

Multimedia Forensics and Security through Provenance Inference

Chang-Tsun Li

School of Computing and Mathematics

Charles Sturt University

Australia

Department of Computer Science

University of Warwick

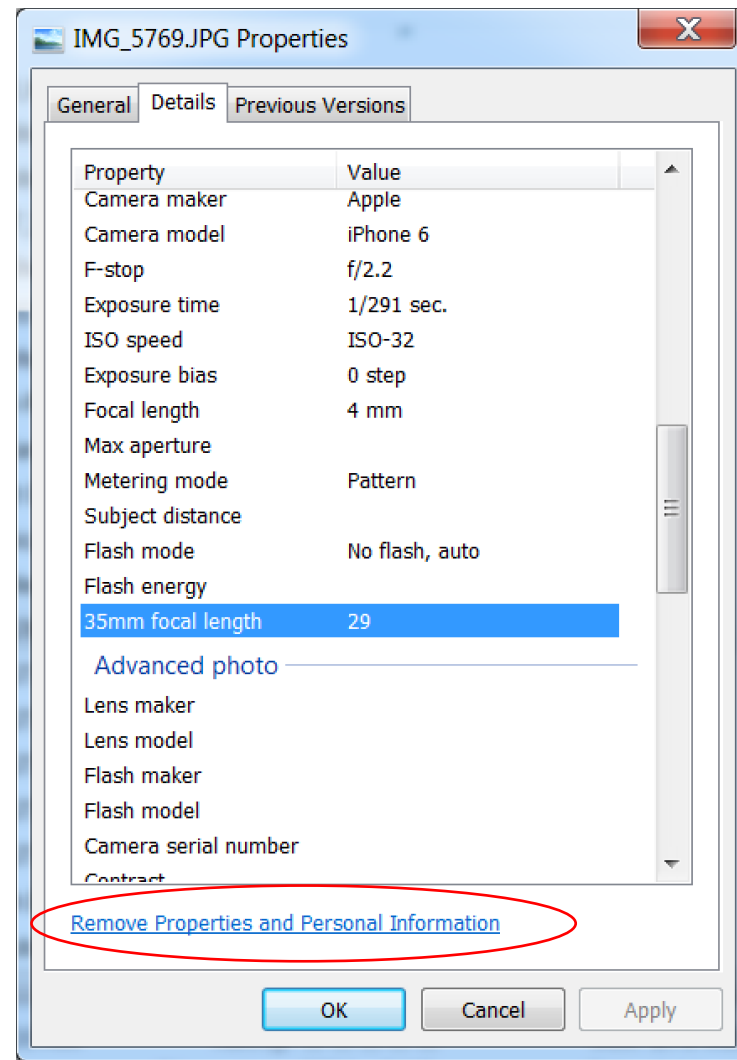
UK

Outline

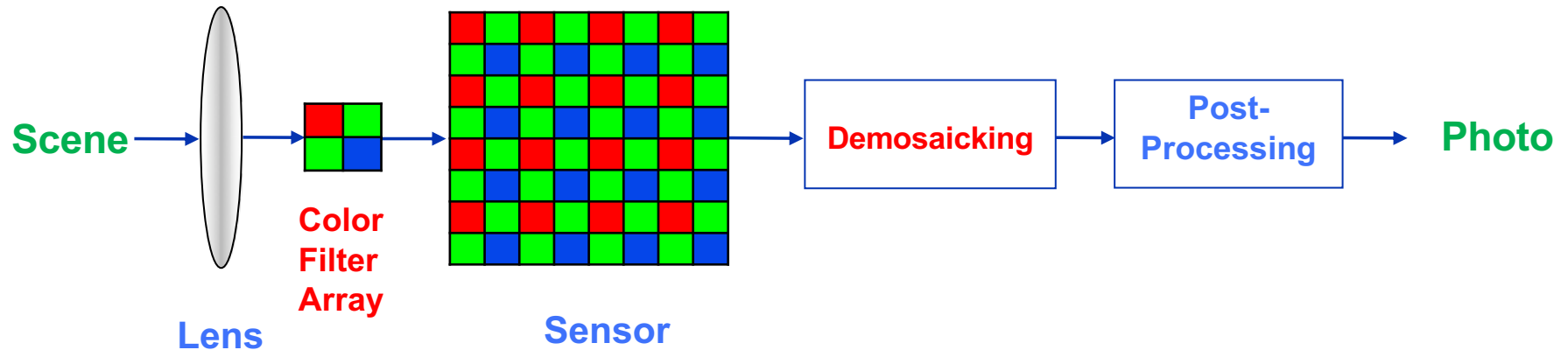
- Device Fingerprints
- Multimedia Forensic Applications
 - Source Device Verification
 - Source Device Identification
 - Common Source Inference
 - Content Authentication
 - Source-Oriented Image Clustering
- Conclusions
- Future Works

Why not Use Metadata - EXIF File

- Metadata is *easily* removable and replaceable.



