STATISTICS OF NATURAL FUSED IMAGE DISTORTIONS

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Source: dailymail.co.uk

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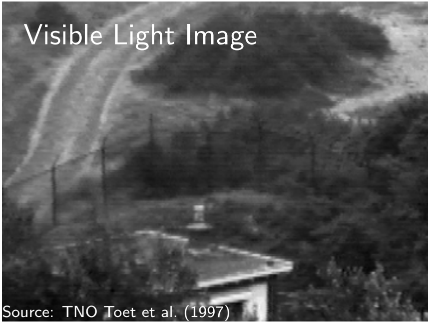
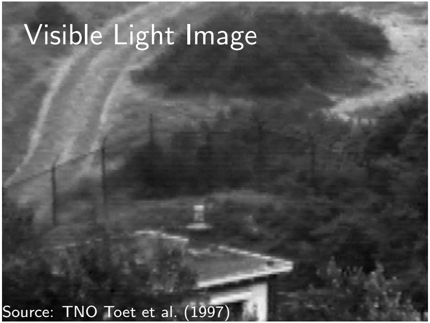


Source: TNO Toet et al. (1997)

Visible light images:

- Give color/relative luminance information
- Contain detailed information of the background



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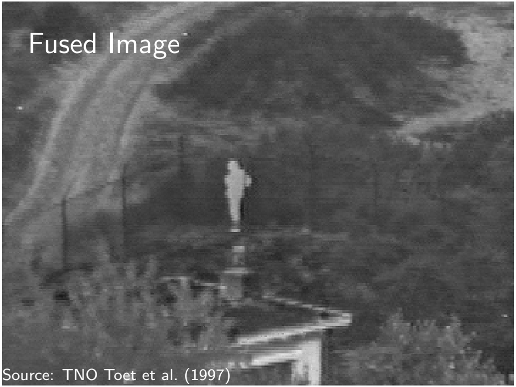
Visible light images:

- Give color/relative luminance information
- Contain detailed information of the background

LWIR images:

- Can capture useful data in low light conditions for night vision applications
- Are unaffected by illumination/environmental variations

Source: TNO Toet et al. (1997)



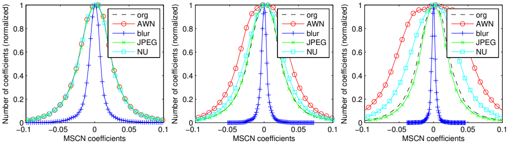
Fused LWIR visible light images:

- Have information redundancy
- Make a surveillance system robust and reliable

How to obtain an optimal fused image?

Previous studies:

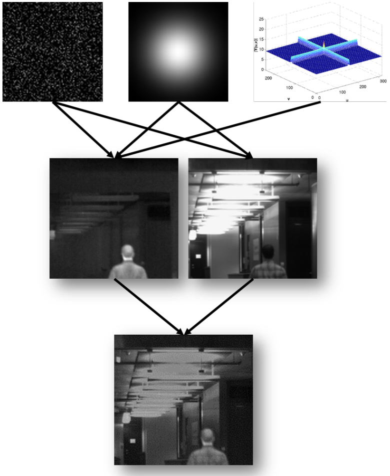
- Developed objective measures of fusion performance (Wang et al., 2008; Zhao et al., 2007; Piella and Heijmans, 2003; Chen and Varshney, 2007; Chen and Blum, 2009)
- Explored the impact of white noise and blur on fused images (Chen and Blum, 2009; Liu et al., 2012)
- Studied the Natural Scenes Statistics in visible and LWIR images (Yuming et al., 2015; Bovik, 2013; Moorthy and Bovik, 2011; Che-Chun et al., 2011; Goodall et al., 2015; Morris et al., 2007)



Outline

1. Processing Models
2. Quality Assessment of Fused LWIR and Visible Images
   - Opinion Aware Image Quality Analyzer
   - Subjective Human Study
3. Conclusion and Future Work

