Fingerprint Quality Analysis: a PC-aided approach

97th International Association for Identification Ed. Conf.
Phoenix, 23rd July 2012

A. Mattei, Ph.D,*
F. Cervelli, Ph.D,*
F. Zampa, M.Sc,*
F. Dardi, Ph.D§

* ***RaCIS, Italy***
§ ***Innovation factory***

Summary

- Motivation
- Forensic quality of images
- Generic purpose contrast index
- Human visual system contrast index
- Results
- Conclusions
- Future works

Motivations

To evaluate different enhancement techniques:

- Can we suggest an objective way to compare the results?
- Can we find an objective way to rank the effectiveness of different development techniques from the point of view of the forensic expert?

Experimental Setup

- Fingerprints left on paper
- Paper cut in two, developed with different reagents and then com

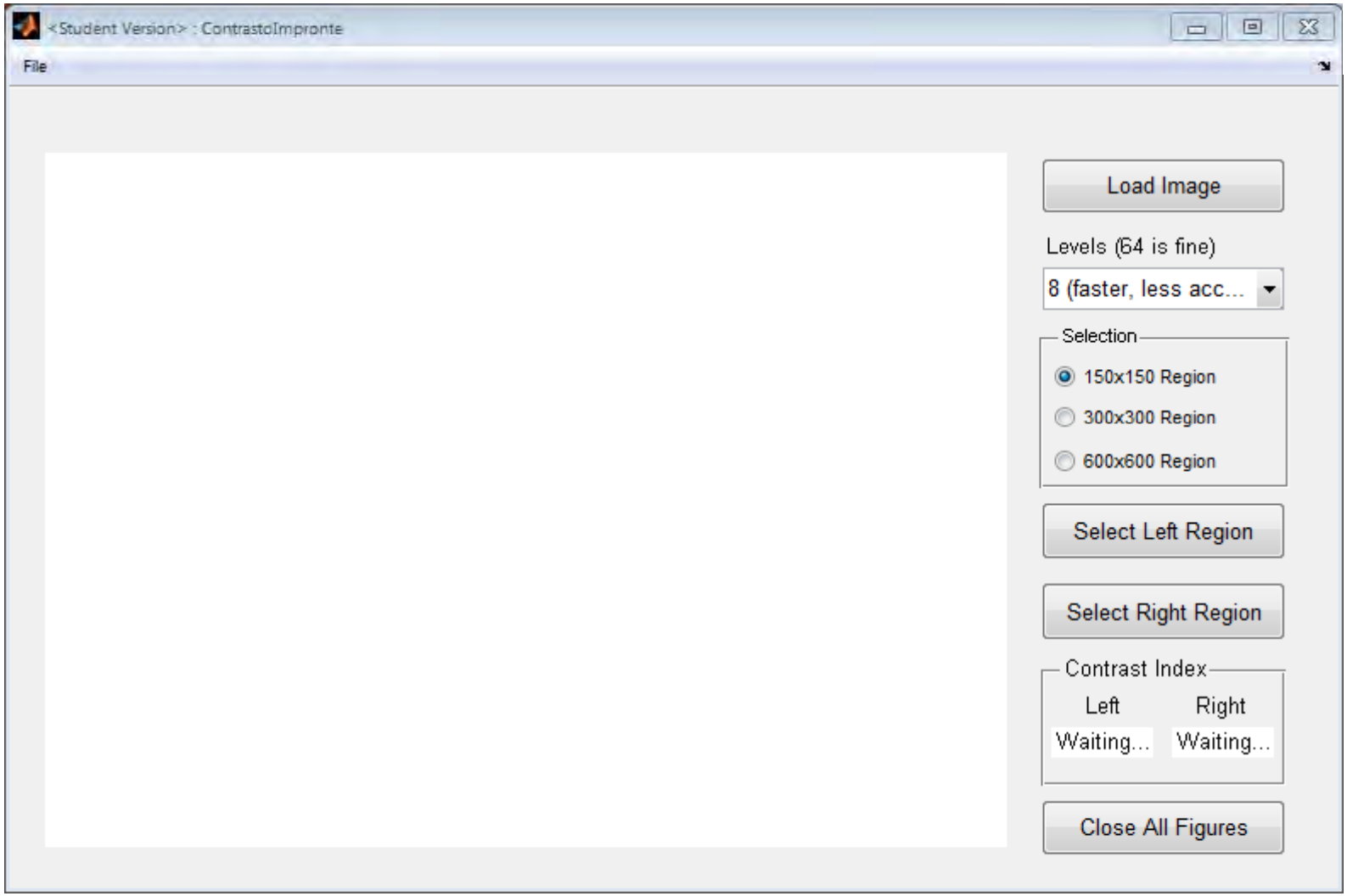
Purpose of Comparison

One to one comparison to see which half of the same fingerprint was developed "better"

