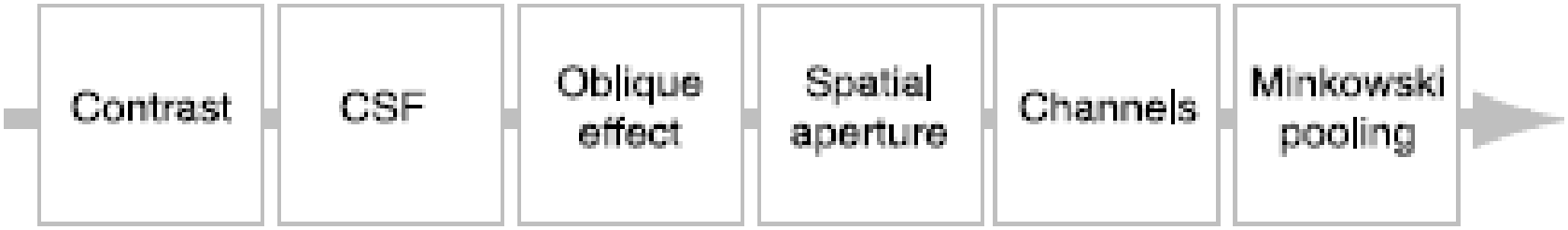
HVS-INSPIRED IMAGE PROCESSING : AN OVERVIEW

Gabriel Dauphin, Azeddine Beghdadi,
and Salim Bouzerdoum

November 2008

Outline



1. Introduction
2. Contrast
3. CSF
4. Masking Effect
5. Pooling (Fusion, Spatial Aperture)

1. HVS-Inspired Quality Measures Applications

- Different Technologies:

  fingerprints, mammography, digital cinema,

  close-circuit television, video on demand.

  HDR, mobile phone (camera/screen)

- Different Aims :

  quality control, compression, watermarking, image enhancement, segmentation, denoising, image retrieval.

=> Can there be a *unique* benchmark ?

Quality Metrics : State-of-the-art

- Distortion-oriented:
  - PSNR
  - ITS Metric (Webster et al. 1993)
  - Picture Quality Scale (Miyahara et al. 1998)
  - Blockwise distortion measure (Franti, 1998)
  - UIQI (Wang & Bovik 2002) -> SSIM (Z. Wang et al. IEEE-IP 2004)
  - W_SNR (Beghdadi & Razvan 2001)
  - VIF (Visual Information Fidelity, C. Bovik, 2008)

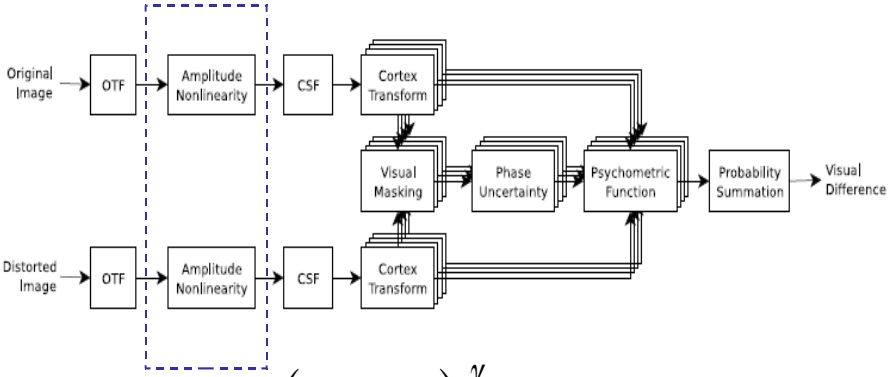
- Human Visual System Modelling-Based:
  - The Visible Difference Predictor (Daly, 1993)
  - Sarnoff JND Vision Model (J. Lubin, 1997)
  - Metrics developed at NASA Vision Group (Watson & Co. - 1993 to 98)
  - Metrics developed at EPFL (Switzerland)