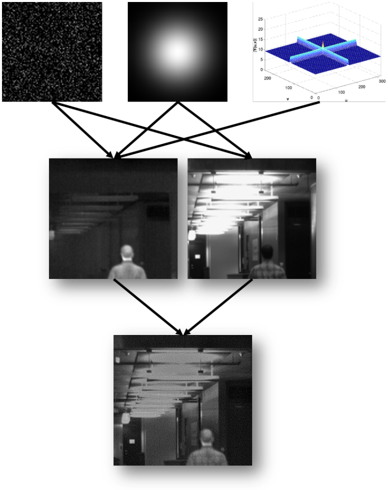
Distortion and Fusion



Distortions:

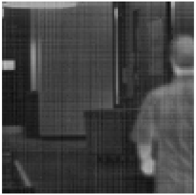
- Additive white Gaussian noise
- Blur

Distortion and Fusion

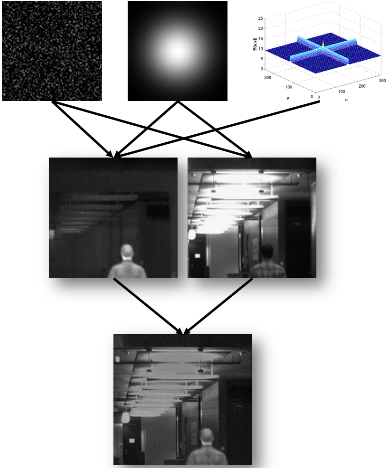


Distortions:

- Additive white Gaussian noise
- Blur
- Non uniformity noise



Distortion and Fusion



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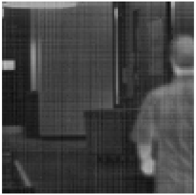


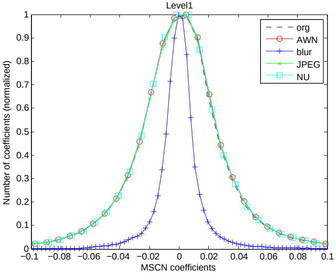
Fusion methods:

- Average
- Gradient pyramid
- Shift-invariant discreet wavelet transform with haar wavelet

NSS Coefficients

- Mean subtracted contrast normalized (MSCN) coefficients
- Paired product coefficients
- Log-derivative coefficients
- Steerable pyramid coefficients

Blur distortion levels

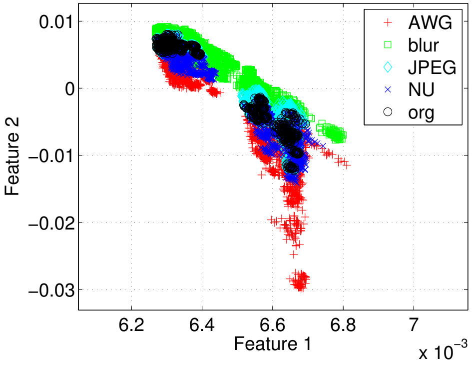


MSCN histograms

NSS Features

Fit the histogram of bandpass coefficients to the probability density function of:

- the Generalized Gaussian Distribution (GGD) and
- the Asymmetric Gaussian Distribution (AGGD)



138 features per image projected in a 2D space using Principal Component Analysis.

