Fast Illumination Normalization for Face Recognition

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Motivation

- Many applications of computer vision, security and surveillance require an accurate and real-time method for illumination neutralization and contrast enhancement.
- We present a new mathematical framework, with a real time implementation performing the task efficiently across multiple image modalities.

Illumination Normalization (IN) Operator

Lambertian Reflectivity Model:

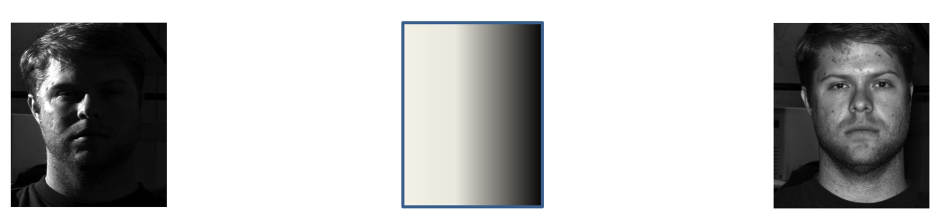
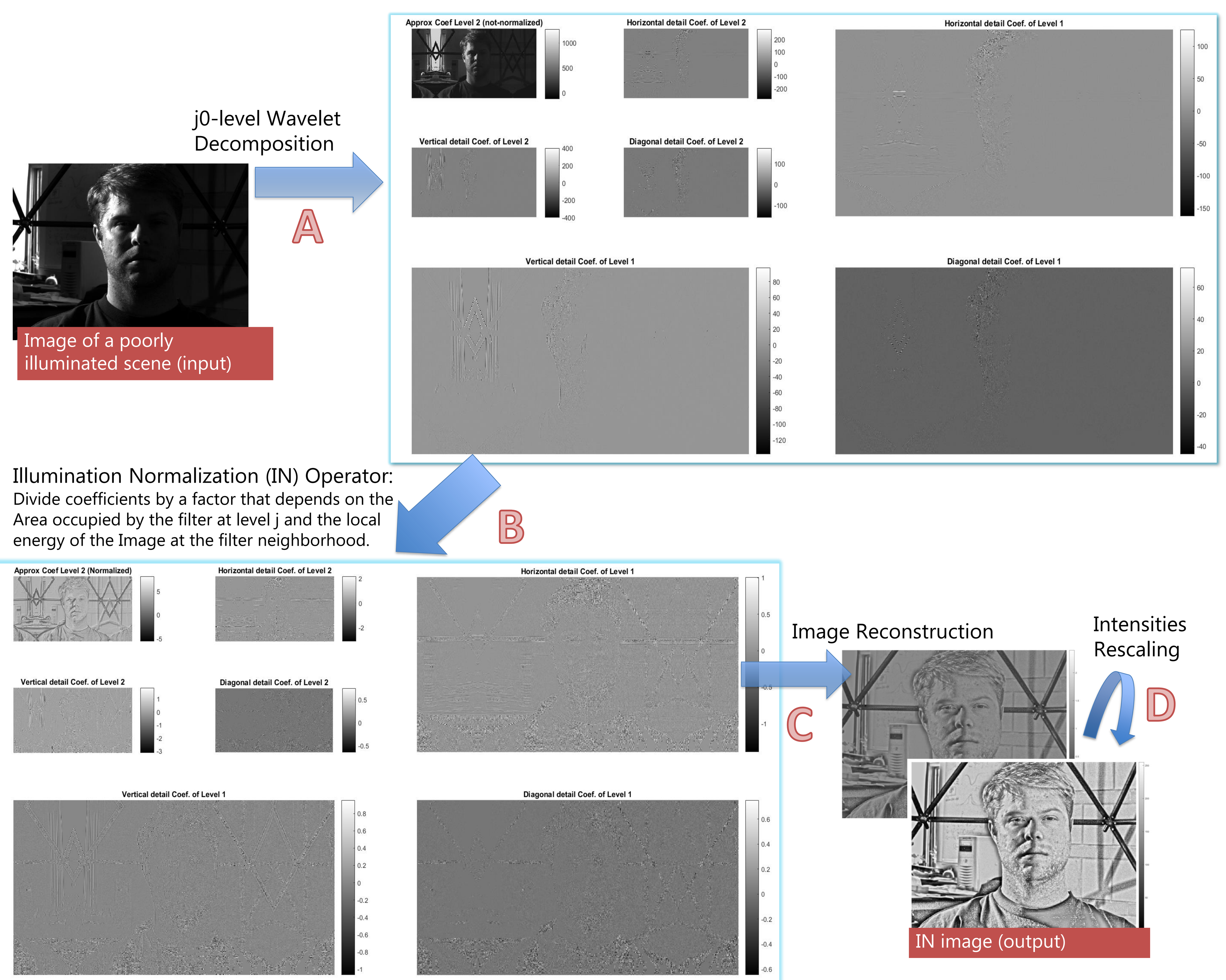
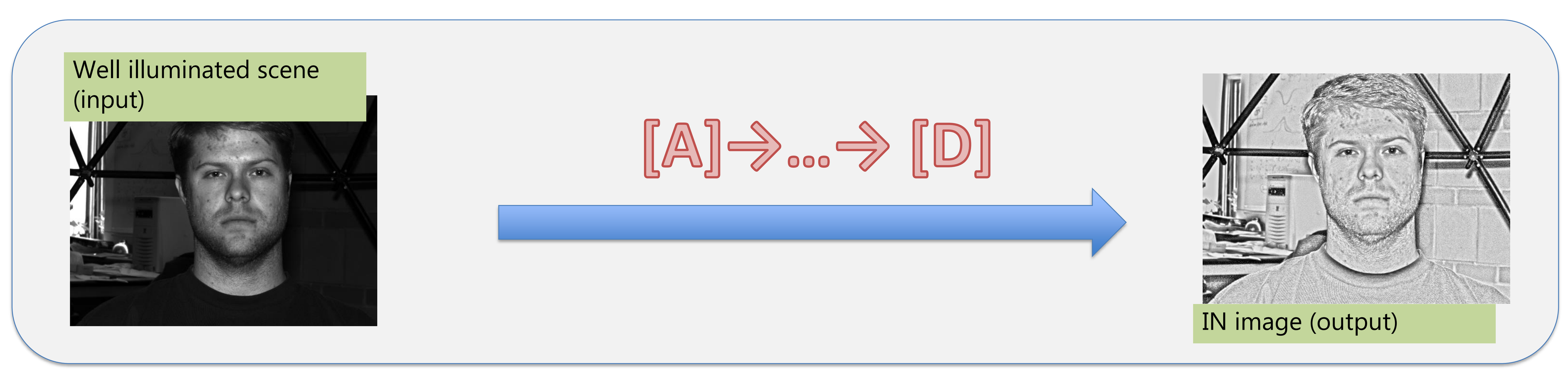


