Illusioni ottiche come potenziali test optometrici

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Use of Optical Illusion

Art and Entertainment $\Rightarrow$ Study Perception and Human Vision

Goal

Create new method for detecting vision disorders

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Hybrid Images

What are they?

Static images with two different stable interpretations, which change as a function of :

- viewing distance
- image size
- observation time

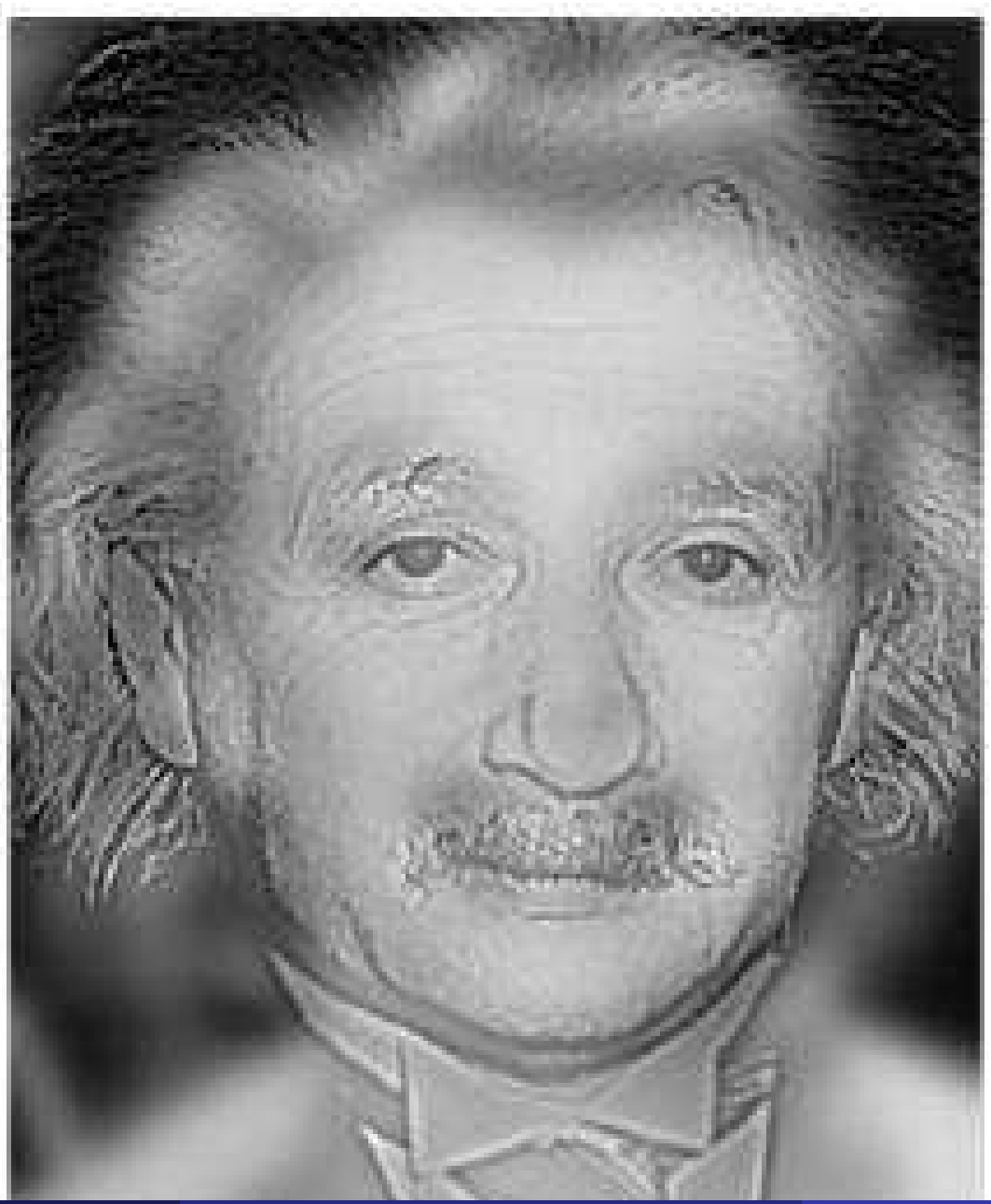
Method

Superposition of two coherent global image $\longrightarrow$ *Hybrid Image* (H):

- *Low Frequency - Image* (I_L)
- *High Frequency - Image* (I_H)

$$H = I_L + I_H$$

Albert Einstein and Marilyn Monroe Aude Oliva *New Scientist* (2007)