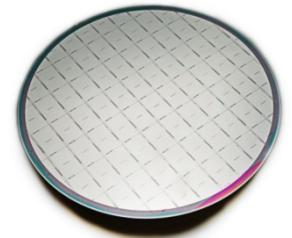
Device Fingerprints



- **Lens aberrations** (accurate to device models)
- **CFA + demosaicking artefacts** (accurate to models)
- **Quantisation table of JPEG** (accurate to models)
- **Sensor pattern noise** (accurate to **individual devices**)

Sensor Pattern Noise (SPN)

- SPN is the invisible artifacts left in the images by the sensors of devices.
- SPN is mainly caused by
 - manufacturing imperfection of silicon wafers and
 - different sensitivity of pixels to light.
- Sensors made from the same silicon wafer produce **unique** SPN
- SPN can differentiate cameras of the same model.



SPN Extraction

- Lukáš et al's model for SPN extraction (IEEE TIFS 2006)

$$\text{SPN}: n = I(i, j) - I'(i, j)$$

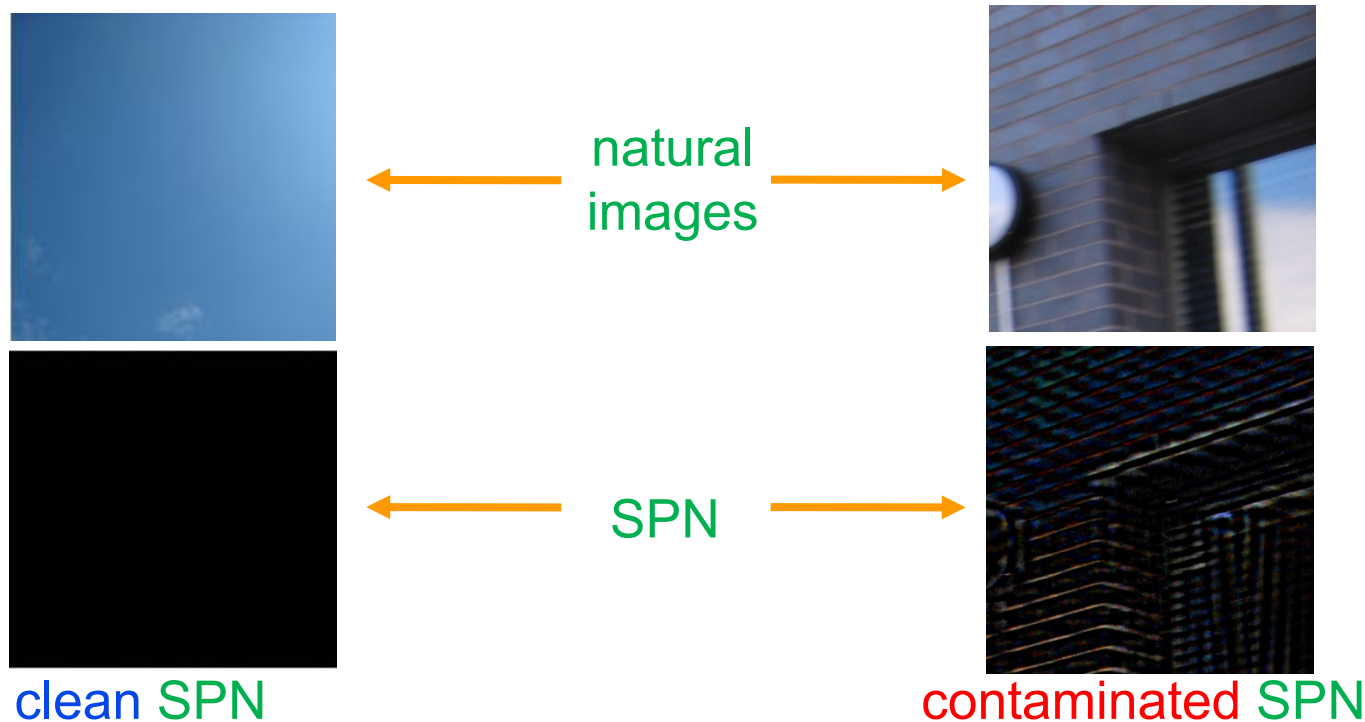
$$I' = \text{Weiner_filter}(I)$$

- I is the original image
 - I' is the low-pass filtered version of I
- SPN is the high-frequency component of the image.



