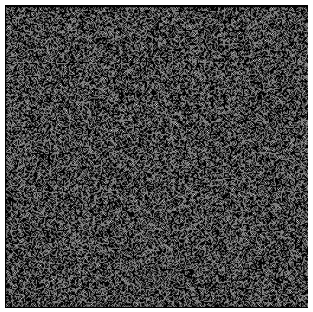
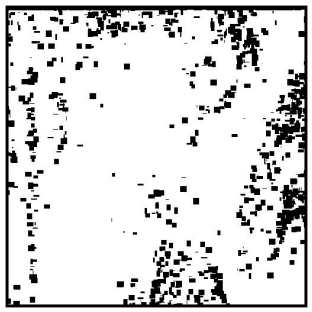
Some definitions

- The set $\Omega_{M_1,M_2,P}(S) \subseteq \mathcal{U}_{M_1,M_2,P}$ contains images with structure S
- Tolerance is the size $K_S(B)$ of a set with a "central" member B (the image in question)
- Capacity $C_S(B) = \log_2(K_S(B))$ (an estimate of the real entropy $H(B)$)
- Log capacity per pixel $A_S(B) = \frac{C_S(B)}{M_1 \cdot M_2}$

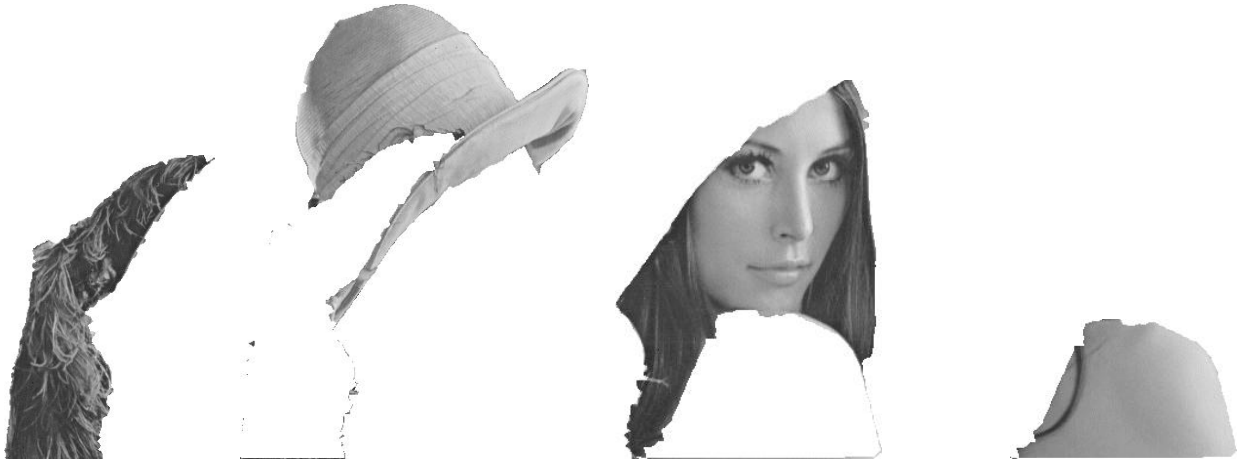
Experiments with capacity measures

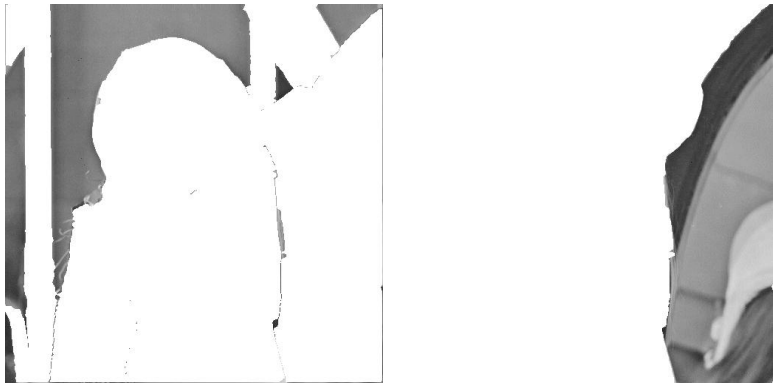

Capacity areas [Hansen and Andersen, paper from SCIA '99], left to right: capacity (black) derived from a multi-resolution representation; capacity (white) derived from an entropy estimate; O Ruanaidh capacity (white) derived from DCT coefficient power spectrum

The Lena image [1]

Segments



Backgrounds



The Lena image [2]

We can estimate the contributions to the $K_{T|S_i}$ and K_N from the six variances in the histogram.