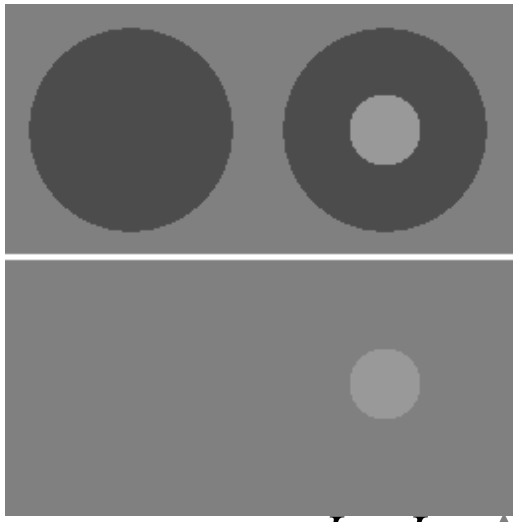
VQEG : Video Quality Expert Group (created in 1997)

Different Kind of Knowledge

Plausible Explanation	HVS	VS seen as a Communication Channel	Gestalt
Experiment	Modelfest	Retinex	Image Databases
Expertise	Calibration (ΔE)		Gamut Mapping (color constancy)

2. Contrasts Versus Perceptual Spaces





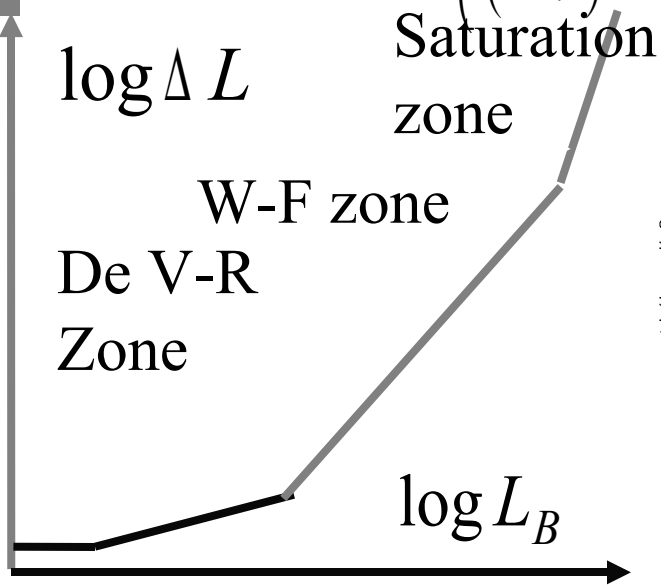
Gamma Correction $L = L_0\left(\frac{g}{g_M}\right)^{\gamma} \quad \gamma \approx 2.3$

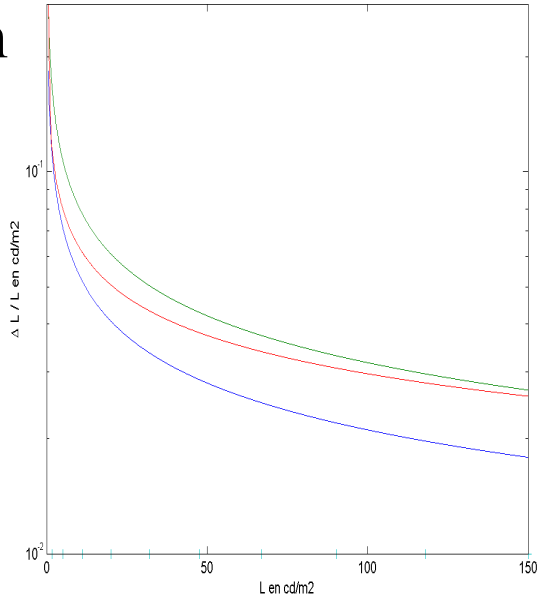
L*a*b* ΔE $L^* = 116 * \left(\left(\frac{Y}{Y_n}\right)^{1/3} - 16\right), qd\ \frac{Y}{Y_n} > 0.009$

