Luca D'Amiano

Tutor: Giovanni Poggi

XXX Cycle – III year presentation

Digital forensics

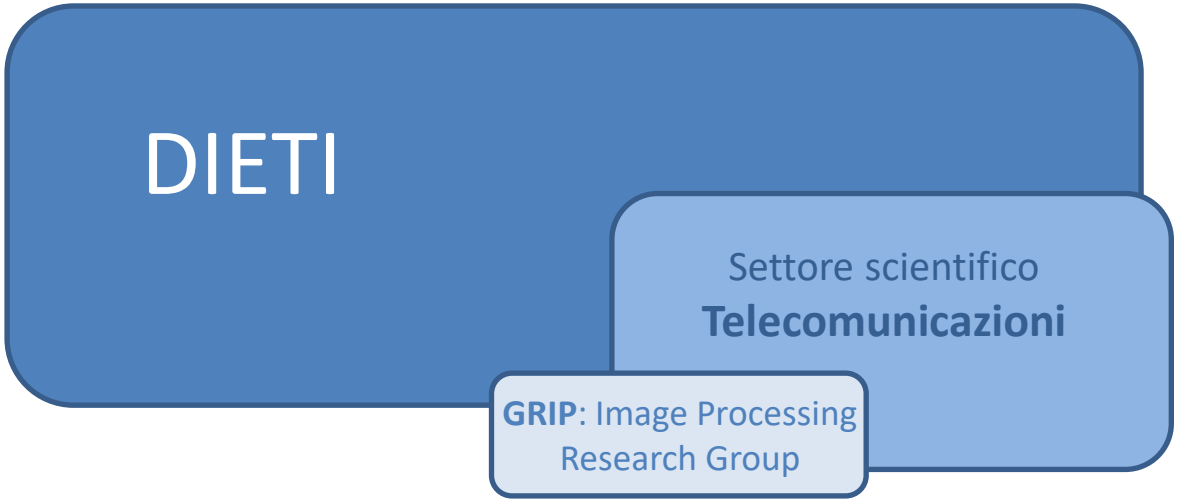
A New Technique for Video Copy-Move Forgery Detection

Summary of Activities

- **Trainig, Credits and Research Activities**
- **Overview on Image and Video Forgery**
- **Proposed Method**

My Background

- MSc in **Telecommunications Engineering** – Università degli studi di Napoli Federico II



Training

	Year	Title
Modules	1	Project Management
	1	Elaborazione Numerica dei Segnali
	1	Fondamenti di Analisi Funzionale
	2	Game Theory and analysis of competitive dynamics for industrial systems
	2	English course at CLA
Seminars	1	Modelli matematici e calcolo scientifico nell'ingegneria e nell'innovazione tecnologica
	1	Social Signal Processing: understanding social interactions through nonverbal behavior analysis
	1	Partial possibilistic regression path modeling
	2	La sintesi sonora dell'ingegnere Laurens Hammond, QUANDO LA SCIENZA INCONTRA L'ARTE
	2	Model Based and Pattern Based GUI Testing
	2	Armi autonome, problemi etici e decisioni politiche
	2	Perception-Based Surround Sound Recording and Reproduction
	2	An overview on image forensics with emphasis on physics-based scene verification
	3	Workshop on Deep Learning for Visual Computing
Exsternal	1	2015 IEEE SPS Italy Chapter Summer School on Signal Processing
	2	ICVSS 2016, International Computer Vision Summer School
	2	IEEE EURASIP S3P 2016, Summer School on Signal Processing
	3	IEEE EURASIP S3P 2017, Summer School on Signal Processing, "Signal Processing meets Deep Learning"

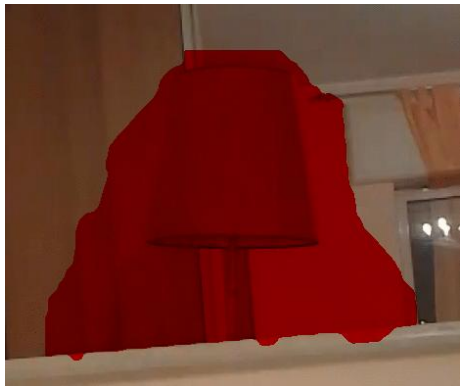
Credits

	year 1						year 2						year 3					
	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth
Modules	-	-	3	-	7	9	-	3	4	-	3	-	-	-	-	-	-	4
Seminars	-	-	0.8	4.4	-	-	1.8	0.2	-	0.2	-	3	1	-	-	-	-	-
Research	5	5	5	9	6	6	7	7	7	7	7	7	9	10	10	10	10	9
	5	5	8.8	13.4	13	15	8.8	10.2	11	7.2	10	10	10	10	10	10	10	13

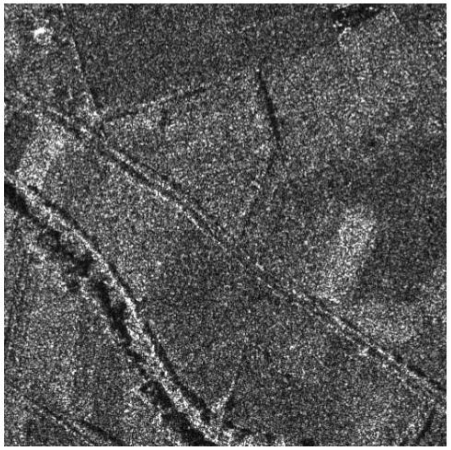
SUMMARY				
Year	Modules	Seminars	Research	Tot.
1	19	5.2	36	60.2
2	10	5.2	42	57.2
3	4	1	58	63
Tot.	33 (30-70)	11.4 (10-30)	136 (80-140)	180.4 (180)

Research

- **Video Copy-Move Forgery Detection**

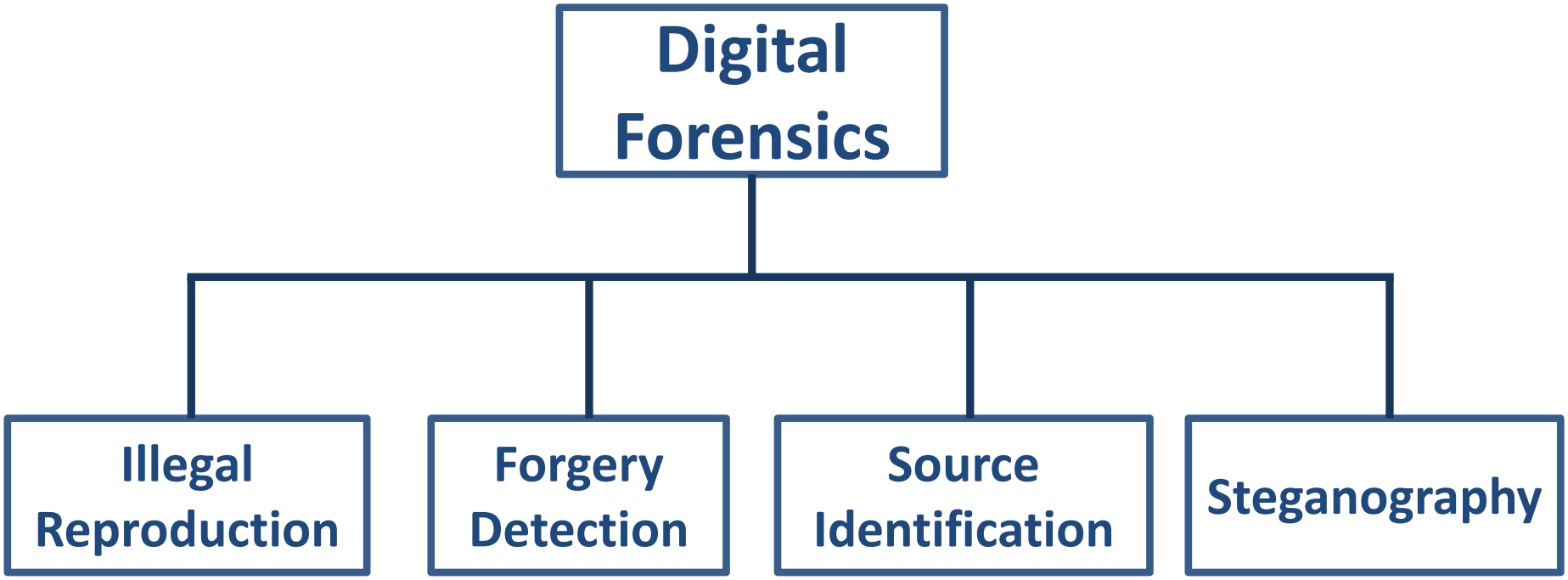


- **SAR despeckling**



BACKGROUND

Digital Forensics



Digital Forensics

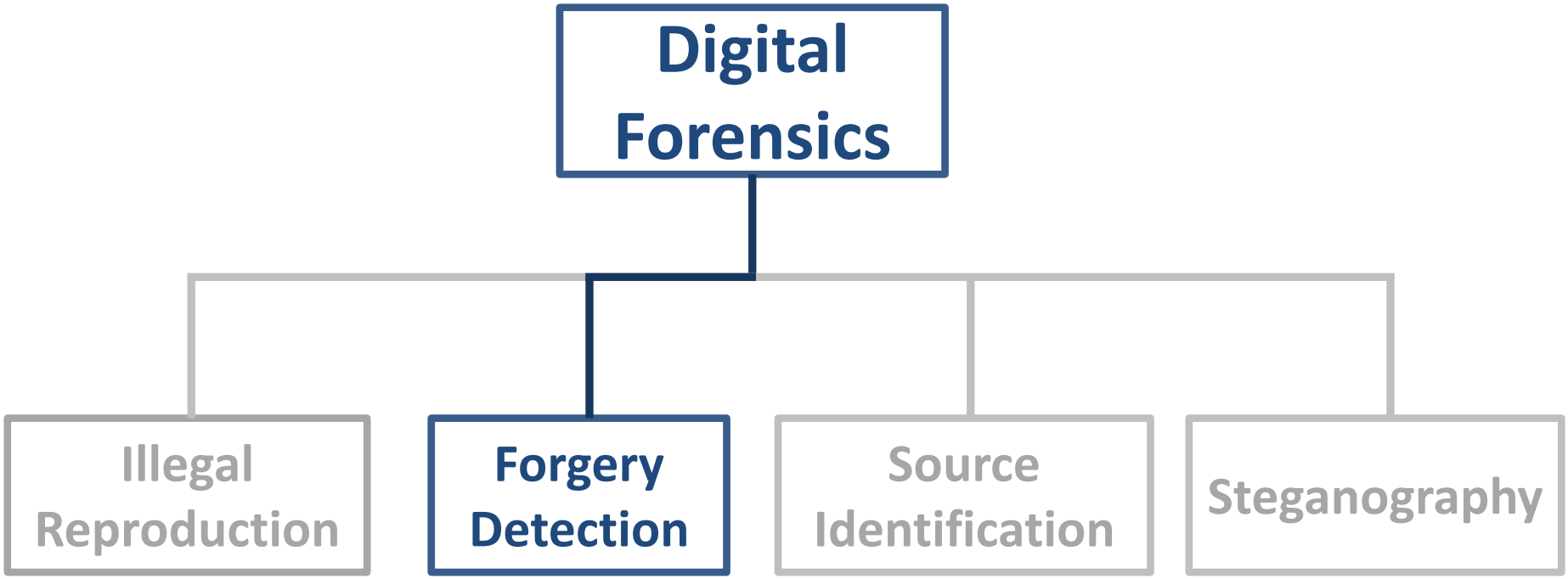


Image Forgery (1/4)