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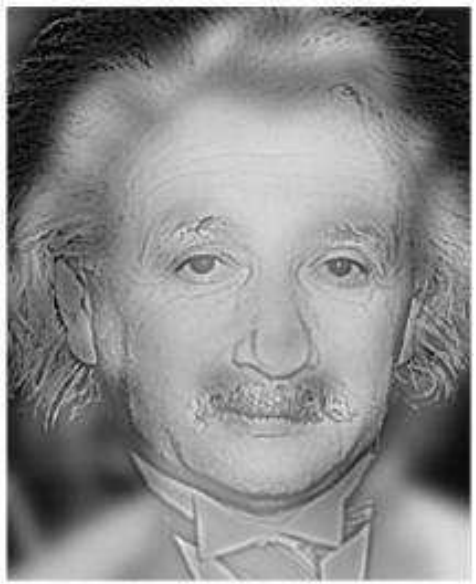

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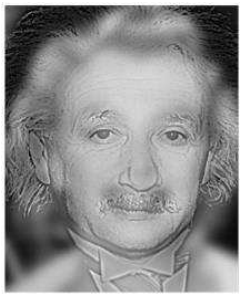

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Interpretation of the images

Stability

For each observation condition, only one interpretation dominates over the other:

- Possible transition condition between the two interpretation
- No switching between the two interpretations once one rules

Low Frequency - Image I_L of a Image I_1

- global luminance variations in the image (broad contours)
- *blurry* version of the original image

High Frequency - Image I_H of a Image I_2

- sharp details
- it appears a highly detailed line drawing

Summary of the method (1)

I_1 and I_2: original images

G_1 and G_2: Low-Pass Filters in Fourier domain of the Spatial Frequencies

α_1 and α_2: possible gain coefficients

Transformation

$$I_L = \alpha_1 G_1 I_1$$

$$I_H = \alpha_2 (1 - G2) I_2$$

Composition

Hybrid Image: $H = I_L + I_H$

Summary of the method (2)

Discrete Fourier Transform (spatial coordinates $(x, y) \longrightarrow$ spatial frequencies (u, v))

Matrix $f(x, y)$ of the Image of dimensions *MxN* pixels

$$f(x, y) \longrightarrow F(u, v) = \frac{1}{NM} \sum_{x=0}^{M-1} \sum_{x=0}^{N-1} f(x, y) e^{-j2\pi\left(\frac{ux}{M} + \frac{vy}{N}\right)}$$

Using the *Fast Fourier Transform Algorithm (FFT)*

2D Convolution Theorem

Filter: $g(x, y)$ in spatial domain, $G(u, v)$ in frequencies domain

$$g(x, y) * f(x, y) \Leftrightarrow G(u, v)F(u, v)$$

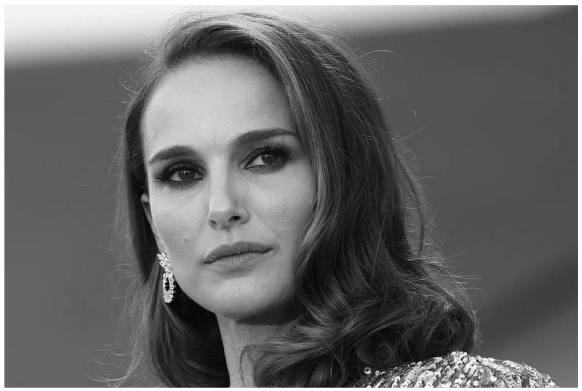
Processed Image $f_F(x, y)$

Inverse Fourier Transform

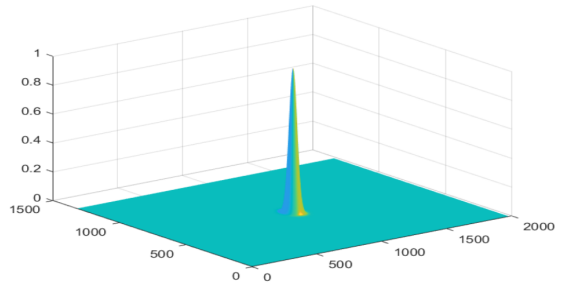
$$f_F(x, y) = \mathcal{F}^{-1}\left[G(u, v)F(u, v)\right]$$

Gaussian Filter of variance D_0^2

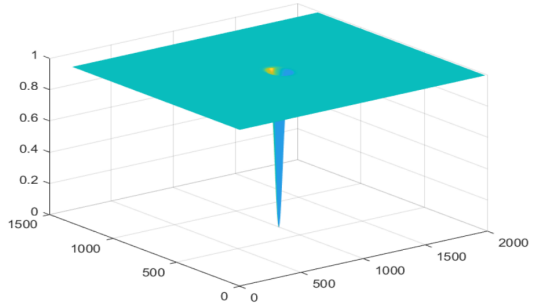
$G(u,v) = e^{-D^2(u,v)/2D_0^2}$ D = distance from the origin