Interference from Scene Details

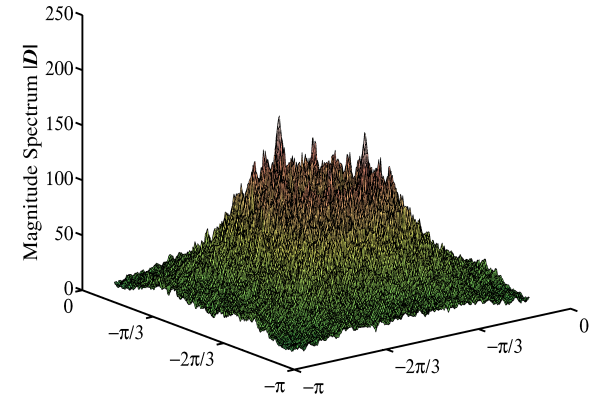
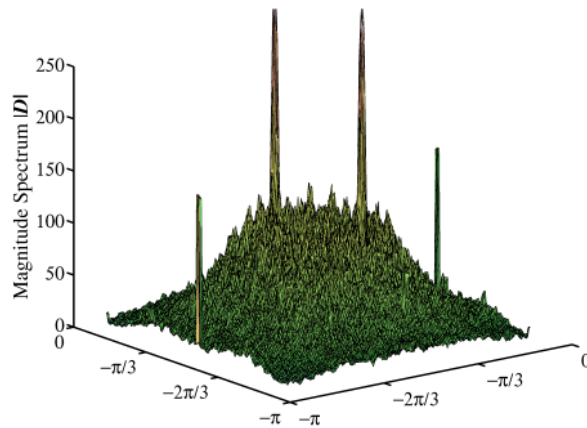
- **Scene details** also contribute to the high-frequency components of images.



- C.-T. Li, "Source Camera Identification Using Enhanced Sensor Pattern Noise," IEEE Trans. on Information Forensics and Security, 2010

Other Sources of Interference

- Periodical operation: e.g., JPEG, demosaicking



Periodical artefacts **before enhancement**

after enhancement

- X. Lin and C.-T. Li, "*Preprocessing Reference Sensor Pattern Noise via Spectrum Equalization*," IEEE Trans. on Information Forensics and Security, 2016
- C.-T. Li and Y. Li, "*Color-Decoupled Photo Response Non-Uniformity for Digital Image Forensics*," IEEE Trans. on Circuits and Systems for Video Technology, 2012