Abraham Lincoln - ~ 1860

Image Forgery (2/4)

Benito Mussolini - 1942

Image Forgery (3/4)

Lebanese city - 2006

Image Forgery (4/4)

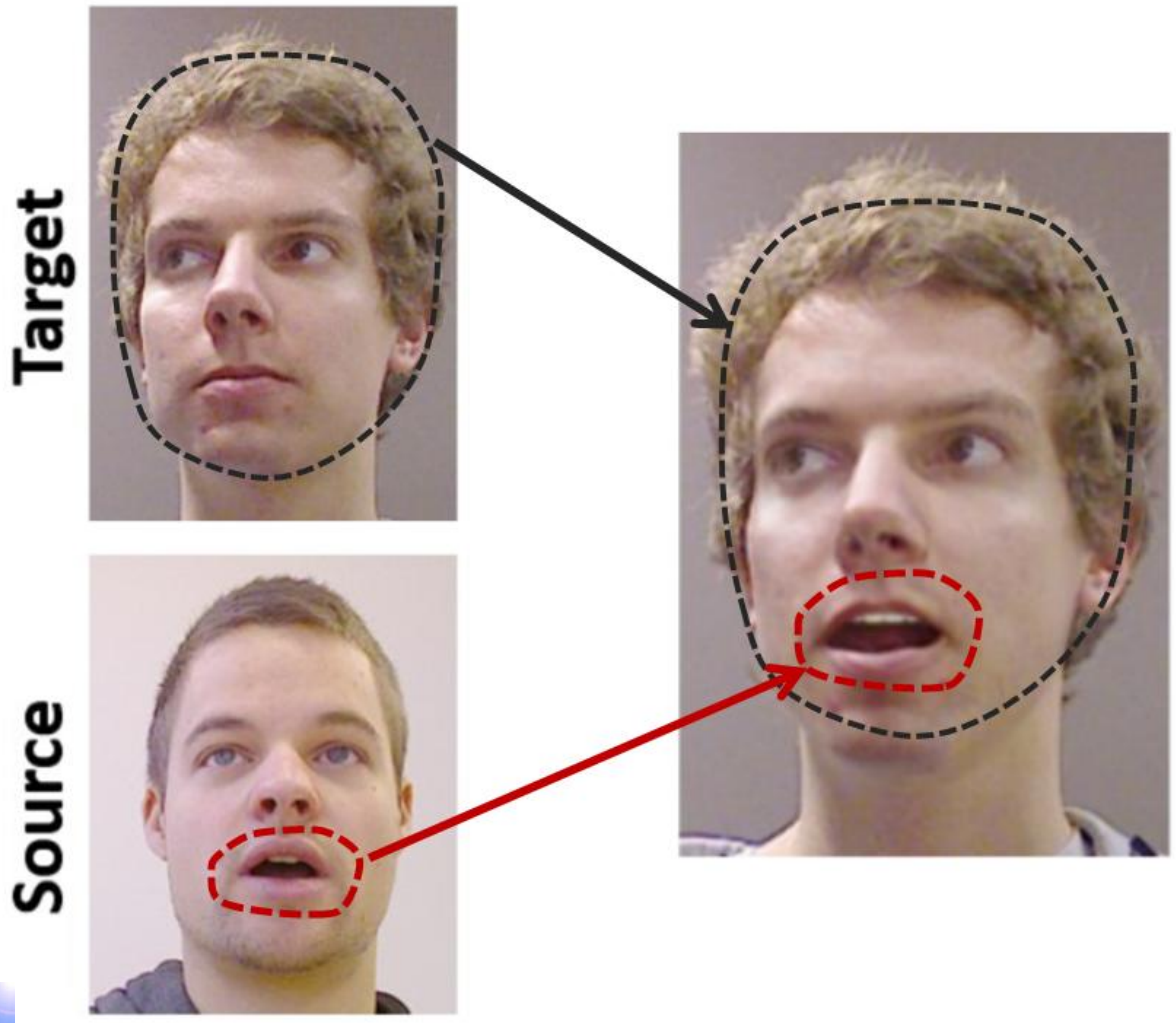
Iranian missile - 2008

Video Forgery (1/3)

Zach King's Videos - 2011 /2017

Video Forgery (2/3)

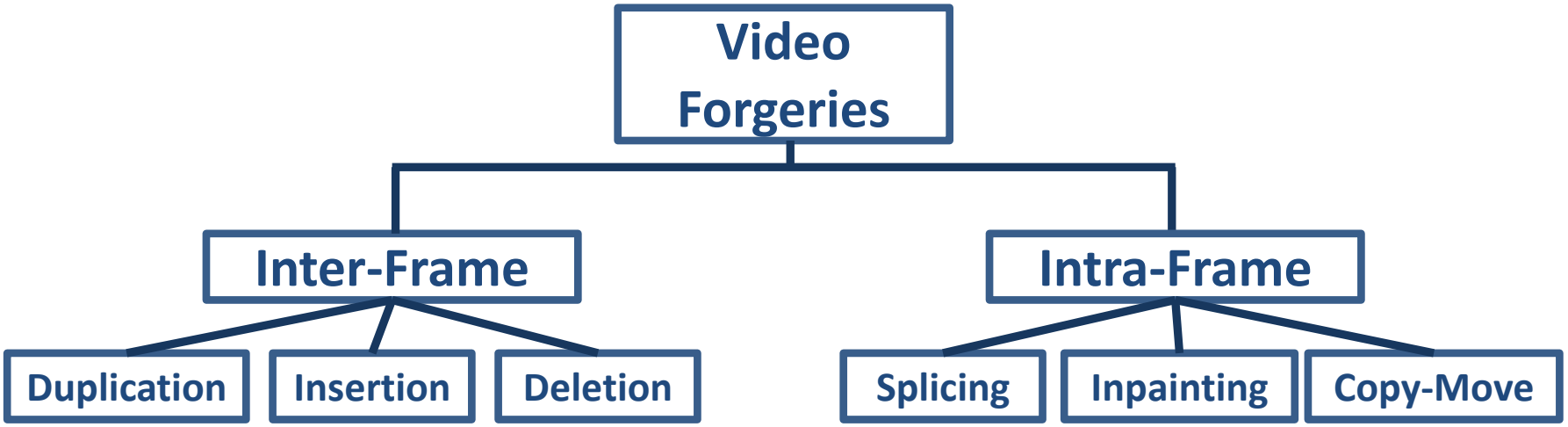
Face to Face - 2015



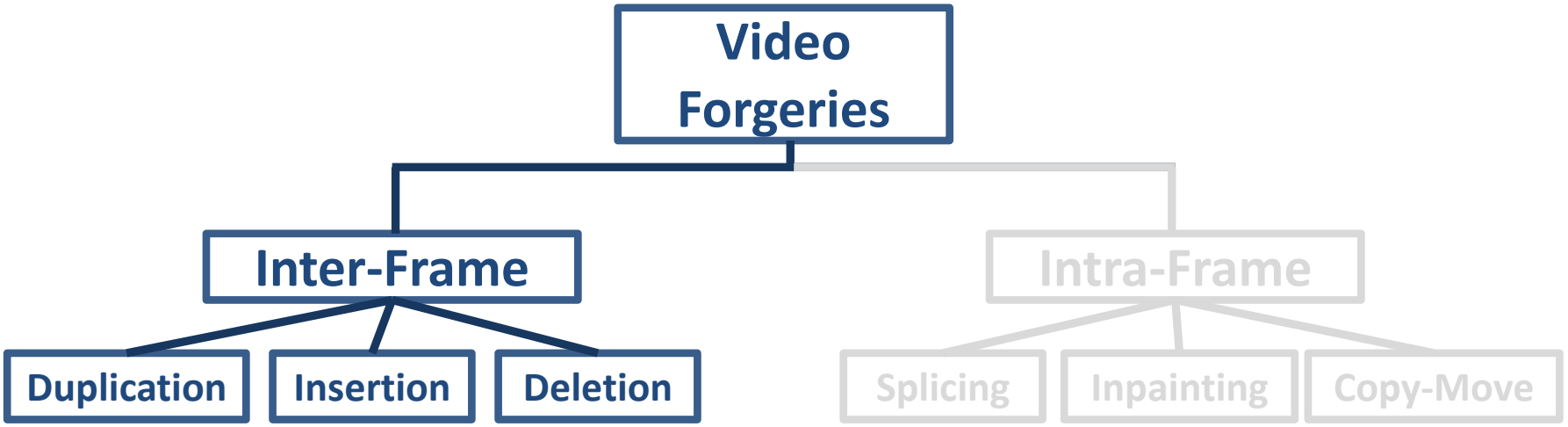
Video Forgery (3/3)