Image = Illuminance (Σ) x Reflectance (F)

Contribution:

- In accordance to the Lambertian Model, an image I is assumed as the product $I(x) = \sigma(x)f(x)$, where f represents the exact same scene under constant floodlight, while the luminance σ lives in a Campanato space $L_{\zeta\eta}$, a space of low oscillating functions. The value of ζ corresponds to the mean oscillation.
- Definition of a mathematical transform (IN) that creates a surrogate image of f and neutralizes the effect of σ without losing the structural content of f.
- Mathematical proof that all structural information is faithfully preserved.
- Numerically robust and fast implementation which is easily scalable to 2-D, 3-D and 4-D data.
- Experimental validation in applications from biometrics, confocal microscopy and safety.



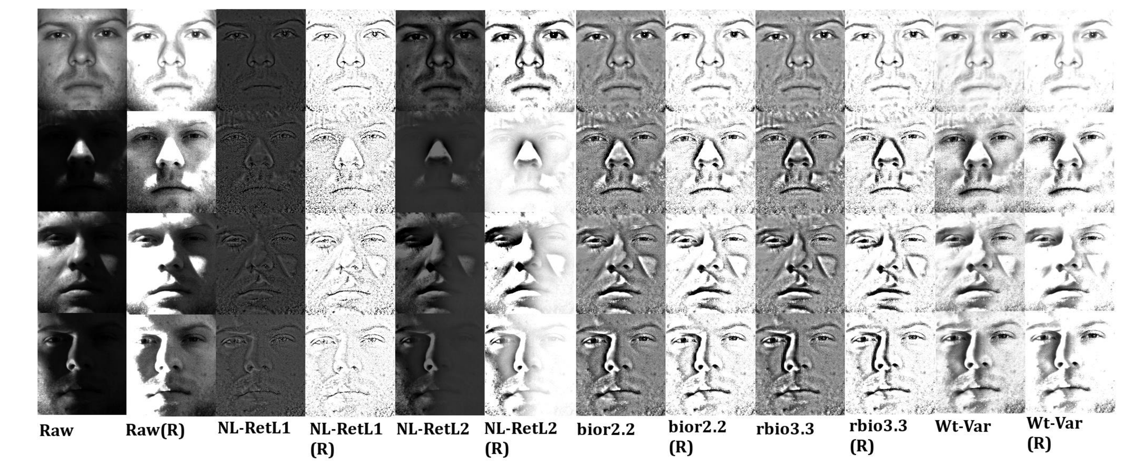


- **Theorem 1:** Difference between illumination normalized images of the same scene is small, provided the illumination varies slowly.
- **Theorem 2:** Microlocal patterns of singularities and their topological organizations are faithfully preserved.

Conclusion:

- Structures (i.e. edges and singularities) appearing in σf and IN(σf,ζ) maintain the same local oscillatory patterns. This result is a consequence of the fact that the decay rate of the sequences of the wavelet coefficients of f and IN(f,ζ), at the same image neighborhood, are identical.