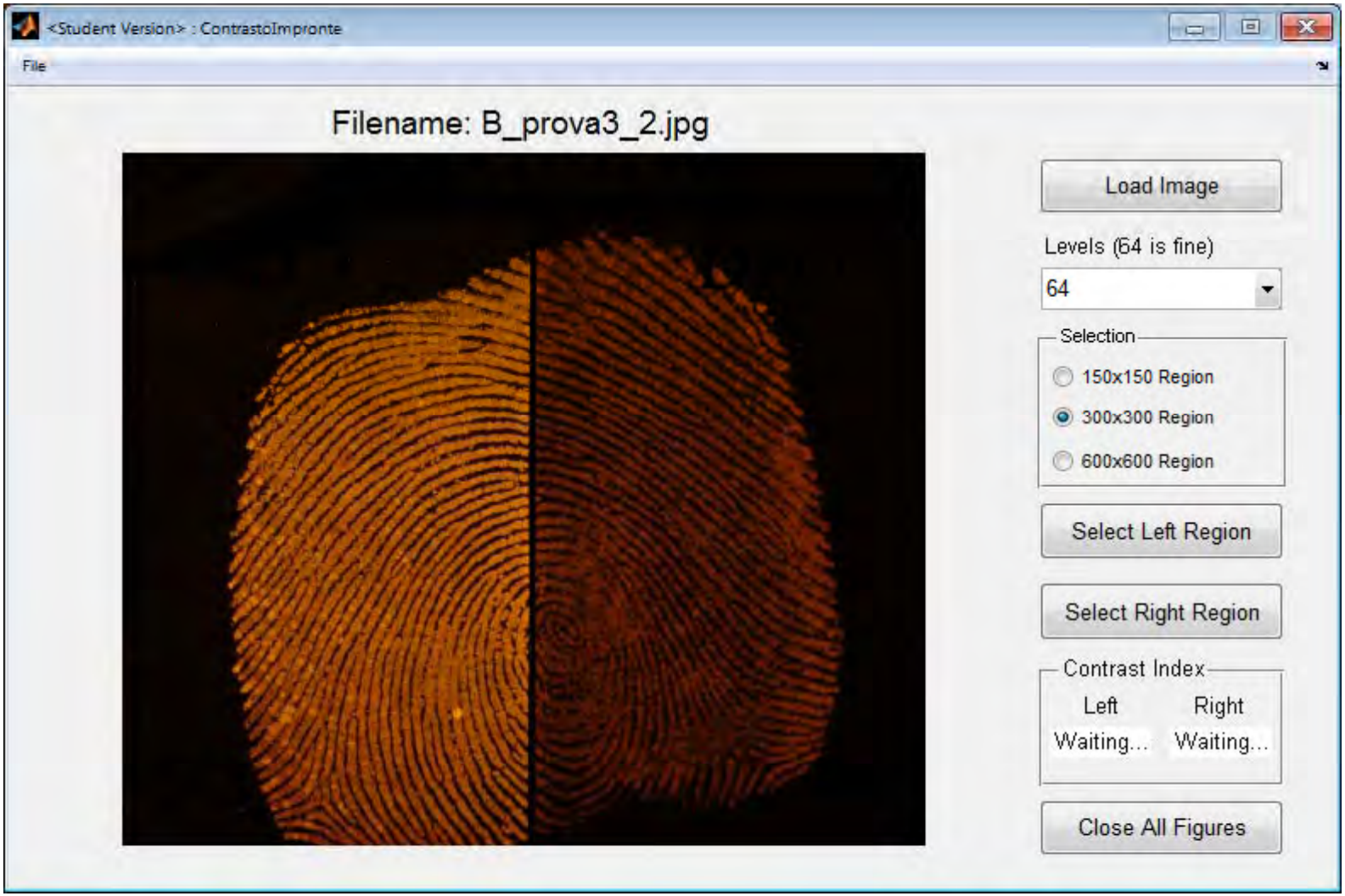
Test Set-up

- All fingerprints acquired at a constant distance from the camera
- Camera settings and light for fluorescence are changed to the expert's opinion
- Each fingerprint halves are acquired together

Fingerprints: How Does It Work?



Fingerprints: How Does It Work?



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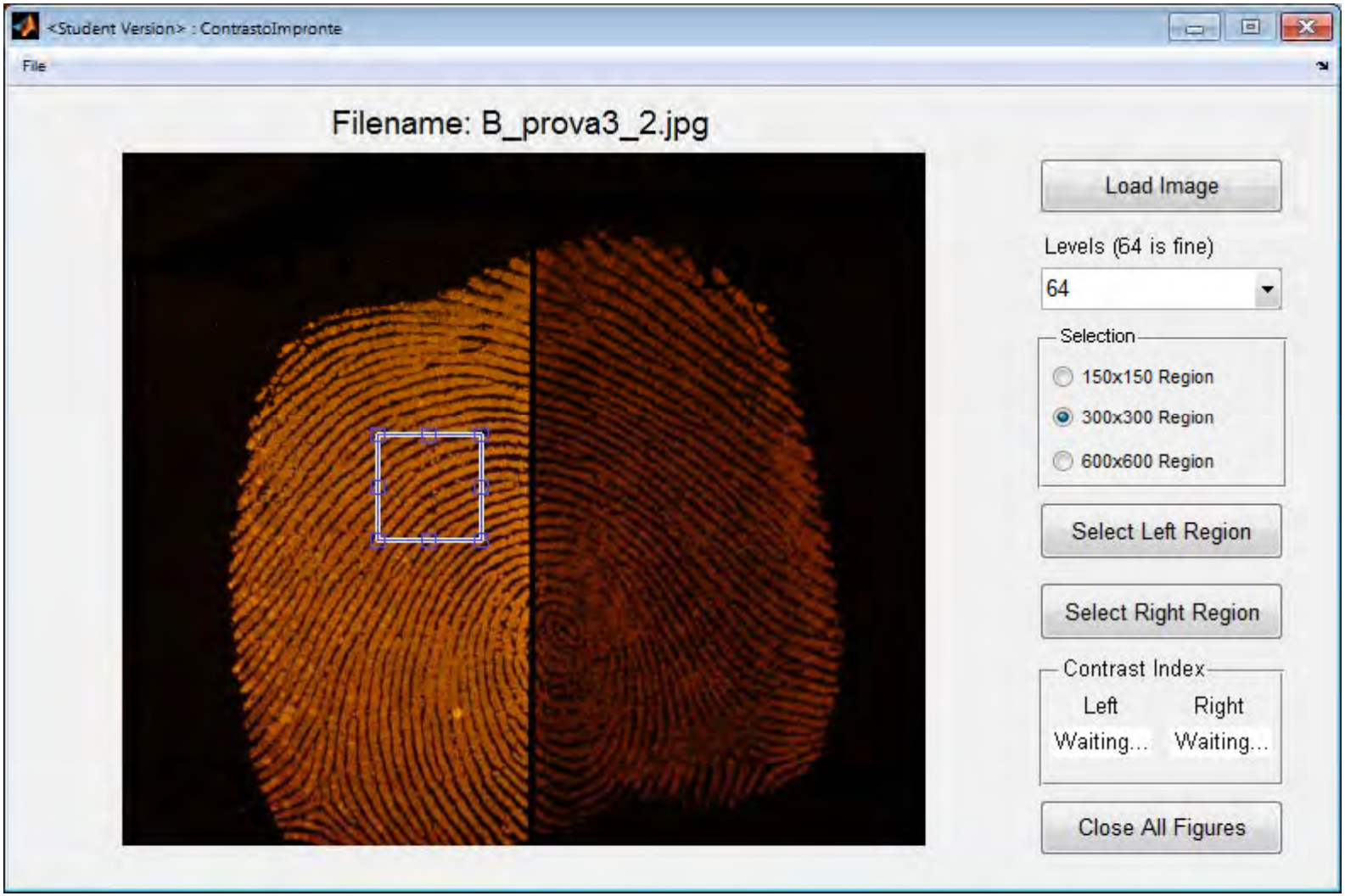

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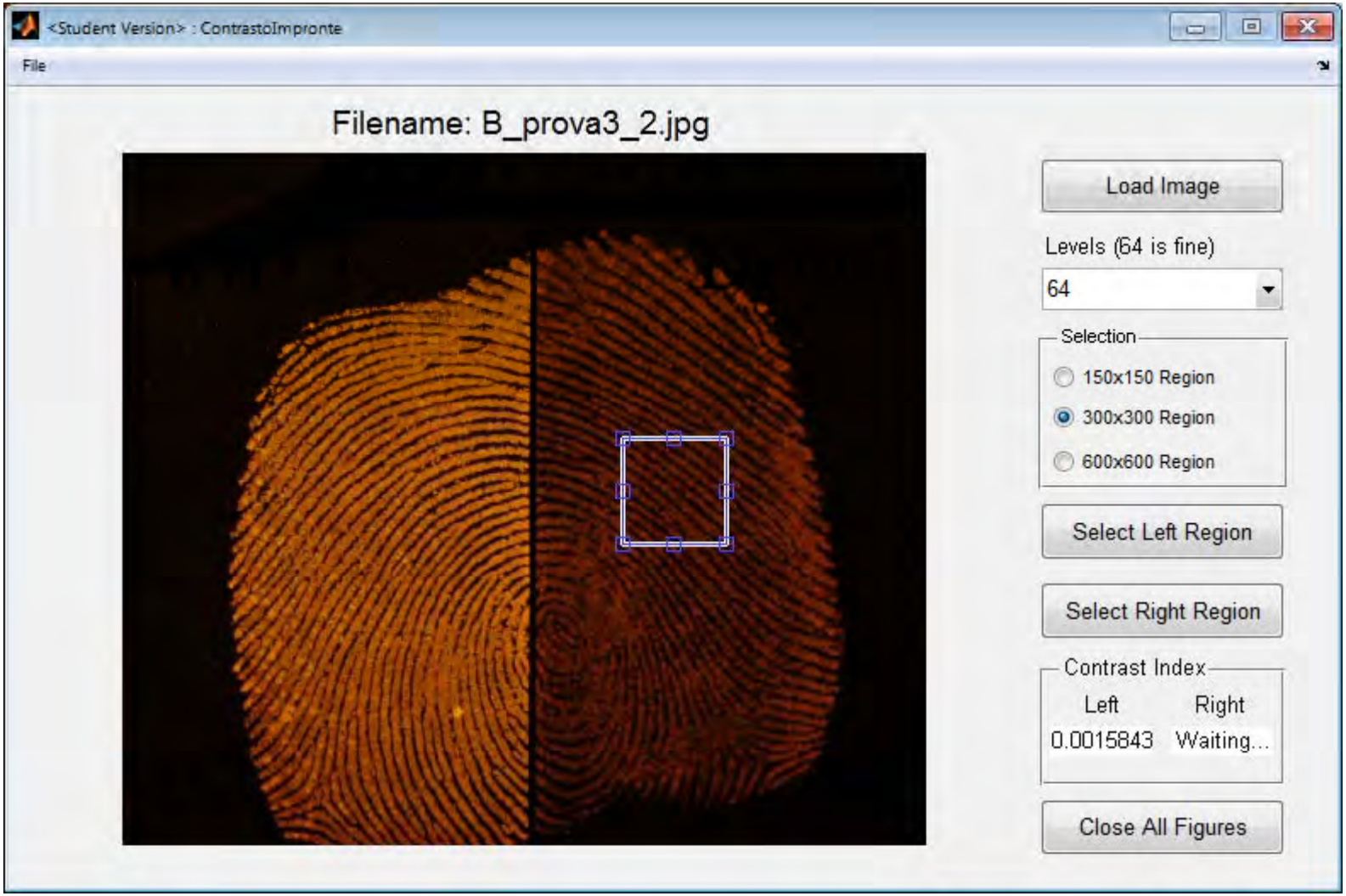