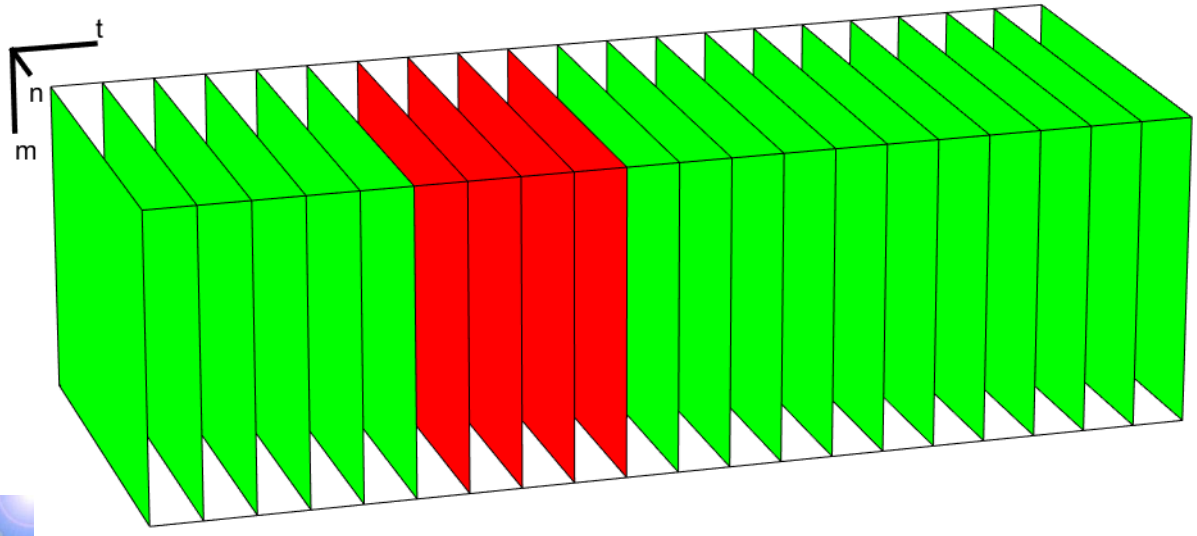
Varoufakis - 2015

Video Forgery Classification

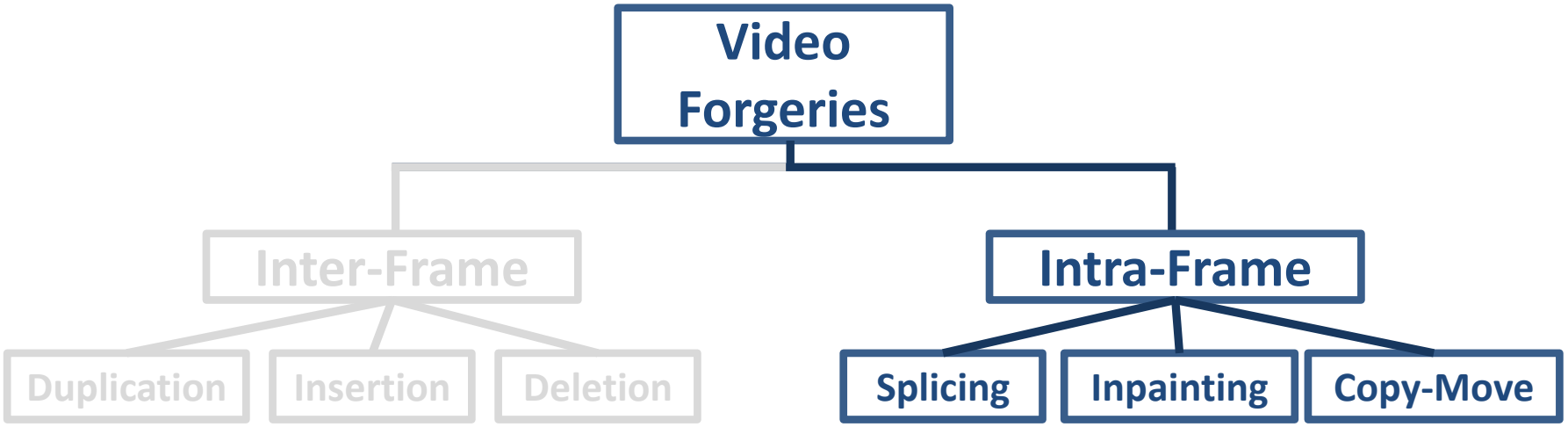


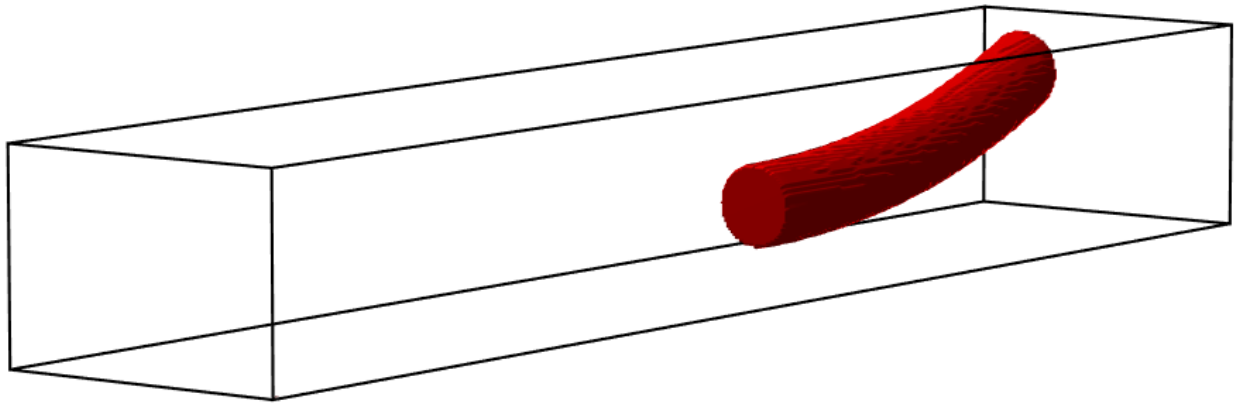
Video Forgery Classification





Video Forgery Classification

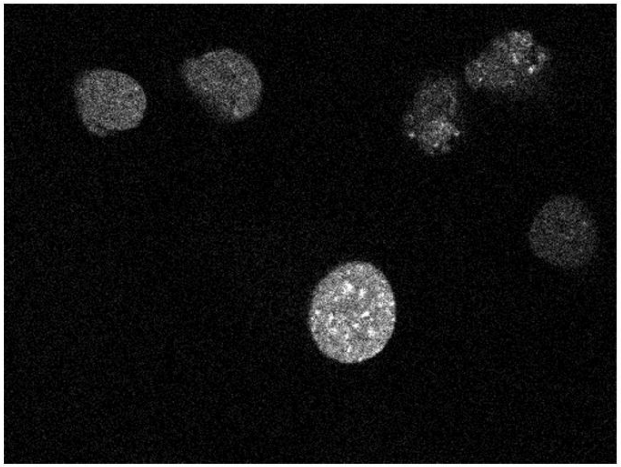




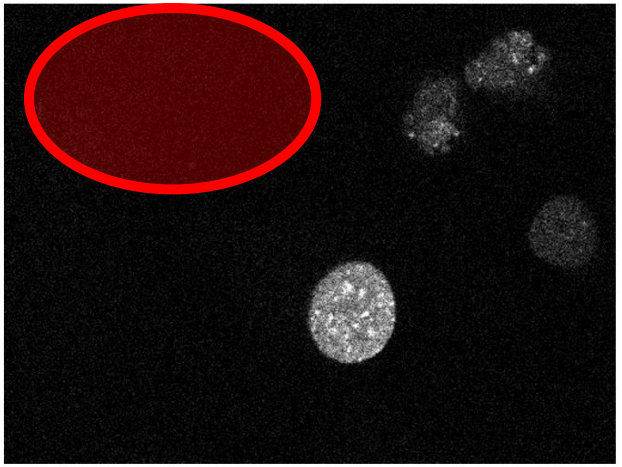
Video Copy-Move Forgery

Original frame

Additive forgery

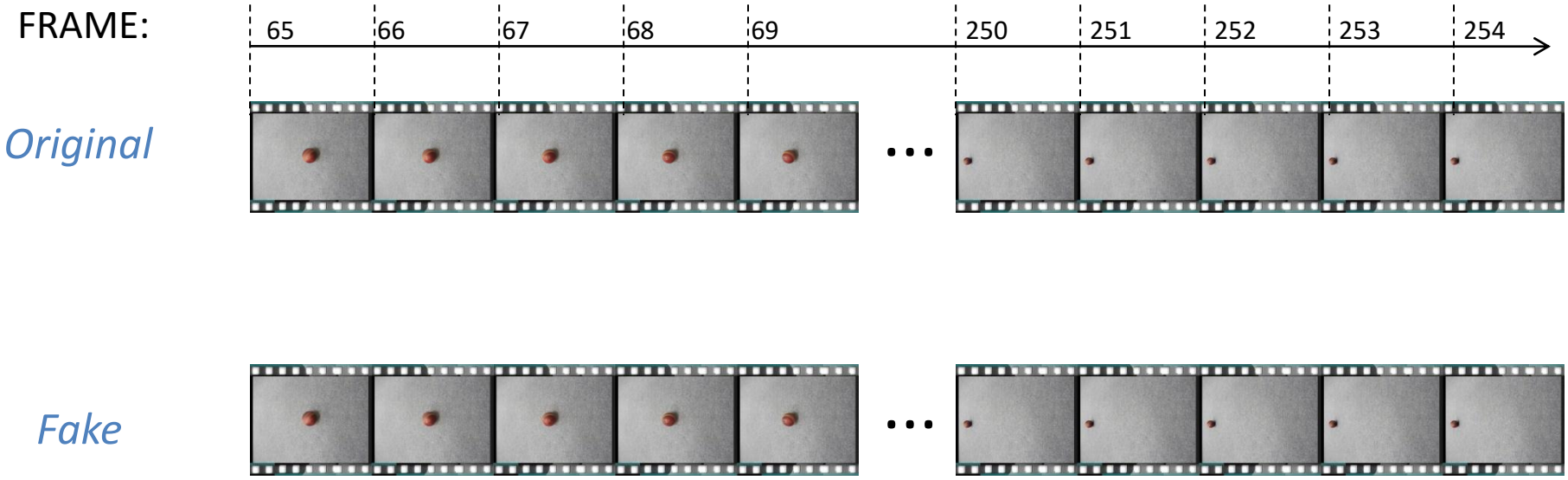


Original frame



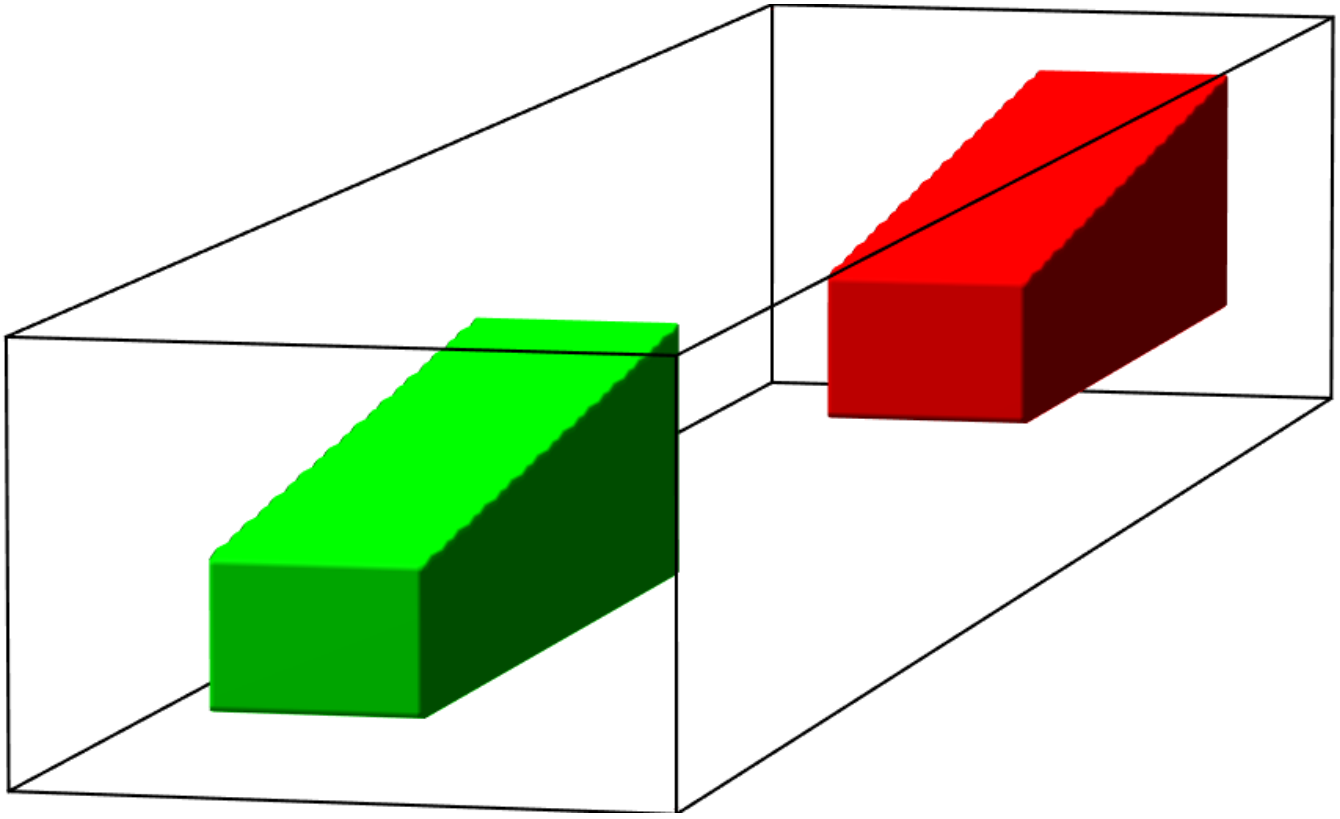
Occlusive forgery

Video Copy-Move Forgery



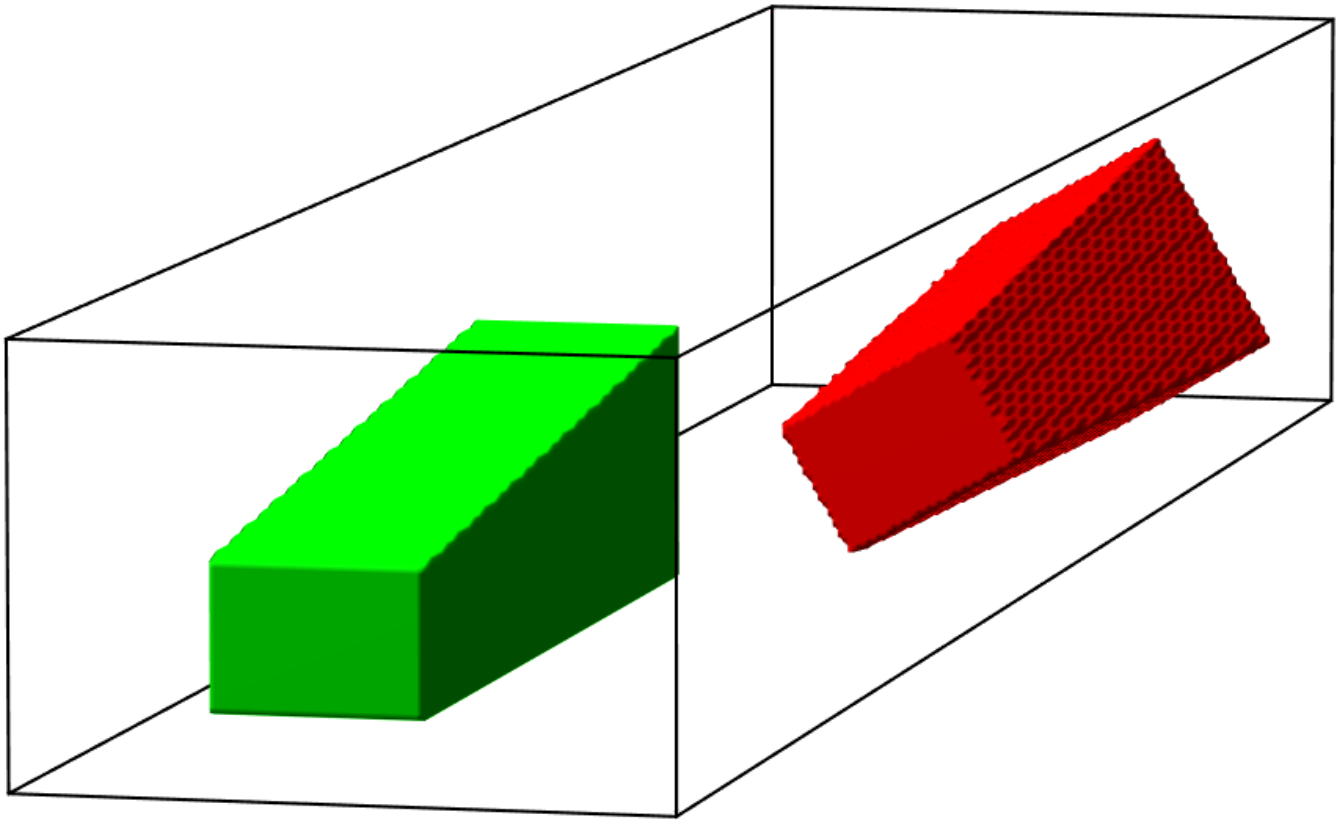
Video Copy-Move Forgery

Plain Copy-Move



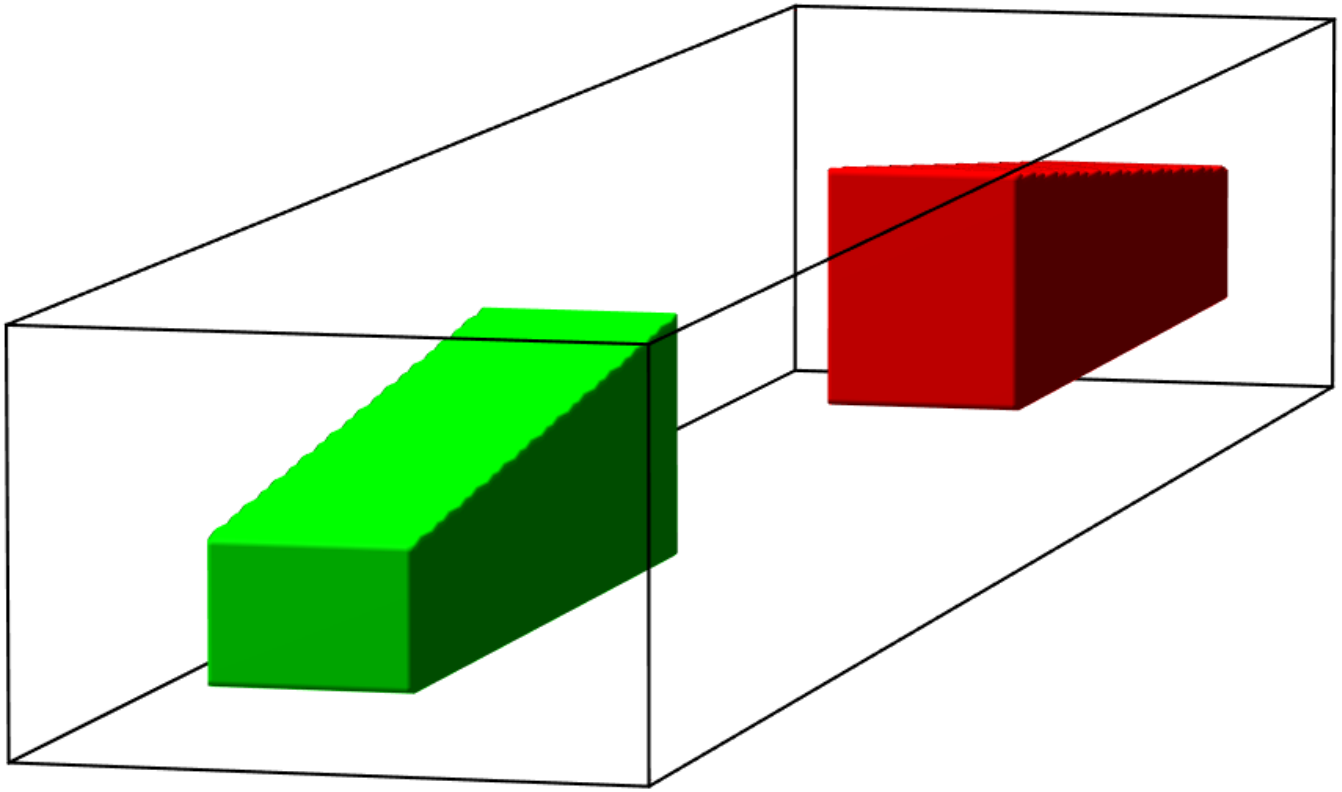
Video Copy-Move Forgery

Copy-Move with rotation



