Applicazioni

Computer Vision

15 Aprile 2008

Giuseppe Messina

Applications

- Dithering
- Registration
- Resize
- Multiple shots Res. Enhancement
- Panoramic
- SVG
- Image Quality Metrics

Dithering

- A process of displaying images using a **random dot pattern** to give the viewer an impression of more detail and colors than the file format or computer display can actually support

- Increase the apparent color range by **mixing dots of colors** to approximate shades of colors that it doesn't have available

  - display a 24-bit image with 256 colors

  - display gray level with only black and white

Dithering (cont.)

Original image (8-bit)

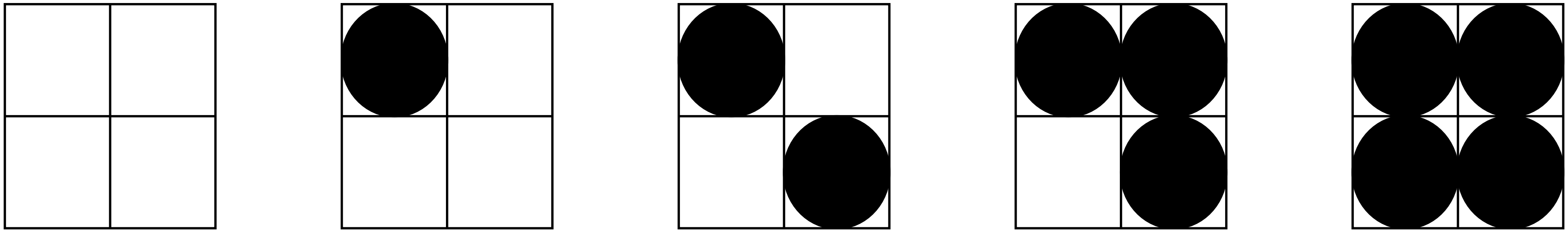
Image after dithering (1-bit)

Dithering (cont.)

Original image (24-bit)

Image after dithering (8-bit)

Dithering (cont.)

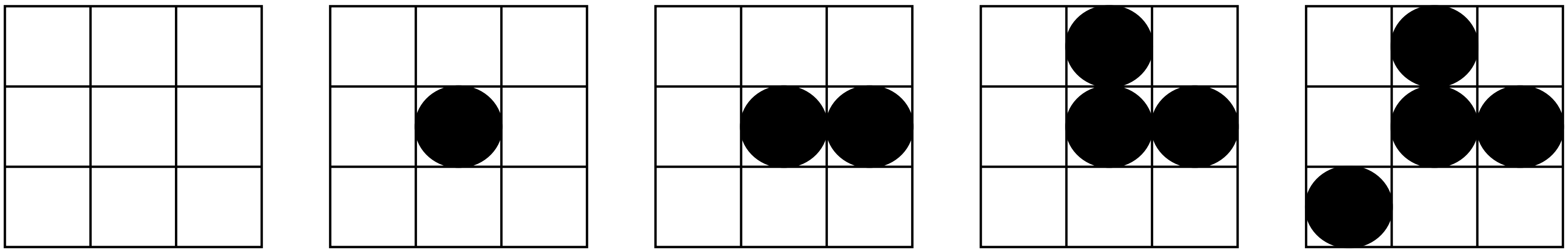


$0 \leq I < 0.2$ $0.2 \leq I < 0.4$ $0.4 \leq I < 0.6$ $0.6 \leq I < 0.8$ $0.8 \leq I \leq 1.0$

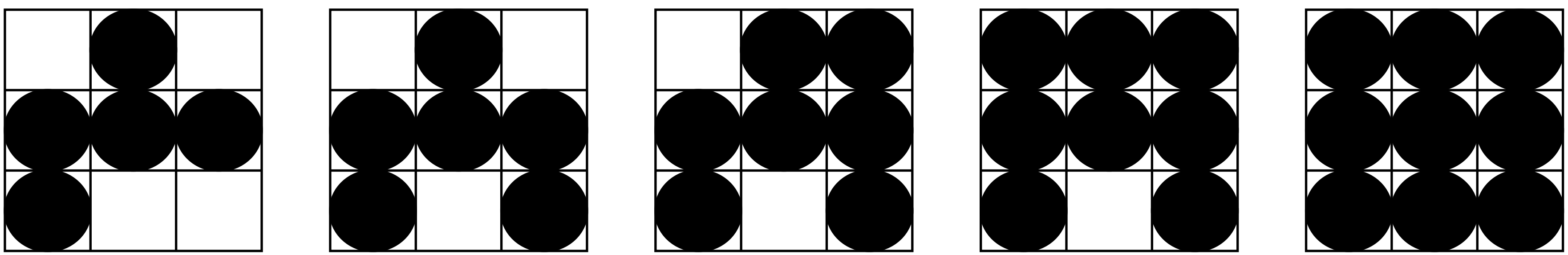
- A 2 x 2 pixel area of a bi-level display can be used to produce **five different intensity** levels at the cost of **halving the spatial** resolution along each axis
- A block of *n* x *n* pixels can simulate $\boldsymbol{n^2 + 1}$ different gray levels

Dithering (cont.)