LOW PASS FILTER

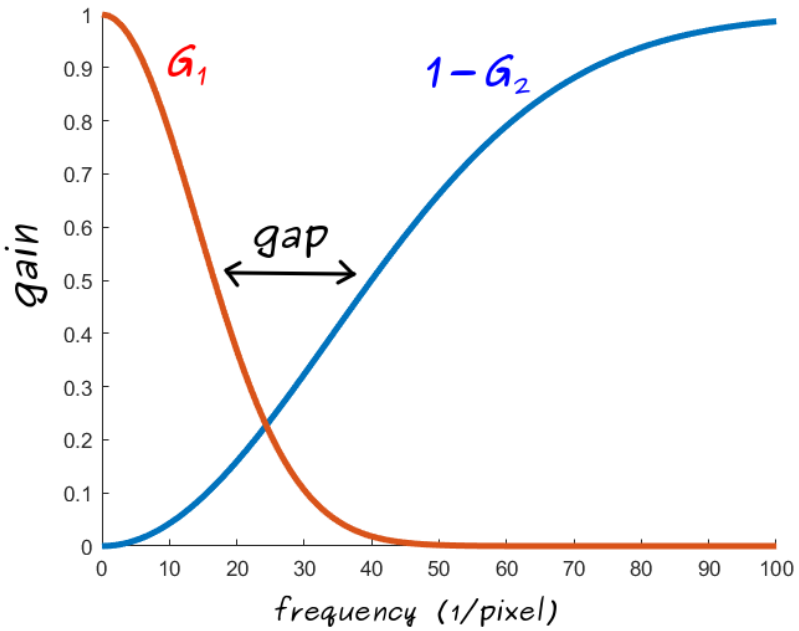


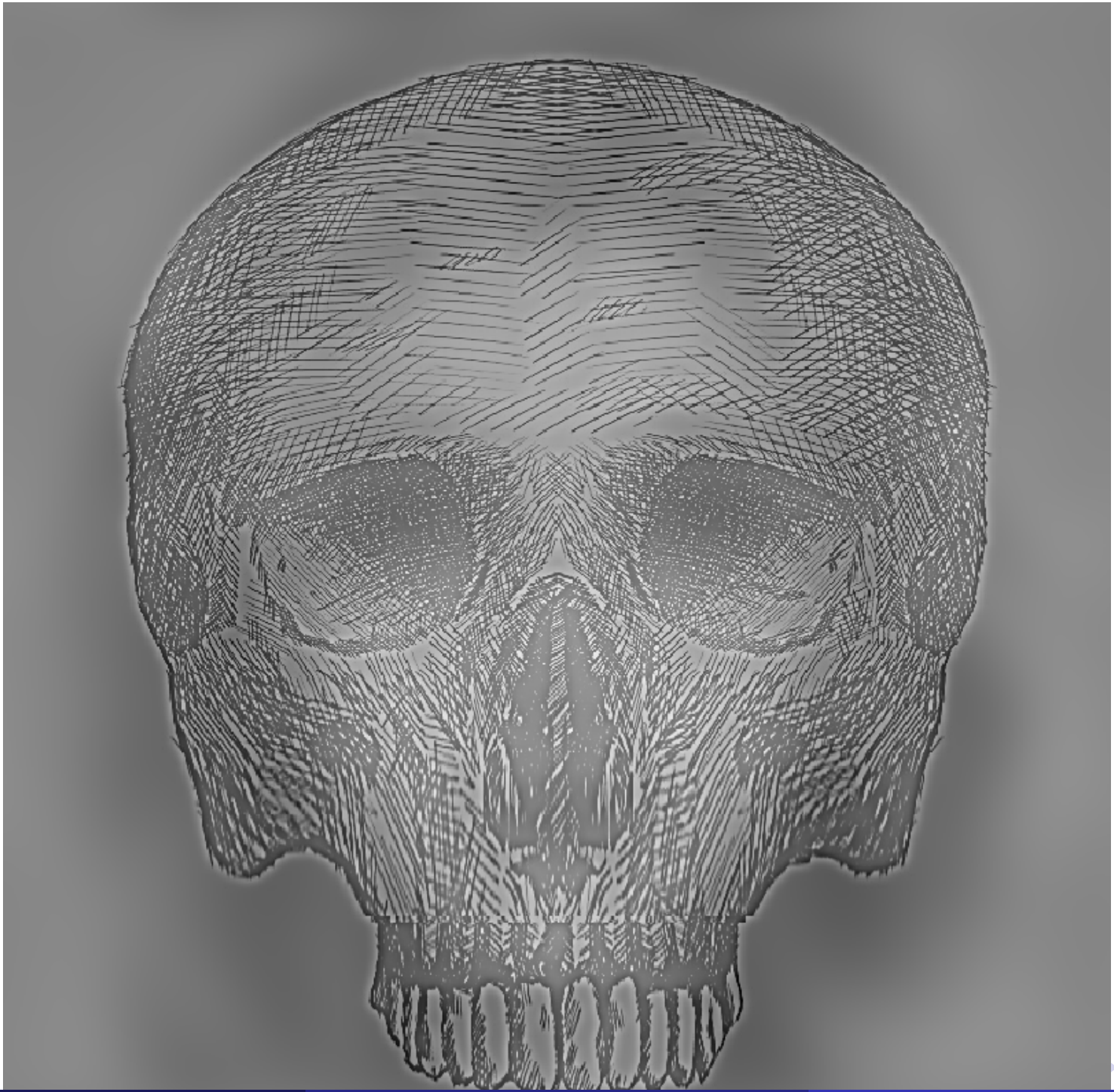
HIGH PASS FILTER

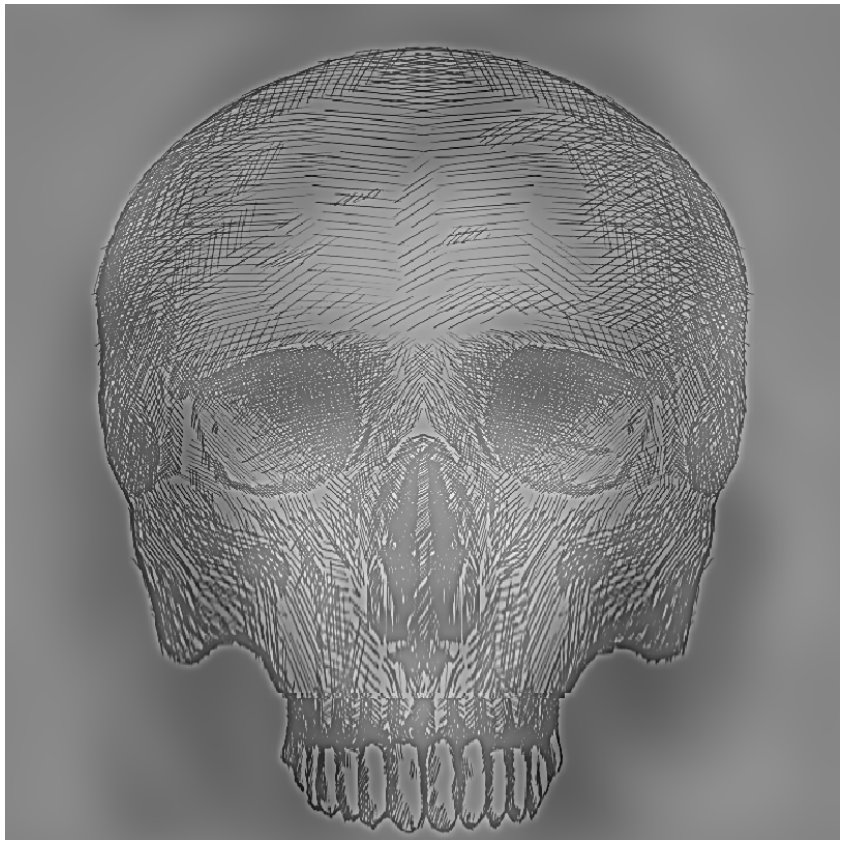


Additional rules for a Hybrid Image

- The other interpretation should be perceived as *noise*
- Introducing an alignment to reduce the influence of one channel over the other
- Different cutoff frequencies between the Low Pass and the High Pass Filter $\Rightarrow$ unambiguous interpretation