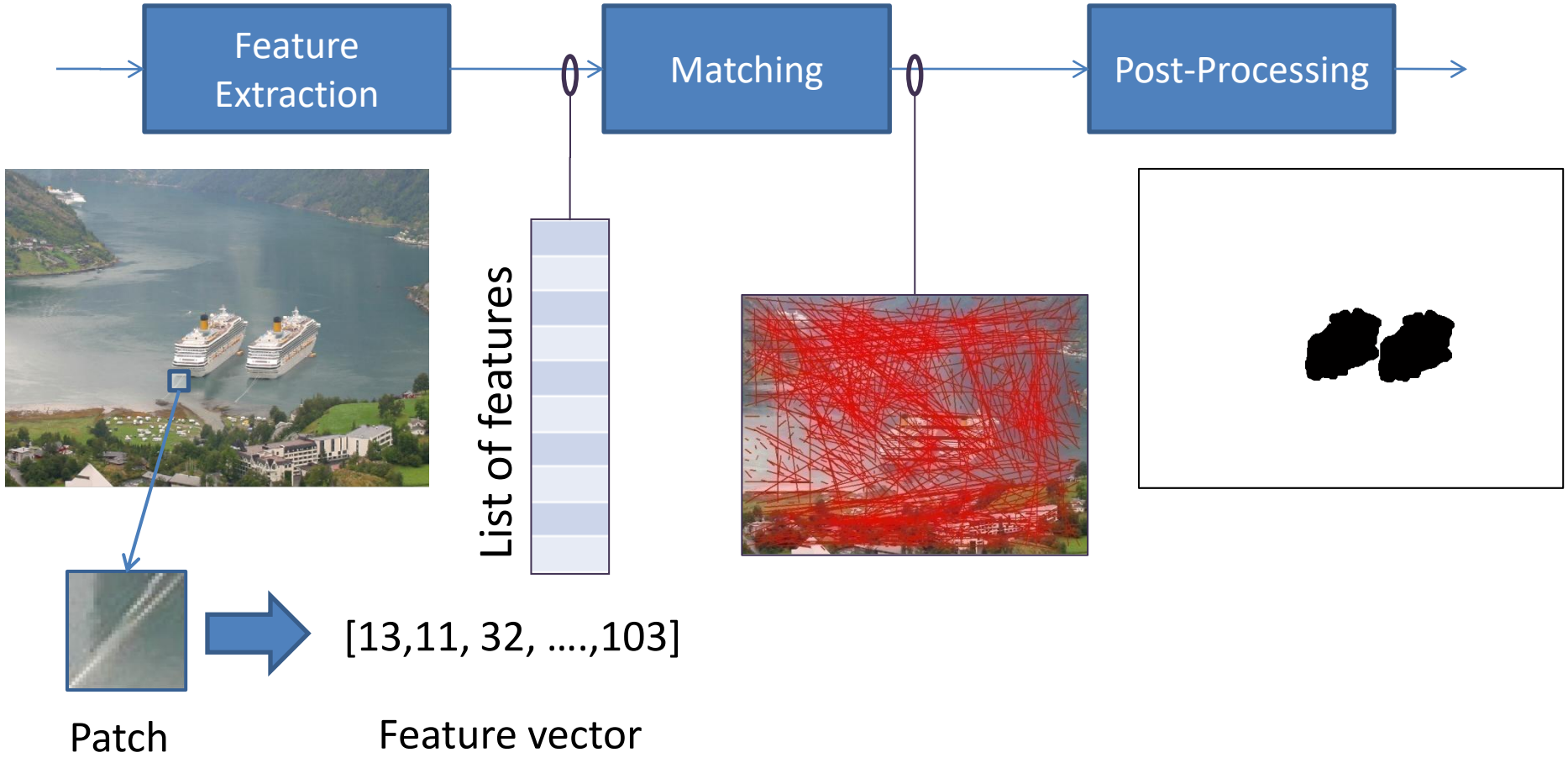
Video Copy-Move Forgery

Flipped Copy-Move



PROPOSED METHOD

Main steps in Copy-Move Forgery Detection



Keypoint-vs-dense CMFD

Keypoint-based

- Work on Salient Points
- Accurate Featuring and Matching

✓ Very Fast

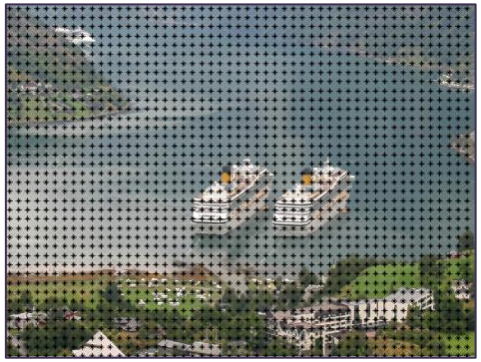
✗ Missing «occlusive» forgeries

Dense-field

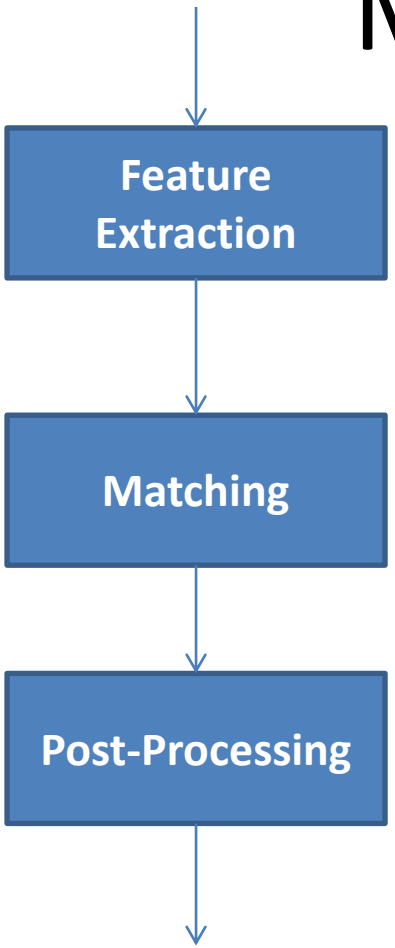
- Work on each patch
- Approximate Matching

✗ Quite slow

✓ Accurate on all copy-move



Main qualifying points



- Zernike Moments ← Invariance to rotation
- 3D Features ← Invariance to flipping

- Dense Field ← Higher reliability
- Multires. PatchMatch ← Faster processing

- Dense linear fitting ← Faster processing