- With 3 by 3 pixel grids on a bi-level system, we can display 10 intensity levels



$0 \le I < 0.1$ $0.1 \le I < 0.2$ $0.2 \le I < 0.3$ $0.3 \le I < 0.4$ $0.4 \le I < 0.5$



$0.5 \le I < 0.6$ $0.6 \le I < 0.7$ $0.7 \le I < 0.8$ $0.8 \le I < 0.9$ $0.9 \le I < 1.0$

Anti Contouring

Pixel Value : *0110 1010*

Sum with pseudorandom noise: *0110 1010* + *0000 1110* =

0111 1000

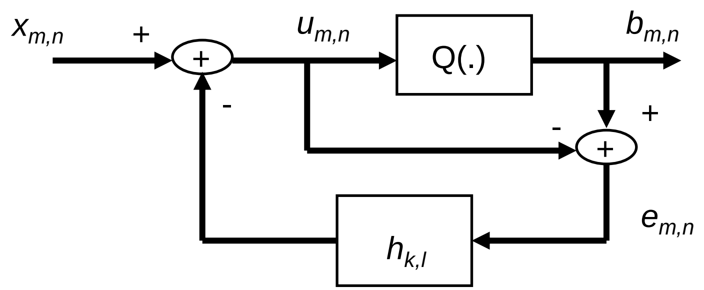
AC Result : *0111*
Simple Q. : *0110*
Reset 4 MSB of Noise: *0000 1000*

Simple Quantization

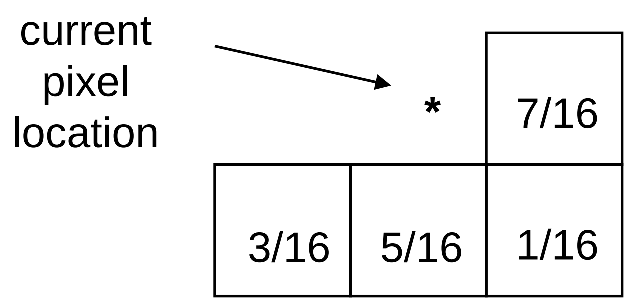
Anti Contouring

Floyd-Steinberg Error Diffusion

- [Floyd and Steinberg 1975]



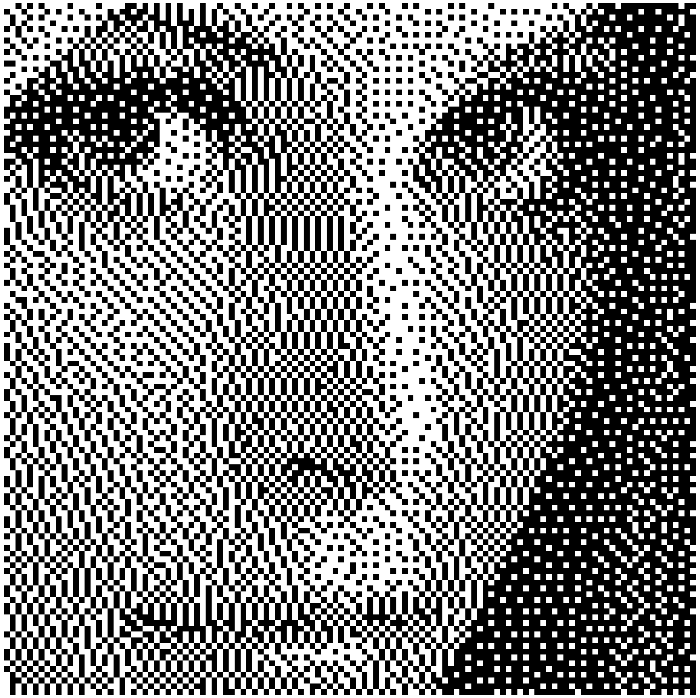
- The filter coefficients for Floyd-Steinberg error diffusion are



- There are two different but equivalent implementations.

