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From single object to contextual authentication

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Outline

- Motivation
- Multimedia forensics
- Hottest challenges
- Contextual authentication
  - Motivation
  - A general framework
  - An early attempts based on image phylogeny
- Conclusions

Seeing is believing. Does it ?

Photographic images have lost their innocence (if they ever had one) a long time ago

Seeing is believing. Does it ?

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Seeing is believing. Does it ?

With digital photography (and videos and audios) the diffusion of fake images has bloomed.

Fake images are virtually everywhere

Gutter press

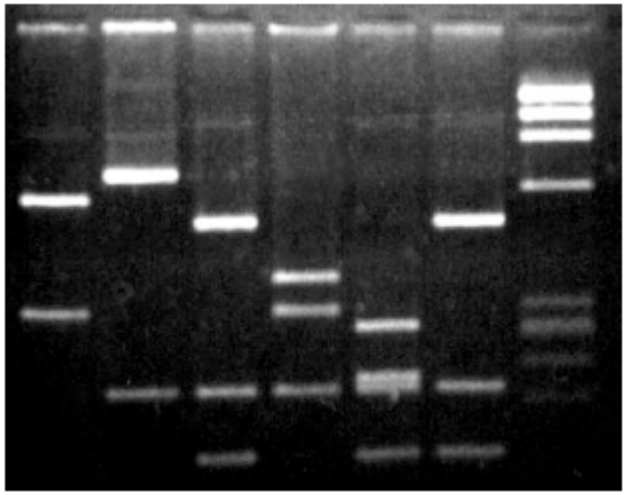
Frontal light

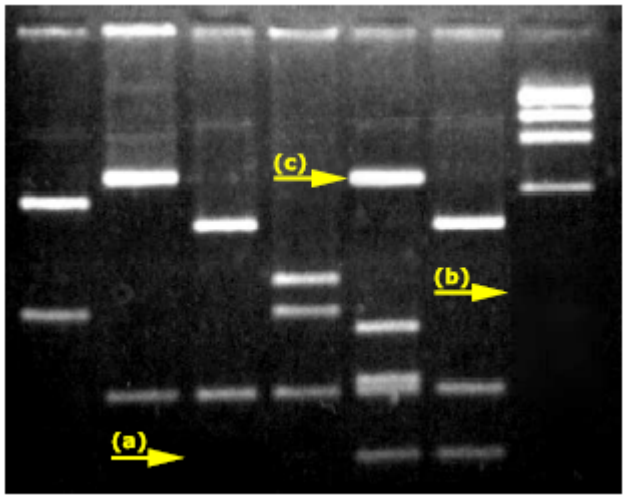
Side illumination

Military propaganda

Anti-regime propaganda

Even scientists





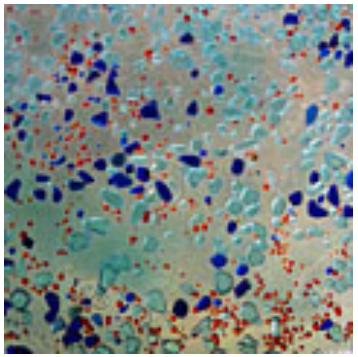
Not only photomontages

CG CG Real CG Real










CG Real CG Real Real

Not only images

Why should we care ?

- Probatory value of digital images, videos, audios
- Opinion manipulation
- Social impact: undermines one of our primary source of information
- Problem worsened by diffusion of UGC paradigm

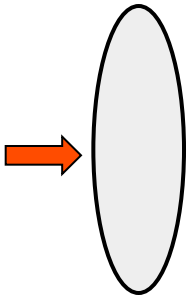
- Scientific question: ultimate reliability of digital media as trustful representation of reality

Multimedia forensics

- Multimedia forensics aims at gathering information about the history of images, video and audio contents
- **Basic idea: each step image life leaves peculiar traces that can be exploited to detect its presence**

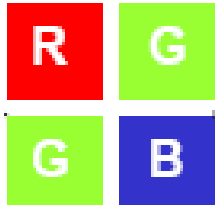
Digital image life cycle

real word



lenses

optical filter



CFA pattern

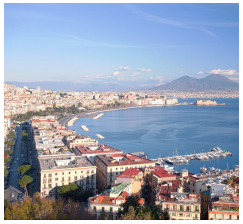
Sensor

CCD/ CMOS

color interpolation

in-camera software processing (white balancing; contrast saturation; etc)

in-camera Jpeg compression



digital image

out-camera processing

final digital image

A rich forensic toolbox

- PRNU analysis for device identification
- CFA analysis for model identification
- Double JPEG compression to retrieve image history
- Resampling traces to detect cat and paste with resizing
- SIFT matching for copy-move detection
- Geometric inconsistencies
  - Shadows
  - Lights
  - Perspective
  - Motion
- ...