- Removal of False Alarms ← Perform. Improvement

Feature Extraction

Zernike Moments

Fourier Series

$$F_I(n,m) = \int_0^1 \left(\frac{1}{\sqrt{2\pi}} \int_0^{2\pi} I(\rho,\theta) \cdot e^{-jm\theta} d\theta \right) R^*_{n,|m|}(\rho) \rho d\rho$$

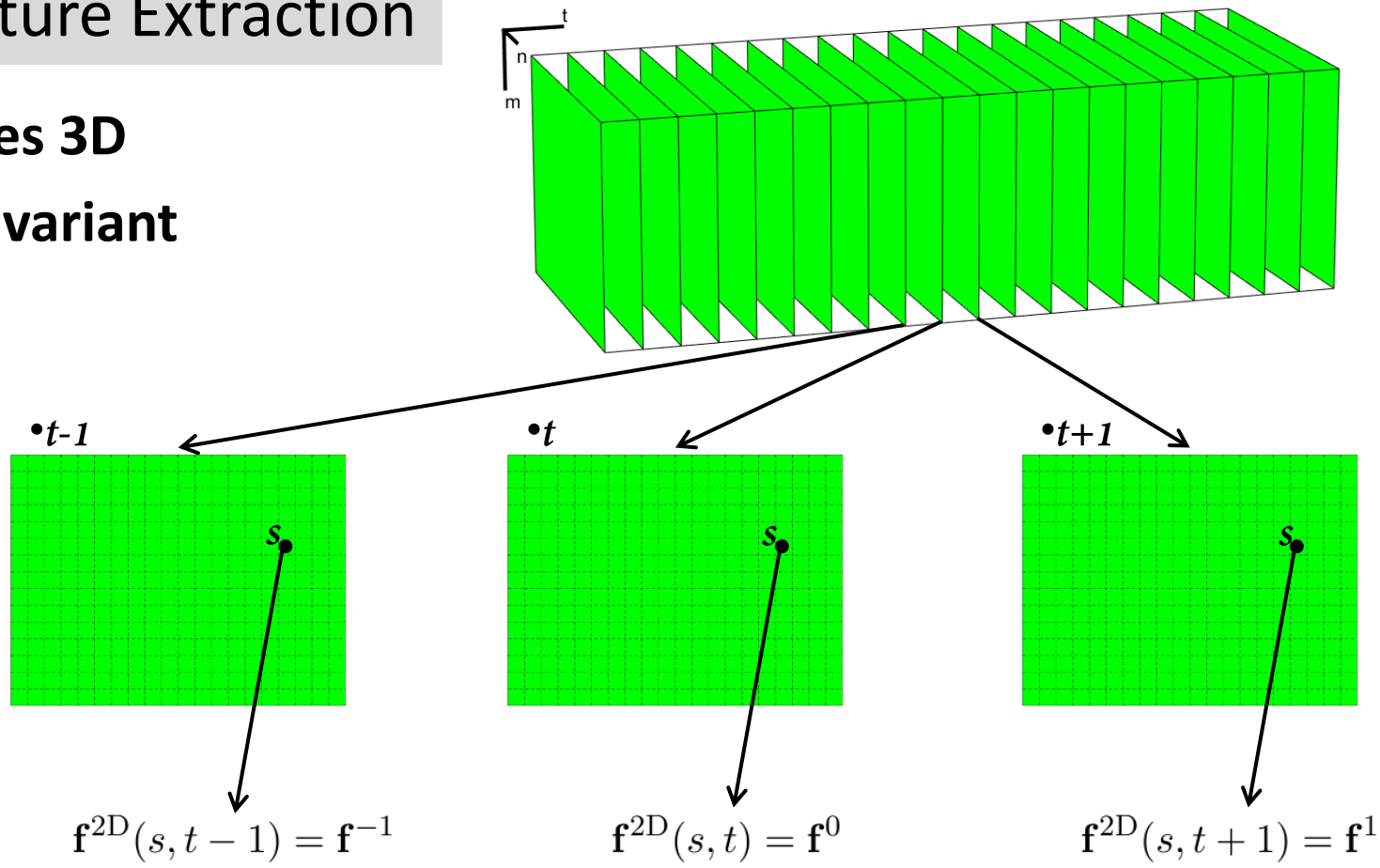
Polar coordinates

Zernike Radial Profile

Feature Extraction

Features 3D

flip-invariant

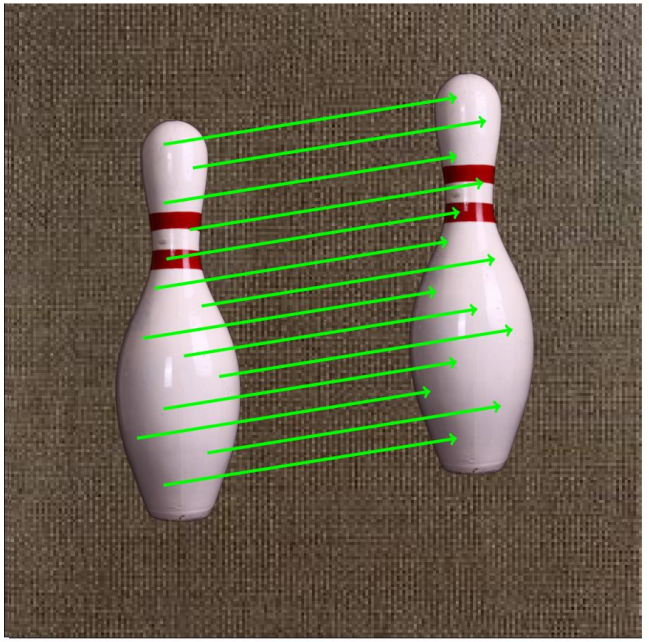


$$\mathbf{f}^{2D}(s,t-1) = \mathbf{f}^{-1} \qquad \mathbf{f}^{2D}(s,t) = \mathbf{f}^{0} \qquad \mathbf{f}^{2D}(s,t+1) = \mathbf{f}^{1}$$

$$\mathbf{f}^{3D,FI}(s,t) = \left[\frac{1}{\sqrt{2}}|\mathbf{f}^{-1} - \mathbf{f}^{1}|, \quad |\mathbf{f}^{0}|, \quad \frac{1}{\sqrt{2}}|\mathbf{f}^{-1} + \mathbf{f}^{1}|\right]$$