Monochrome Error Diffusion Example

2 colors, 1 bit per pixels



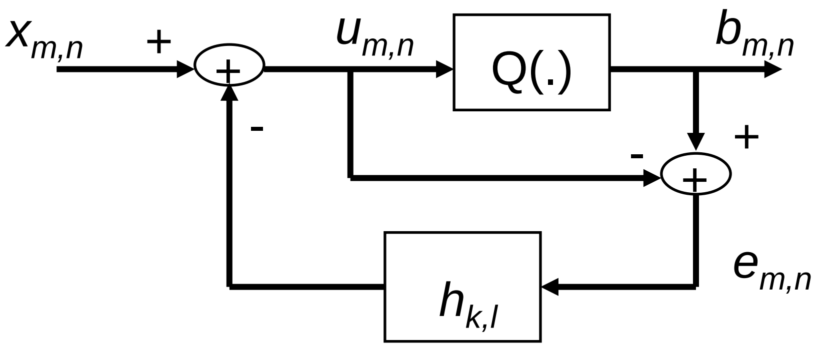
Color Error Diffusion Example

8 colors, 3 bits per pixels

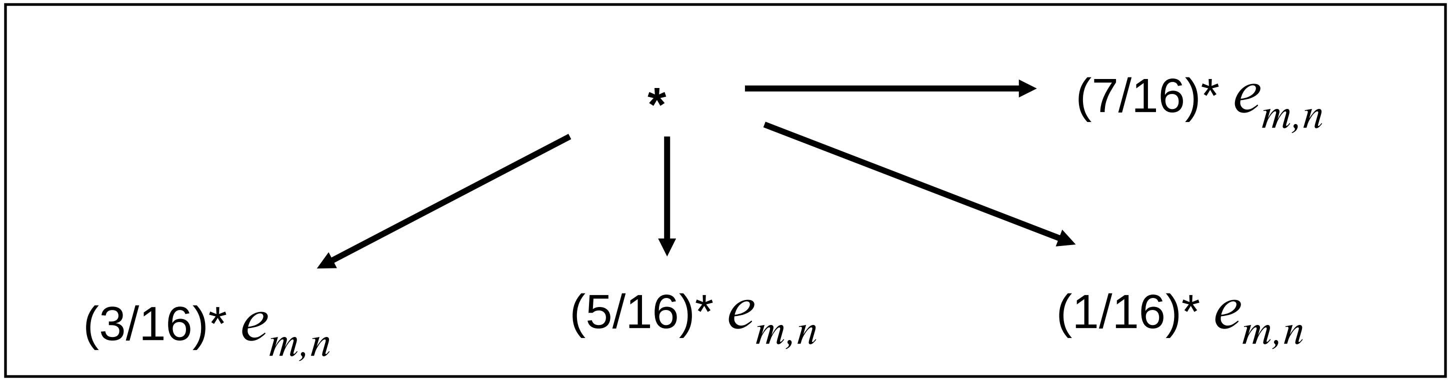
Observations

- **Rather poor quality**, particular in the color example.
- **Resolution** is rather low (to show the dots).
- Generic Floyd-Steinberg error diffusion are known to generate halftones with **undesirable patterns** (worms and others).
- The color planes are **put together independently** without regard to interference between different primary colors.
- **Loss of details** is obvious.

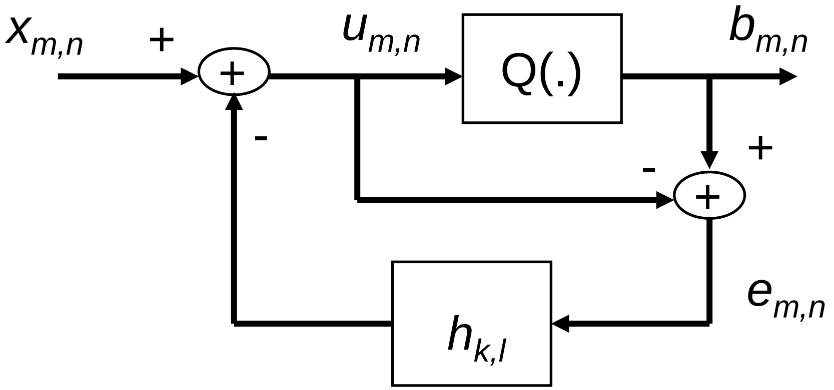
Implementation 1 (Diffusion Approach)