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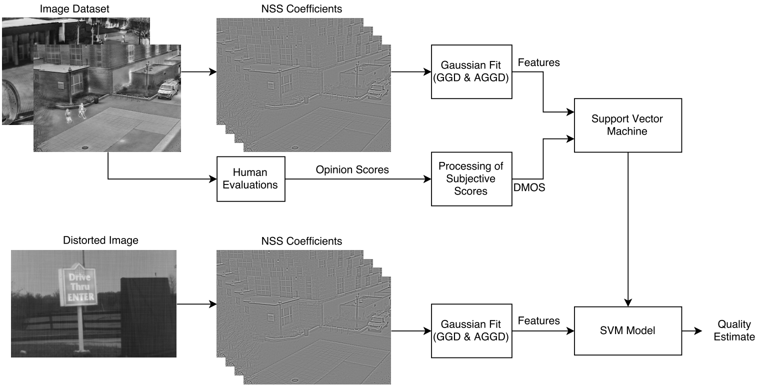
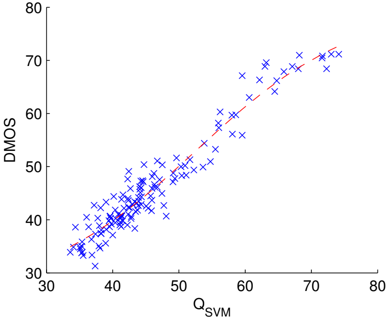
Opinion Aware Image Quality Analyzer



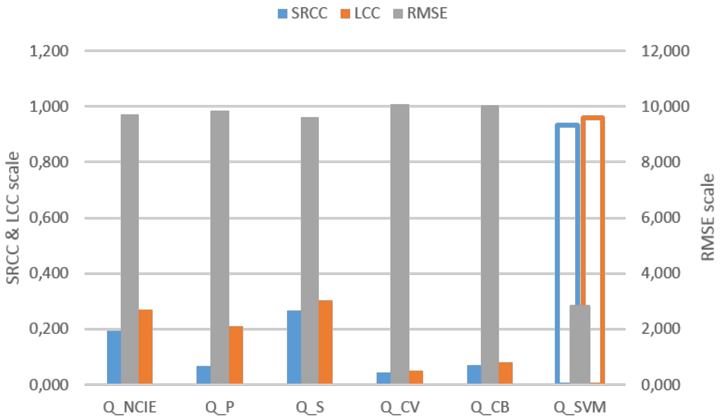
Todd Goodall, Alan C. Bovik, and Nicholas G. Paulter Jr Goodall et al. (2015)

Opinion Aware Image Quality Analyzer



Scatter plot of Q_{SVM} prediction scores versus the DMOS and the best fitting logistic function.

Opinion Aware Image Quality Analyzer

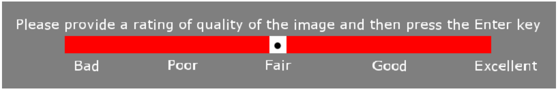


Median SRCC, LCC, and RMSE between DMOS and predicted DMOS measured over 1000 iterations

Subjective Human Study

- 27 subjects, five testing sessions, 750 fused LWIR-visible images
- Absolute category rating with hidden reference
- Single stimulus

Screen resolution: 1024×768

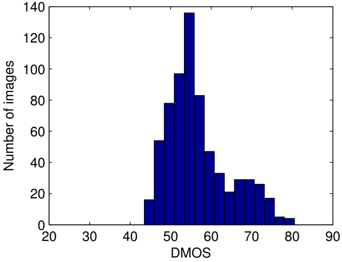


Subjective Human Study

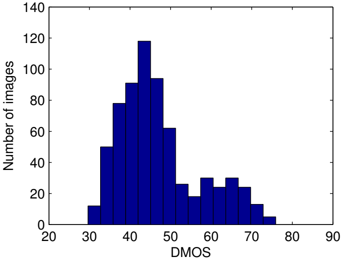
1	2	3	4
Diff-Scores	Z-Scores	Rejection	DMOS

Subjective Human Study

1. Diff-Scores
2. Z-Scores
3. Rejection
4. DMOS



(a) Scores before subject rejection



(b) Scores after subject rejection

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Conclusion

- Natural scene statistics demonstrated being potent descriptors for the quality estimation of fused LWIR-visible light images
- NSS features play an important role when analyzing distortions in fused LWIR-visible light images
- Opinion-aware quality analyzer outperforms state-of-the-art fusion quality models when correlating to human evaluations

Future Work

- Use a broader range of distortion in images for the subjective study
- Future studies might be able to use the proposed models to evaluate other distortions in fused LWIR-visible images, such as the "halo effect" in LWIR images, and image or video compression
- Surveillance videos could be well modeled and studied with the aid of natural scene statistics to improve tracking algorithms

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THANK YOU!