PatchMatch

- Inizialization
- Propagation
- Random search

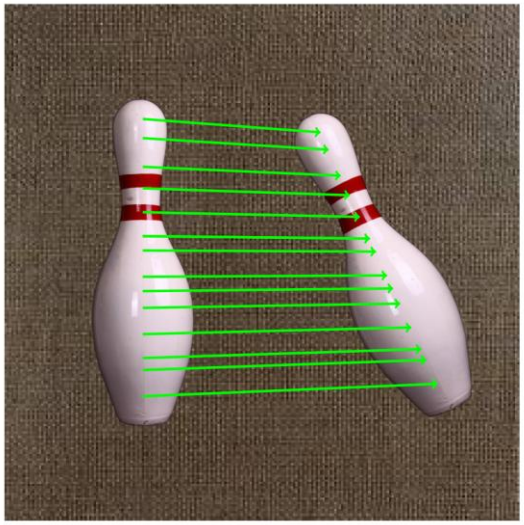


ITERATIVE

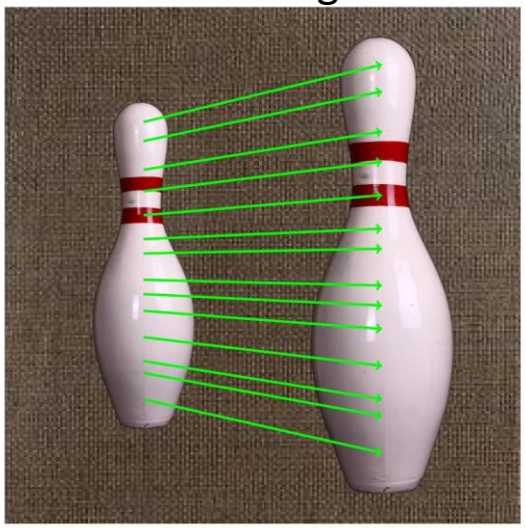
PatchMatch: modified version

- **Order 1 propagation**

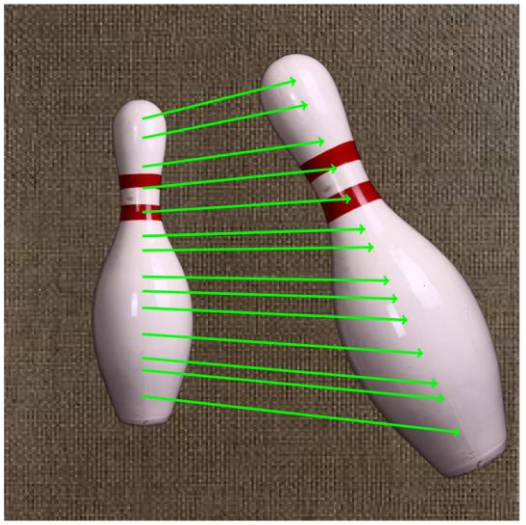
rotations



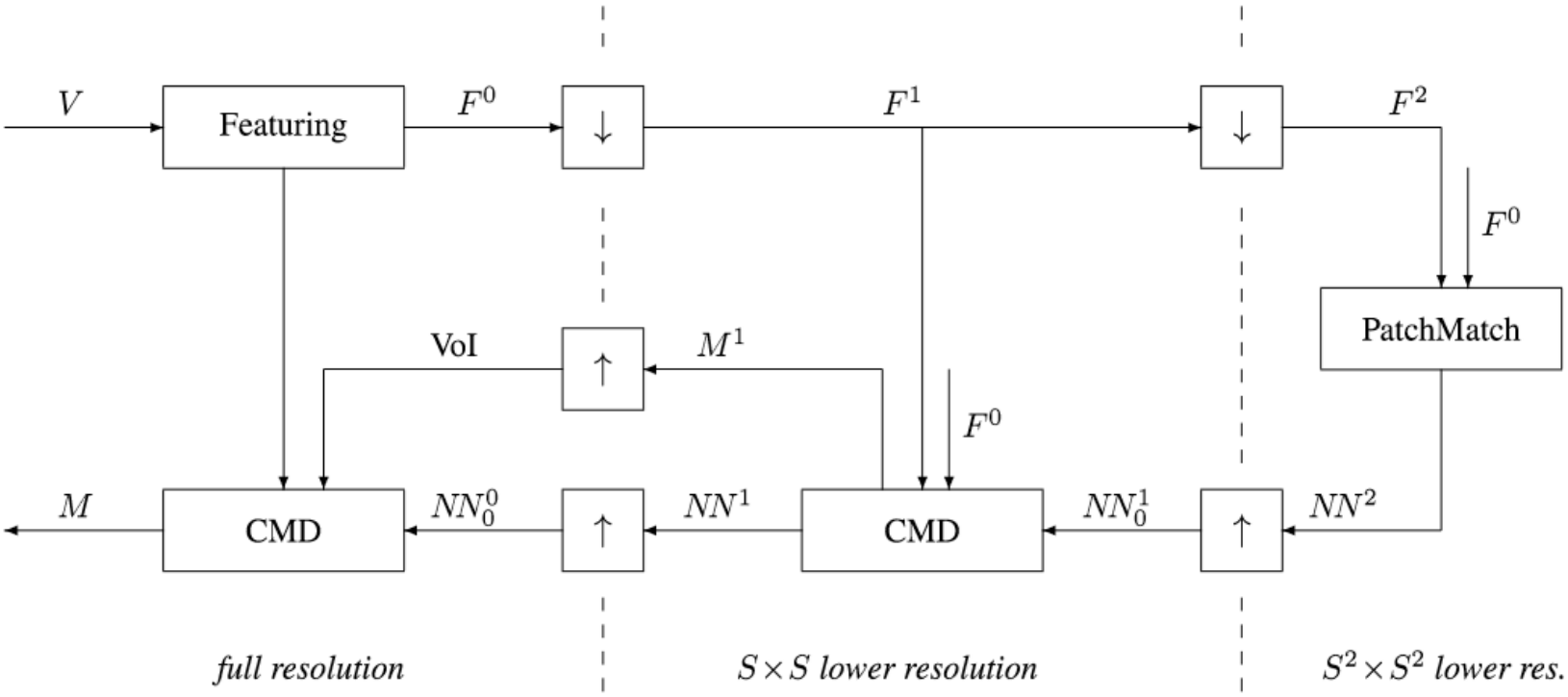
re-sizing



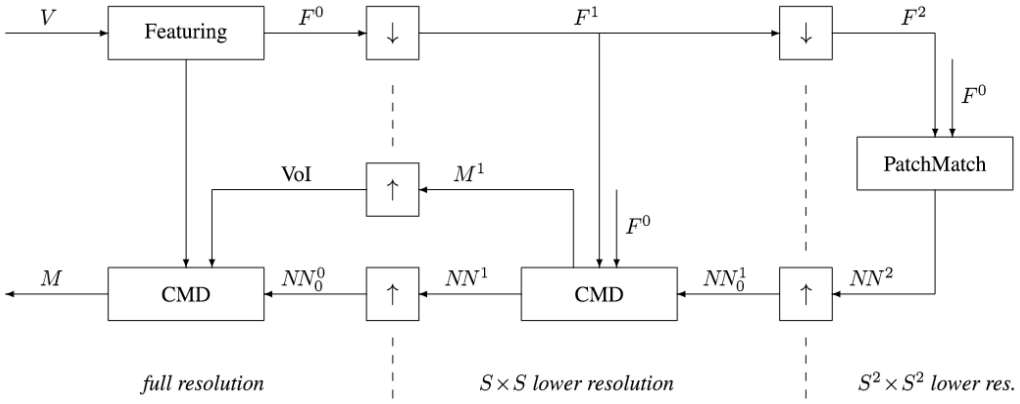
re-sizing
+
rotation

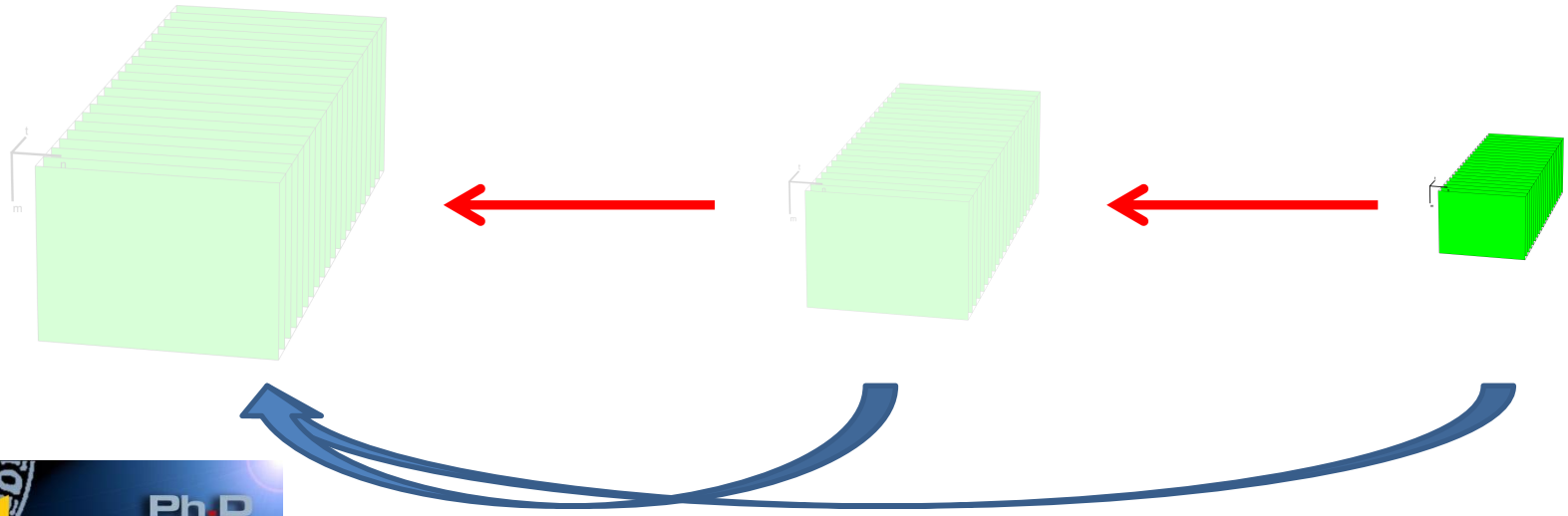


PatchMatch multiresolution



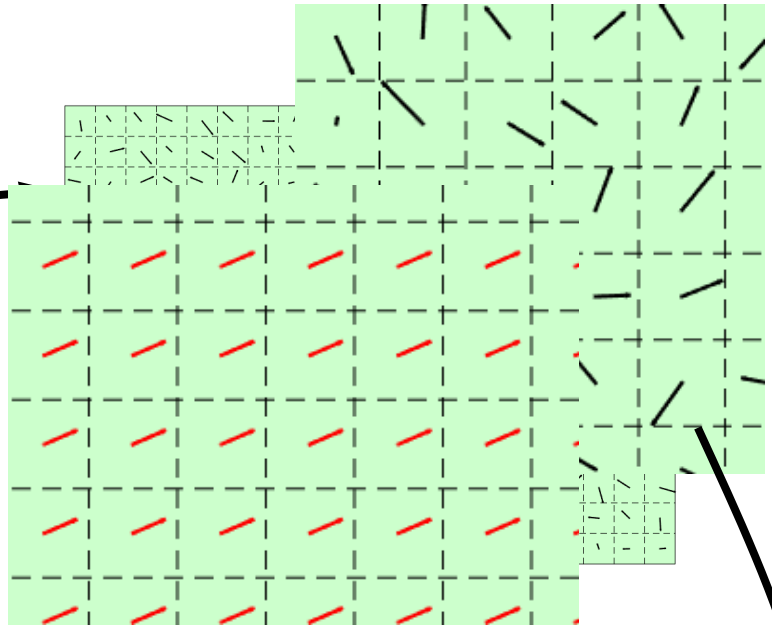
PatchMatch multiresolution

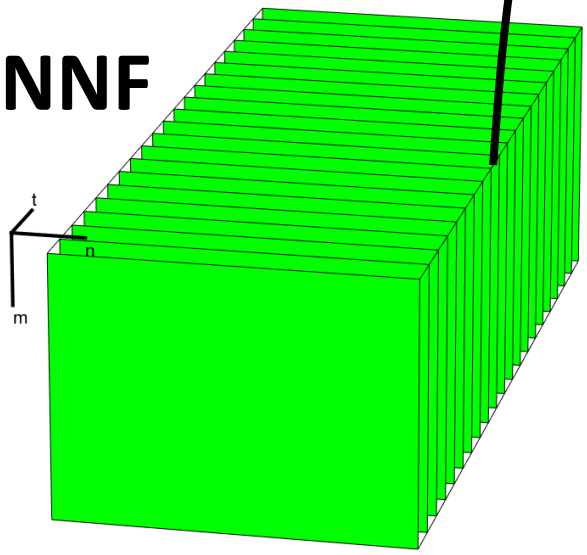


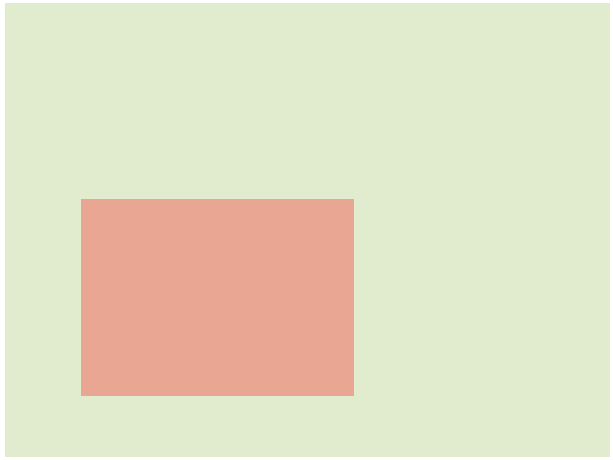


Post-Processing

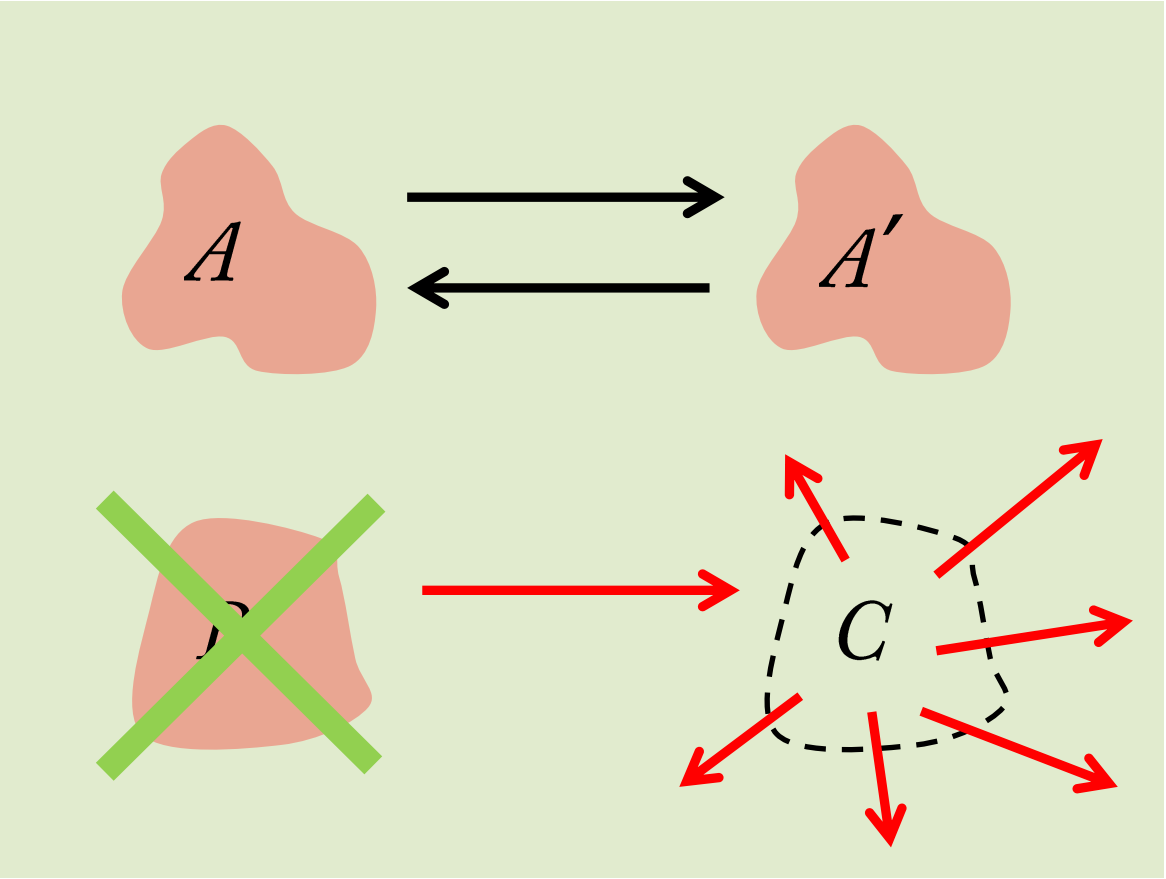
Dense Linear Fitting







Removing False Alarms



GRIP Dataset

Video 1

Video 2

Video 3

Video 4

Video 5

Video 6

Video 7

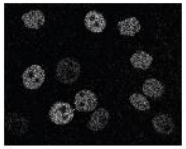
Video 8

Video 9

Video 10

Video 11

Video 12



Video 13

Video 14

Video 15

Additive Copy-Move