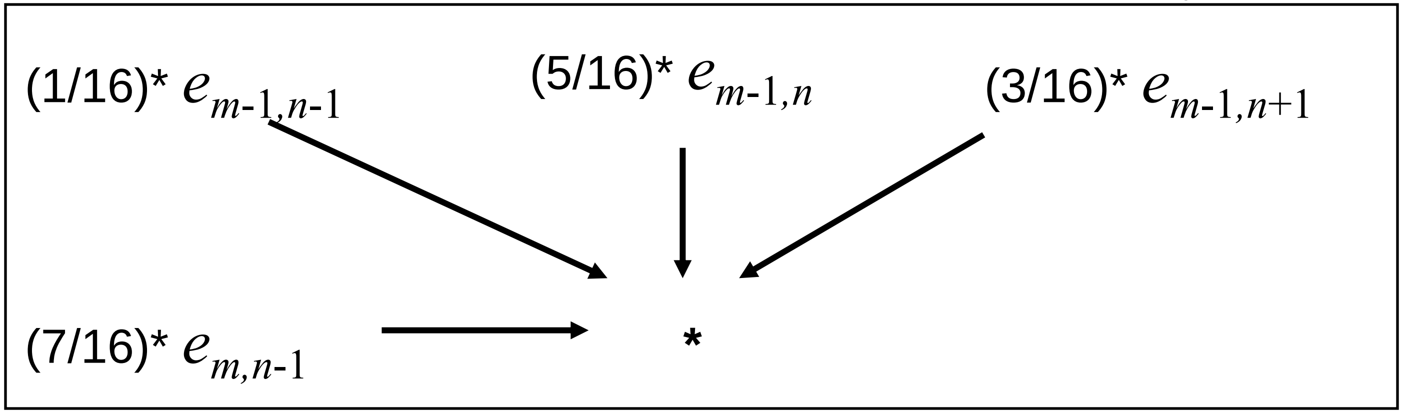
- At each pixel location, threshold $u_{m,n}$.
- Calculate the quantizer error $e_{m,n}$.
- Distribute the quantizer error according to the filter coefficients. $u_{m+k,n+l} = u_{m+k,n+l} - h_{k,l} e_{m,n}$



Implementation 2 (Filtering Approach)

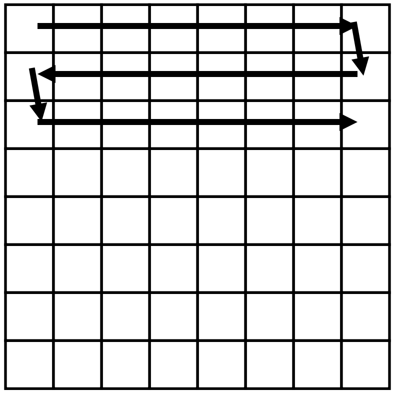


- At each pixel location, compute $u_{m,n}$.
- Threshold $u_{m,n}$ to give the output $b_{m,n}$.
- Calculate and store the quantizer error $e_{m,n}$.

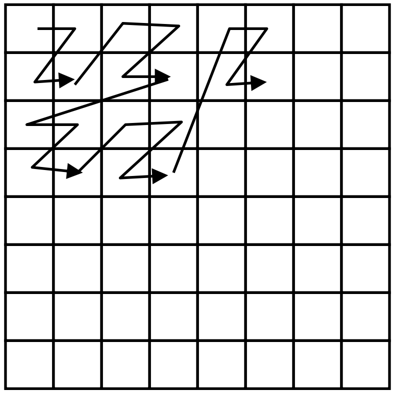


Alternative Scanning Strategy

- Serpentine Scanning [Ulichney, 1987]
  - scan odd lines right to left, and even lines left to right

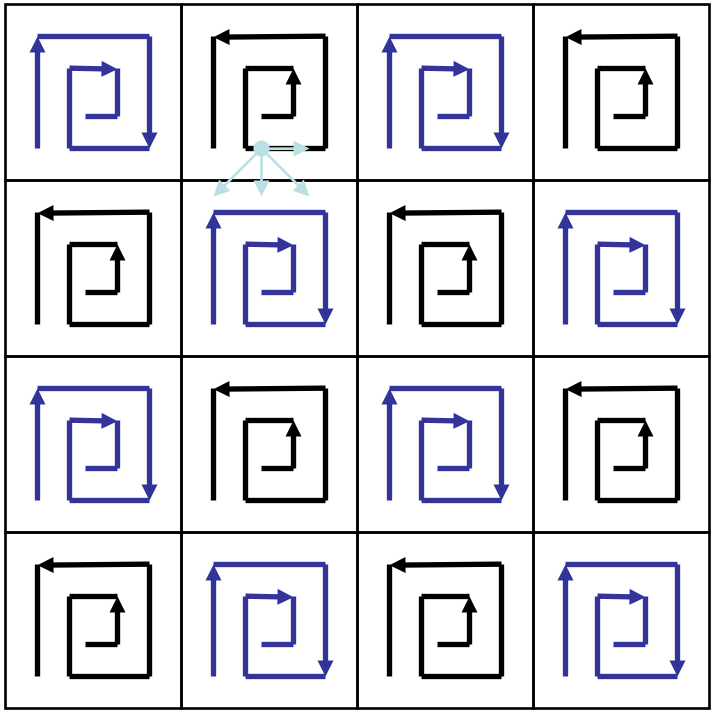


- Use a space filling curves, e.g., Peano Scanning [Witten and Neal, 1982]