Weber's Contrast $\frac{L - L_b}{L_b}$

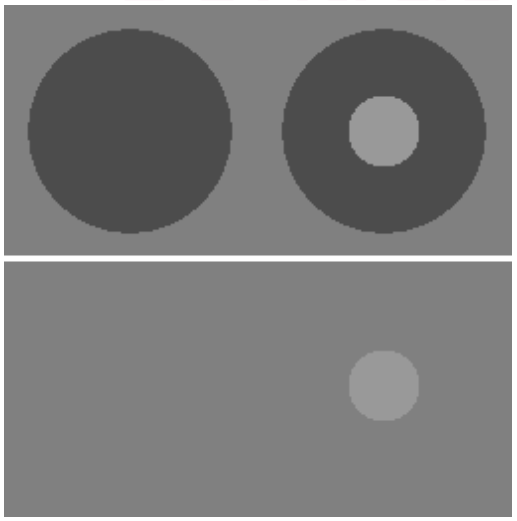
Peli $\frac{BP_i(x,y)}{LP_i(x,y)} = \frac{g * L}{\delta + h * L}$

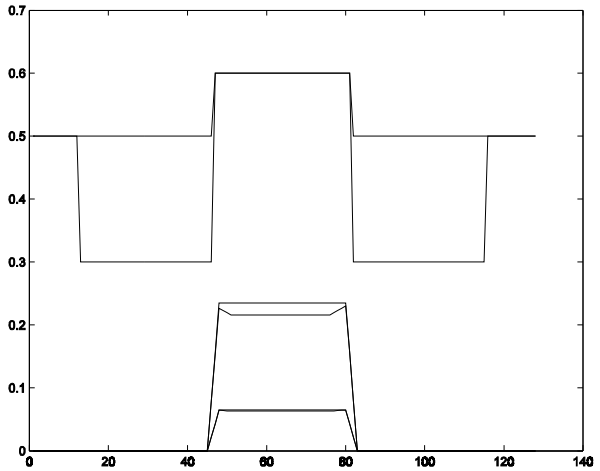
Weber F. $\frac{\Delta L}{< L >}$





Contrast // Perceptual Space





Mach Bands

Lateral Inhibition Contrast

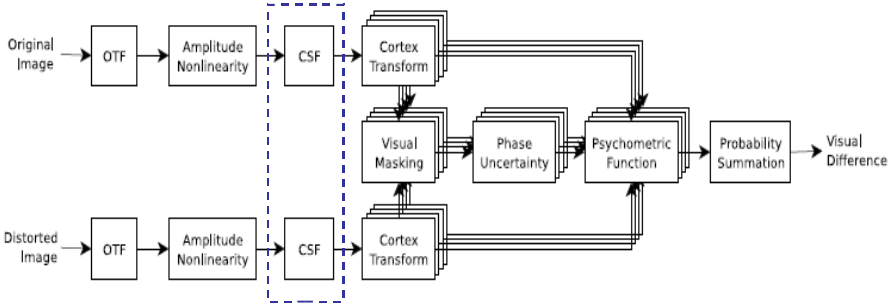
$$c = \frac{g * \left(L^0 - L^D\right)}{\left(\delta + h * L^O\right)^{\alpha}} \approx \frac{1}{1-\alpha}\, g * \left(\left(\delta + L^O\right)^{1-\alpha} - \left(\delta + L^D\right)^{1-\alpha}\right)$$

Gamma Correction $1-\alpha \approx 1/2.3 \Rightarrow \alpha \approx 0.57$

L*a*b* $1-\alpha \approx 1/3 \Rightarrow \alpha \approx 0.67$

Hence, $Q(g_0, g_0 + \Delta g\delta_{mn}) = Q(g_1, g_1 + \Delta g\delta_{mn})$

3. Contrast Sensivity Function



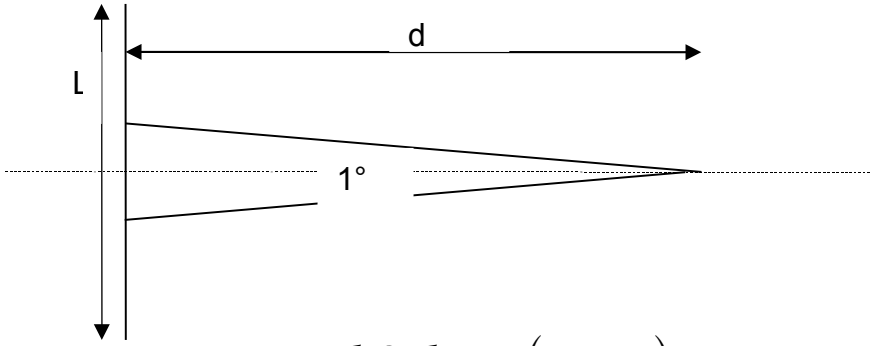
1.12

4

11.3

ModelFest (Watson)

