What is an average shape and what is an average texture?

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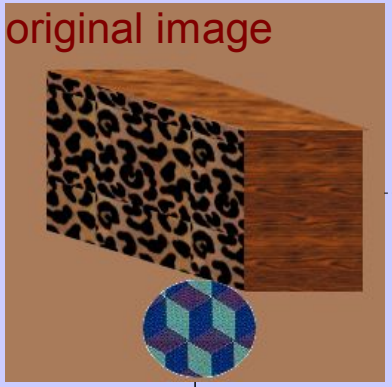
These slides are a modified version of a presentation for HBES conference in Berlin, July 2004

Morphing to average shape and texture

- Images have two distinctive features: shape and texture
- to obtain an average image, shape and texture are averaged separately: this is called morphing
- how is morphing done?
- what does “averaged” mean?

morphing



shape

warper

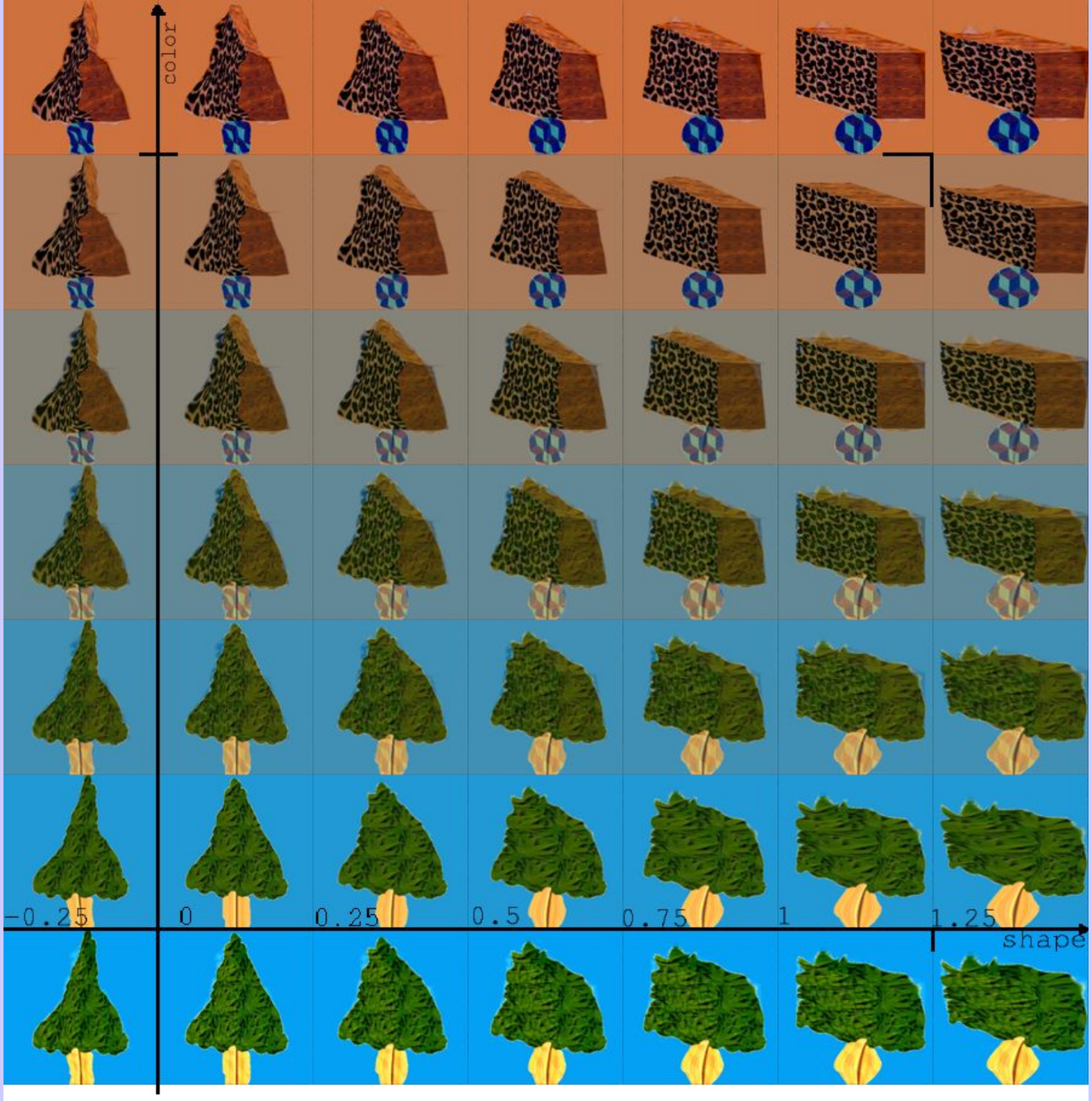
average shape

shape averaging

warper

texture averaging

parameters of morphing create a shape/texture space

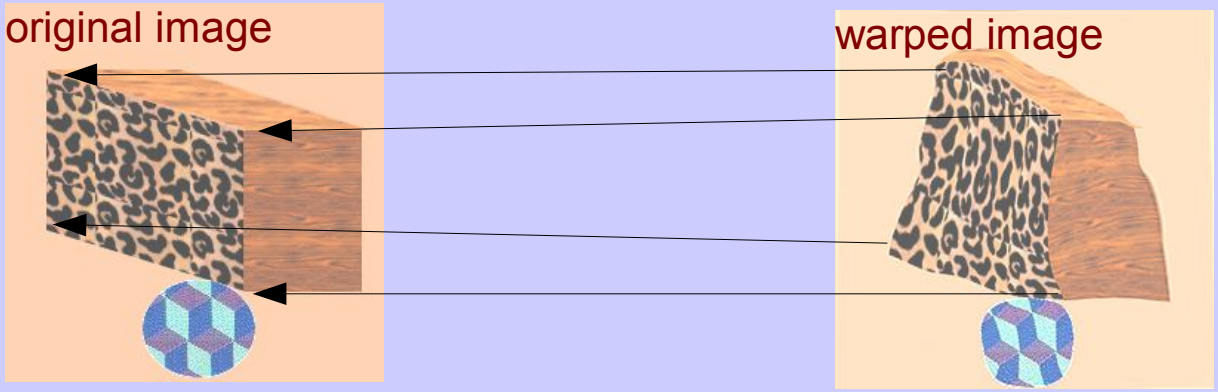


Shape averaging

- Feature points vs feature curves: it would be useful to use curves; but, what is the average of curves? Unfortunately, there is not a satisfying mathematical definition of *shape space of curves,* and of *average of curves.*
- Once we decide that the *shape* is a collection of points, we should use Kendall *shape space* of feature points, and define the average of a shapes accordingly.
- But we currenty approximate that by doing the arithmetic mean of feature points