All that glitters ain't gold

- **From the lab to real world**
  - Lack of good statistical models
  - Multi-clue forensics analysis
- **Counter-forensics**
  - What if ...
  - Counter-counter-forensics
  - Adversarial MMF
- **There's more to authenticity than single object analysis: Contextual authentication**

The importance of context (1)

- Truthfulness of multimedia contents does not depend on the content only
- The context wherein the content is used must be considered as well
- Together with its intended meaning

The importance of context

The importance of context

The importance of context

The importance of context

EL PAÍS

www.elpais.com — EL PERIÓDICO GLOBAL EN ESPAÑOL

JUEVES 24 DE ENERO DE 2013 | Año XXXVI | Número 12.994 | EDICIÓN AMÉRICA

El presidente Hugo Chávez, durante el tratamiento médico recibido en Cuba. / DERECHOS MUNDIALES DE EDICIONES EL PAÍS. PROHIBIDA SU REPRODUCCIÓN

El secreto de la enfermedad de Chávez

El estado de salud del presidente de Venezuela, Hugo Chávez, se ha convertido en uno de los secretos mejor guardados de los últimos años y objeto de polémica política en dicho país ante la ausencia del dirigente en su toma de posesión tras las últimas elecciones. La imagen que hoy publica EL PAÍS, tomada hace unos días, muestra un momento del tratamiento médico en Cuba, según las fuentes consultadas por este diario. Ni el Gobierno venezolano ni el cubano han dado información detallada del tipo de cáncer que sufre Chávez ni de los cuidados que está recibiendo, lo que ha generado una agria controversia y la exigencia de transparencia por parte de la oposición venezolana. Las últimas informaciones oficiales hablan de una mejoría de Chávez y de su posible vuelta a Caracas. PÁGINA 6

Yet, the image is authentic

Or to better say ... it has not been manipulated

The importance of context (2)

- Images do not live in isolation
- The web (and not only) forms a kind of collective background knowledge
- Image content can be checked against such a background knowledge

- **Image with Bin Laden face after death**

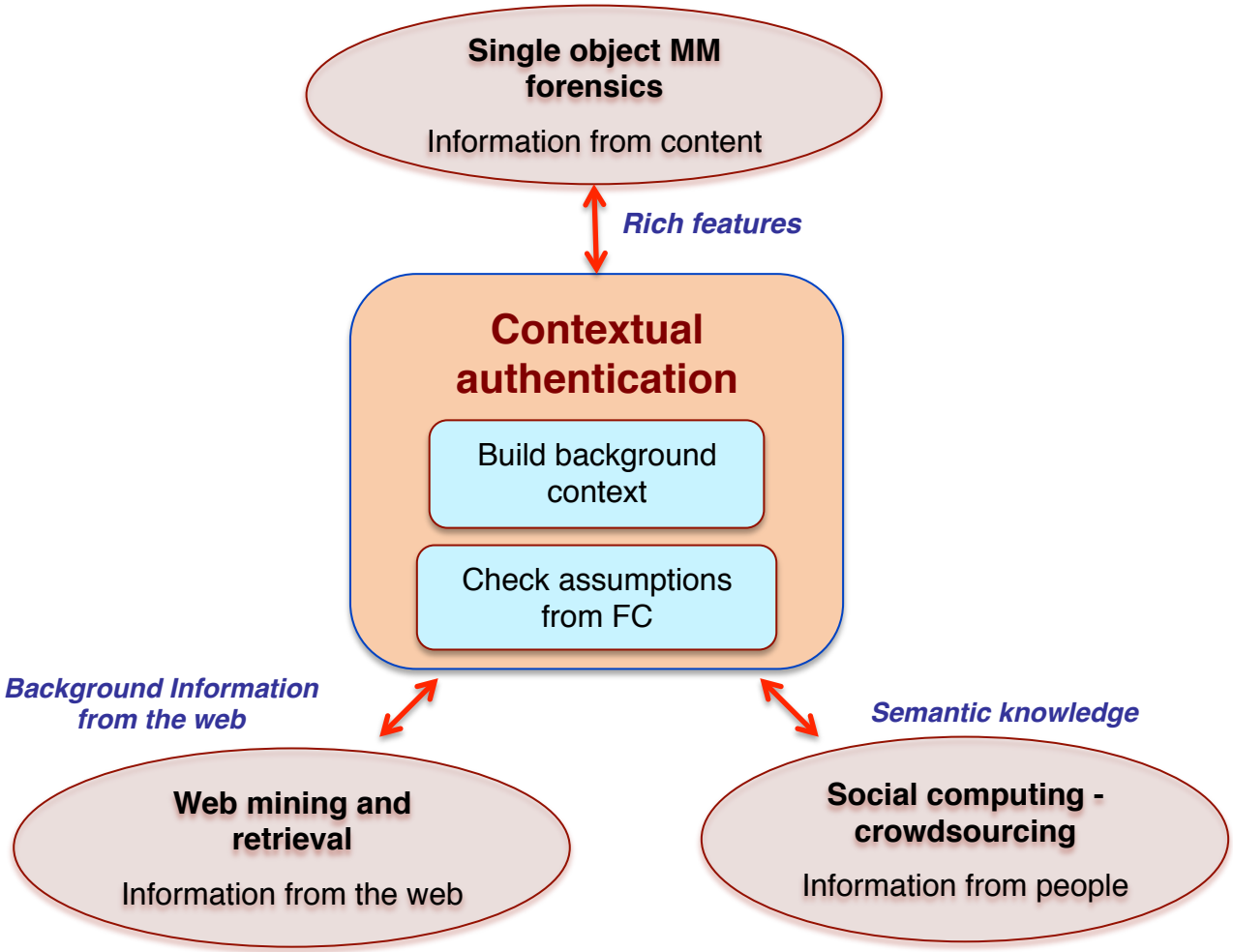
A less critical example

A framework for contextual authentication

- **Foreground Context (FC):** the context – document, web page, text – wherein the content is used
  - Explicit assumptions
  - Implicit assumptions
- **Background context (BC):** pre-existing information about the analyzed content and the foreground context wherein the content is used