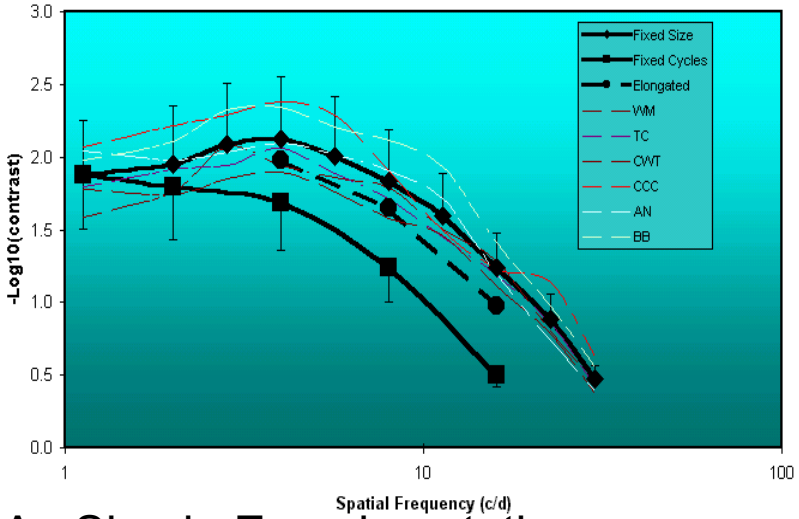
$$\sum_{i,j}\left(\frac{L_{ij}^{O} - L_{ij}^{D}}{< L^{O} >}\right)^{2} \leq c_T$$



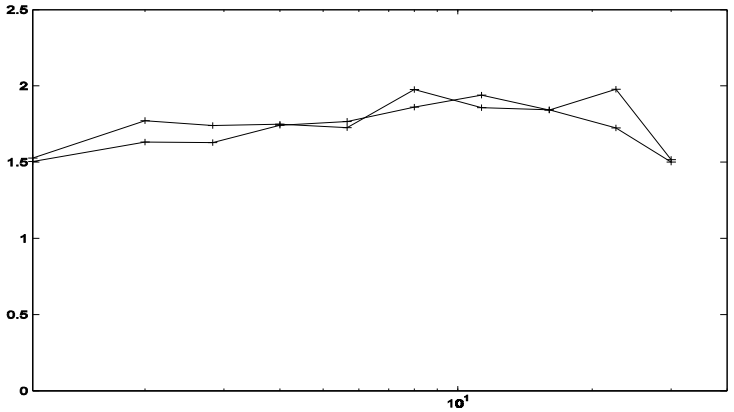
$$f_{c/d} = \frac{k2d}{L}\tan\left(\frac{\pi}{360}\right)$$