Block Interlaces Pinwheel Error Diffusion

[Li and Allebach, 2000]

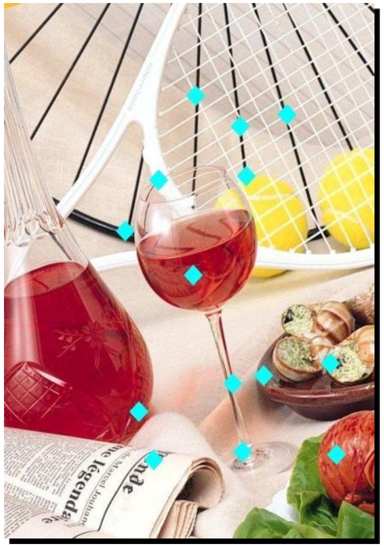


- Process outward spiral (black) blocks first. Then process inward spiral (blue) blocks.

Image Registration

The usual steps of a registration process are:

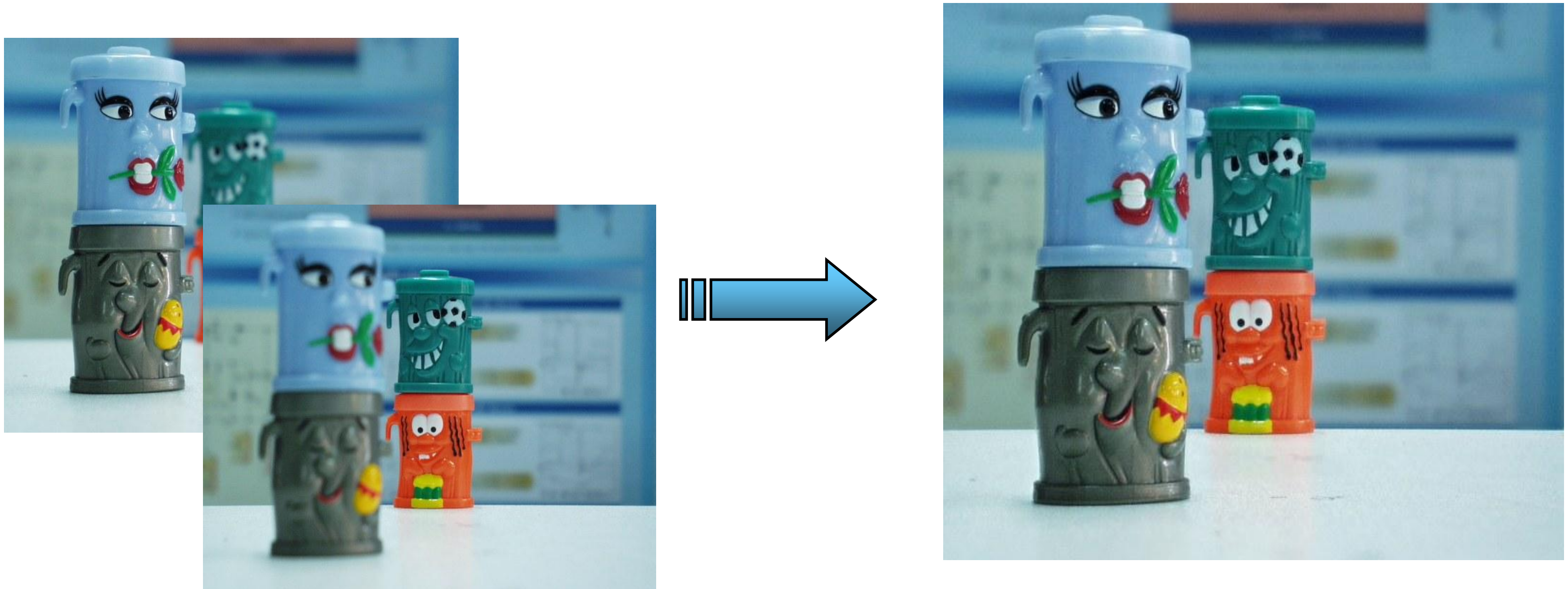
- ✓ Features selection
- ✓ Features matching
- ✓ Selection of control points
- ✓ Estimation of transformation parameters