- Pixel frequencies gives 7.5 bit/pixel, but the six variances contributes only $\approx$ 4.5 bit/pixel
- If real noise level is 30 dB then $A_N \cong 0.2$ bit/pixel
- Structural part assumed to be 0.1 bit/pixel
- $A_S = 4.2$ or $C_S(l) = 512 \cdot 512 \cdot 2^{4.2}$ or 4,817,990 bit

Estimation of tolerance[1]

We define the *perceptual tolerance* at a pixel coordinate in an image P as the amount that each pixel component (e.g. RGB, or HSV) can be changed without changing the perception.

The actual capacity depends e.g. on the coding method.

Estimation of tolerance[2]

The perceptual tolerance may be determined experimentally by combining a number of filter responses (here F_i for i in $1 \ldots 6$) each enlarging the tolerance interval. For each pixel component $p_{ijk} \in P$ (i, j being the pixel coordinates, k indicating the component) the tolerance is the interval from $\underline{p}_{ijk}$ to $\overline{p}_{ijk}$. These values are stored in the images $\underline{P}$ and $\overline{P}$.

Estimation of tolerance[3]

The algorithm has the following steps:

- Initially $\underline{P} = \overline{P} = P$.

Estimation of tolerance[4]

- For each filter index i:

1. Given P and a filter F_i an image $P^* = F_i(P)$ is generated. F_i is chosen in such a way that there will be no perceptual difference between P and images having pixels in the interval from P to P^*.

2. $\underline{P}$ and $\overline{P}$ are updated by $\underline{P} = min(\underline{P}, P^*)$ and $\overline{P} = max(\overline{P}, P^*)$.

Estimation of tolerance[5]

- The resulting tolerance (the number of images in the equivalence class) is

$$K_S = \prod_{ijk} (\overline{p}_{ijk} - \underline{p}_{ijk} + 1)$$

- In the following tolerance images $(\overline{p}_{ijk} - \underline{p}_{ijk} + 1)$ are shown for each position (i, j), the values for $k = 1, 2, 3$ being coded in the R, G and B components

HVS characteristics

- Mono- and polychromatic assimilation - thin lines with the same intensity or hue (polychromatic) as the surrounding area
- Area homogeneity - variance
- Just noticeable distortion JND
- Edge enhancement

Filters [1]

Six filters (based on local texture and noise):

Assimilation: threshold based mean filters $F_1(P_{assim,m})$ (equal weight) and $F_2(P_{assim,w})$ (weighted). The following 3×3 matrices were used:

$$\frac{1}{9}\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \text{ and } \frac{1}{18}\begin{pmatrix} 1 & 1 & 1 \\ 1 & 10 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

Filters [2]

Area homogeneity (HSV colour model): $F_3(P_{H_v})$ (value) and $F_4(P_{H_h})$ (hue). In a 3×3 pixels neighborhood $N_8(p)$ the variances

$$\sigma^2_{value} = \frac{1}{9} \sum_{j \in N_8(p)} (value_j - \overline{p}(N_8))^2$$

(where $\overline{p}(N_8)$ is the average value) determines the homogeneity $H_v = 1 - 4\sigma^2$ (in $[0; 1]$), and a similar formula for hue.

Filters [3]

JND: F_5 is JPEG compression (quality P_{jnd}) and decompression, using JASC Paint Shop Pro software

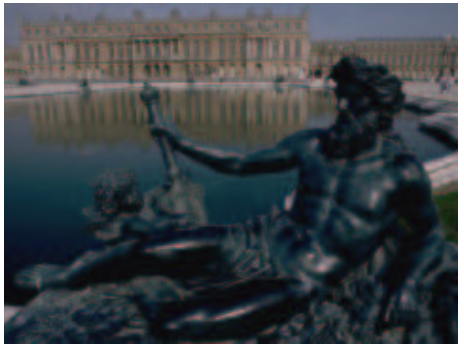
Sobel edge detector with threshold $F_6(P_{edge})$, using

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \text{ and } \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