Other Sources of Interference

- Filters used in SPN extraction

$$\text{SPN: } n = I(i, j) - I'(i, j)$$

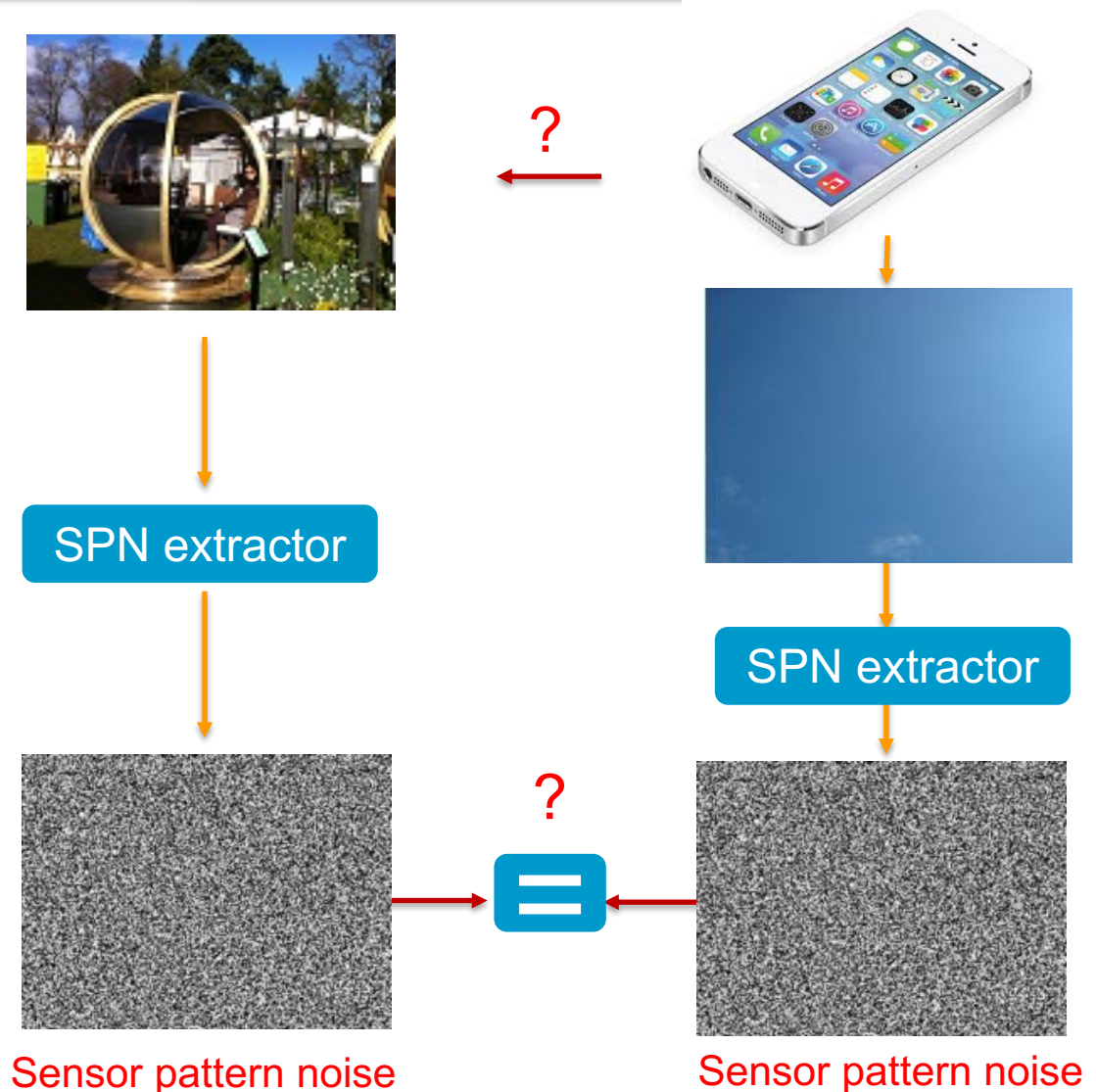
$$I' = \text{Weiner_filter}(I)$$

- X. Lin and C.-T. Li, "*Enhancing Sensor Pattern Noise via Filtering Distortion Removal*," IEEE Signal Processing Letter, 2016

Source Device Verification

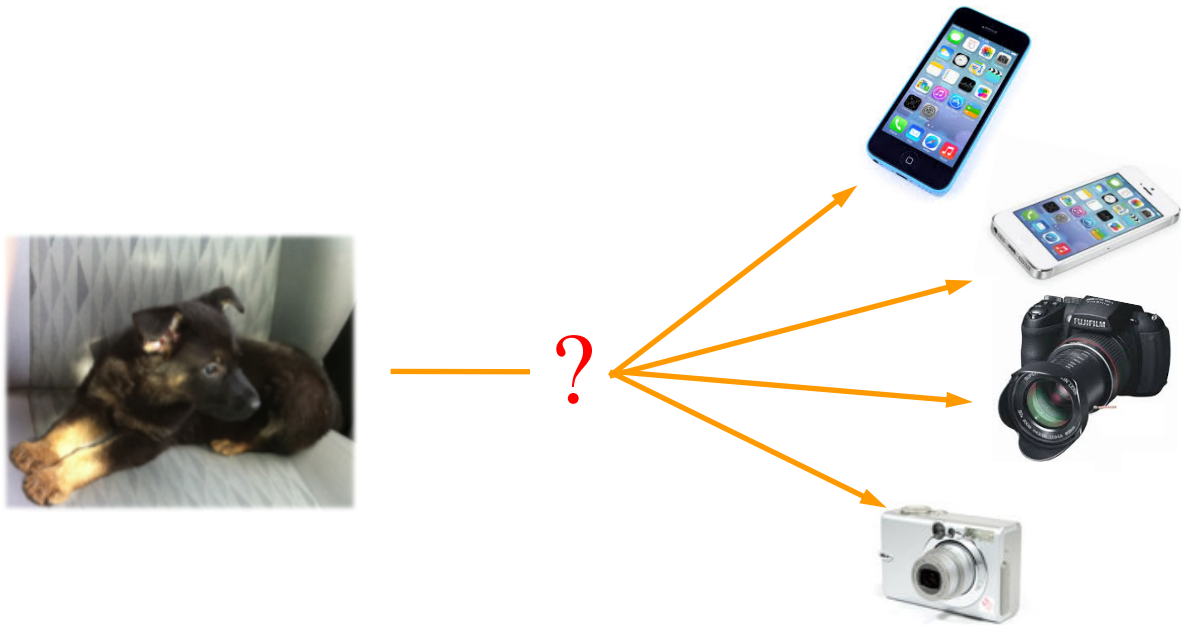
- Task: Determine whether a given image is taken with a particular device based on device “fingerprints”
- Similarity: Normalized Cross Correlation