According to features used, I.R. techniques can be classified into two categories:

Intensity-based	Feature-based
Statistical properties of images (auto-correlation…)	Edges, corners, contours, …

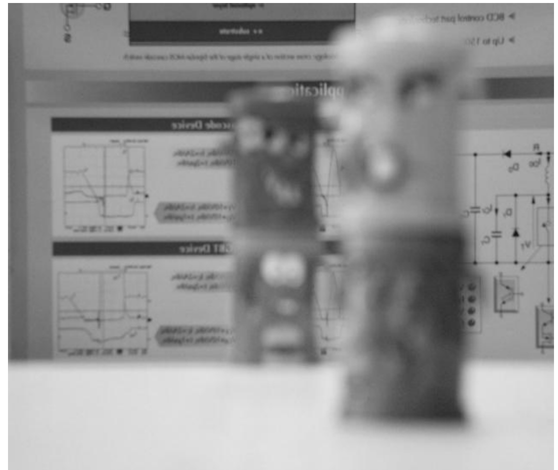
Multi Picture Acquisition



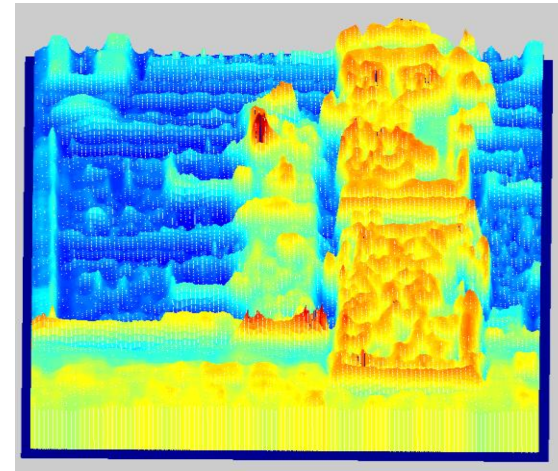
- Extended Depth of field;
- Dynamic Range Extension;
- Resolution Enhancement;
- …..

Multi picture Acquisition

Near focused image



Far focused image



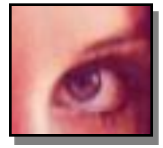
Depth map in matlab

Depth From Defocus (Nayar 1998)
In zone where there are strong variations and homogeneous areas, the depth map presents slightly different levels for the same object.

Gray level depth map

Zooming - Replication

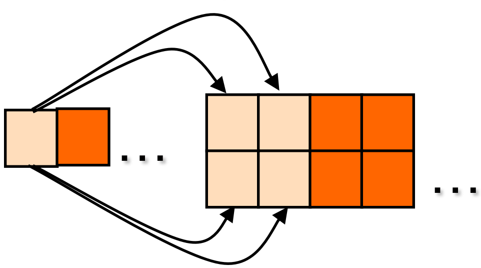
An image can be expanded by using *zooming operation*:



The simplest zooming operator "*Replication*" use the following steps:

- For every pixels of the image
  - Put the same value of the pixel in a grid of NxN pixels(N^2 replications of the value).

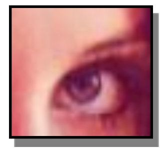
Ex: Zooming x2



This method introduces the problem of ***Pixelization***.

Zooming - Bicubic

To remove *Pixelization* intelligent and/or adaptive zooming operator can be used.



The most popular zooming method is "*Bicubic*":

- For every pixels of the image do
  - Convolve pixel value with complex mathematical models to fit the interpolated information to the original information.

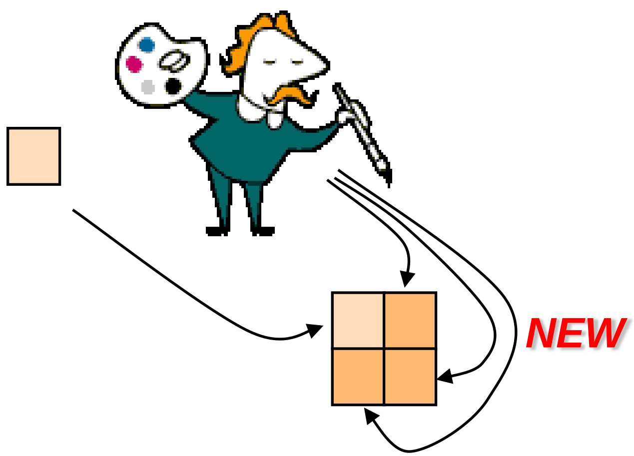
The ***Bicubic*** method is used for the ***huge enlargement*** of image size and for off-line elaborations.

