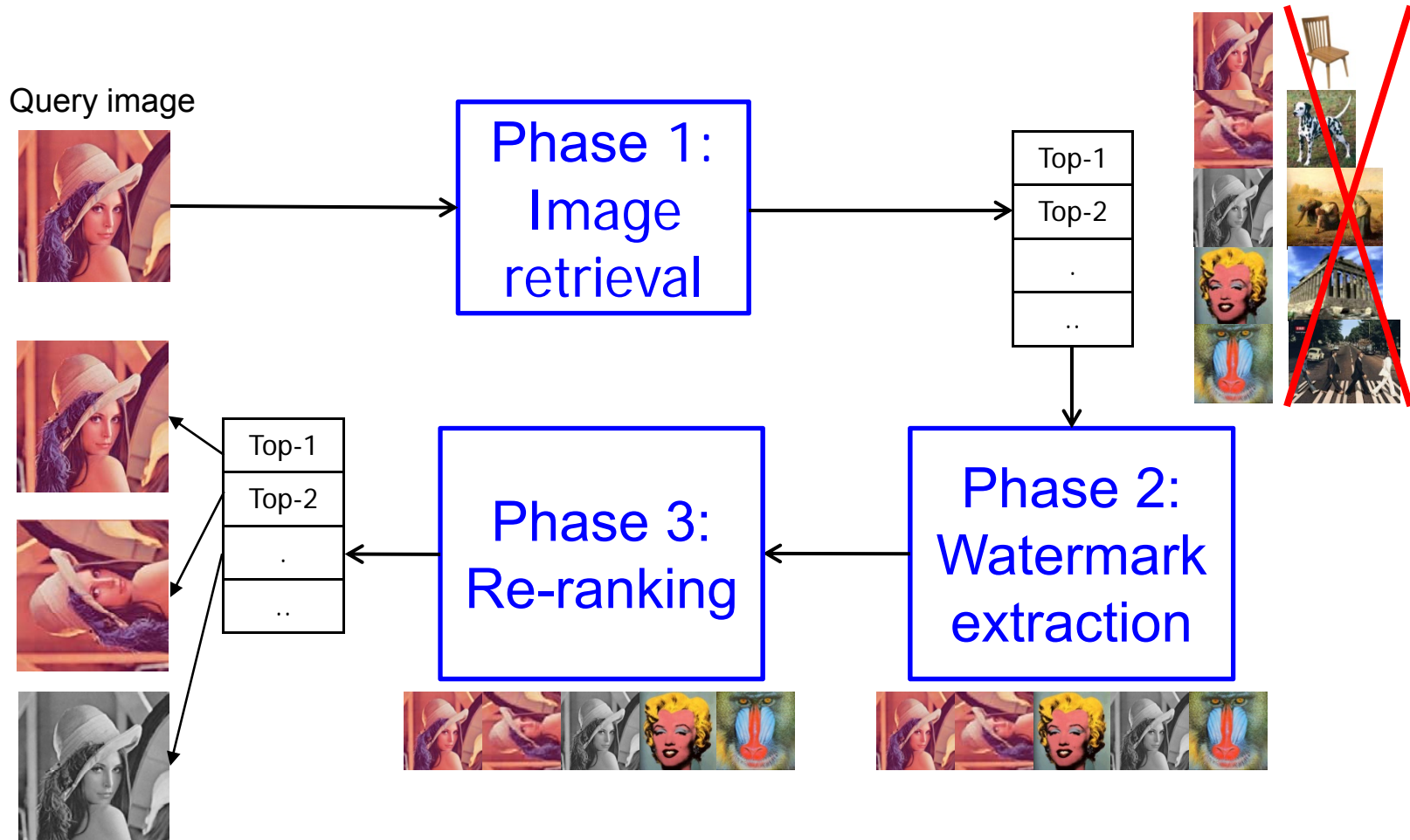
Phase 1 – Image Retrieval

- **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**

IR output list (Image similarity)		WM extraction (Watermark similarity)		Output list	
	9		9		18
	8		8		16
	7		7		
	2		2		
	1		1		3

IR output list
(Image similarity)

WM extraction
(Watermark similarity)