Warping method

•Operator manually specifies the correspondence of feature points



- Warping needs a continuous function f(x,y) that is an interpolation of feature points

$$f(x, y), f: R^2 \rightarrow R^2$$

f(x,y)

- Warping algorithm pulls pixels from original to warped image using *f*

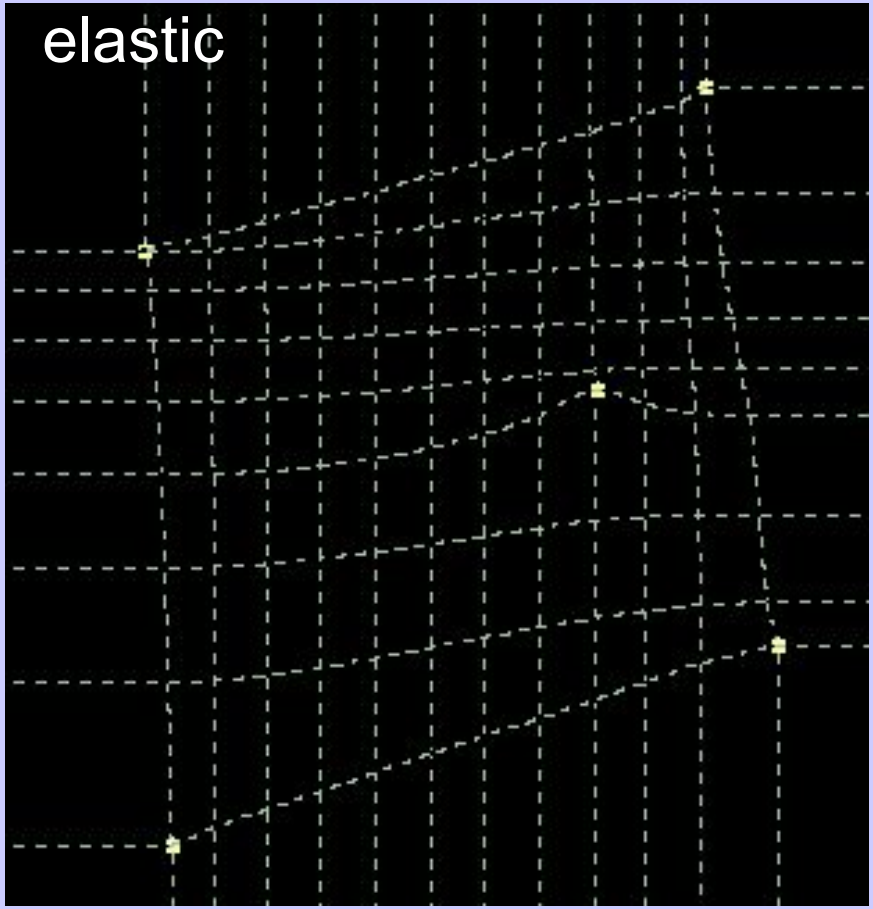
pixels

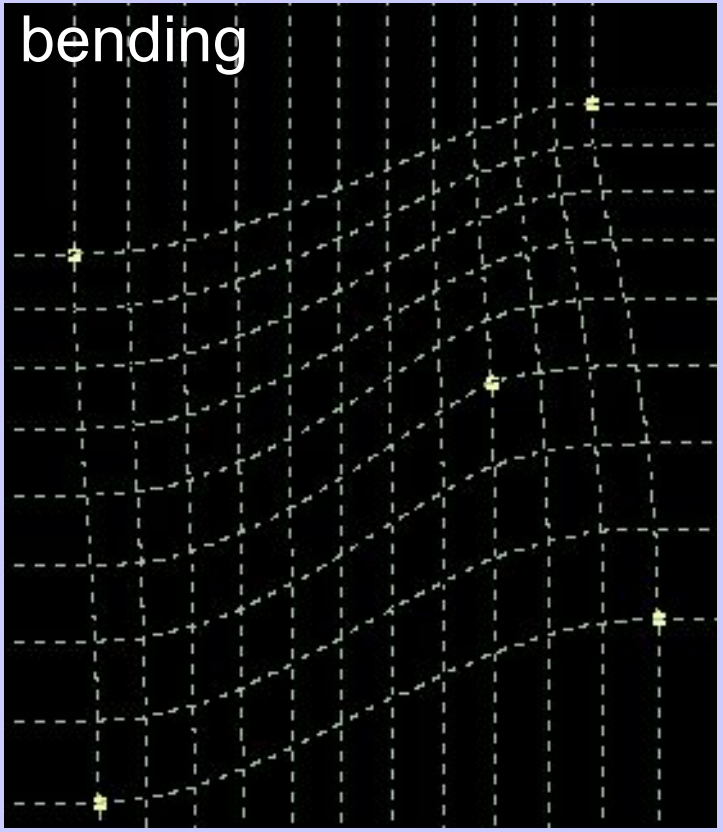
Interpolation of feature points

- Feature points must be interpolated
- *f(x,y)* is determined by minimizing an energy
  - elastic energy $$min \iint \left\| \frac{\partial f}{\partial x} \right\|^2 + \left\| \frac{\partial f}{\partial y} \right\|^2 dxdy$$
  - bending energy
    (no cost in affine transformations) $$min \iint \left\| \frac{\partial^2 f}{\partial x^2} \right\|^2 + 2 \left\| \frac{\partial^2 f}{\partial x y} \right\|^2 + \left\| \frac{\partial^2 f}{\partial y^2} \right\|^2 dxdy$$
  - thin plate spline
    closed solution of bending energy, due to Bookstein
    (will be implemented in future versions)