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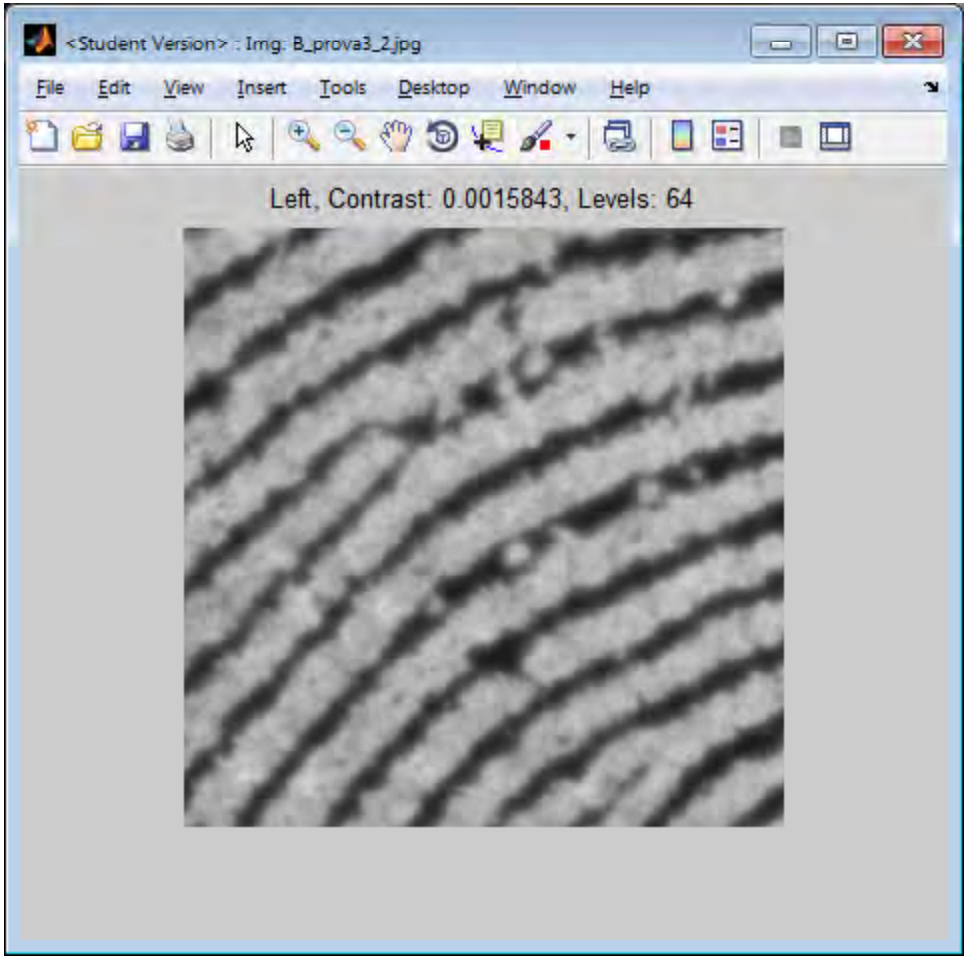

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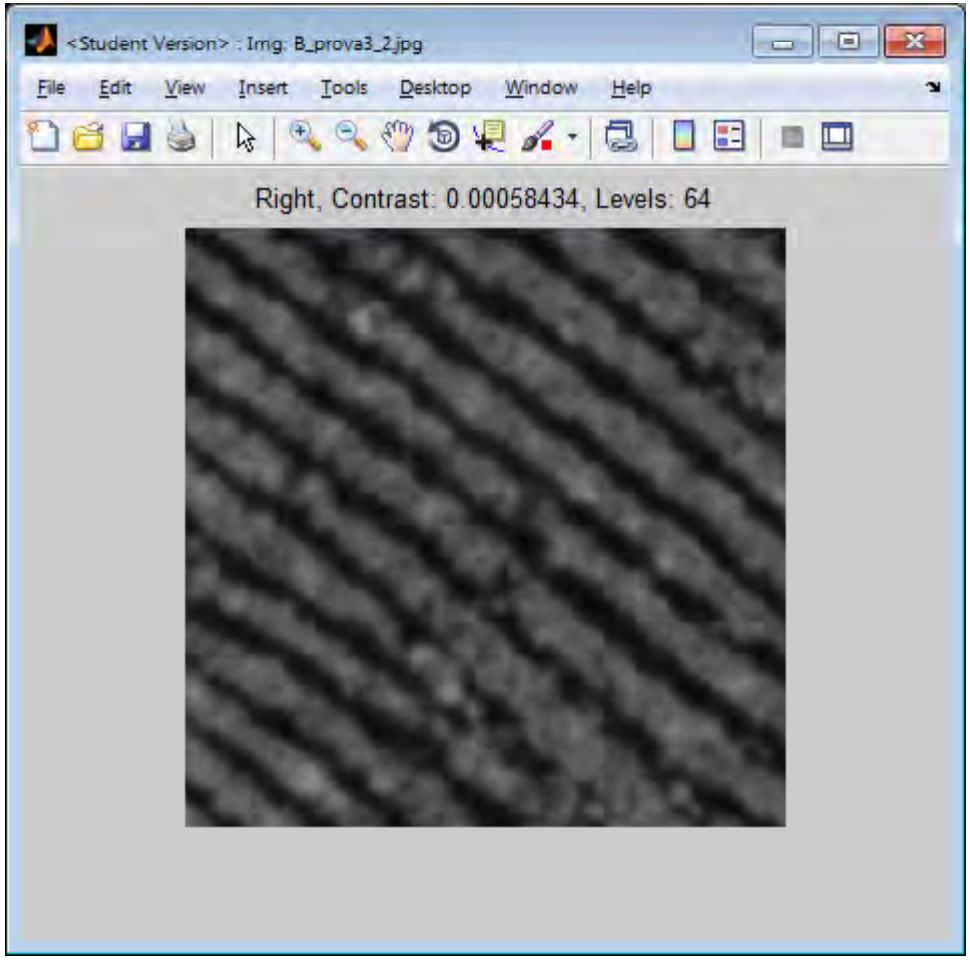


Consequence

- We can compare fingerprints deposited at different times
- Then, we can compare the expert's opinion to the software outcome and see how they compare and teach the software how to rank fingerprint quality

Consequence

- If done properly, this will be useful to assess the forensic quality of fingerprint well before they are even shown to the expert

Extend the Concept

- Change the word "fingerprint" with the forensic image of your choice

Easy? Maybe not ….