$$\rho(i, j) = \frac{(n_i - \bar{n}_i) \cdot (n_j - \bar{n}_j)}{\|n_i - \bar{n}_i\| \cdot \|n_j - \bar{n}_j\|}$$



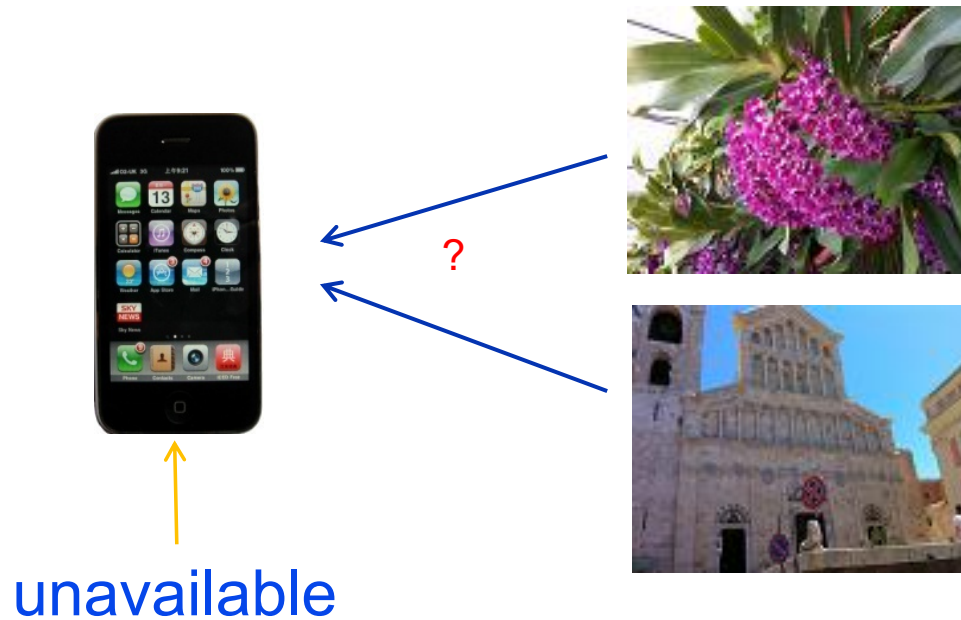
Source Device Identification

- **Task:** Given an image and the reference SPNs of k cameras, identify the camera that has taken the image



Common Source Inference

- **Task:** determine whether two images are taken by the same camera or not without possessing the camera