elastic vs tps 1

small deformations

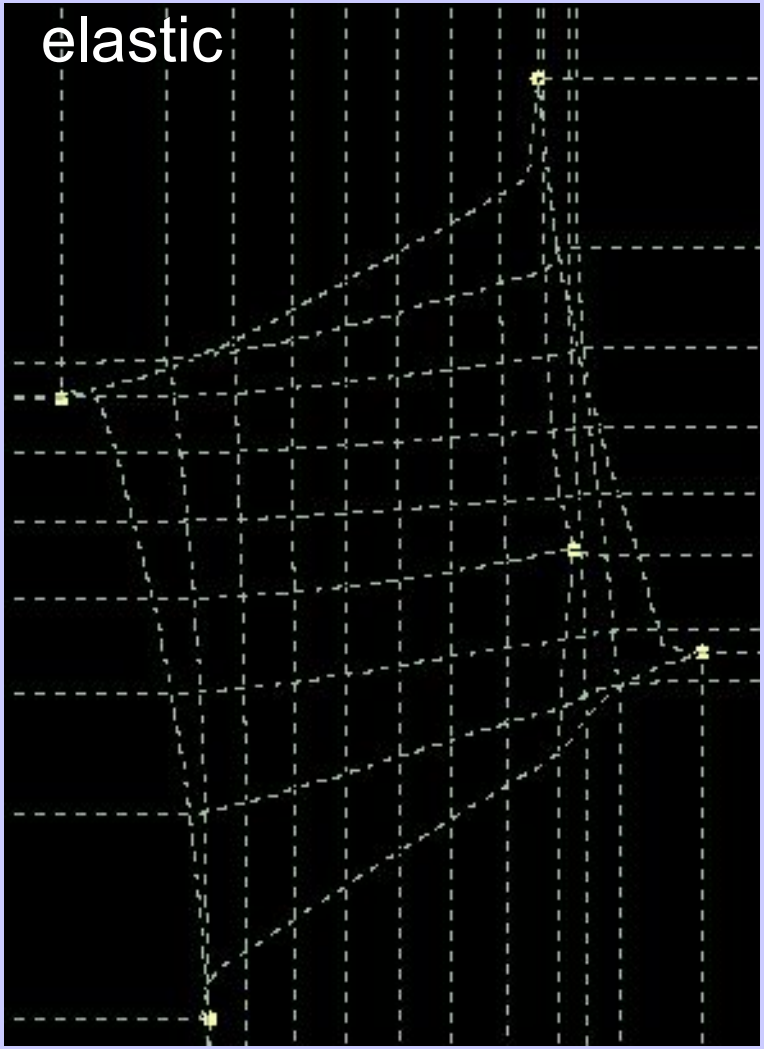


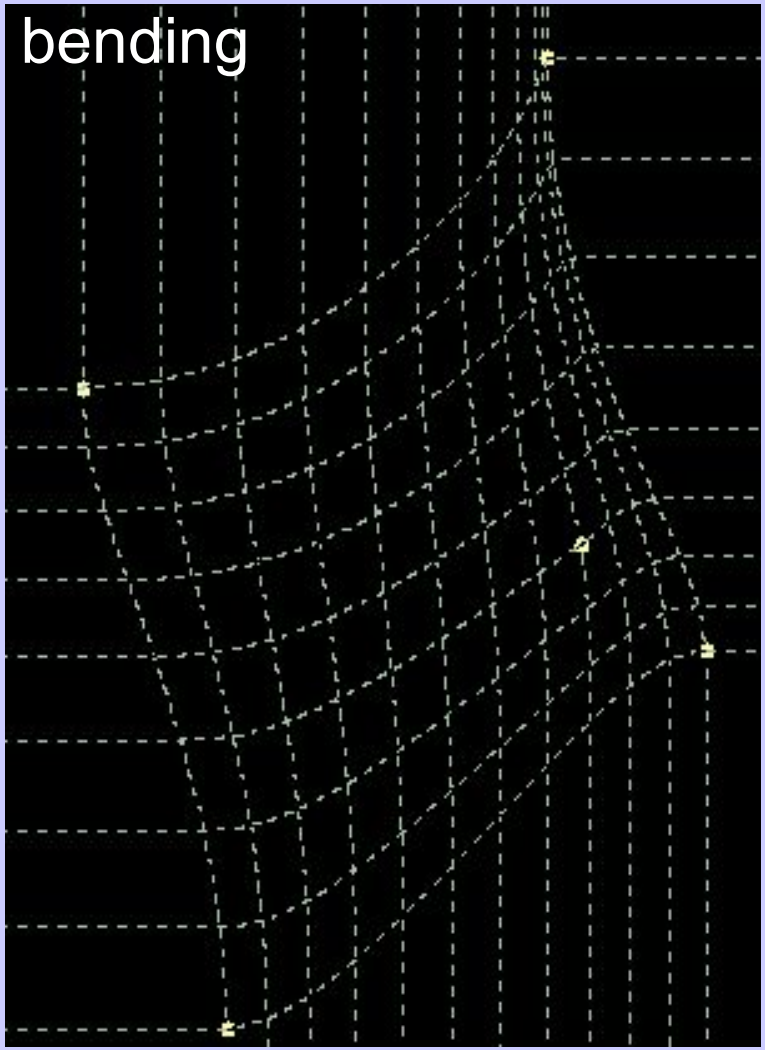


elastic vs tps 2

bigger deformations

(mesh at left is unusable:
lines cannot intersect)





tps vs elastic on images

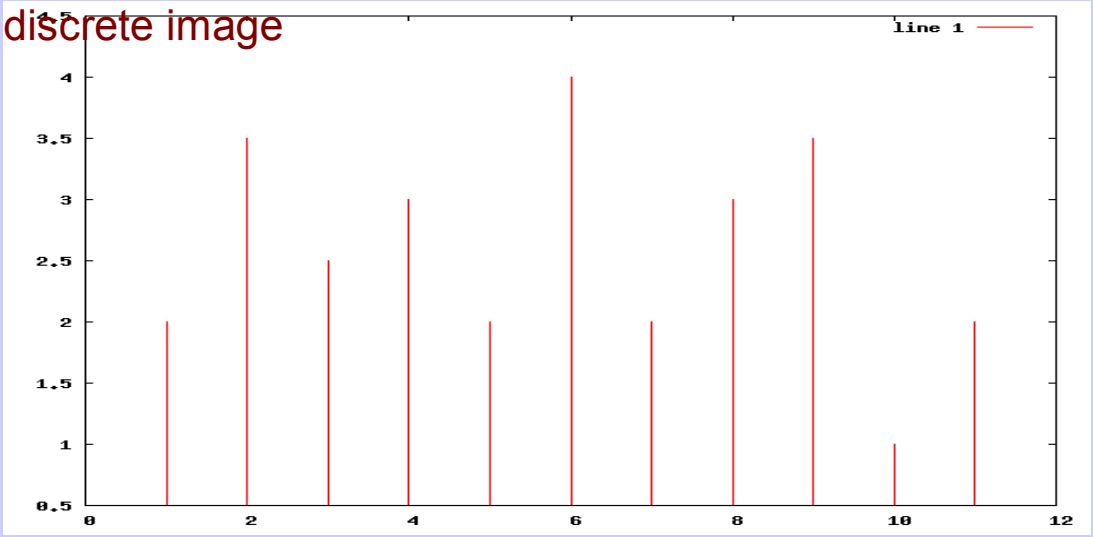
extrapolation of a mesh will outline mesh distortions due to elastic interpolation (to prevent this, many more feature points should be used)