Test images used



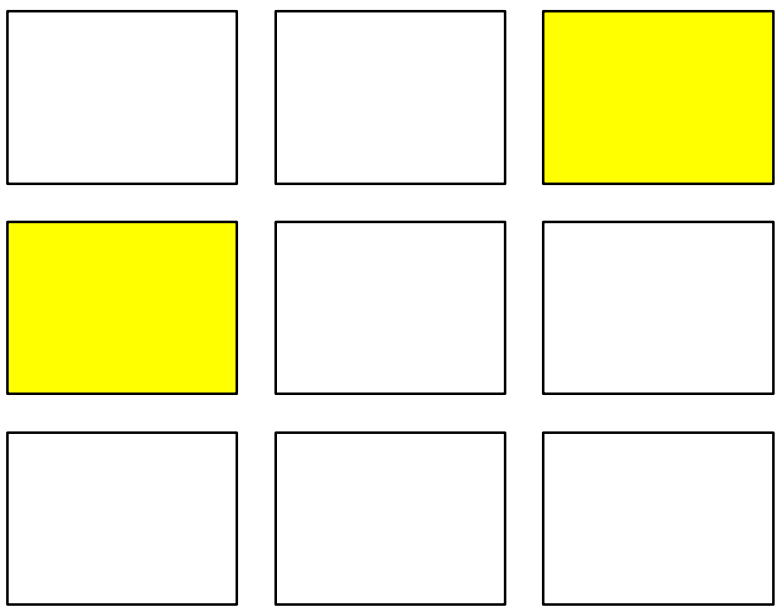


Determining filter parameters [1]

- 18 persons, including one color-blind and one using only one eye
- 106 sets of 9 images, presented by StegoViewer
- Each set were either 9 identical images, or two were different
- The sets were presented in a randomized sequence
- The position of the two images were randomized

Determining filter parameters [2]



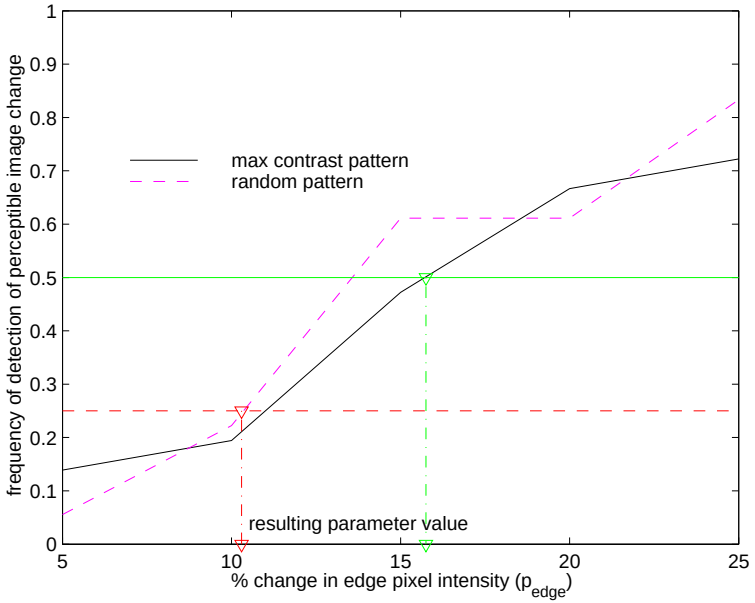
Left: the images in the yellow positions have been modified according to one selected parameter to give a chosen filter response. The test persons mark an image if a change is visible.

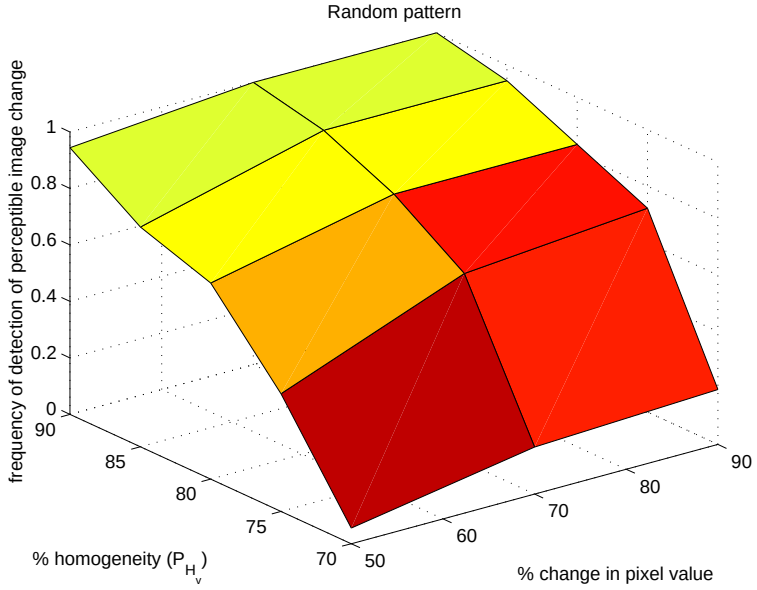
Determining filter parameters [3]



Left original, middle random change of hue, right alternating maximal change of hue.

Filter parameters





Third part