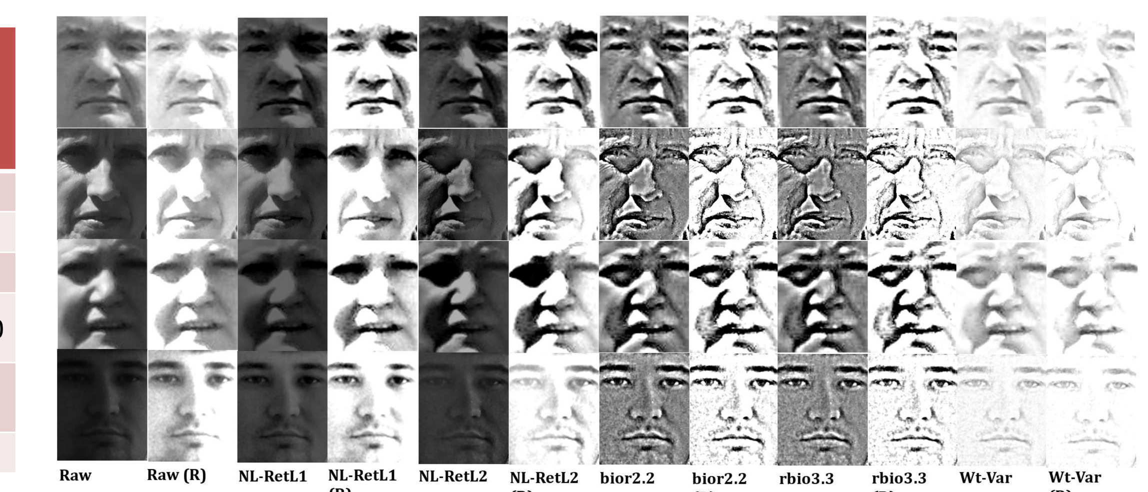
Results: Face Matching with OpenBR



Method	%TPR at 1%FPR	%TPR at 0.5%FPR	μ ± σ processing time (sec)
Raw	51.56	40.75	-
bior2.2	71.04	**64.89**	**3.59 ± 0.04**
bior2.2(R)	70.98	64.47	3.61 ± 0.04
rbior3.3	70.06	63.69	3.78 ± 0.07
rbior3.3(R)	68.33	61.68	3.80 ± 0.07
NL-RetL1.03	68.79	63.44	58.69 ± 14.02
NL-RetL2.02	30.10	25.50	39.74 ± 47.09
Wt-Var.02	**71.13**	64.08	17.66 ± 6.18

(Above) Yale ext. database processed with various illumination correction methods, before and after intensities re-scaling (R). From left to right: Raw images, Non Local RetinexL1, Non Local RetinexL2, proposed method using bior2.2 and rbio3.3 wavelets with ζ=1 and j0=2, Weighted Variational method. Training: 29 randomly chosen subjects. Accuracy: on the remaining 9 subjects. Total number of True Positives: 18,144. Total number of True Negatives: 147,456. **(Below)** Equivalent experiment using still images from the PaSC database. 220 randomly chosen subjects were used for training and the performance is evaluated on the remaining 73 subjects of the database. Total number of True Positives: 1,673. Total number of True Negatives: 131,713.

Method	%TPR at 1%FPR	%TPR at 0.5%FPR	μ ± σ processing time (sec)
Raw	39.27	31.02	-
bior2.2(R)	46.62	39.81	**3.68 ± 2.56**
rbio3.3(R)	**46.92**	**40.29**	3.83 ± 2.65
NL-RetL1.01	44.11	35.09	27.47 ± 40.10
NL-RetL2.02	40.23	31.62	2.17 ± 1.50
Wt-Var.02	45.43	37.9	6.26 ± 4.68



Sensitivity to parameters:

Adjusting the values of ζ and j0 we obtain surrogate images that differ with respect to their visual characteristics. An optimal parameter choice would minimize the difference between the IN outputs of a well illuminated (left table) and a poorly illuminated (right table) representation of the same scene.

Deep Network Face Detection

State of the Art face detection systems, such as Tiny Face Detector (CVPR2017), can benefit significantly in their task, if allowed to "see" IN surrogate images (bottom row).

First 2 images: WIDER FACE A Face Detection Benchmark, Yang et al. CVPR2016.

CACDS NSF

[1] Non-local retinex - a unifying framework and beyond, D.Zosso,G.Tran,S.J.Osher(Siam Journal on Imaging Sciences,2015) [2] A weighted variational model for simultaneous reflectance and illumination estimation,X.Fu,D.Zeng,Y.Huang,X.P.Zhang,X.Ding(CVPR 2016) [3]Open source biometric recognition, J.C.Klontz, B.F.Klare, S.Klum, A.K.Jain, M.J.Burge (BTAS 2013) [4] Finding Tiny Faces, Hu,Peiyun and Ramanan, Deva, CVPR 2017.