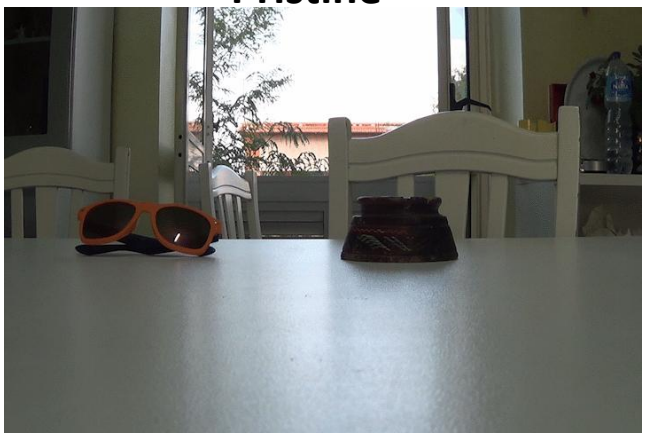
Pristine

Forged

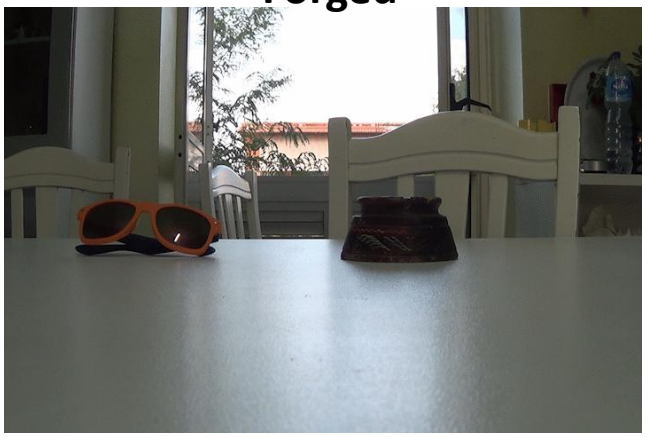
Detection Map

Occlusive Copy-Move

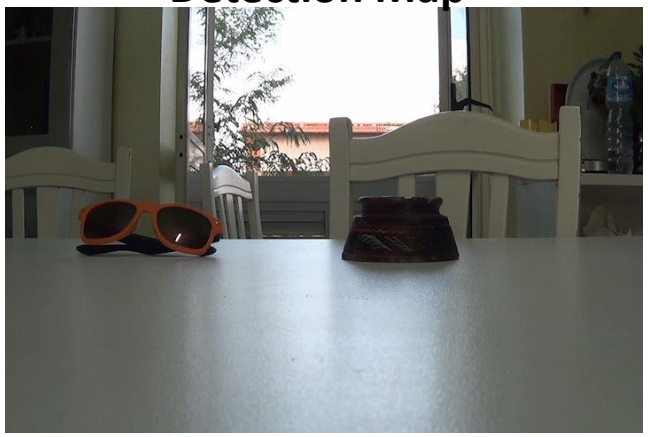
Pristine



Forged



Detection Map



GRIP Dataset

video				copy-move				
#	name	frame size	frames	add./occ.	$\rho_{\max}$	$d_{\max}$	rot.	flp.
1	TV screen	576×720	141	add	182.7	43	✓	✓
2	Fast Car	370×720	140	add	203.2	9		✓
3	Felt-Tip Pen	550×720	100	add	62.3	4	✓	✓
4	Rolling Can	480×660	125	add	229.6	18	✓	✓
5	Falling Can	480×720	174	add	71.3	29		
6	Walnuts	480×720	221	occlusive	199.5	102		
7	Can 1	520×720	201	add	220.6	28		✓
8	Can 2	720×720	210	add	112.1	15	✓	✓
9	Lamp	390×465	455	add	159.9	129	✓	
10	Ball	640×360	200	add	195.4	31		✓
11	Student	400×380	340	occlusive	176.3	60		
12	Cell 1	400×500	92	add	63.7	92	✓	✓
13	Cell 2	512×512	92	occlusive	107.5	92	✓	✓
14	Wall Frame	500×570	200	occlusive	50.6	155	✓	
15	Statue	590×480	100	occlusive	65.9	61		