hyper-masculinization (+90%) of avg male face

Warping method

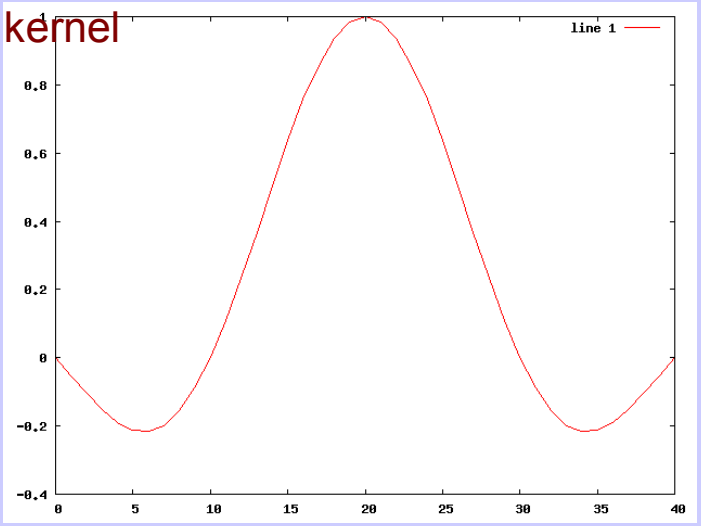
Images are discrete: to warp at subpixel precision, we need to interpolate; mathematically we convolve with a kernel

discrete image



*

kernel



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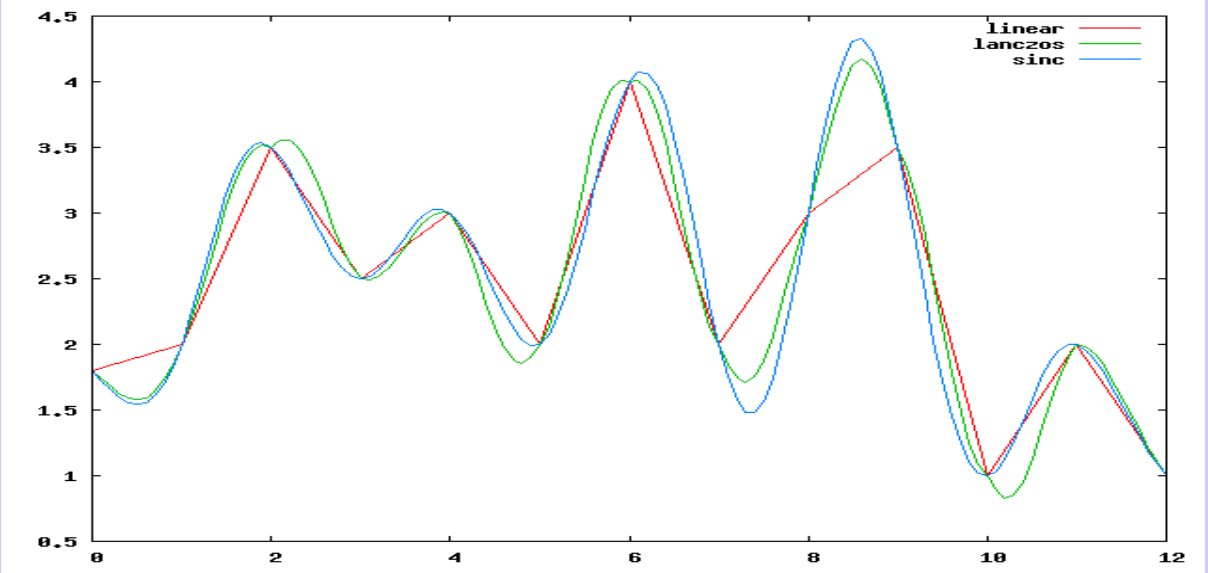
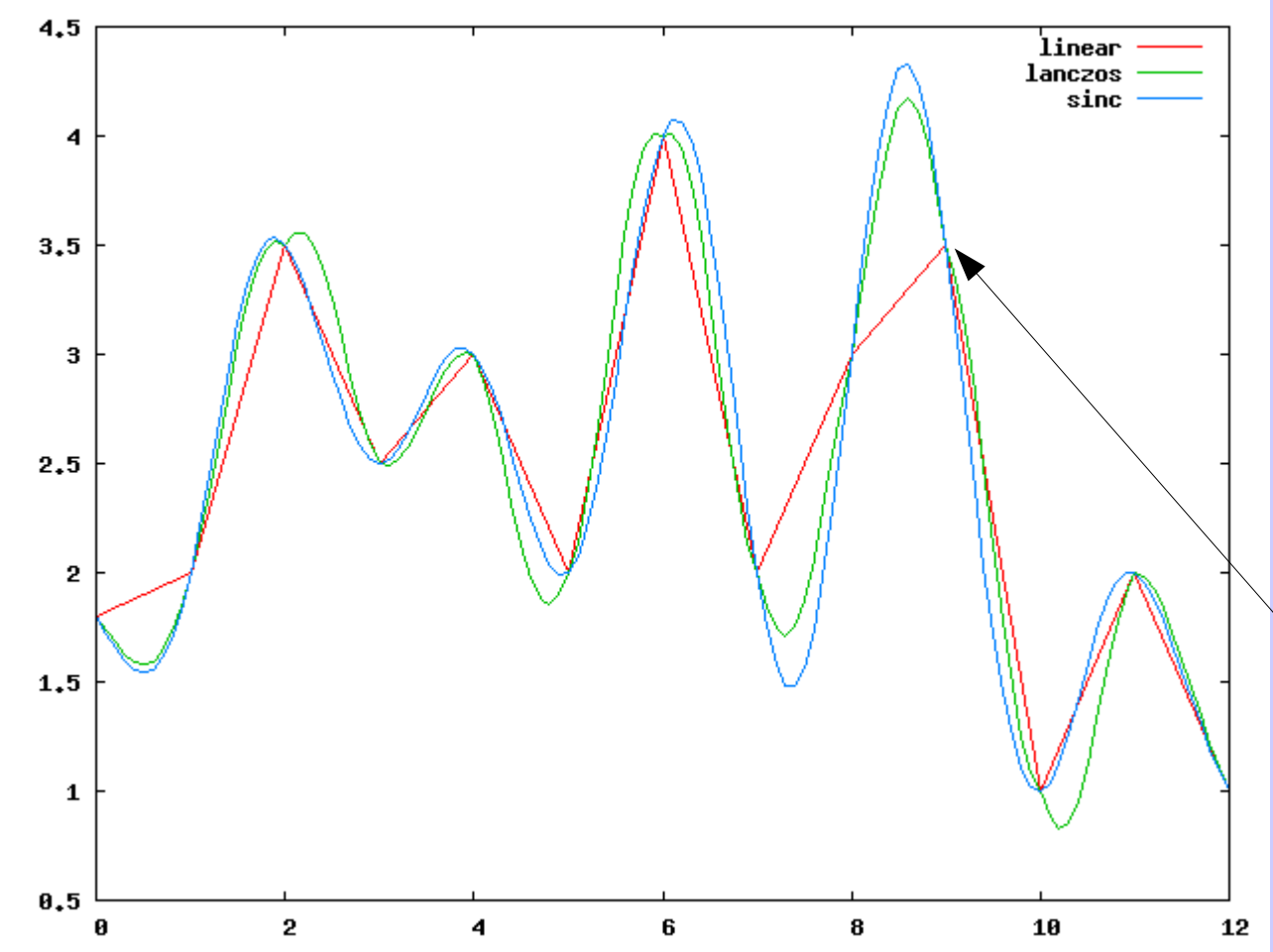