- **Contextual authentication:** verification of explicit and implicit assumptions deriving from the FC, by the light of content analysis and BC

Information from different sources



Several challenges

- **Information from content**
  - Strengthen forensics analysis to exit the lab
  - Multiple object, multimodal analysis
- **Information from the web**
  - Content-based retrieval
  - Big-data scenario
- **Information from people:**
  - Chavez example
  - Efficient use of social resources
  - Effective engagement of people
  - Interaction with automatic components

Several challenges

- **Foreground Context definition**
  - Derive all implicit and explicit assumptions linked to the foreground context
  - Bring the analysis to a sufficiently high semantic level
- **Background context**
  - Definition of proper models
  - Semantic analysis
  - Data deluge

Image phylogeny: a first small step

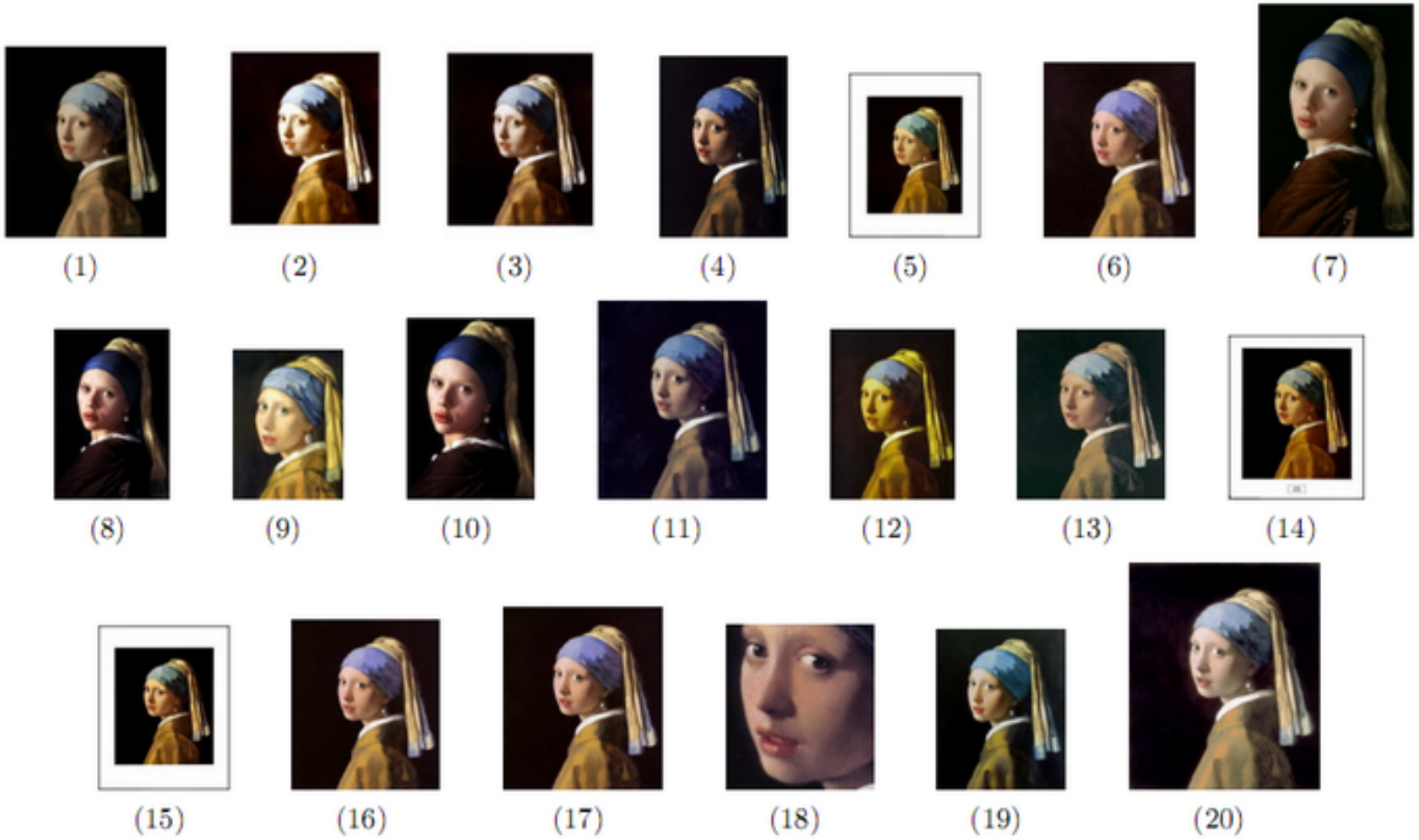
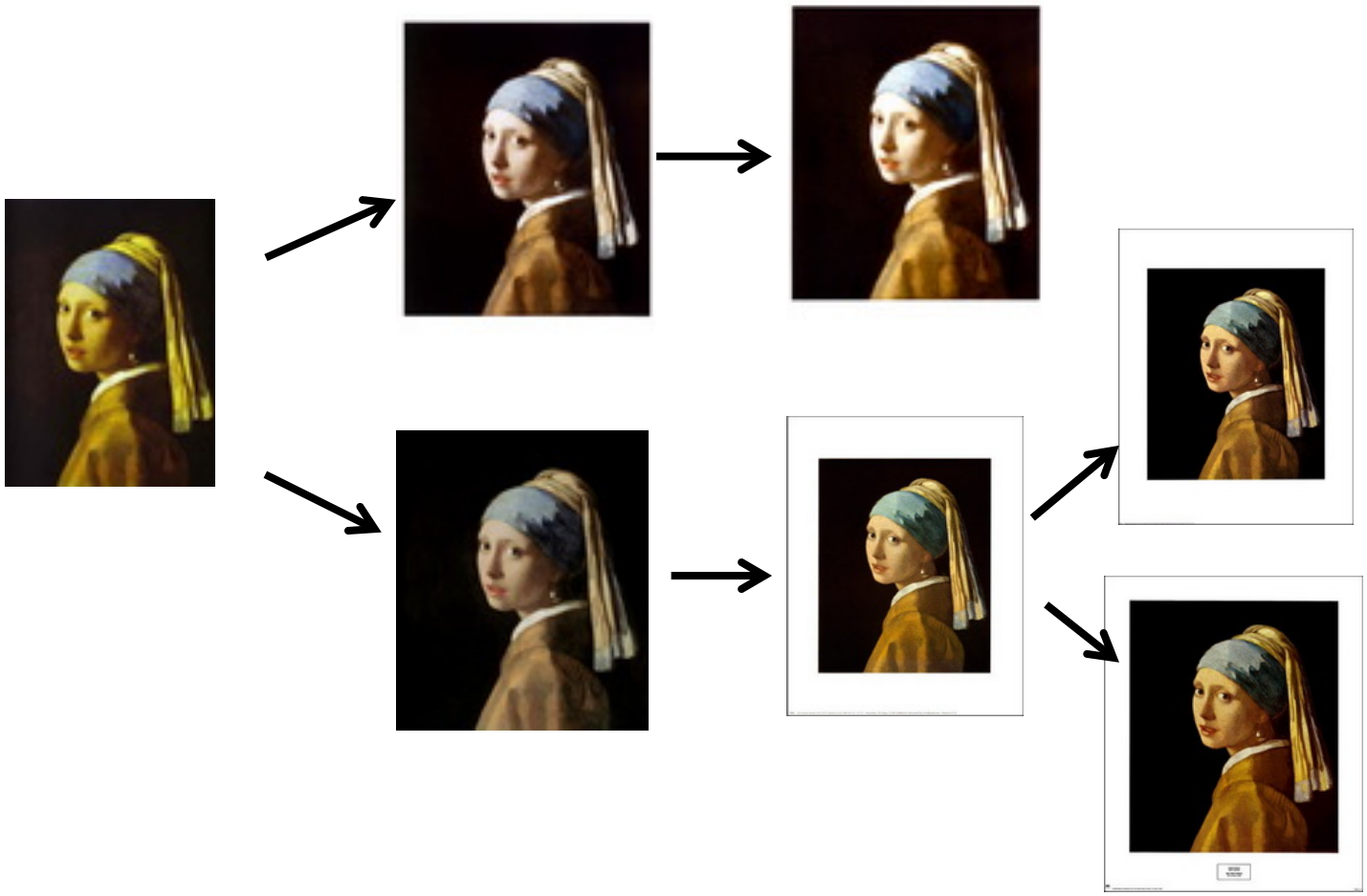