- Need to translate the concept of forensic quality in a PC computable quantity
- Forensic quality: usefulness for forensic analysis
- We chose to use contrast in order to capture forensic quality

Available Methods

- We have to choose a contrast computation method to evaluate the forensic quality of an image
- Methods fall in three main categories:
  - general purpose
  - image specific (knows the kind if image it is looking at)
  - human visual system (HVS) aware

Forensic Quality: State of Art (Partial)

- Chen *et al.* "Fingerprint Quality Indices for Predicting Authentication Performance", *Springer LNCS-3546, p.* 160 (2005).
- Tabassi *et al.* "A Novel Approach to Fingerprint Image Quality", Proc. of ICIP 2005, p. 37 (2995).
- Fronthaler *et al.* "Automatic Image Quality Assessment with Application in Biometrics", Proc. of *IEEE WB 2006,* p. 30 (2006).
- Vanderwee *et al.* "The Investigation of a Relative Contrast Index Model for Fingerprint Quantification" *FSI 204*, 74 (2011).

Forensic Quality: State of Art Evaluation

- Mainly devoted to fingerprint, with no real mention to other forensic relevant imagery (faces, tool marks, shoe marks, tire marks)
- Interest in image quality effects on AFIS performance
- Interest in fingerprint quality after being acquired by dedicated, proper devices
- Few works care about the expert's opinion

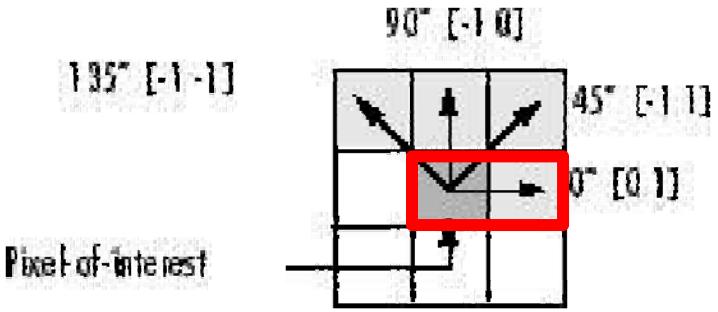
Used Methods

- We have used the following two methods:
  - gray level co-occurrence matrix (general purpose method)
  - number of just noticeable difference levels (HVS method)

GLCM

- Gray level co-occurrence matrix (GLCM):
  - is a matrix created by calculating how often a pixel with grayscale intensity value *i* occurs horizontally (or vertically or diagonally) adjacent to a pixel with grayscale intensity value *j*
  - thus element (*i*,*j*) of GLCM specifies the number of times that the pixel with value *i* occurred horizontally (or vertically or diagonally) adjacent to a pixel with value *j*

GLC Matrix: Example



1	1	5	6	8
2	3	5	7	1
4	5	7	1	2
8	5	1	2	5

GLCM

	1	2	3	4	5	6	7	8
1	1	2	0	0	1	0	0	0
2	0	0	1	0	1	0	0	0
3	0	0	0	0	1	0	0	0
4	0	0	0	0	1	0	0	0
5	1	0	0	0	0	1	2	0
6	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	0

GLCM: Contrast

- Many quantities can be defined by the GLCM:
  - contrast:

$$\sum_{i,j} |i-j|^2 p(i,j)$$

assumes 0 value for constant image
need to be calculated for every orientation
(horizontal, vertical and diagonal)

GLCM: Properties

- Changes with rotation
- Changes with scale
- Doesn't know the image structure

- Need to:
  - renormalize images (so that they are the "same")
  - be cautious in interpretation, as this is method is unaware of what a fingerprint is

Number of Just Noticeable Different Levels

- The method quantifies the perceptive contrast experienced by the human eye
- Must be initialized with average physiological and viewing quantities:
  - screen size and resolution
  - distance of view
  - area of foveola (region of the retina where the focus of attention of the eye is situated)

Number of Just Noticeable Different Levels

- Same luminance variation is differently perceived according to the average luminance
- For each value L of the luminance and its surrounding average S it is possible to calculate the luminance variation needed to produce a perception of difference
- This is called just noticeable

JND: Additional Information

- In this work the perceived contrast between two luminance extremes L_{min} and L_{max} is assessed as the number of JNDs between them
- We look at the JNDs distribution to try to deduce information on the particular class of images that is analyzed

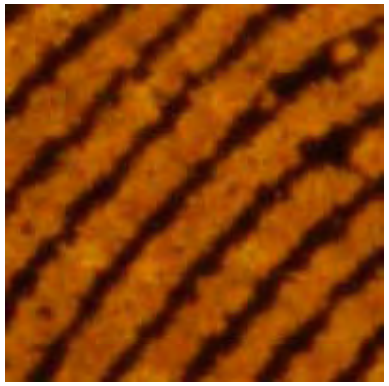
JND: Properties

- Changes with viewing conditions
- Changes with processing

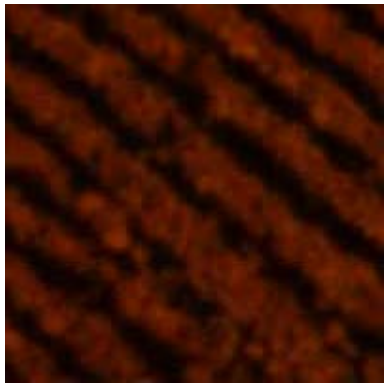
- Need to:
  - modify parameters to respect viewing conditions if comparison with others is needed

JND: Examples

No processing



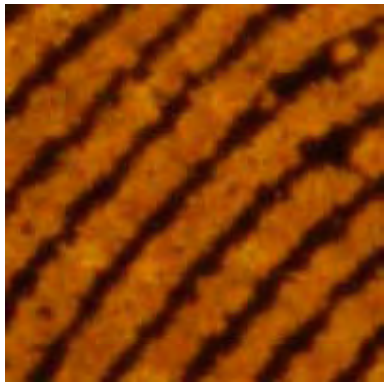
N = 285



N = 187

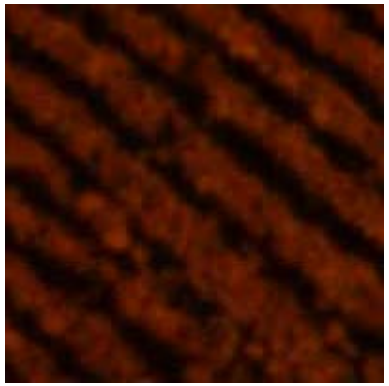
JND: Examples

No processing



N = 285

Histogram equalization

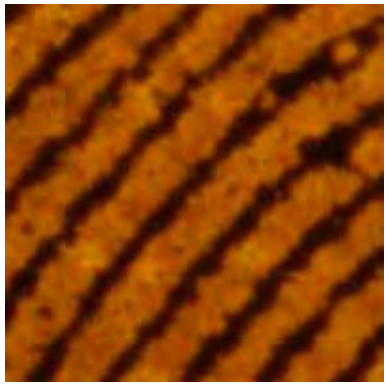


N = 187

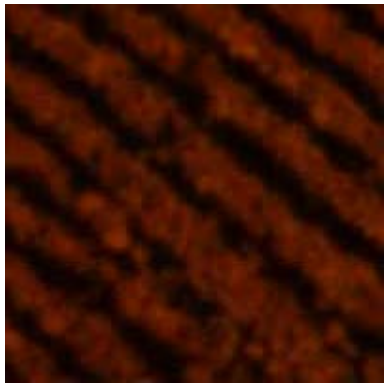
?