Effect of different kernels

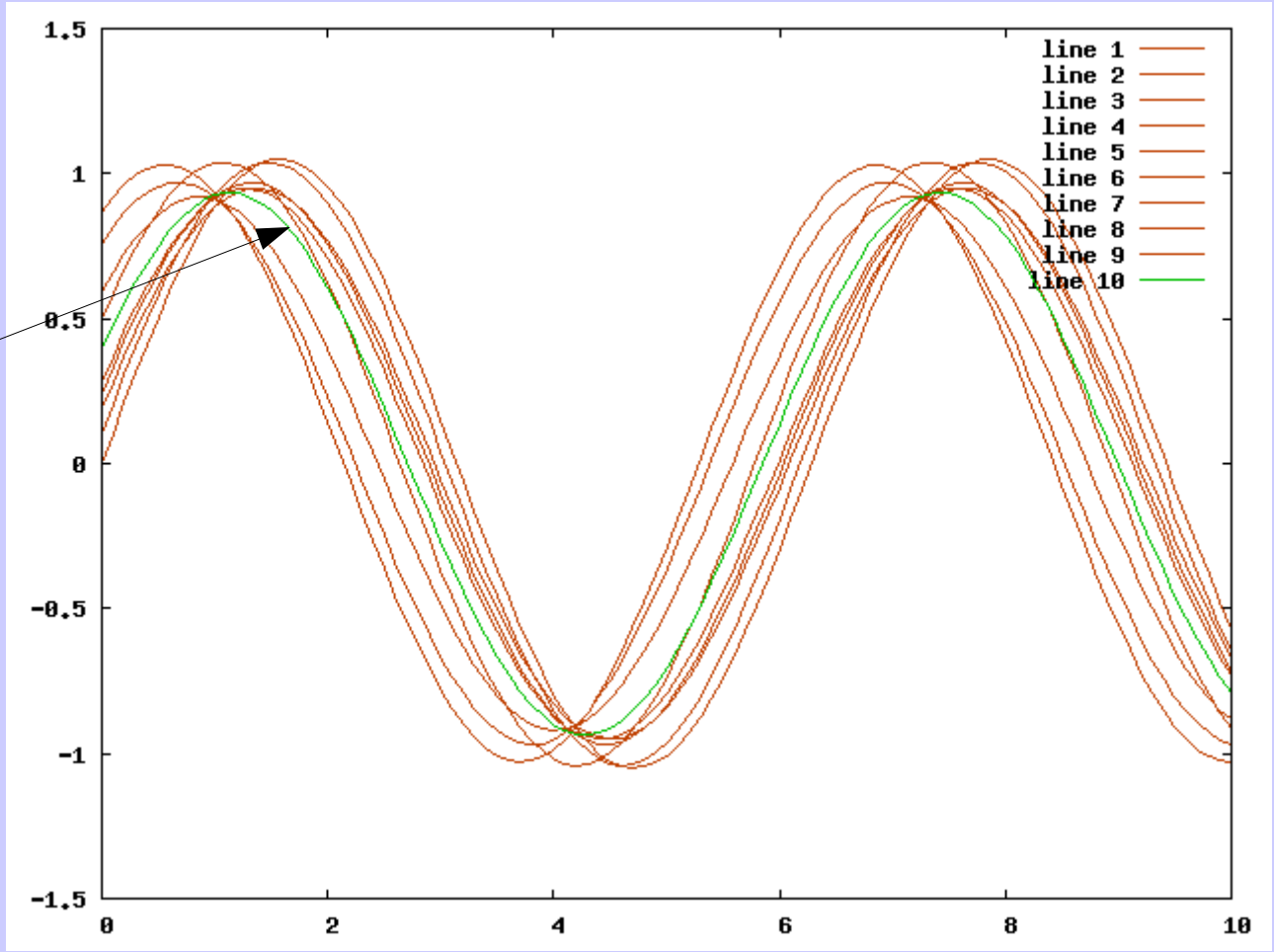


- Linear interpolation will never exceed the given discrete values: this entails a smoothing effect.
- By Shannon theory, sinc provides perfect reconstruction; this is called antialiasing
- Lanczos is a fast approximation of sinc