Real-World Applications

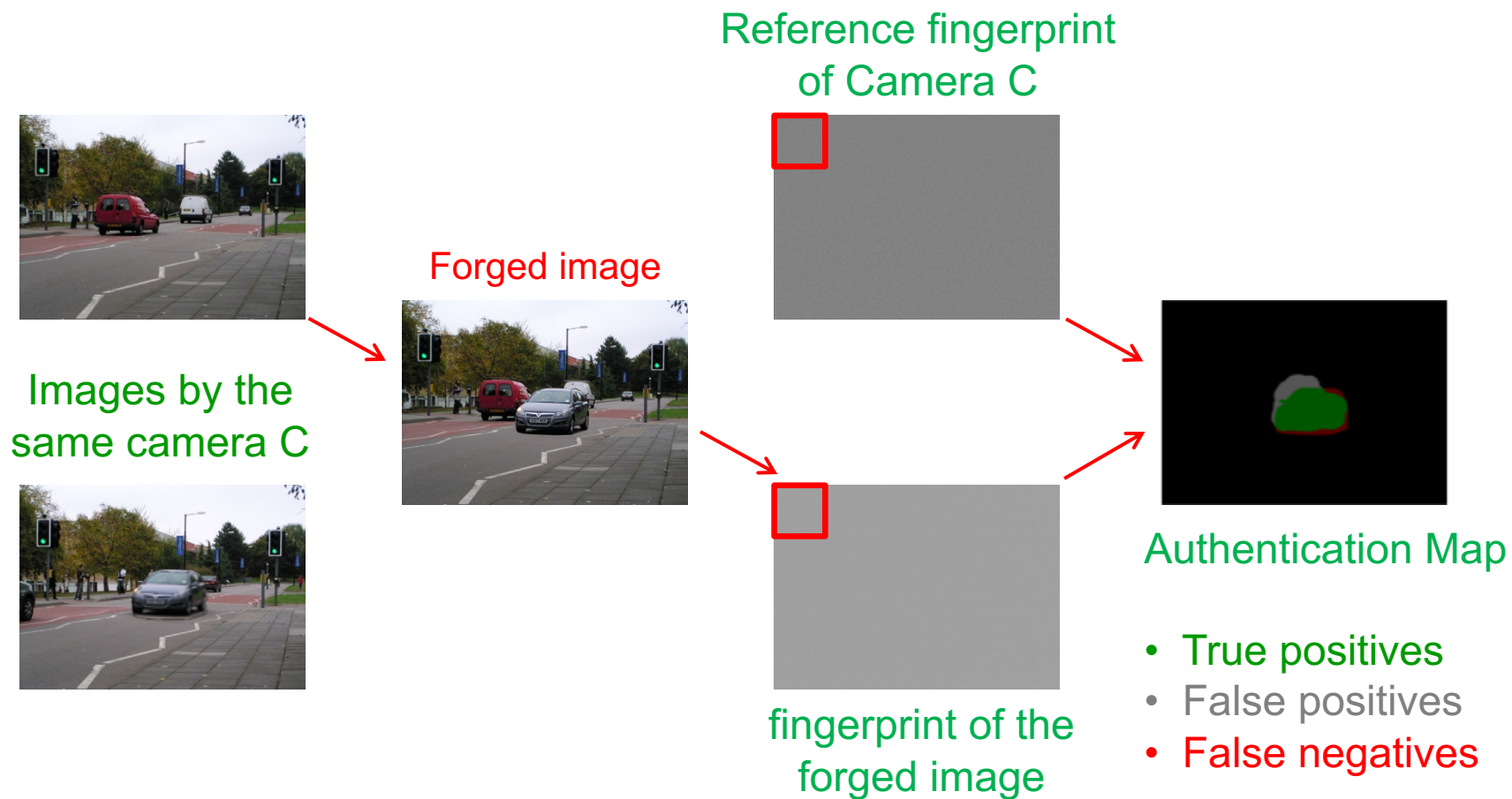
- Sussex Police (UK)

- Linking child pornography to an offender's mobile phone
- Leading to a 9-year prison sentence using SPN in 2014

- Guildford Crown Court (UK)