JND: Examples

No processing

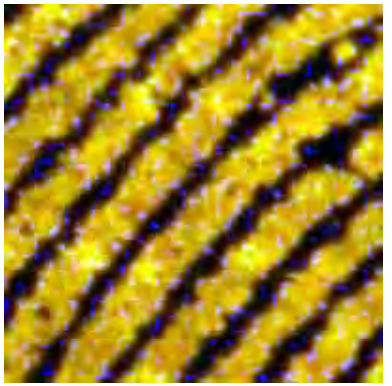


N = 285



N = 187

Histogram equalization



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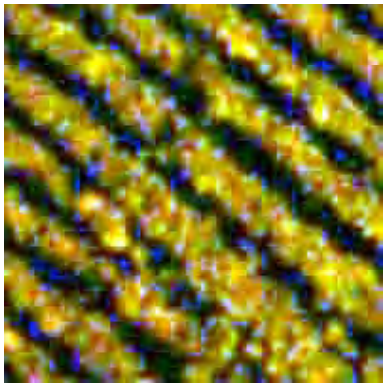
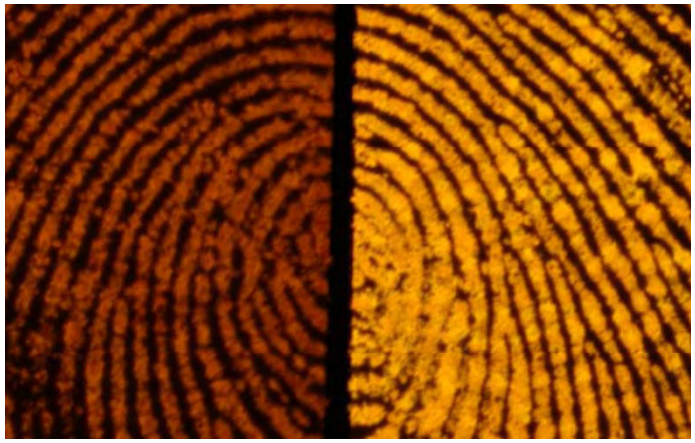
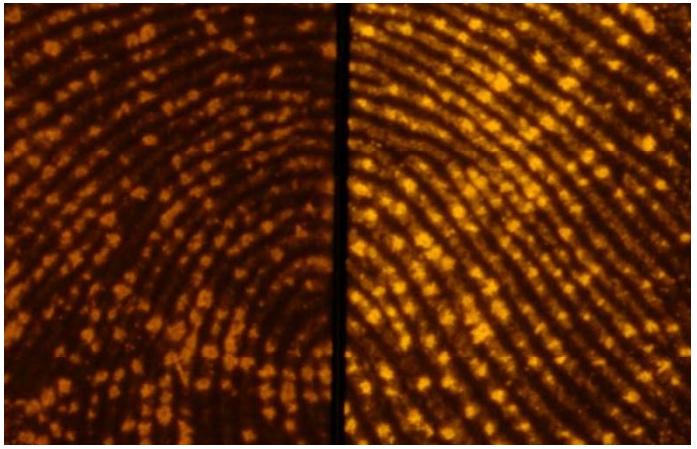


N = 444

Results

- GLCM method is able to rank only the quality of fingerprints with defined ridges (even if faint)





- HVS method is able to correctly rank all fingerprints and to detect automatically the dotted ones