This method introduces the following problems:

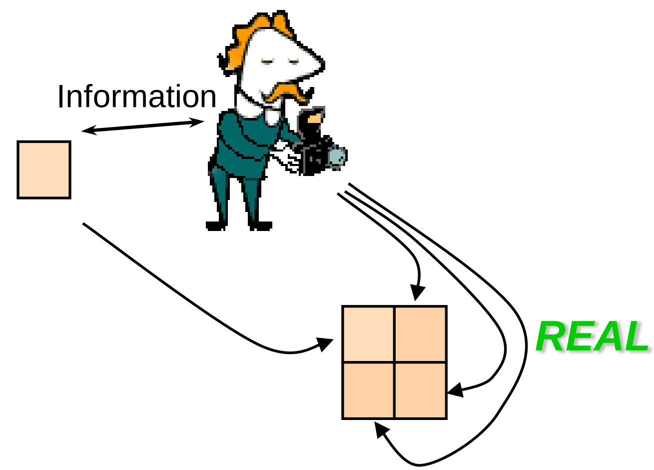
- ***Blurring***;
- ***Computationally expensive***;

Zooming vs SuperResolution

- The principal objective of zooming methods is "***Interpolation* of new information**".



- The *Resolution Enhancement* approach wants "***To restore* the *REAL* information**".