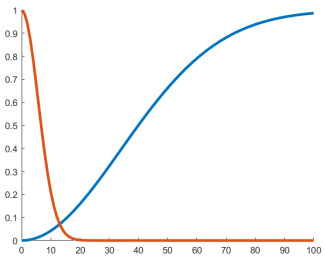
$\rightarrow I_L$

$+$

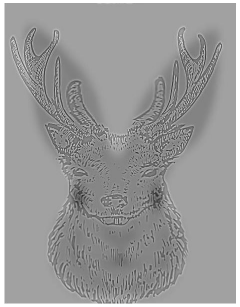
$\rightarrow I_H$

$=$

frequency gap



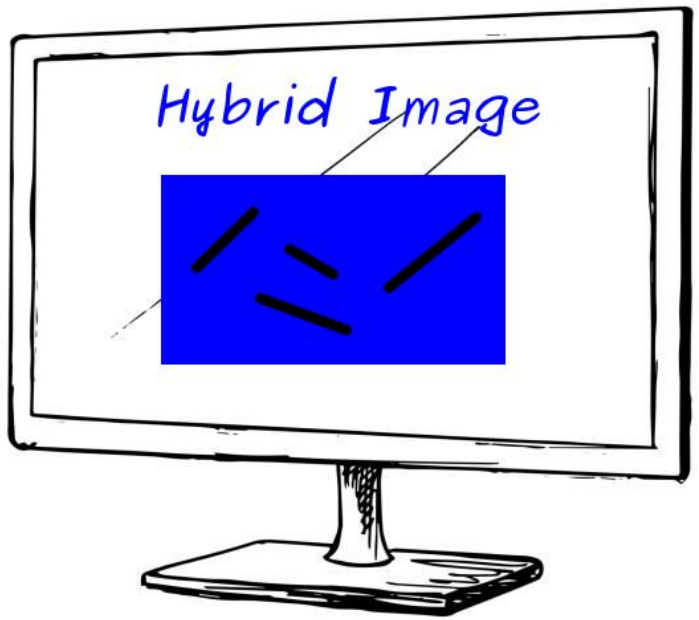
H

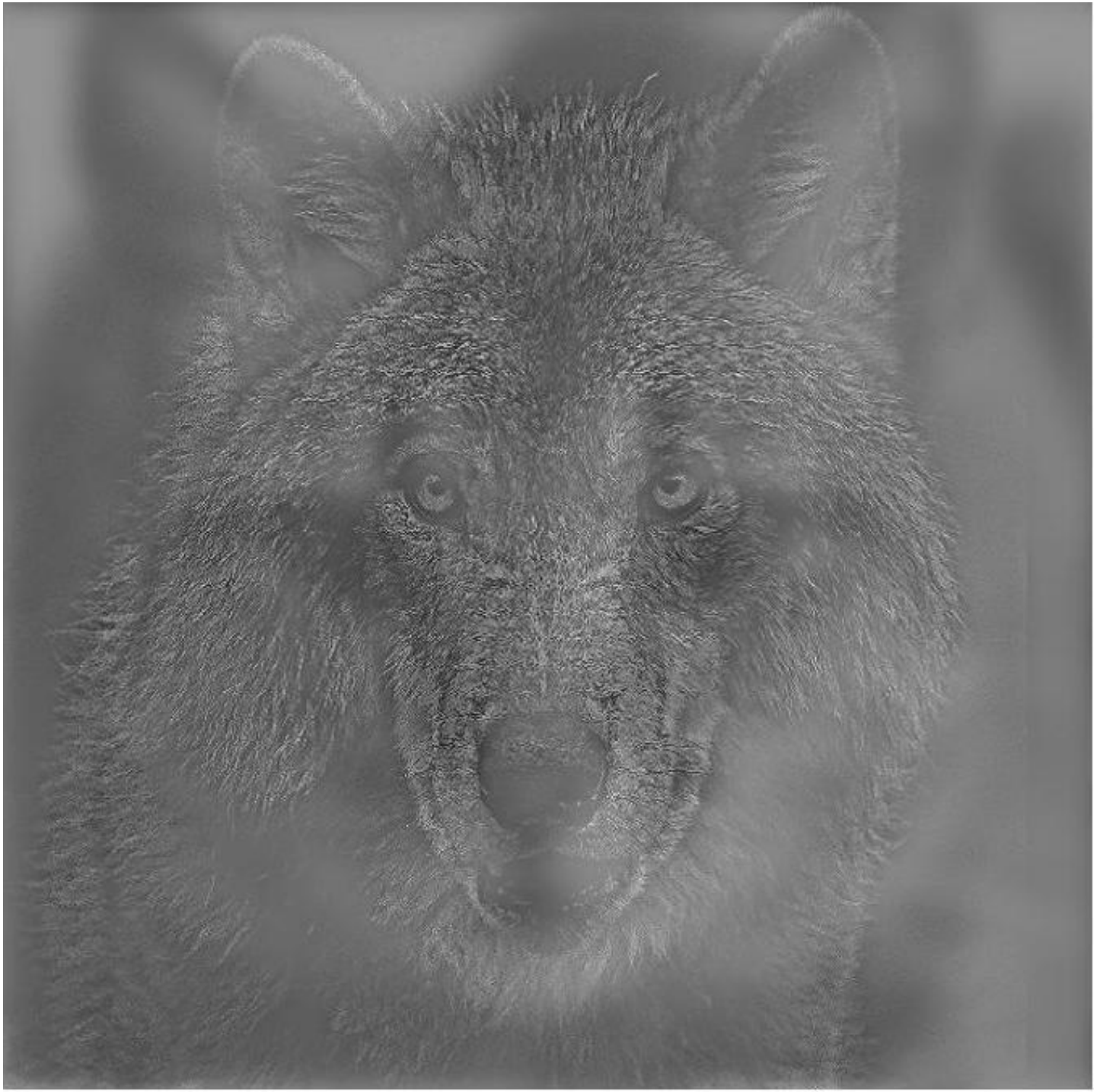


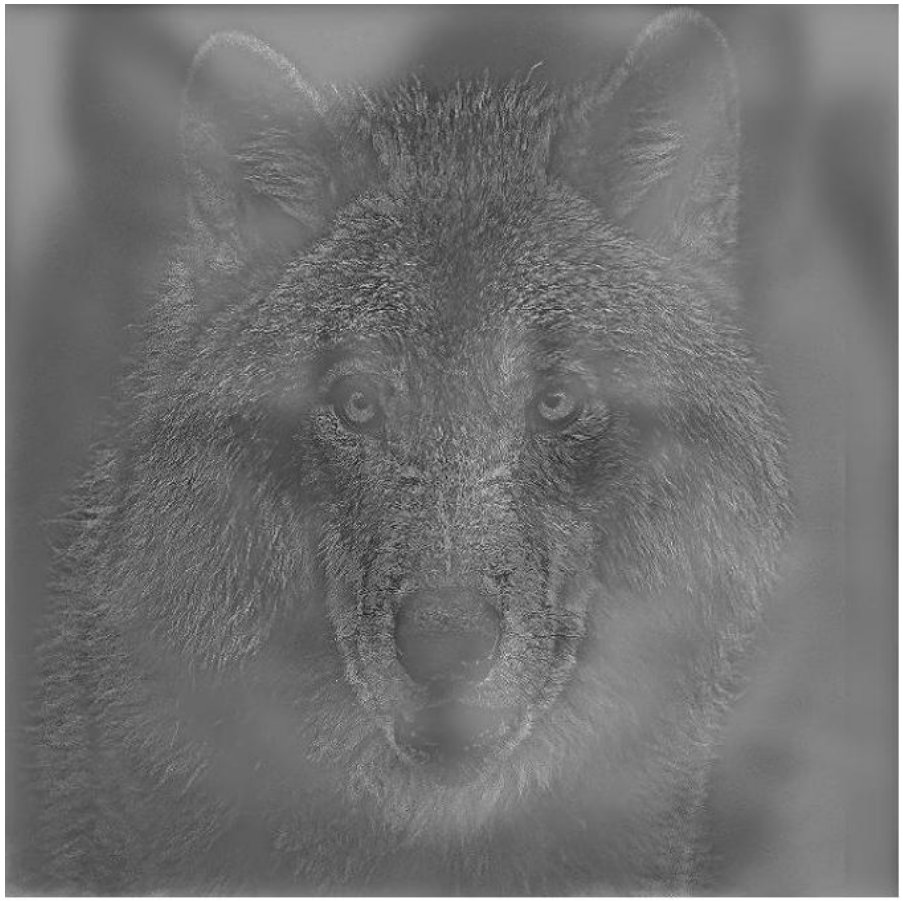
Early screening of possible myopia in childhood