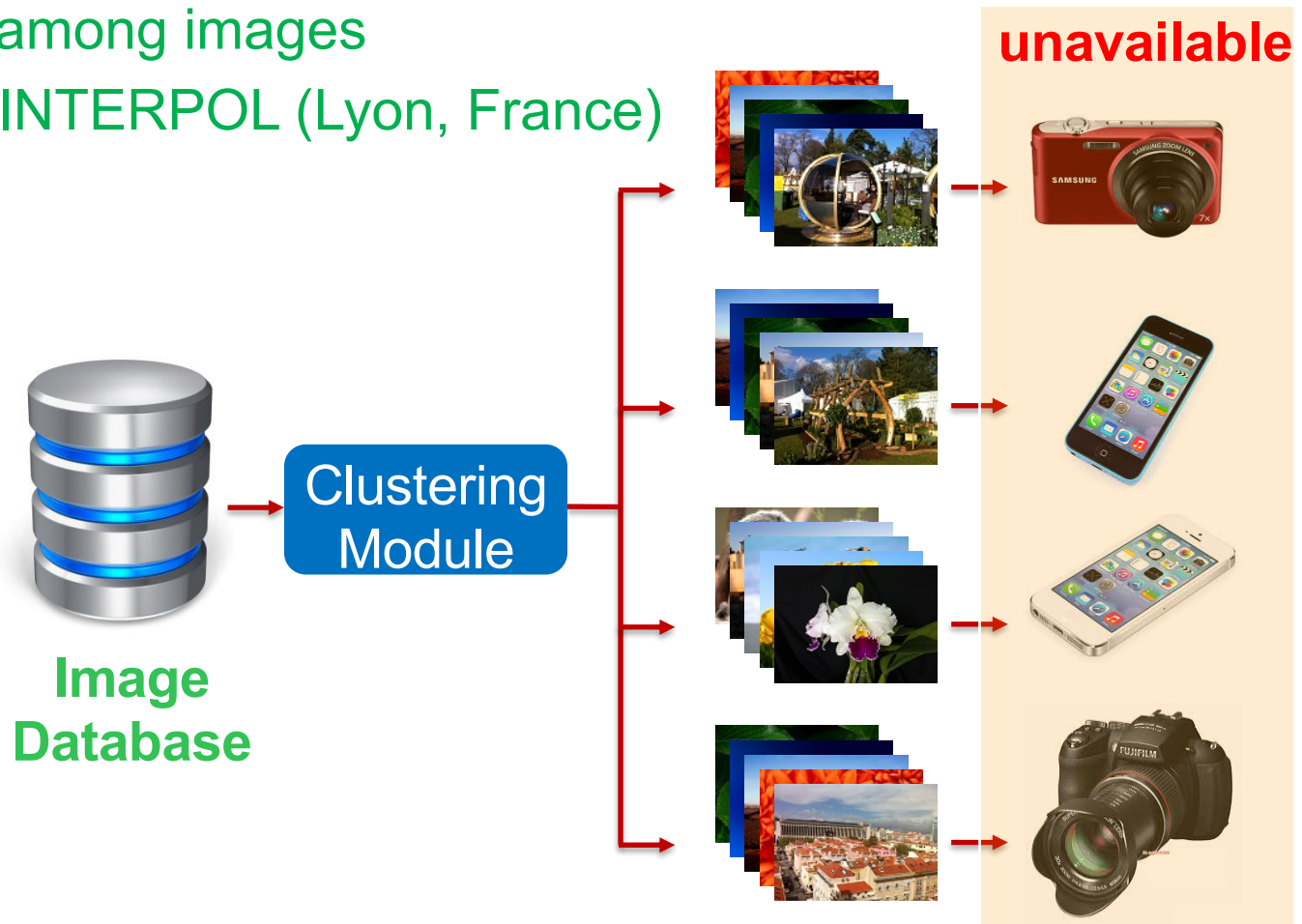
- Linking a set of voyeuristic videos in the **disk of a spy camera** to another video store in the defendant's **mobile phone original produced by the defendant's spy camera**
- Defendant pleading guilty for installing spy camera in June 2016