Image phylogeny: a first small step

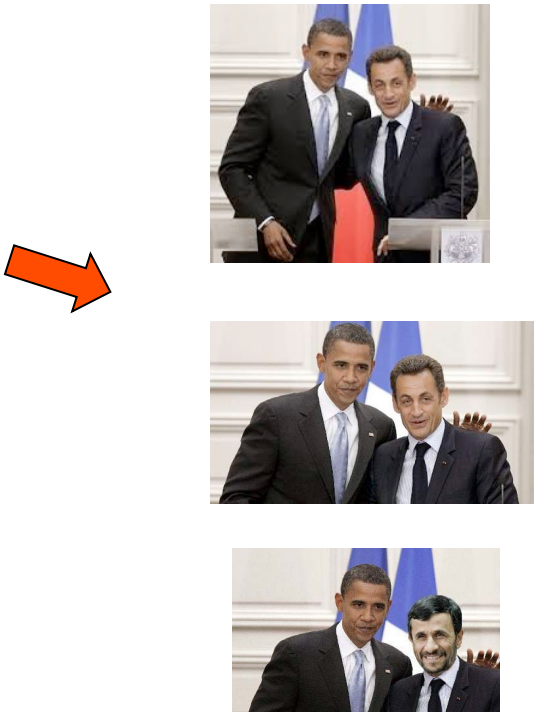


More formally

- **Foreground Context assumption**
  - The image content has not been manipulated
  - that is: the objects and people shown in the picture correspond to the real world scene the picture refers to
  - that is: no copy-move, no photo- montage

Information from the web

- Background information from the web is limited to the collection of near duplicate images
- A search for near duplicates is run



Information from people

- Suspect objects are identified through crowdsourcing (very limited amount of semantic information)

Alternatively: information from content

- A conventional single image forensic analysis could be run to identify suspect areas