Bilinear vs antialiasing

Texture averaging

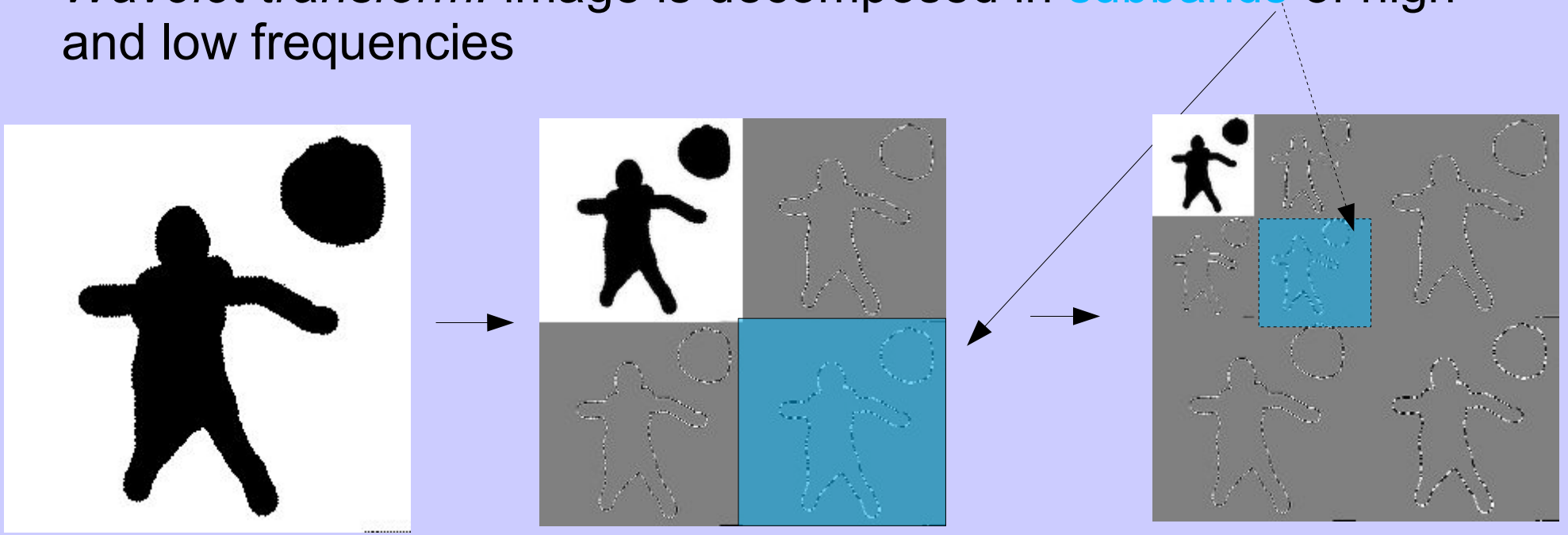
- The average of texture is done by linear blending
- Consequently, high frequencies are dampened
- To counteract this, we will equalize the histgrams of a wavelet transform (*)



(after presenting this talk we learned that a similar method had already been implemented by Bernard Tiddeman in 2001)

Wavelet equalization

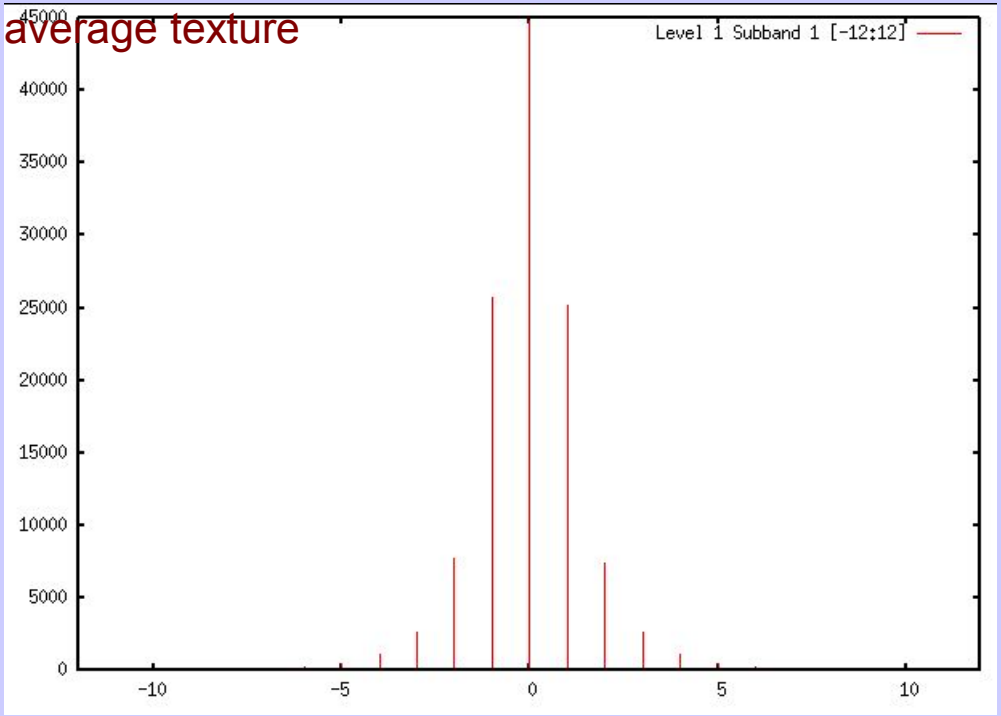
- *Wavelet transform:* image is decomposed in subbands of high and low frequencies



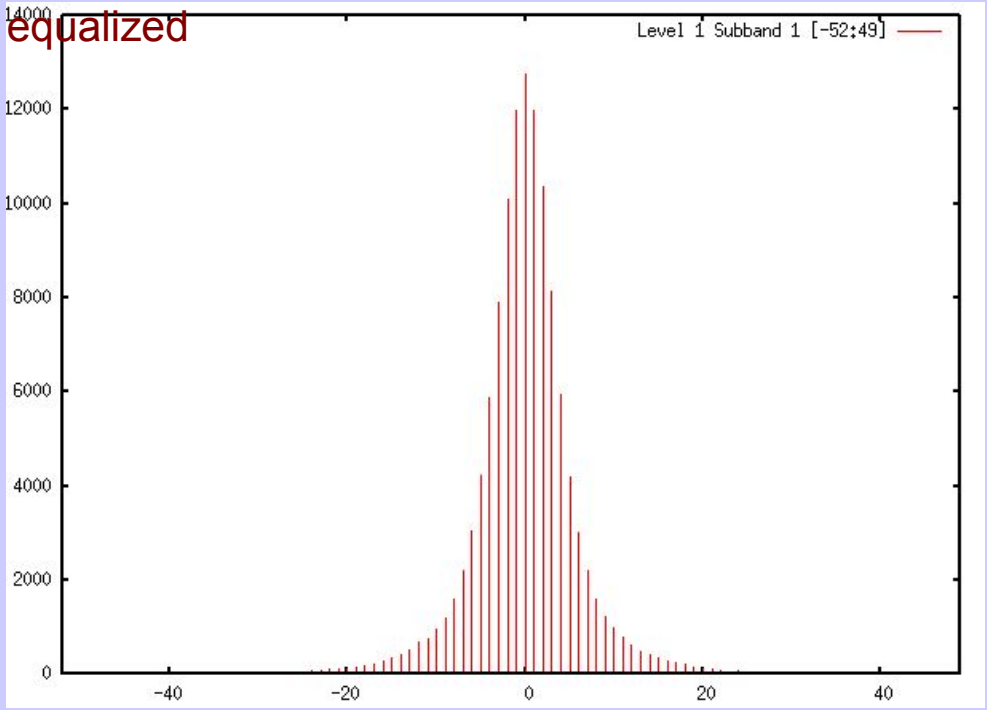
- *Wavelet equalization:* compute average energy (=variance) of subbands in the input images, and enhance output subbands to match the average energy
- With ~3 images, it preserves texture and blemishes; with ~20 images, it enhances skin (but introduces some shading artifacts)
- *Fake test*: if subbands are replaced by Gaussian noise of correct variance, the skin texture is replaced by noise.