Output list

False Positive

False Negative

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**

Before re-ranking / After re-ranking

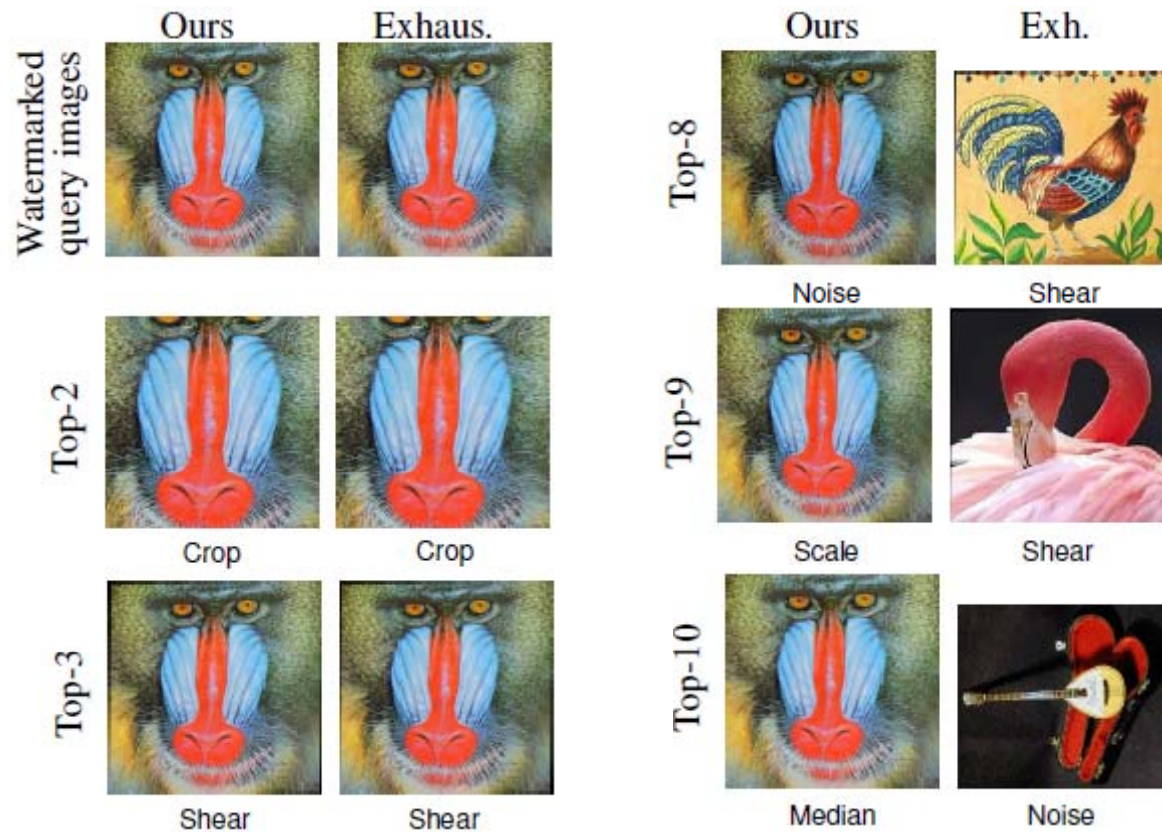(a) Top-1   (b) Top-2   (c) Top-3
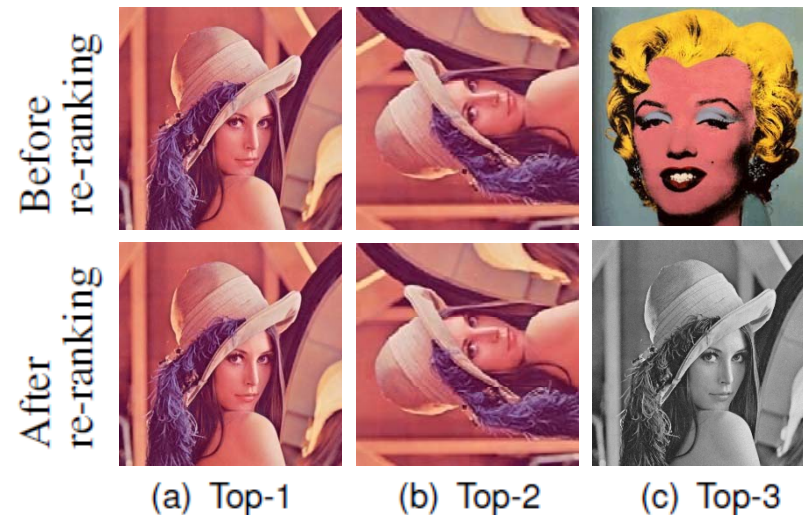
Result

- **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**

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Result

- **Accuracy (100 tests)**
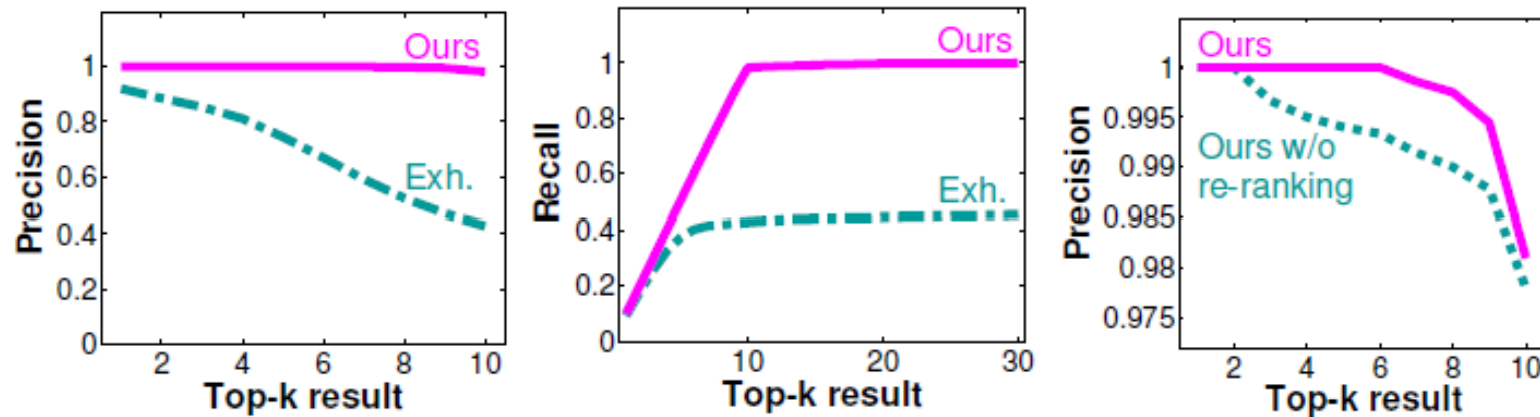
$$\text{Precision} = \frac{\#\,\text{of}\,(I \cap R)}{\#\,\text{of}\,(R)}$$

$I :$ ground truth set

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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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