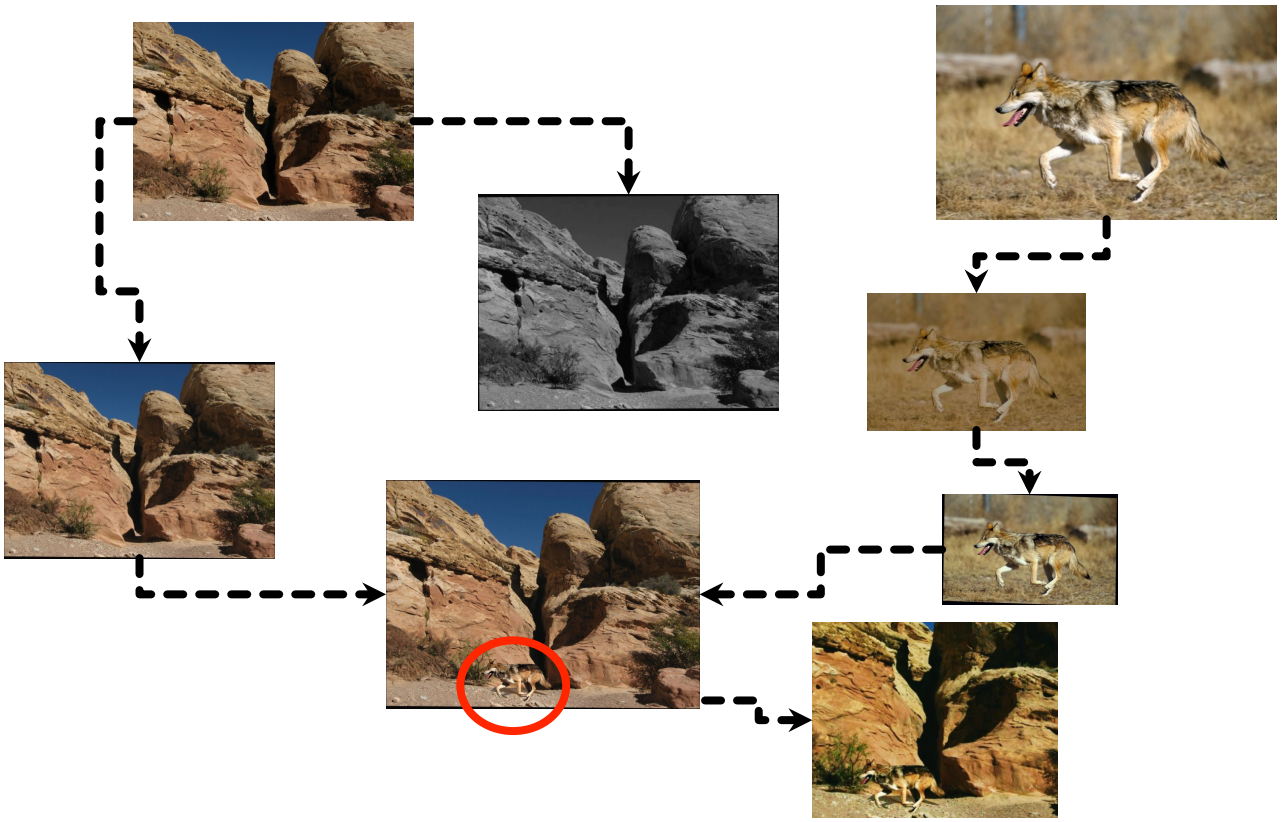
- Change detection techniques could also be used to identify possibly tampered areas

Information from the web (again)

- A web search is carried out looking for near duplicates of suspect regions

Background context model

- The model for background context corresponds to an **image phylogeny graph with multiple parents**



Construction of the graph (1/3)

- Evaluate the dis-similarity between each pair of images

$$d(I_A \rightarrow I_B) = \min_{T \in C}[dist(I_B, T(I_A))]$$

- Evaluate the similarity between random part of images

$$I = [I_C, I_R] \quad e.g.\ I_R = I - denoise(I)$$

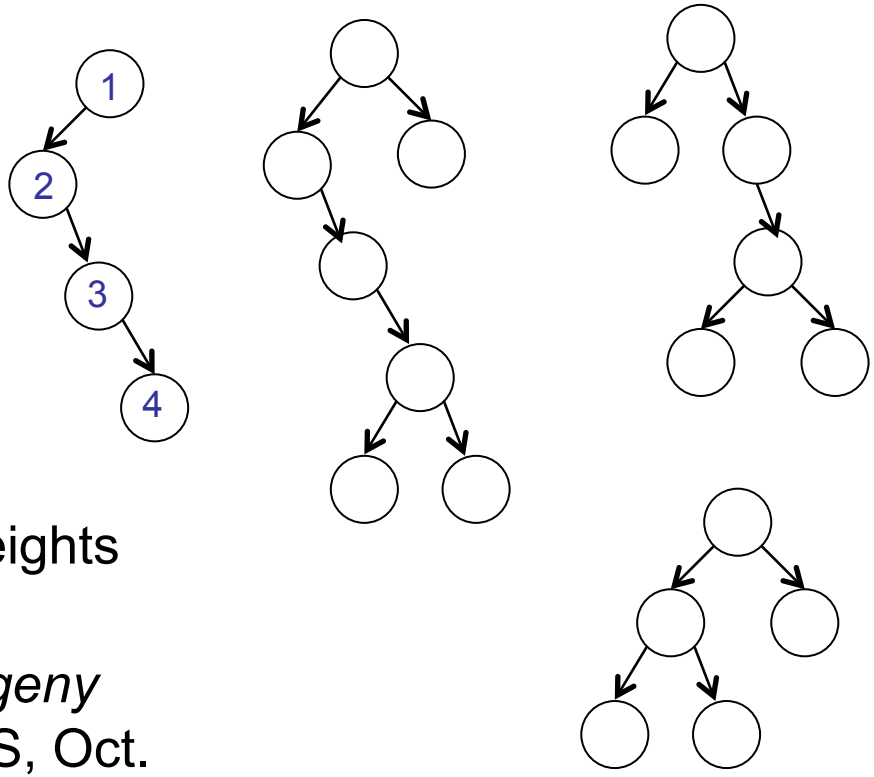
$$sim(I_A \rightarrow I_B) = corr(I_{A,R}, T(I_B)_R)$$