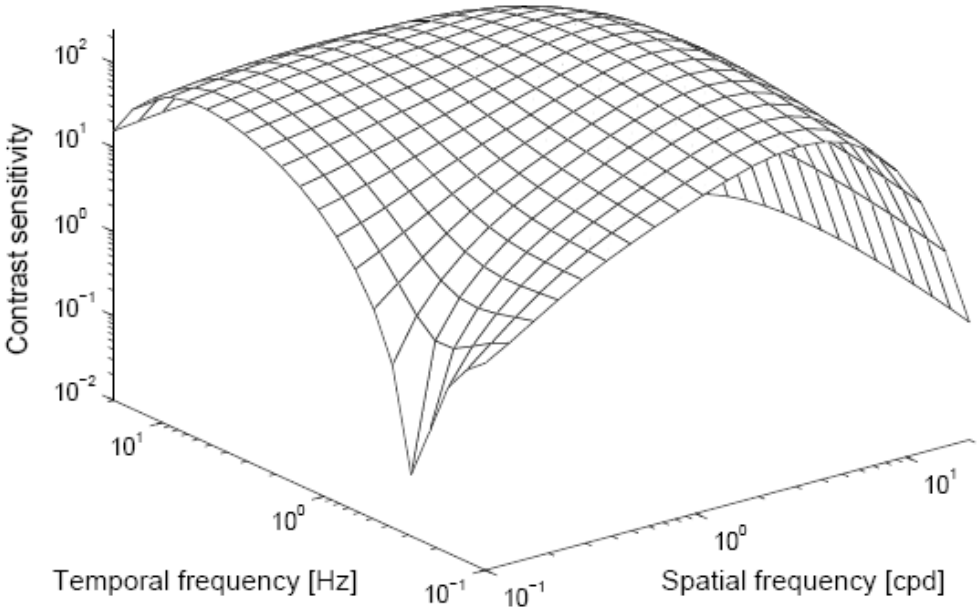
Experimentations => CSF

MODELFEST



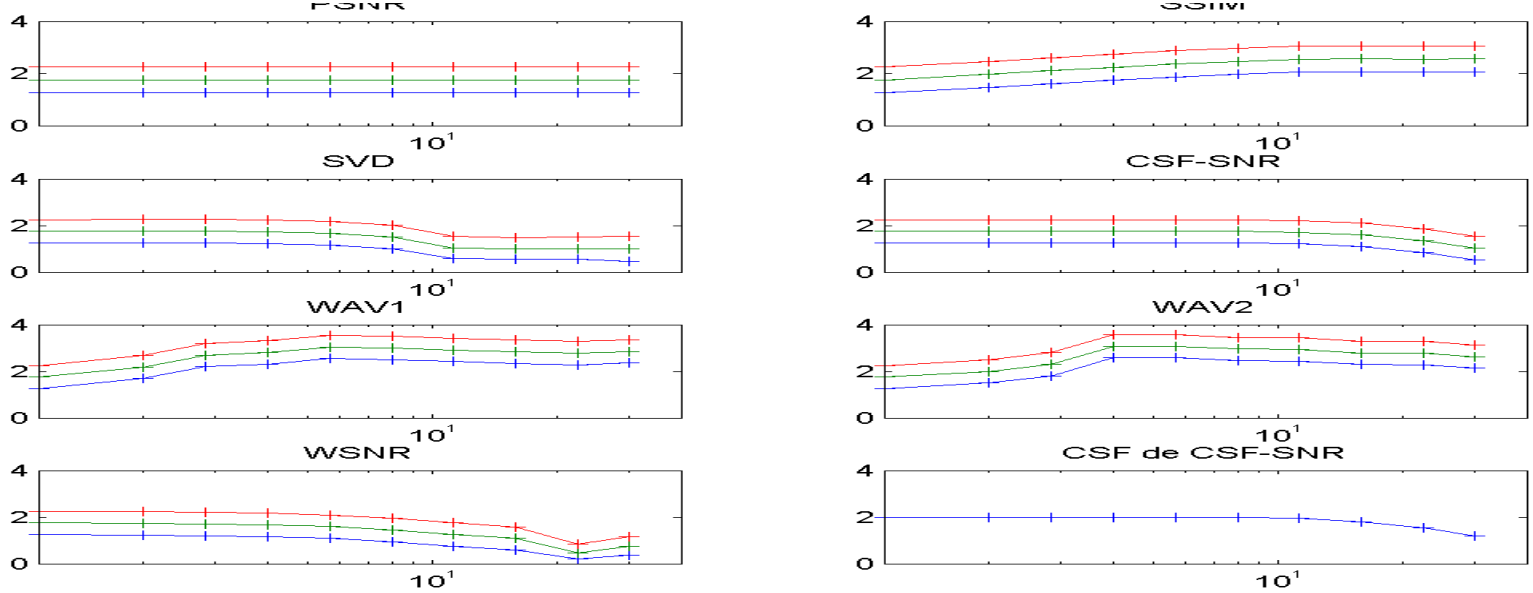
An Simple Experimentation