Fingerprint Quality: Comparison

- More than 400 fingerprints analyzed

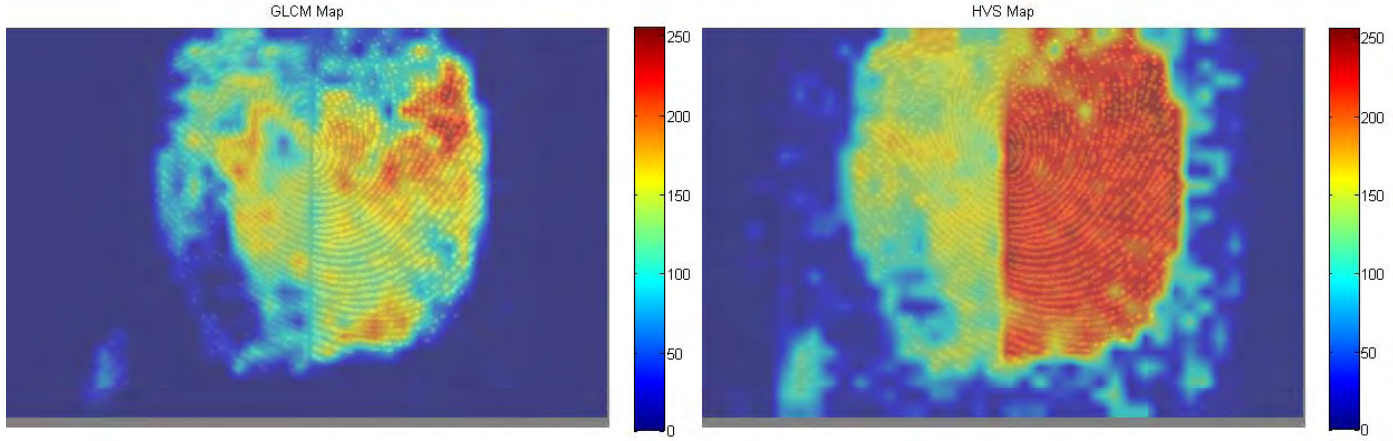
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	impronta	SX MAX	SX fsm<10%	SX fsm 10-30	SX > 50%	DX max	DX fsm<10%	DX fsm 10-30	DX > 50%	Qualità SX	Metodo SX	Qualita DX	Metodo DX	Condizioni	x,y sinistra	x,y destra	Qualità Operatore	Note Operatore
120	B_prova4_5	205	0.03	0.48	0.13	205	0.01	0.4	0.09	0.0005065	IND	0.000581	DFO	150x150; 256	1358, 808	2133, 345	IND=DFO	nessuna
121	B_prova4_6	166	0.03	0.43	0.14	288	0.19	0.55	0.05	0.0003991	DFO	0.0001434	IND	150x150; 256	1103, 611	1792, 1027	DFO	nessuna
122	C_prova4_1	176	0.31	0.44	0.07	201	0.02	0.6	0.11	0.0002303	IND	0.0002997	DFO	300X300; 256	1204, 670	1622, 670	IND=DFO	DFO peggio contrastata mi estesa
123	C_prova4_2	210	0.04	0.62	0.11	251	0.32	0.34	0.15	0.0003377	DFO	0.0005184	IND	300X300; 256	1193, 670	1627, 622	IND=DFO	puntinate
124	C_prova4_3	122	0.14	0.71	0.01	180	0.01	0.8	0.02	0.0001481	IND	0.0001287	DFO	300X300; 256	1257, 665	1643, 638	IND=DFO	DFO peggio contrastata mi estesa
125	C_prova4_4	178	0.01	0.75	0.04	224	0.15	0.64	0.03	0.0001767	DFO	0.0002383	IND	300X300; 256	1225, 665	1643, 579	IND	nessuna
126	C_prova4_5	110	0.07	0.64	0.04	190	0.01	0.71	0.05	7.10E-05	IND	0.0002918	DFO	300X300; 256	1220, 446	1675, 409	DFO	IND si vede poco
127	C_prova4_6	187	0.02	0.76	0.04	163	0.37	0.5	0.01	0.0001806	DFO	0.0001141	IND	300X300; 256	1177, 500	1675, 563	IND	ai limiti utilità; DFO appia
128	D_prova4_1	208	0.3	0.39	0.1	219	0	0.4	0.27	0.0006196	IND	0.0005647	DFO	300X300; 256	1204, 191	1617, 830	DFO	puntinate
129	D_prova4_2	195	0.04	0.56	0.15	257	0.11	0.42	0.2	0.0004035	DFO	0.0006298	IND	300X300; 256	1257, 776	1654, 489	IND=DFO	puntinate
130	D_prova4_3	229	0.17	0.55	0.09	192	0.09	0.55	0.13	0.0001937	IND	0.0002079	DFO	300X300; 256	1188, 718	1585, 633	IND0,	nessuna
131	D_prova4_4	181	0.05	0.7	0.05	136	0.13	0.7	0.01	0.0001938	DFO	8.64E-05	IND	300X300; 256	1204, 1144	1574, 936	non utili	nessuna
132	D_prova4_5	187	0.15	0.35	0.24	222	0.02	0.2	0.41	0.0004465	IND	0.0007672	DFO	300X300; 256	1257, 547	1654, 766	DFO	puntinate
133	D_prova4_6	183	0	0.56	0.08	176	0.21	0.59	0.03	0.0002658	DFO	0.0001696	IND	300X300; 256	1241, 1048	1611, 1000	non utili	nessuna
134	E_prova4_1	195	0.26	0.26	0.24	235	0.07	0.32	0.28	0.000635	IND	0.0008019	DFO	300X300; 256	1268, 505	1585, 414	IND=DFO	puntinate
135	E_prova4_2	235	0.13	0.47	0.11	207	0.16	0.47	0.13	0.0005055	DFO	0.0003919	IND	300X300; 256	1231, 473	1574, 398	DFO	puntinate
136	E_prova4_3	228	0.07	0.3	0.24	201	0	0.25	0.25	0.0007611	IND	0.0003321	DFO	300X300; 256	1247, 846	1585, 691	IND=DFO	nessuna
137	E_prova4_4	211	0	0.14	0.13	177	0.14	0.65	0.05	0.000348	DFO	0.0003109	IND	300X300; 256	1231, 537	1595, 516	DFO	leggera puntinatura
138	E_prova4_5	198	0.02	0.23	0.24	194	0	0.22	0.28	0.0005677	IND	0.000479	DFO	300X300; 256	1236, 723	1563, 723	IND=DFO	nessuna
139	E_prova4_6	236	0.03	0.35	0.12	242	0.14	0.58	0.02	0.0003798	DFO	0.0003672	IND	300X300; 256	1199, 633	1553, 649	IND=DFO	nessuna
140	F_prova4_1	215	0.37	0.25	0.16	257	0.11	0.45	0.2	0.0006102	IND	0.0006516	DFO	300X300; 256	1241, 798	1617, 723	DFO	puntinate
141	F_prova4_2	240	0.22	0.5	0.1	206	0.18	0.61	0.05	0.0004584	DFO	0.0002377	IND	300X300; 256	1220, 542	1595, 579	non utili	nessuna
142	F_prova4_3	205	0.31	0.48	0.03	176	0.02	0.66	0.07	0.0002636	IND	0.0002042	DFO	300X300; 256	1236, 595	1558, 590	IND	ai limiti utilità
143	F_prova4_4	228	0.04	0.55	0.16	220	0.3	0.39	0.1	0.0004004	DFO	0.0002848	IND	300X300; 256	1193, 686	1601, 617	DFO	ai limiti utilità
144	F_prova4_5	180	0.1	0.36	0.22	194	0.02	0.32	0.67	0.0005415	IND	0.0004872	DFO	300X300; 256	1241, 681	1590, 675	IND=DFO	leggera puntinatura
145	F_prova4_6	201	0.01	0.5	0.15	174	0.17	0.54	0.05	0.0002992	DFO	0.0002019	IND	300X300; 256	1172, 830	1585, 691	DFO	ai limiti utilità
146	B_prova5_1	242	0.01	0.14	0.57	316	0.02	0.21	0.44	0.0011548	IND	0.0012941	DFO	150x150; 256	1433, 180	2096, 303	DFO	nessuna
147	B_prova5_2	193	0.04	0.21	0.32	286	0.01	0.2	0.49	0.0004158	DFO	0.0014771	IND	150x150; 256	1114, 574	2135, 84	IND	nessuna
148	B_prova5_3	254	0	0.2	0.5	220	0	0.2	0.51	0.0010328	IND	0.0004554	DFO	150x150; 256	1390, 1394	1649, 1250	IND	nessuna
149	B_prova5_4	190	0	0.11	0.52	292	0	0.21	0.51	0.0003288	DFO	0.0009803	IND	150x150; 256	1369, 888	1728, 1197	IND	nessuna
150	B_prova5_5	314	0.01	0.2	0.5	215	0	0.15	0.47	0.0016865	IND	0.0005484	DFO	150x150; 256	1252, 936	1595, 1000	IND	zone di puntinatura
151	B_prova5_6	222	0.01	0.18	0.5	322	0.03	0.17	0.5	0.0005884	DFO	0.0019609	IND	150x150; 256	1343, 808	1617, 963	IND	zone di puntinatura

Fingerprint Quality: Results

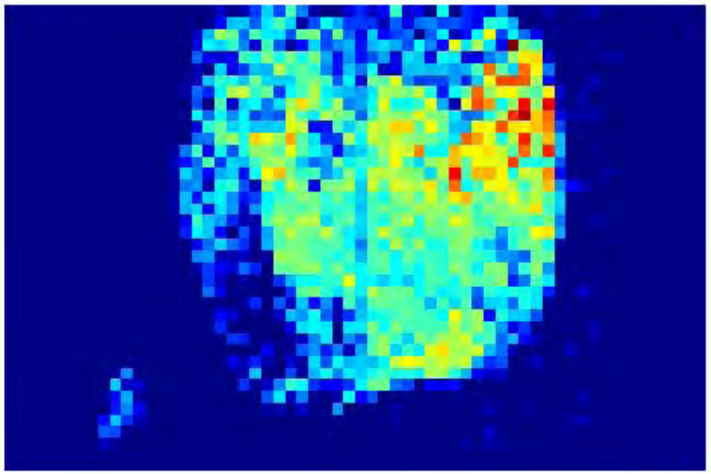
- Tested all fingerprints with two different quality assessment algorithms
- Comparison to fingerprint expert to see difference with algorithms and to tune them
- If done properly useful to assess forensic utility of fingerprint before showing them to the expert