Experimental Results

	Basic 2D				Basic 3D				Fast 2D				Fast 3D				Bestagini			
video	det.	f.a.	F	time	det.	f.a.	F	time	det.	f.a.	F	time	det.	f.a.	F	time	det.	f.a.	F	time
1	✓		0.96	15.42	✓		0.95	17.50	✓		0.97	2.17	✓		0.97	3.25	✓		–	8.9
2	✓		0.88	15.45	✓		0.68	17.19	✓		0.78	2.77	✓		0.67	3.44	✓		–	7.3
3	✓		0.56	16.39	✓		0.29	23.24	✓		0.60	2.67	✓		0.31	3.00	✓		–	6.7
4	✓		0.88	14.92	✓		0.79	16.75	✓		0.88	2.77	✓		0.76	3.32	✓		–	7.2
5	✓		0.84	16.70	✓		0.86	20.29	✓		0.81	2.07	✓		0.86	3.24	✓	✓	–	14.9
6	✓	✓	0.72	16.50	✓		0.74	18.58	✓	✓	0.73	2.35	✓		0.81	3.45			–	11.7
7	✓		0.83	18.45	✓		0.78	20.25	✓		0.90	2.54	✓		0.81	3.41	✓	✓	–	11.5
8	✓		0.87	19.73	✓		0.77	24.23	✓		0.89	2.20	✓		0.76	3.32	✓	✓	–	15.2
9	✓		0.93	17.80	✓		0.92	20.31	✓		0.94	2.40	✓		0.93	4.02	✓	✓	–	14.4
10	✓		0.91	15.69	✓		0.89	16.67	✓		0.94	2.30	✓		0.92	3.45	✓	✓	–	6.3
11	✓	✓	0.88	14.14	✓		0.87	18.00	✓	✓	0.86	3.05	✓		0.88	4.15			–	7.7
12	✓		0.80	16.23	✓		0.77	18.78	✓		0.87	1.96	✓		0.83	3.81			–	2.6
13	✓		0.91	15.43	✓		0.90	18.26	✓		0.92	2.49	✓		0.91	4.02			–	4.4
14	✓		0.74	16.66	✓		0.71	19.42	✓		0.77	2.35	✓		0.77	3.39			–	8.8
15	✓		0.72	16.05	✓	✓	0.51	20.17		✓	0.00	2.26	✓	✓	0.41	3.32			–	3.8
Σ, μ	15	2	0.83	16.37	15	1	0.76	19.31	14	3	0.79	2.42	15	1	0.75	3.51	9	5		8.8

Experimental Results

			Basic 2D			Basic 3D			Fast 2D			Fast 3D			Bestagini		
dataset	case	# videos	det.	f.a.	F	det.	f.a.	F	det.	f.a.	F	det.	f.a.	F	det.	f.a.	F
GRIP	plain	15	15	2	0.83	15	1	0.76	14	3	0.79	15	1	0.75	9	5	–
GRIP	QF = 10	15	15	1	0.84	15	1	0.77	14	2	0.74	14	1	0.75	9	5	–
	QF = 15		15	1	0.76	15	1	0.72	13	2	0.65	15	1	0.70	9	4	–
	QF = 20		12	1	0.54	12	1	0.56	13	2	0.53	12	0	0.52	9	5	–
GRIP	$\theta = 5^o$	8	8	–	0.81	7	–	0.73	5	–	0.40	7	–	0.68	2	–	–
	$\theta = 25^o$		7	–	0.71	4	–	0.60	3	–	0.25	4	–	0.44	2	–	–
	$\theta = 45^o$		5	–	0.56	4	–	0.43	2	–	0.12	4	–	0.43	2	–	–
GRIP	flipping	9	8	–	0.81	9	–	0.76	6	–	0.59	7	–	0.59	3	–	–

Publications

L. D'Amiano, D. Cozzolino, G. Poggi, and L. Verdoliva,
"Video forgery detection and localization based on 3D PatchMatch",
IEEE International Conference on Multimedia & Expo Workshops (ICMEW),
Turin (I), June 2015.

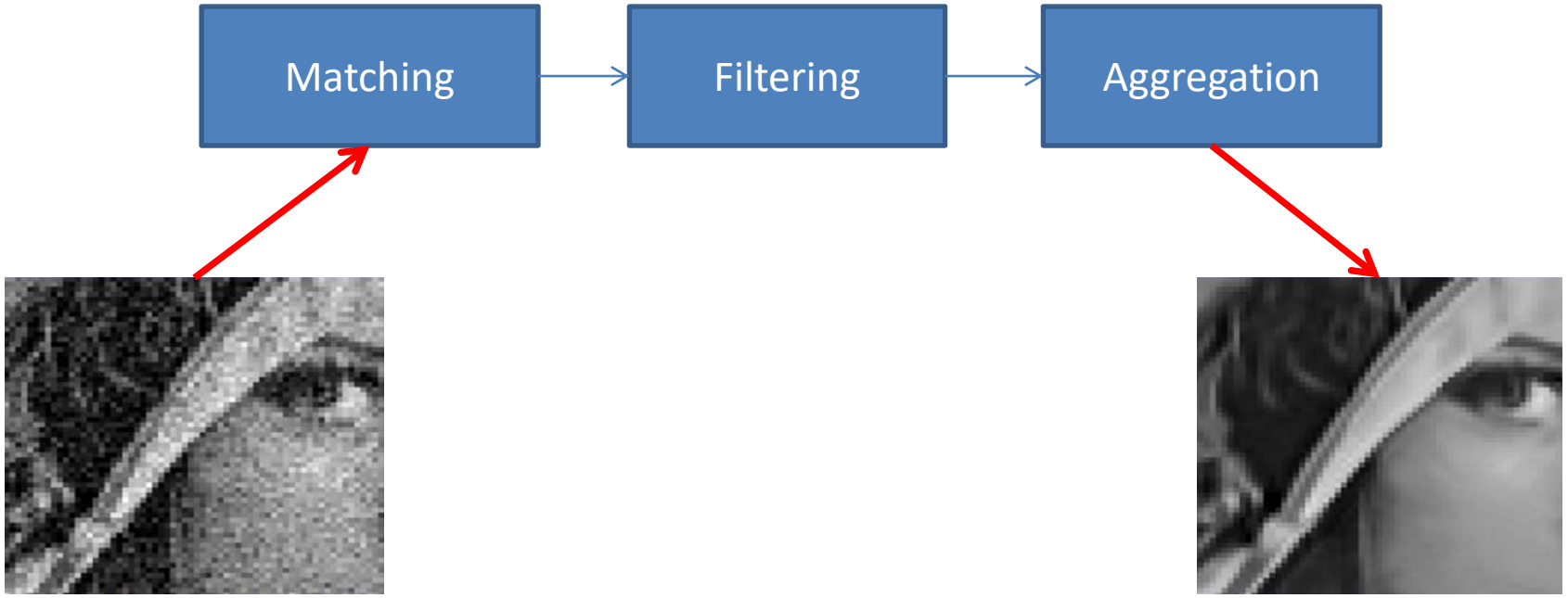
L. D'Amiano, D. Cozzolino, G. Poggi, and L. Verdoliva,
"A PatchMatch-based dense-field algorithm for video copy-move detection and localization".
IEEE Transactions on Circuits and Systems for Video Technology
Second revision submitted, september 2017
available on arXiv:1703.04636

R. Gaetano, D. Cozzolino, **L. D'Amiano**, L. Verdoliva, G. Poggi,
"Fusion of SAR-optical datafor land cover monitoring",
International Geoscience and Remote Sensing Symposium (IGARSS),
Fort Worth (USA), July 2017.

THANK YOU !

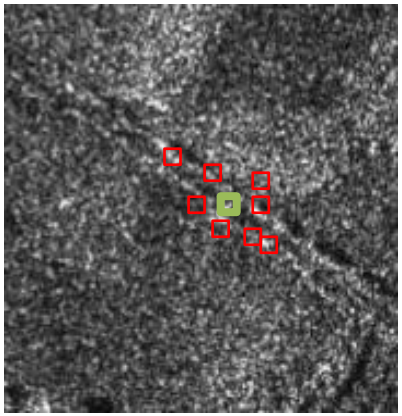
SAR Despeckling (1/4)

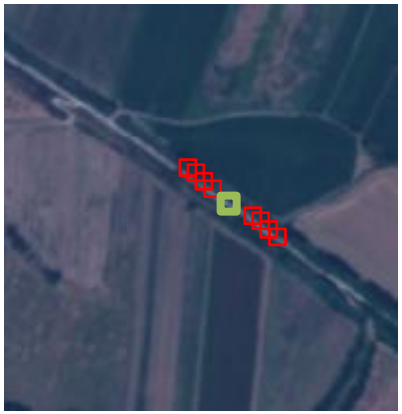
Patch-Based Nonlocal Fltering Scheme



SAR Despeckling (2/4)

- **MATCHING**
- **FILTERING**





$$d(t,s) = \alpha d_S(t,s) + (1-\alpha) d_O(t,s)$$

$$d_O(t,s) = \sum_{\delta \in \mathbb{P}} \|o(t+\delta) - o(s+\delta)\|^2$$

$$d_S(t,s) = \sum_{\delta \in \mathbb{P}} \log\left(\frac{v(t+\delta)+v(s+\delta)}{2\sqrt{v(t+\delta)\cdot v(s+\delta)}}\right)$$

SAR Despeckling (3/4)

- MATCHING
- **FILTERING**

$$\widehat{u}(t+\delta) = \sum_{i=1}^{N_p} w_i \cdot v(s_i+\delta) \quad \forall \delta \in \mathbb{P}$$

$$w_i = C \exp\left(-\lambda_S d_S(t, s_i) - \lambda_O d_O(t, s_i)\right)$$

SAR Despeckling (4/4)