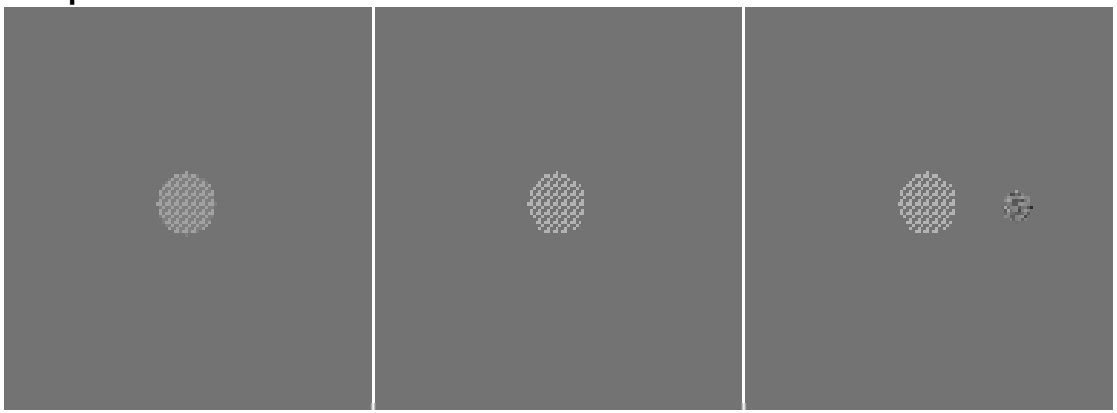


Claimed CSF and Effective CSF

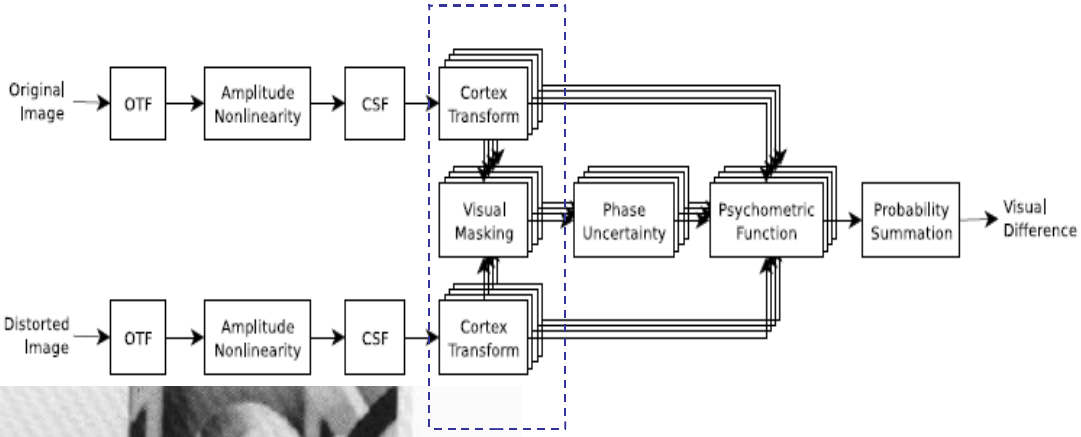
$$Q(g_0, g_0 + a(u,v)cos(2\pi mu + nv)) = C^{te}$$