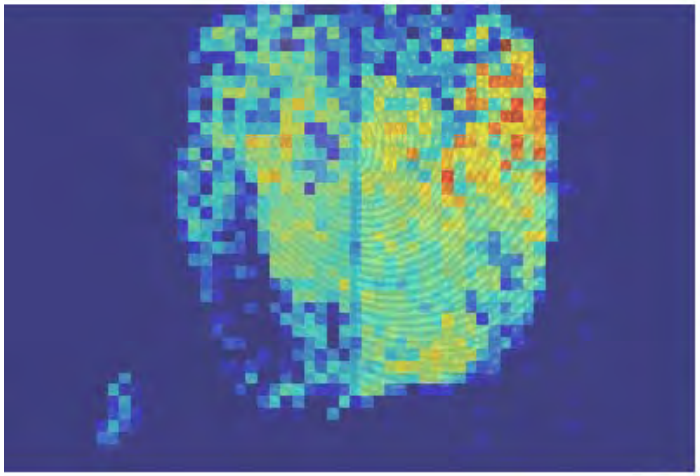
Fingerprint Quality Maps

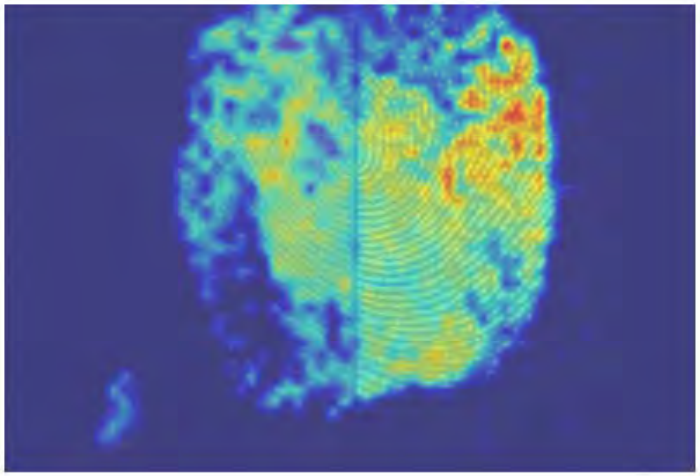
Fingerprint Quality Maps



Fingerprint Quality Maps

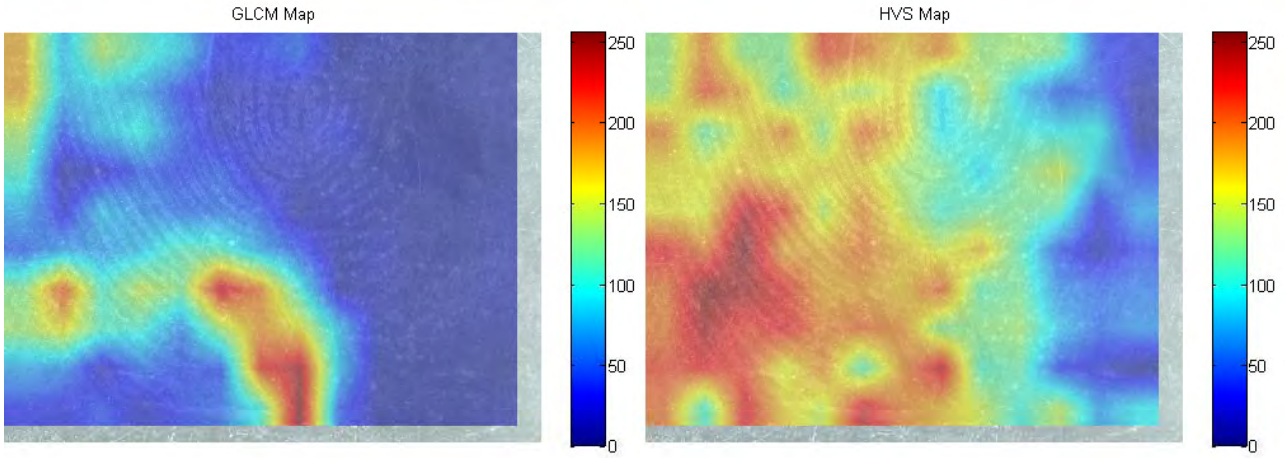






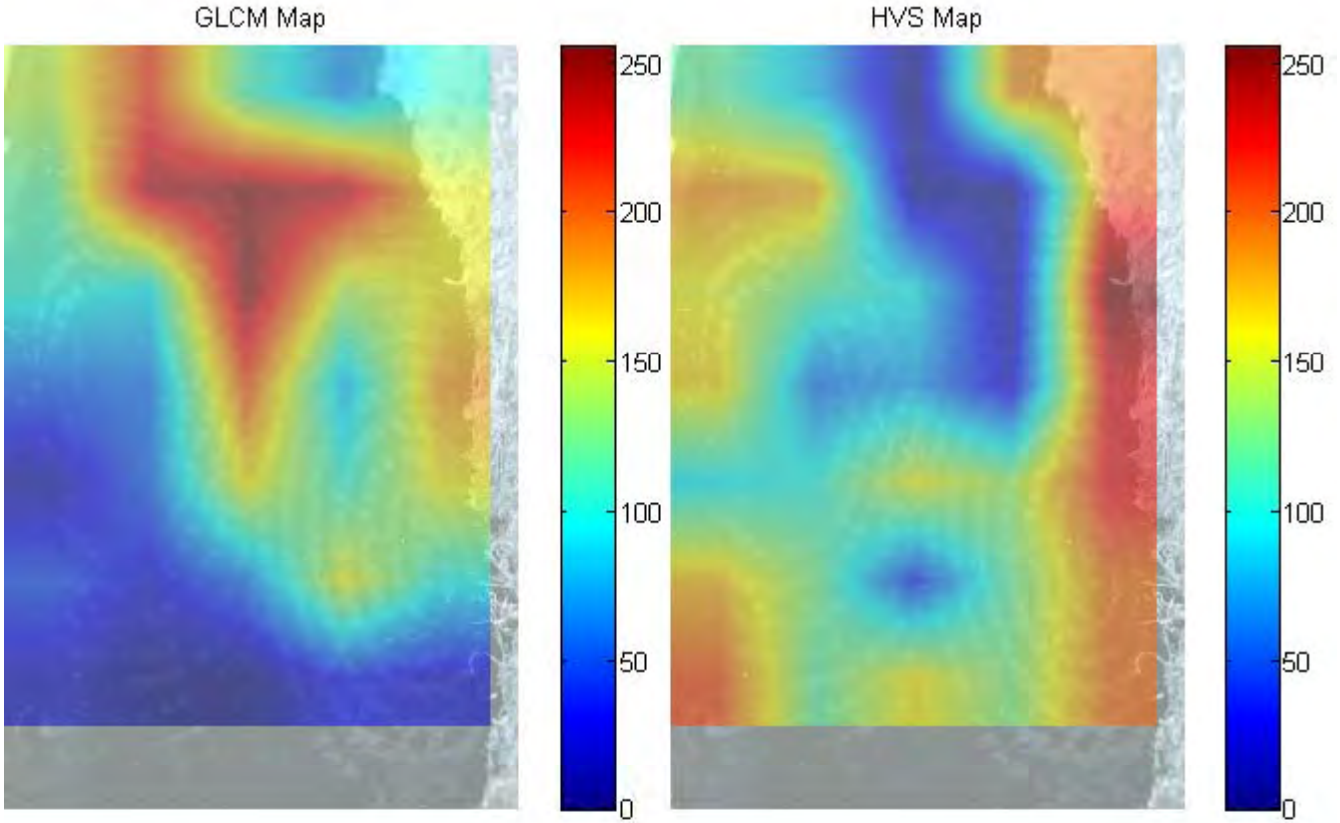
Fingerprint Quality Maps

Fingerprint Quality Maps

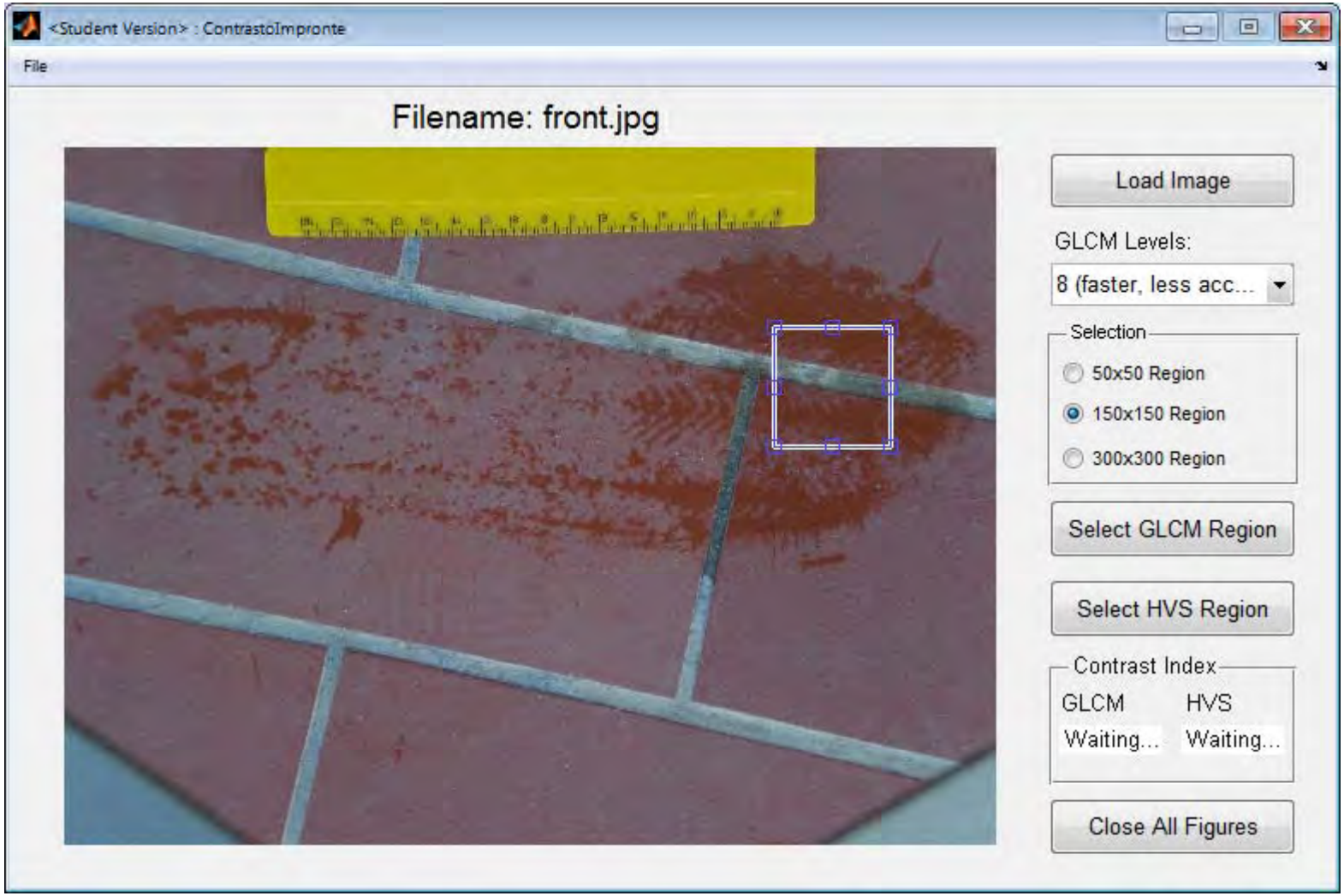


Fingerprint Quality Maps

Fingerprint Quality Maps



Other application: Shoemarks



Publications

- "No-reference measurement of perceptually significant blurriness in video frames", *Signal Image and Video Processing* **5**, 271-282 (2011)
- "A set of features for measuring blurriness in video frames", Melecon 2010, IEEE Mediterranean Electro-technical Conference, Valletta, Malta, 26-28 April 2010.
- "Blurriness estimation in video frames: a study on smooth objects and textures", in Proceeding of the SPIE Electronic Imaging Conference, San Jose (CA) USA, (2010).