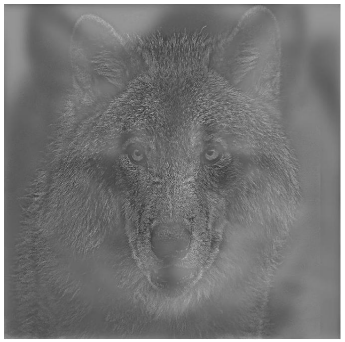
Our proposed method

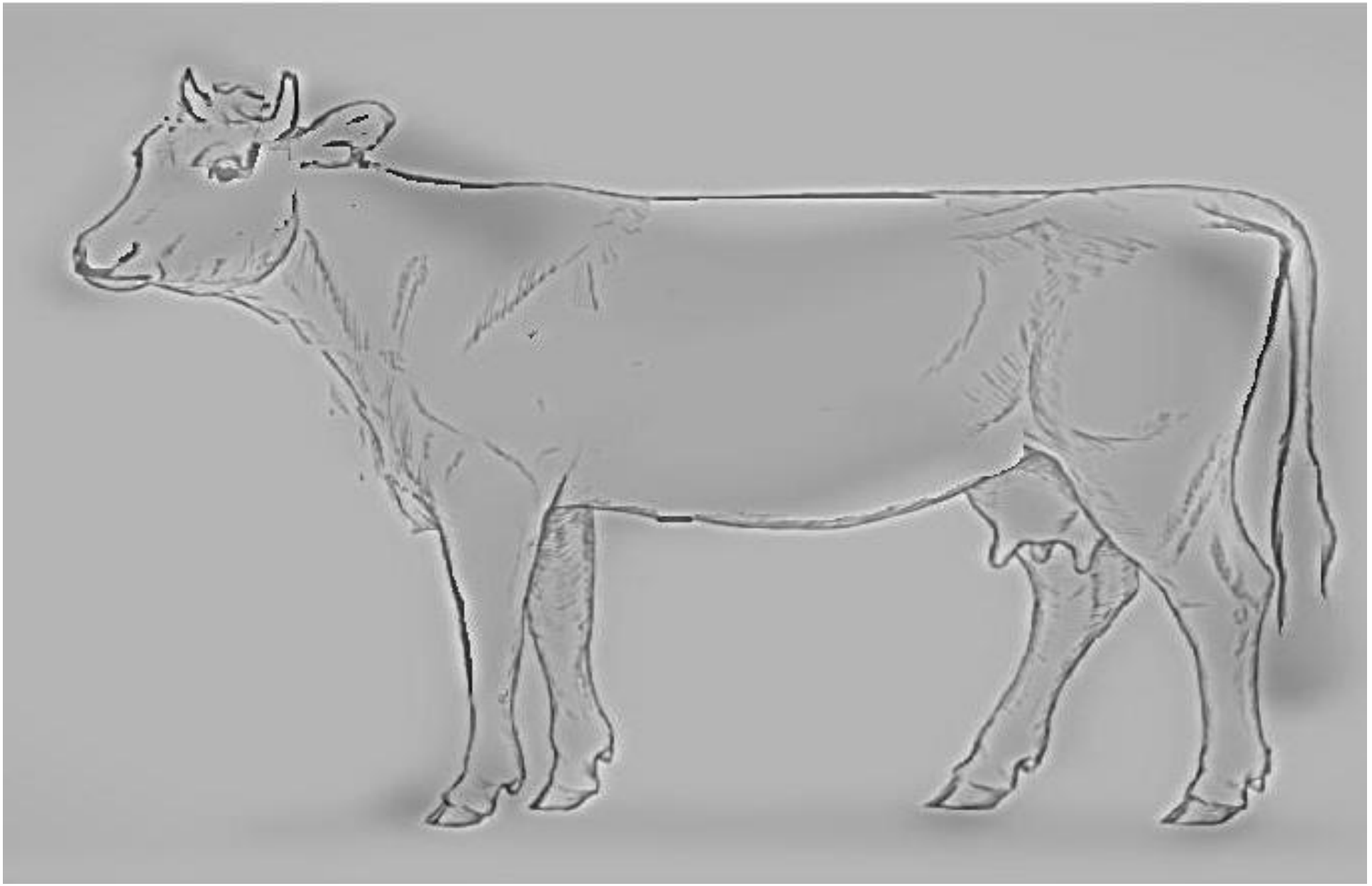
- Vision of hybrid image at a screen
- The child should be able to recognize the shape of a well known animal
- The High Frequency Image of the Hybrid Image should prevail in the vision