Content Authentication

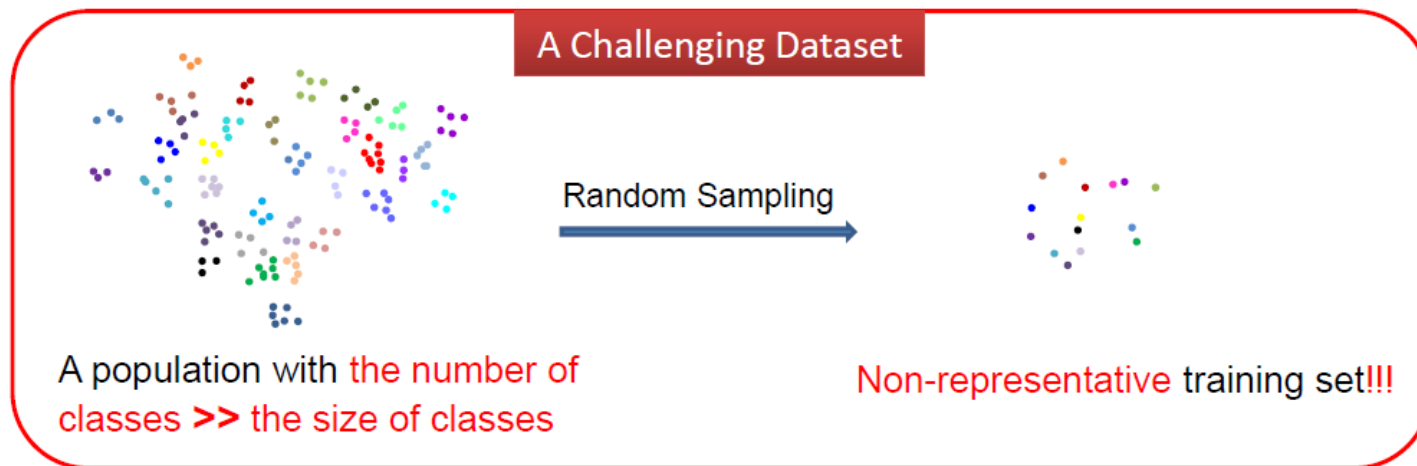
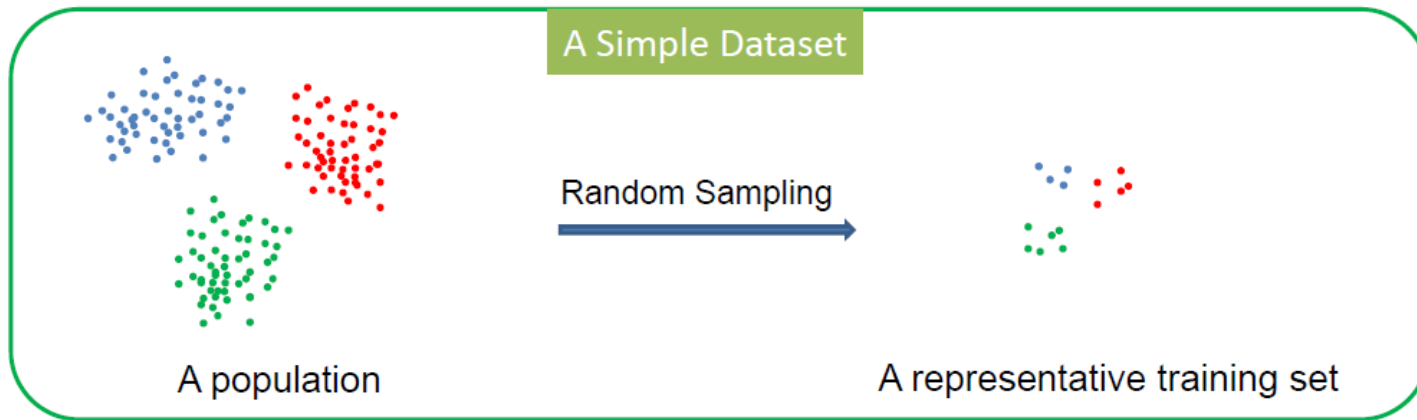


Source-Oriented Image Clustering

- **Objective:** each formed group contains only images taken by the same camera
- **Significance:** establishing relationship among images
- Delivered to INTERPOL (Lyon, France)



Novelty of Our Clustering Alg



X. Lin and C.-T. Li, "Large-Scale Image Clustering based on Camera Fingerprint," IEEE Transactions on Information Forensics and Security, vol. 12, no. 4, pp. 793 – 808, April 2017

Conclusions

- Device fingerprint can facilitate
 - Source Device Verification
 - Source Device Identification
 - Common Source Inference
 - Content Authentication
 - Source-Oriented Image Clustering
- Multimedia forensics through device fingerprint analysis is of great interest to law enforcement.
- The most promising fingerprint is SPN at the moments
- Many future works to be done

Future Works

- We have the following now:
 - Lens aberrations
 - Colour filter array (CFA) interpolation artefacts
 - Camera Response Function (CRF)
 - Quantisation table of JPEG compression
 - Sensor pattern noise
- Any other modalities?
- Any way to fuse them?

Future Works

Issues surrounding SPN:

- **A compact representation of SPN** is needed for fast search and clustering: SPN is as big as the host image
- **SPN is removable**: sensitive to compression, transcoding, blurring, etc.
- **SPN is replaceable!**