$$T = \underset{T \in C}{\operatorname{argmin}}[dist(I_{B,C}, T(I_{A,C}))]$$

Construction of the graph (2/3)

- Given the dissimilarity matrix build a Image Phylogeny Forest

	I_1	I_2	I_3	I_4
I_1	-	**1.81**	2.98	3.85
I_2	2.71	-	**1.88**	2.74
I_3	3.98	2.56	-	**2.50**
I_4	22.43	19.62	19.44	-

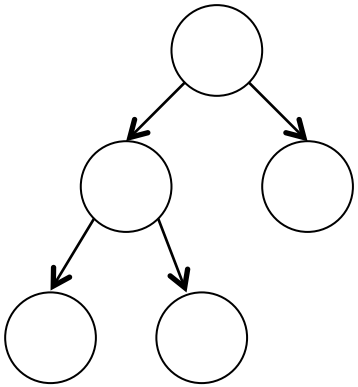
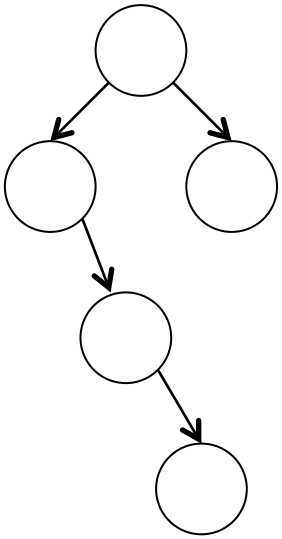
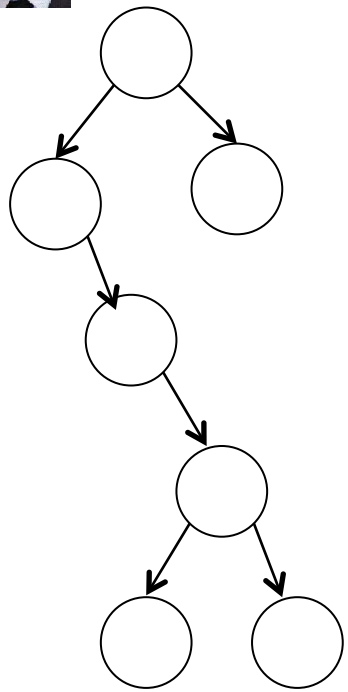
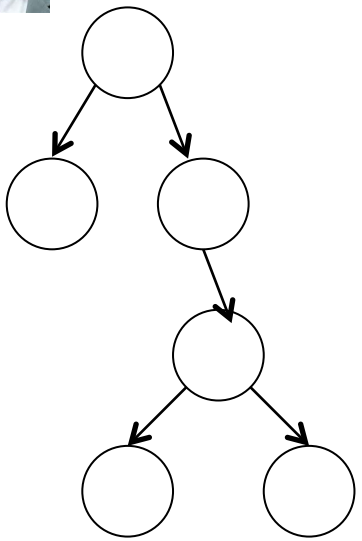


- Minimum spanning tree (Kruskal, optimum branching)
- Tree clustering based on edge weights variance thresholding
- F. de O. Costa et al, *Image phylogeny forests reconstructions*, IEEE TIFS, Oct. 2014

Construction of the graph (3/3)