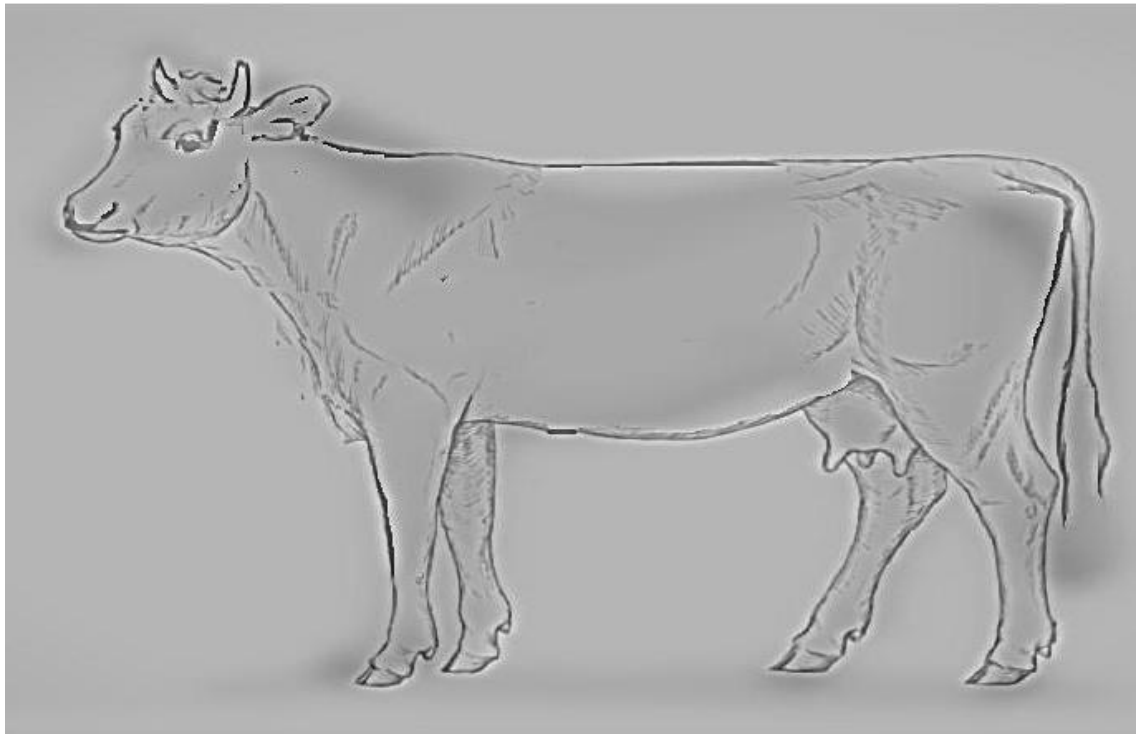


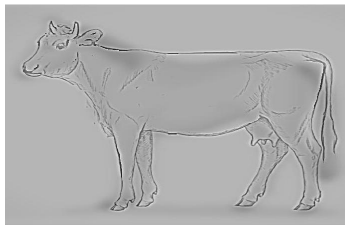


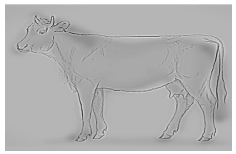






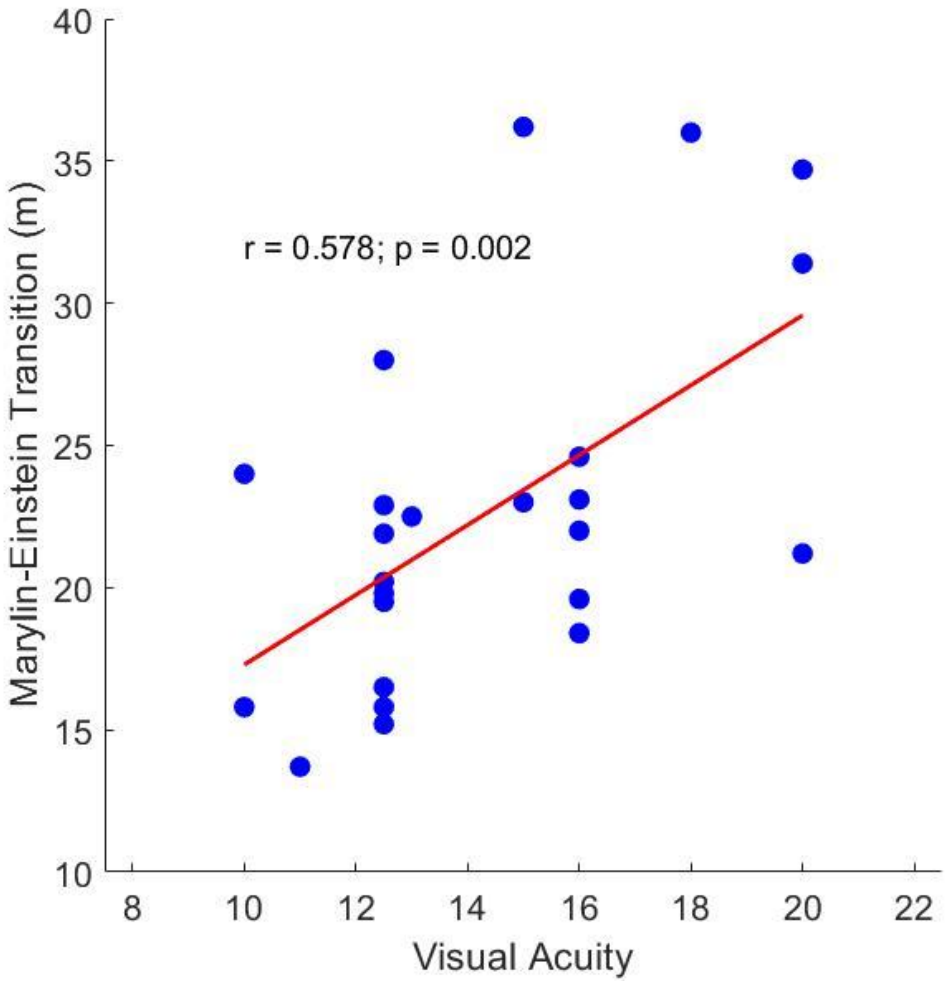






Preliminary Results

A. Einstein / M. Monroe: Correlation Transition - Visual Acuity



Preliminary Results

Wolf/Cat: Correction for the Transition

- Induced 10/10 visual acuity with a correction
- Fixed distance of the Hybrid Picture (A4)
- Additional correction for the transition

Subject 1:

- Wolf at 1.2 m
- Cat: correction
  +1.00 OD, +1.00 OS

Subject 2:

- Wolf at 1.3 m
- Cat: correction
  +0.75 OD, +0.50 OS

Thanks for your attention