- "Causes and visual experience of blurriness in video frames", submitted

Conclusions

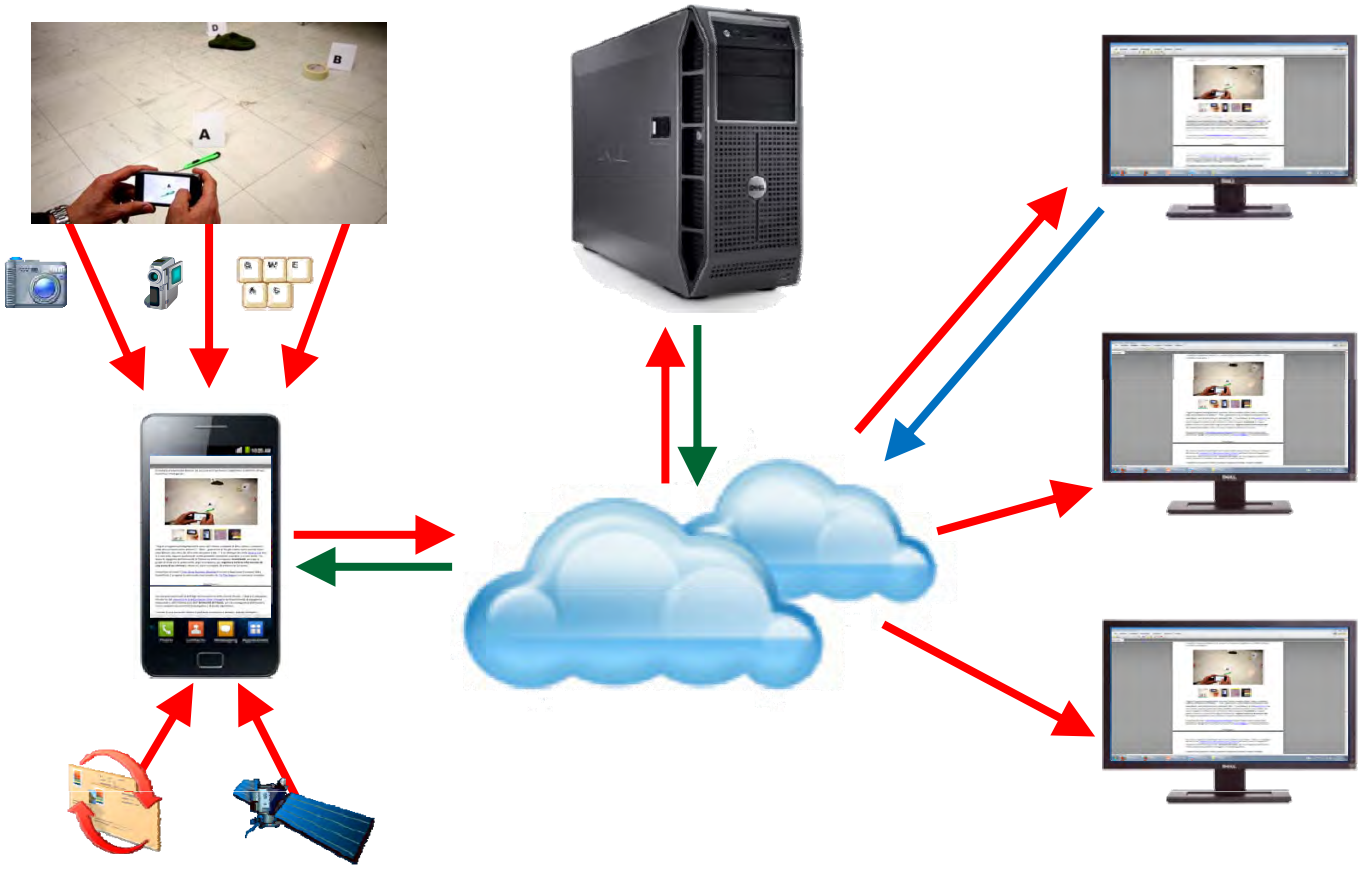
- The forensic quality (i.e. usefulness) of images can be assessed by using some contrast definition for images
- Generic purpose systems need to be used with caution if they do not allow teaching them the kind of object under analysis
- HVS systems can be used to assess quality and degradation causes of images
- This could support the expert's analysis

Future Works

- Complete analysis of HVS distribution to teach the software extended features and what are the most common cause of quality degradation
- Try quality index tool to other forensic fields (shoes, faces, tool marks, tire marks, etc.)

- Notice that the system will be tuned using expert's opinions

Future works: full system



Contacts

aldo.mattei@gmail.com

fcube@innovationfactory.it