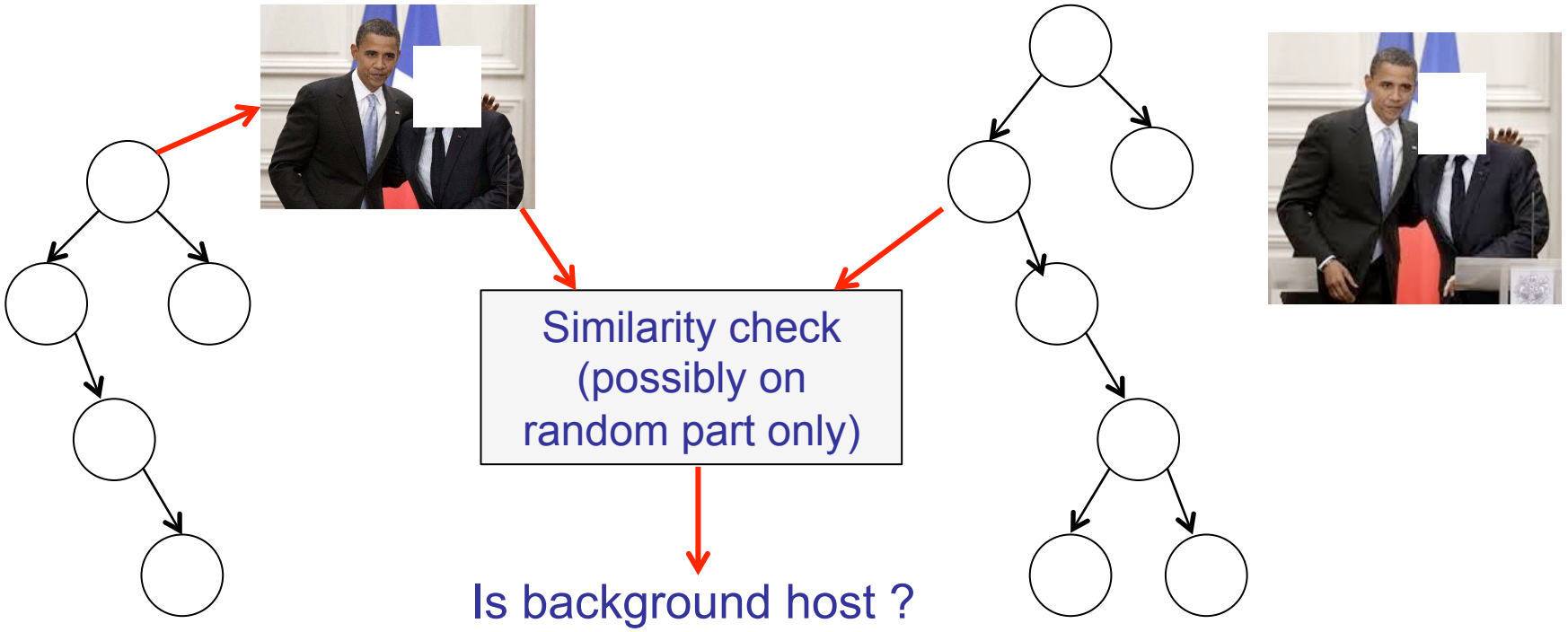
- Identification of multiple parents and FC assumption verification



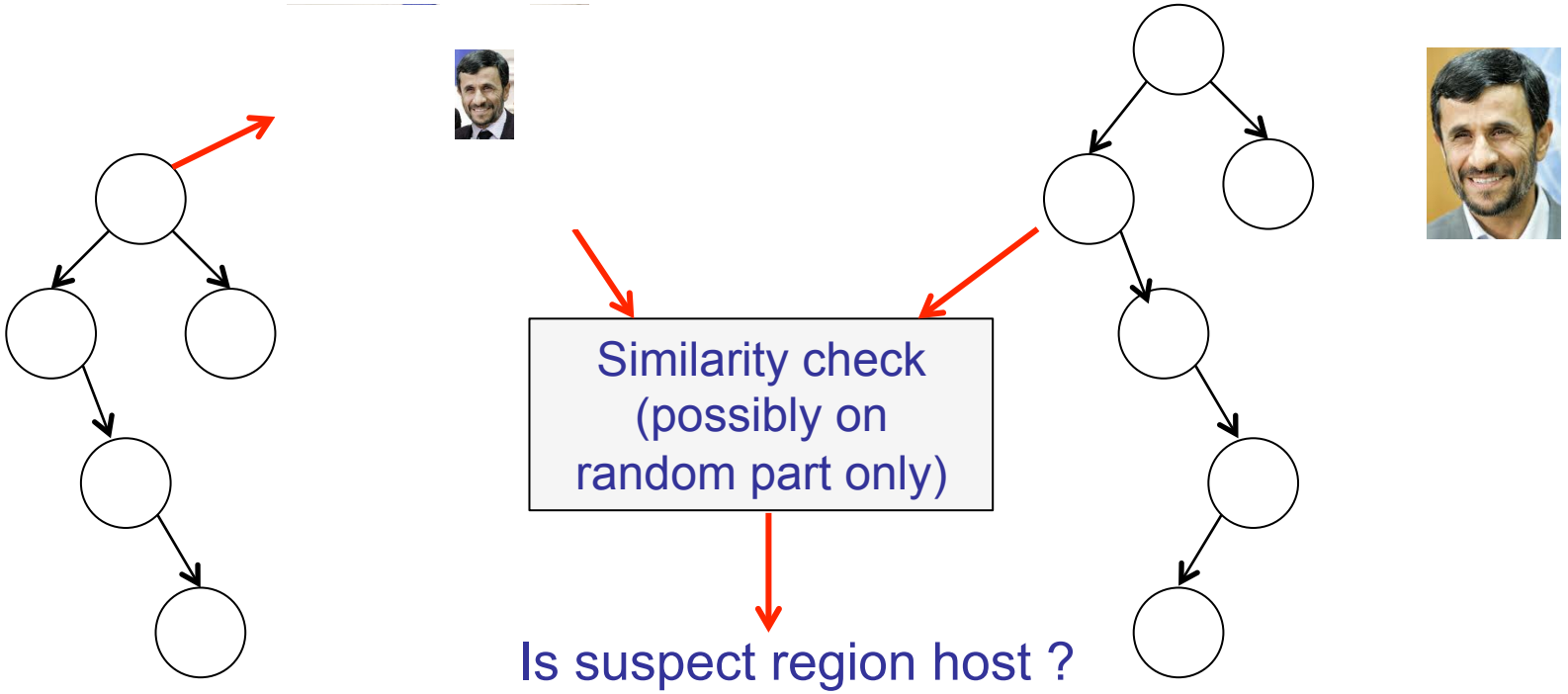
Construction of the graph (3/3)