Bibliography

A. C. Bovik. Automatic prediction of perceptual image and video quality. *Proceedings of the IEEE*, 101(9):2008–2024, September 2013.

S. Che-Chun, A. Bovik, and L.K Cormack. Natural scene statistics of color and range. In *18th IEEE International Conference on Image Processing (ICIP)*, pages 257–260, 2011.

Hao Chen and Pramod K. Varshney. A human perception inspired quality metric for image fusion based on regional information. *Information Fusion*, 8:193–207, 2007. ISSN 15662535. doi: 10.1016/j.inffus.2005.10.001.

Yin Chen and Rick S. Blum. A new automated quality assessment algorithm for image fusion. *Image and Vision Computing*, 27(10):1421–1432, 2009. ISSN 02628856. doi: 10.1016/j.imavis.2007.12.002.

Todd Goodall, Alan C Bovik, and Nicholas G Paulter Jr. Tasking on Natural Statistics of Infrared Images. *IEEE transactions on image processing : a publication of the IEEE Signal Processing Society*, pages 1–17, 2015.

Zheng Liu, Senior Member, Erik Blasch, and Zhiyun Xue. Objective Assessment of Multiresolution Image Fusion Algorithms for Context Enhancement in Night Vision : A Comparative Study. *IEEE transactions on pattern analysis and machine intelligence*, 34(1):94–109, 2012. ISSN 0162-8828. doi: 10.1109/TPAMI.2011.109.

Anish Mittal, Rajiv Soundararajan, and Alan C. Bovik. Making a 'completely blind' image quality analyzer. *IEEE Signal Processing Letters*, 20(3):209–212, 2013. ISSN 10709908. doi: 10.1109/LSP.2012.2227726.

Anush Krishna Moorthy and Alan Conrad Bovik. Blind image quality assessment: from natural scene statistics to perceptual quality. *IEEE transactions on image processing : a publication of the IEEE Signal Processing Society*, 20 (12):3350–64, 2011. ISSN 1941-0042. doi: 10.1109/TIP.2011.2147325. URL http://www.ncbi.nlm.nih.gov/pubmed/21521667.

Nigel J W Morris, Shai Avidan, Wojciech Matusik, and Hanspeter Pfister. Statistics of infrared images. In *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, pages 1–7, jun 2007. ISBN 1424411807.

Bibliography

Jorge E. Pezoa and Osvaldo J. Medina. Spectral model for fixed-pattern-noise in infrared focal-plane arrays. In *Proceedings of the 16th Iberoamerican Congress Conference on Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications*, CIARP'11, pages 55–63, Berlin, Heidelberg, 2011. Springer-Verlag. ISBN 978-3-642-25084-2. doi: 10.1007/978-3-642-25085-9_6. URL http://dx.doi.org/10.1007/978-3-642-25085-9_6.

G. Piella and H. Heijmans. A new quality metric for image fusion. In *Proc. International Conference on Image Processing*, 2003. ISBN 0-7803-7750-8. doi: 10.1109/ICIP.2003.1247209.

Daniel L Ruderman. The statistics of natural images, 1994. ISSN 0954898X.

a Toet, J.K IJspeert, a.M Waxman, and M Aguilar. Fusion of visible and thermal imagery improves situational awareness. *Displays*, 18(2):85–95, 1997. ISSN 01419382. doi: 10.1016/S0141-9382(97)00014-0.

Qiang Wang, Yi Shen, and Jing Jin. *Performance evaluation of image fusion techniques*, chapter 19, pages 469–492. Elsevier, 2008.