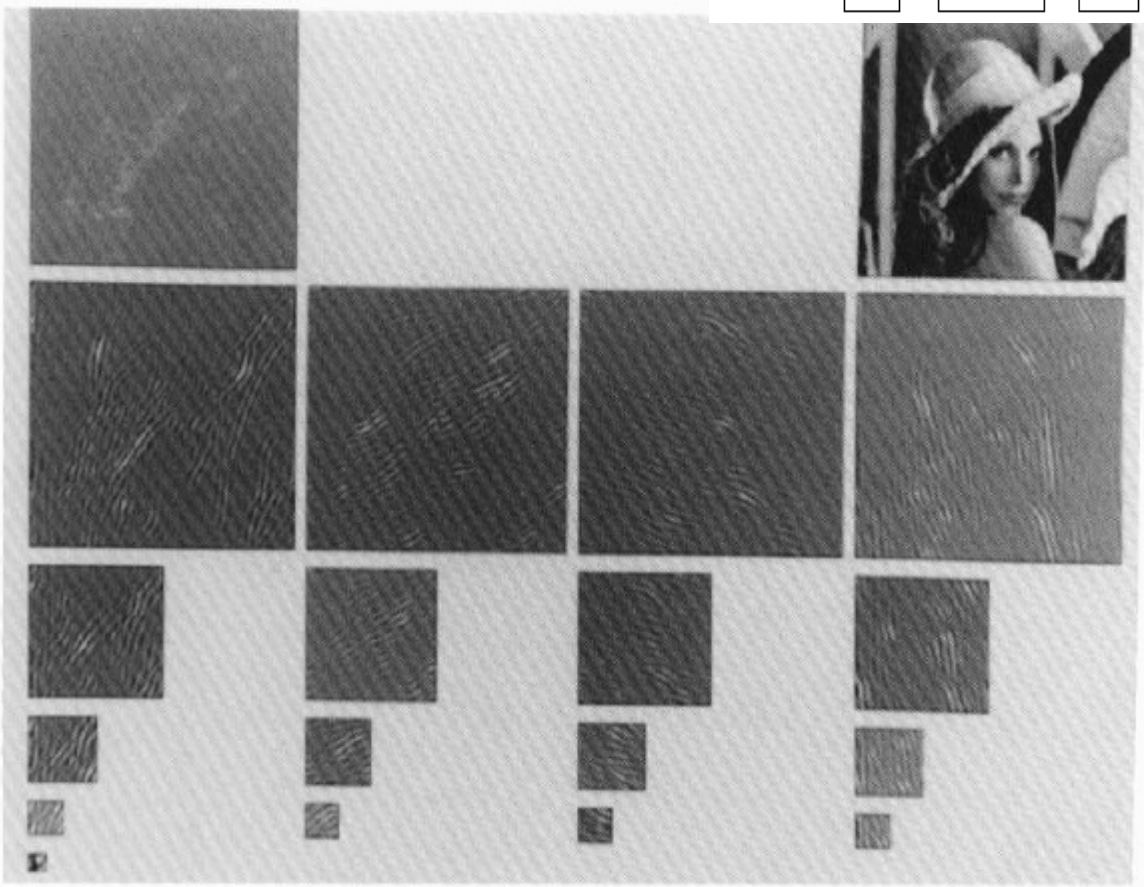


Practical Consequences:



5. Cortex Transform





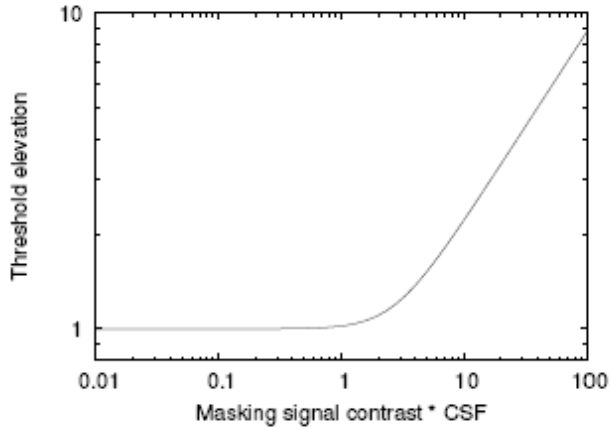
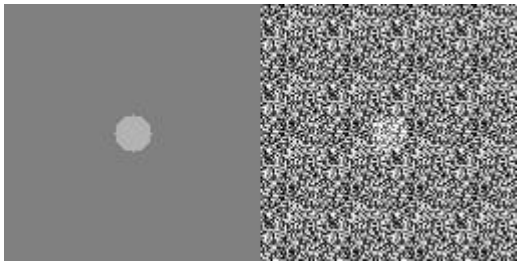