- Focus on root of to-be-authenticated image tree: for all the other trees look for **original background image**

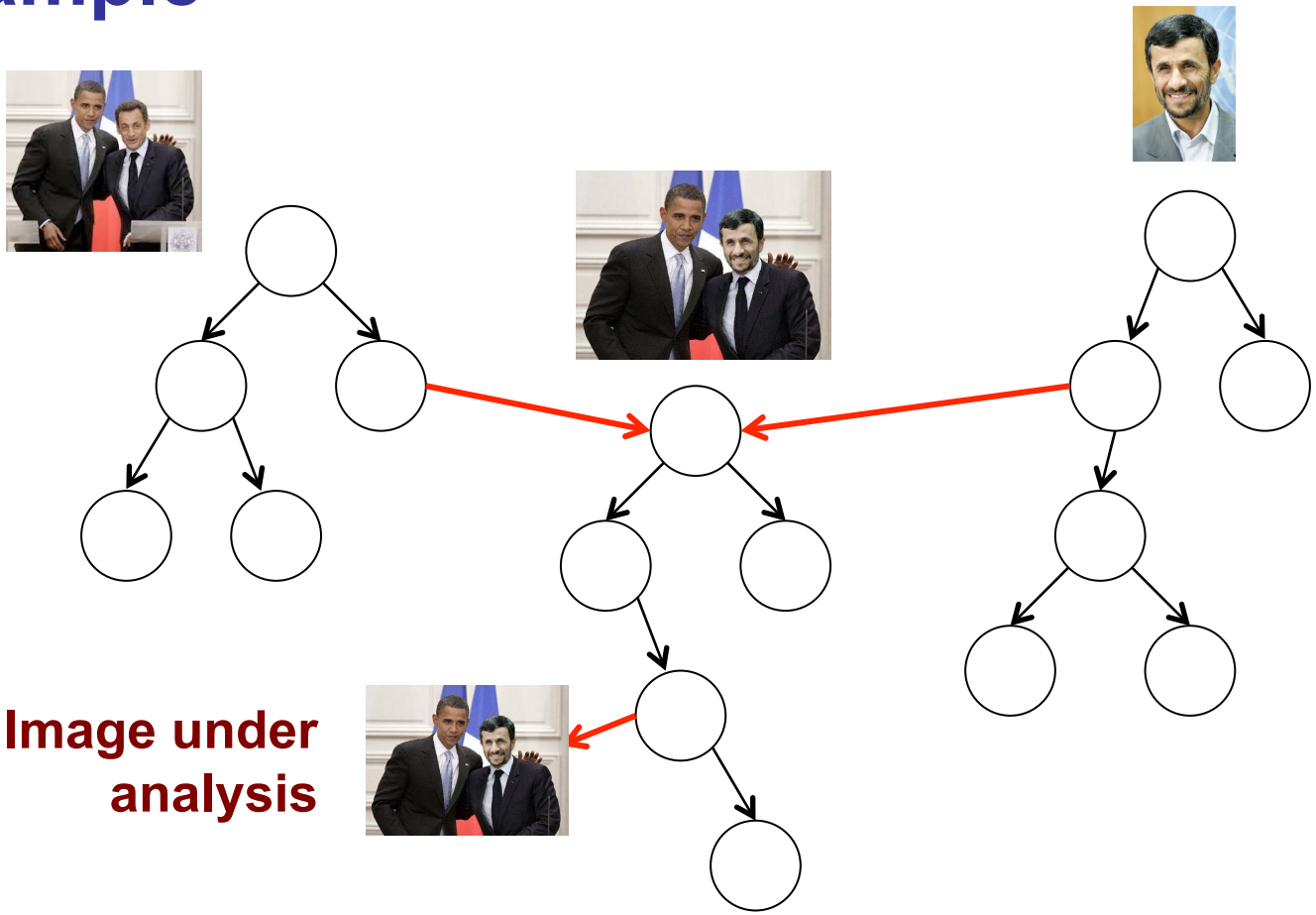


Construction of the graph (3/3)

- Focus on root of to-be-authenticated image tree: for all the other trees look for **original suspect region**



Example



Suspect image is not authentic, since it does not satisfy the FC assumption by the light of BC information

Discussion: an over-over-simplified case

- Trivial FC assumption
- Simple model for background context
  - Yet it gives richer information than needed
- Low semantic level
- Very simply composition
  - Only one copied-region
  - Assume search is nearly perfect
  - Assume thresholds always work
- Very high complexity
  - Does not scale to big data
- **It shows potentiality (and challenges) of multiple-object contextual investigation**

Conclusions

- Diffusion of MM content and popularity of UGC paradigm
- Importance of web for information exchange, collective awareness, opinion formation
- Increasing pervasiveness of social networks

Call for

- Means to **authenticate** MM contents (and not only) by taking into account the **digital ecosystem wherein the contents are produced, used and diffused**

Conclusions

- Multimedia forensics represent a first partial answer
- Several challenges ahead of MMF
  - Application in realistic environments
  - Multiclue analysis
  - Adversarial version of the problem
  - **Contextual authentication**
- MM forensics, web mining, content-based retrieval, social computing: **synergistic** effort **to reach the next level of web dependability**

Thank you
for your attention