F. Yuming, M. Kede, W. Zhou, L. Weisi, F. Zhijun, and Z. Guangtao. No-reference quality assessment of contrast distorted image based on natural scene statistics. *IEEE Signal Process. Lett*, 22(7):838–842, 2015.

Jiying Zhao, Robert Laganiere, and Zheng Liu. Performance assessment of combinative pixel-level image fusion based on an absolute feature measurement. *International Journal of Innovative Computing, Information and Control*, 3(6): 1433–1447, December 2007.

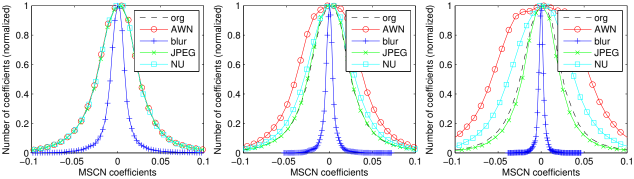
Outline

Natural Scene Statistics

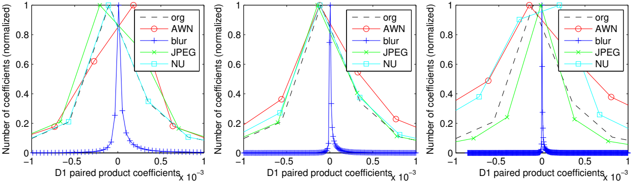
Highly successful IQA models have been based on the early work by Ruderman on 'natural images' Mittal et al. (2013); Ruderman (1994).

$$\hat{I}(i,j) = \frac{I(i,j) - \mu(i,j)}{\sigma(i,j) + C} \tag{1}$$

Natural Scene Statistics

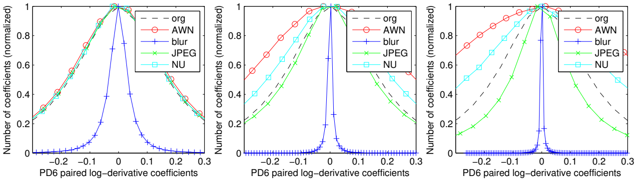


(a) MSCN histograms

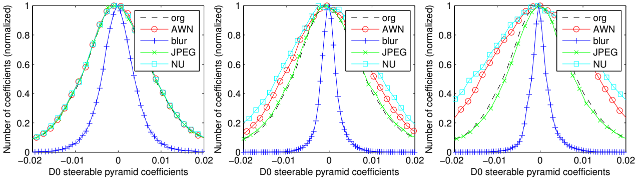


(b) Paired product histograms

Natural Scene Statistics



(c) Log-derivative histograms



(d) Steerable pyramid histograms

Figure 1: NSS Histograms

Distortion Models

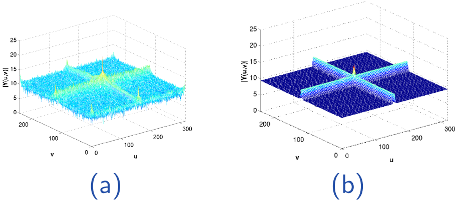


Figure 2: (a) Magnitude of the FFT of a frame. (b) Magnitude of synthetic NU. Images taken from Pezoa and Medina (2011).

$$|\tilde{I}(u,v)| = B_u \exp\left(\frac{-(u-u_0)^2}{2\sigma_u^2}\right) + B_v \exp\left(\frac{-(v-v_0)^2}{2\sigma_v^2}\right) \quad (2)$$

$$\angle\tilde{I}(u,v) \sim U[-\pi,\pi] \quad (3)$$

Natural Scene Statistics

Paired Product Coefficients

- Multiplication of neighboring MSCN
- Directional behavior
- High sensitivity to blur

Log-Derivative Coefficients

- Sensitivity to high frequency noise
- High sensitivity to JPEG

Steerable Pyramid Coefficients

- Area V1 of visual cortex
- Band-pass characteristics
- High sensitivity to NU in 0° and 90°