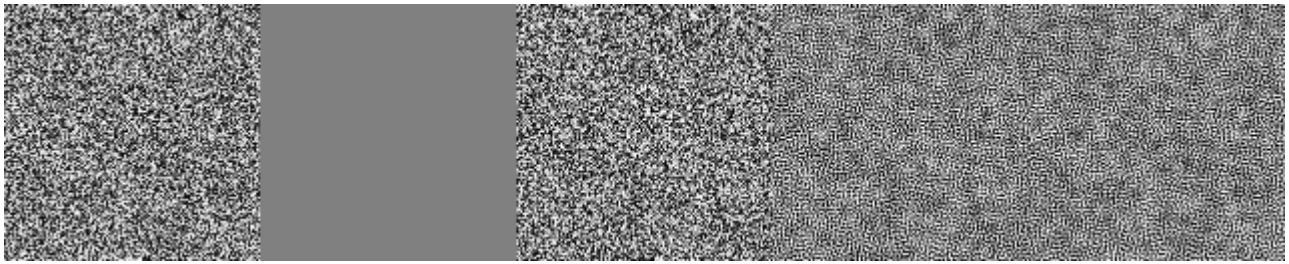
FIG. 12. Cortex transform of an image. Layers vary in resolution from row to row, and in orientation from column to column. The high and low frequency residues are also shown. All layers are scaled to full contrast to maximize visibility.



Masking Effect

Yet for texture:

Source | Average | Reverse polarity | LF added | HF added



6. Pooling

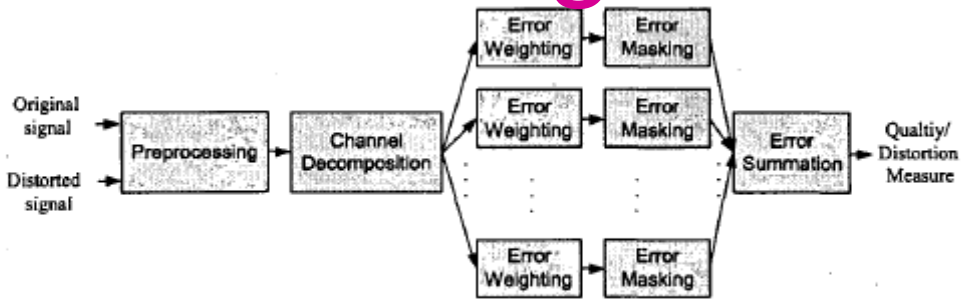
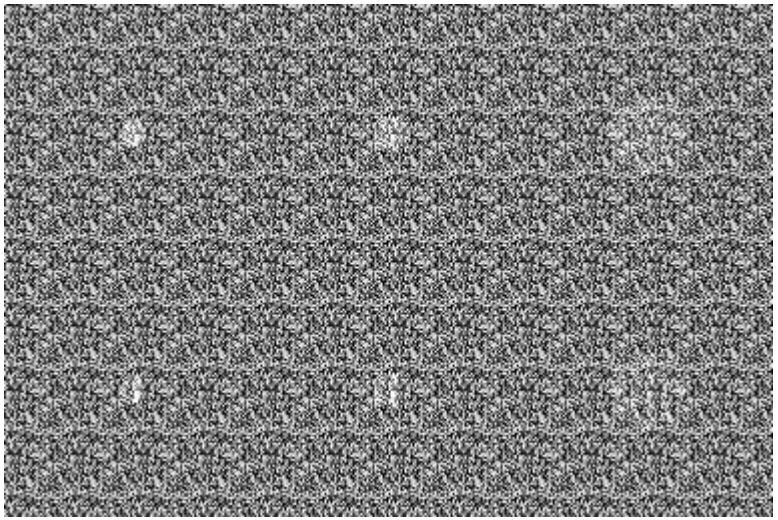


Fig. 1. Error sensitivity based image quality measurement.

- Area of Patch Versus Intensity of Patch



$$\Rightarrow \beta \approx 2,3,4$$

in the Minkowsky sum

There may be some interaction with spatial aperture.

$$Q(g_0, g_0 + b(card(A))\Delta g 1_A) = C^{te}$$

Conclusion

- Different applications

  different technologies, different aims
- Different HVS-inspired quality measures
- How to choose ?

(contrast, CSF, masking, fusion)

-> Geometrical invariant properties ?