Histograms of wavelet coeff.

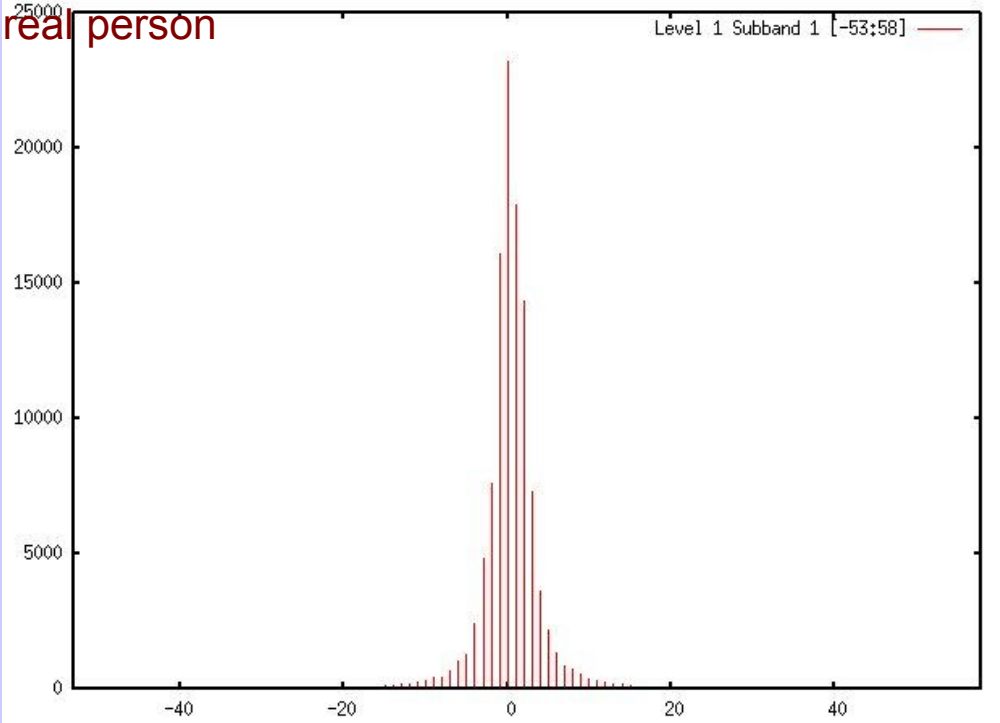
average texture



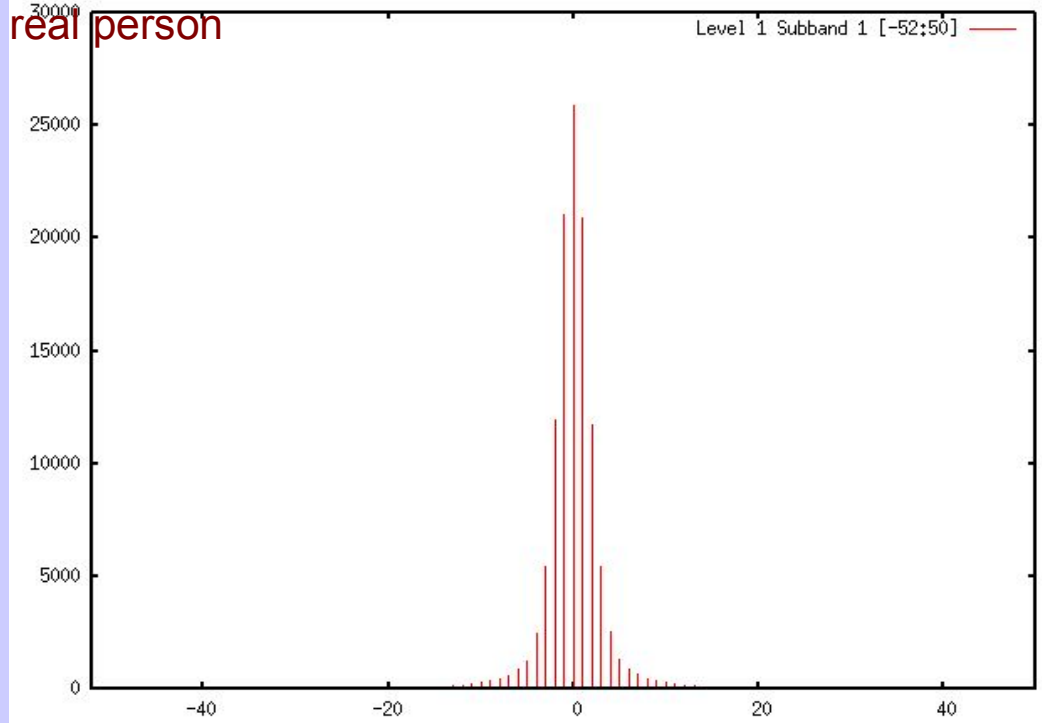
equalized



real person

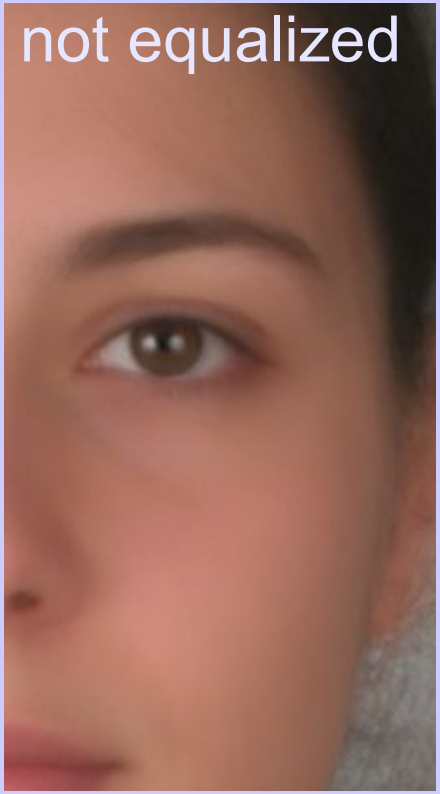


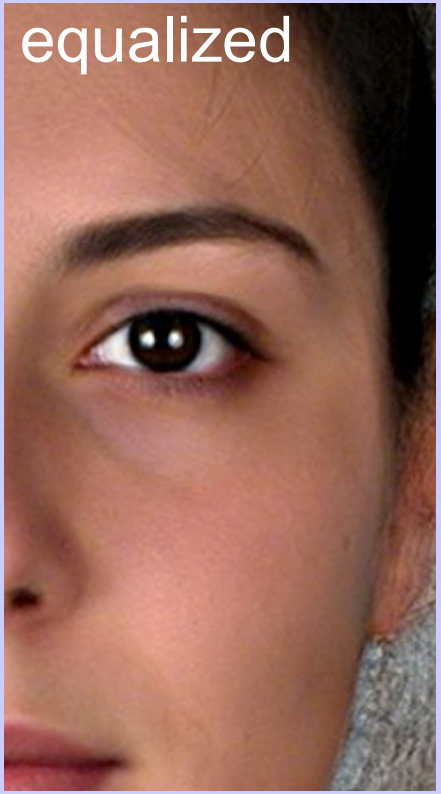
real person

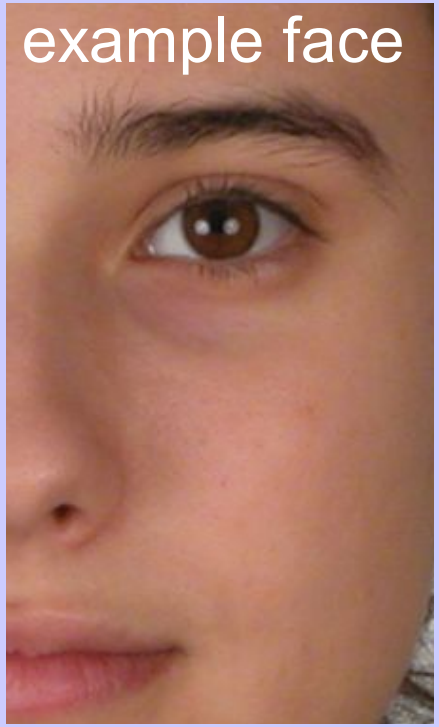


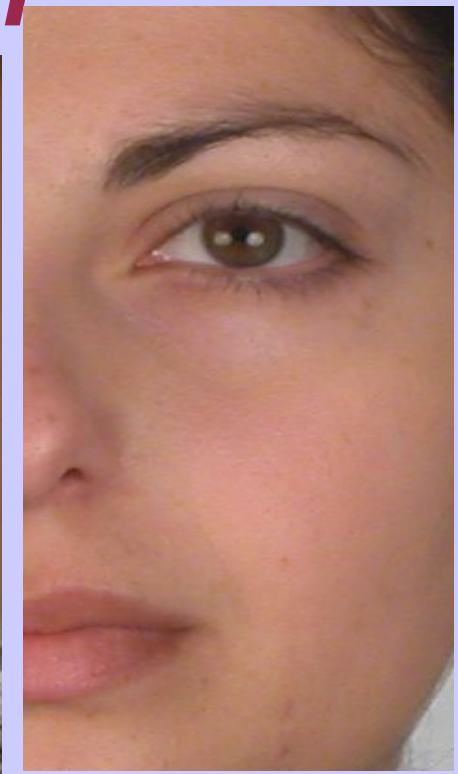
Wavelet equalization and antialiasing

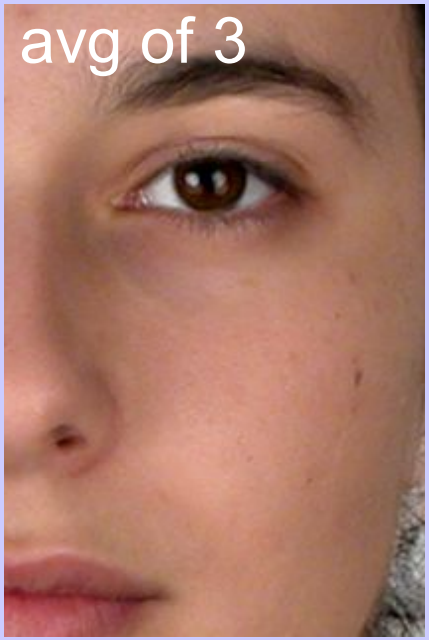
Wavelet equalization

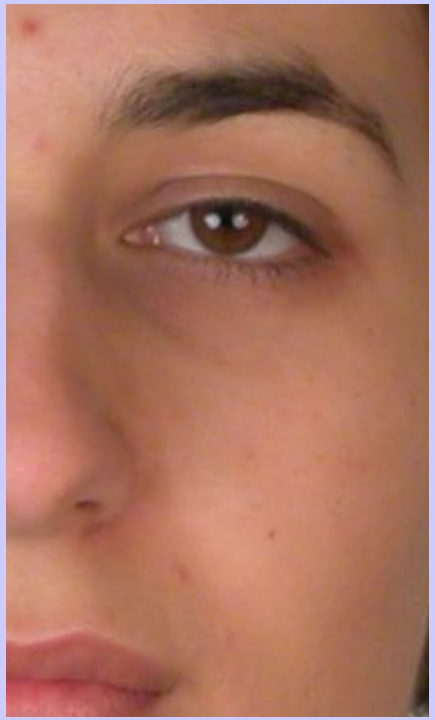












Conclusions

Averaged faces do not show an average (ie real looking) texture

Wavelet normalisation can recover small-scale skin texture

Other methods need to be developed to recreate larger-scale skin texture elements such as nevi, pimples, freckles etc...

Whether average texture is attractive or not remains an open question....

gtkmorph

gtkmorph was developed to meet all the above problems.

gtkmorph is *open source,* available from

`http://xmorph.sf.net`

for both Windows© and GNU/Linux©.

Installation in 5 minutes.