Multi-frames R.E.ST

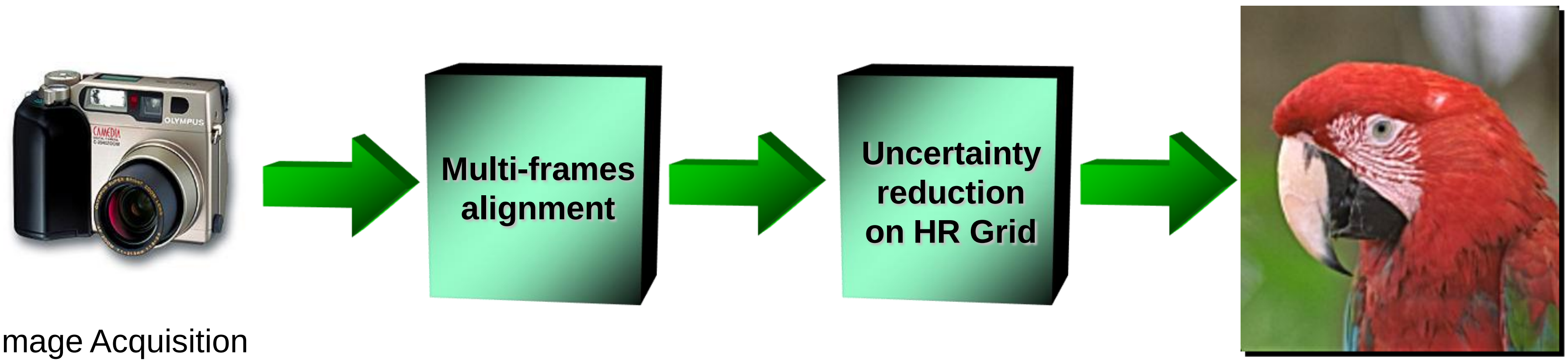


Image Acquisition

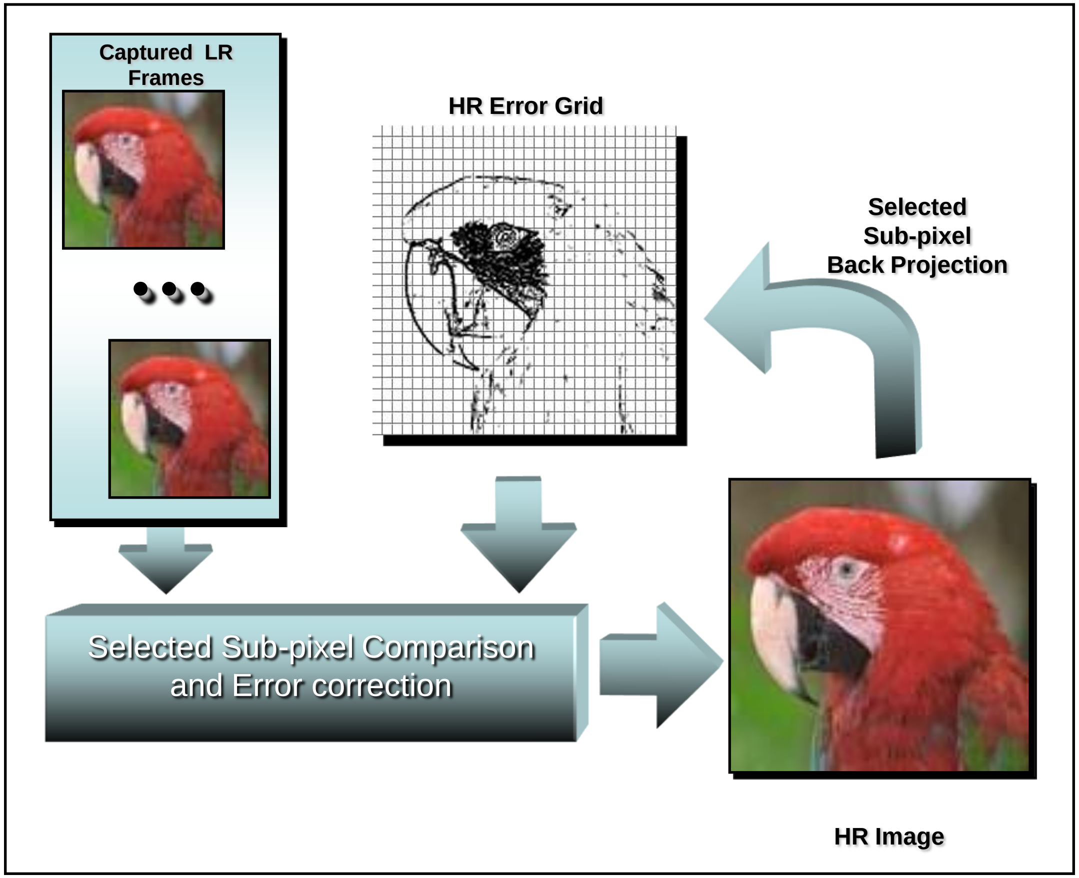
High Resolution Image

- Low Resolution Frames alignment (Global/Local Motion Estimation);
- Uncertainty Reduction:
  - Back-projection step(s);
  - *Auto-iterative* Error Correction approach;

Multi-Frames R.E.ST

Algorithm Steps:

- First construction of a Draft HR Image;
- Construction of an HR Error Grid with fixed maximum error;
- Back-projection:
  - If pixel have to be computed: calculation of Error with one of the various approach;
  - If the new Error is minor than memorized : memorization of new Error and improvement of HR pixel value;
  - Else: go over;
  - Repeat back projection until number of pixels processed is under a given threshold.

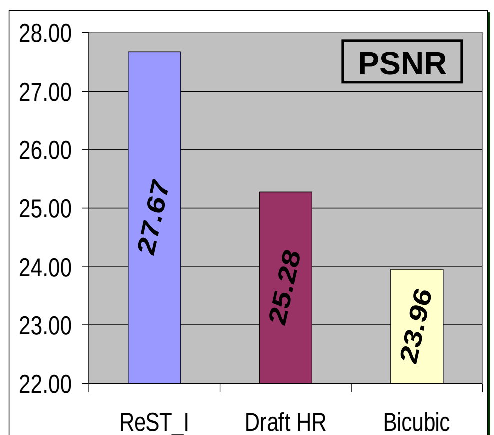


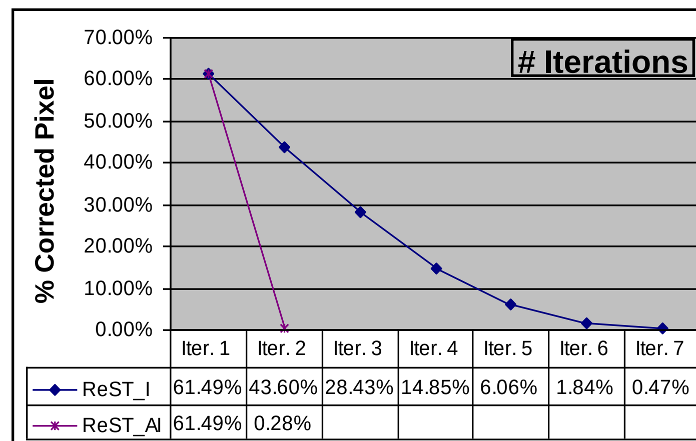
Multi-Frames R.E.ST

Back-projection based algorithm, improved by ***adaptive techniques,*** able to reconstruct a HR image from multiple LR frames.

Adaptive techniques:

- ***"Uncertainty Degree":*** reduces sensibly the amount of computation necessary to correct pixels values at each iteration step (ReST-Iterative); only edge pixels are processed
- ***"Local Error Correction":*** corrects the value of the pixel in function of the errors in its neighbourhood; this method converges quickly than normal Back-projection method (ReST-Auto Iterative): from 6 to 2 iterations

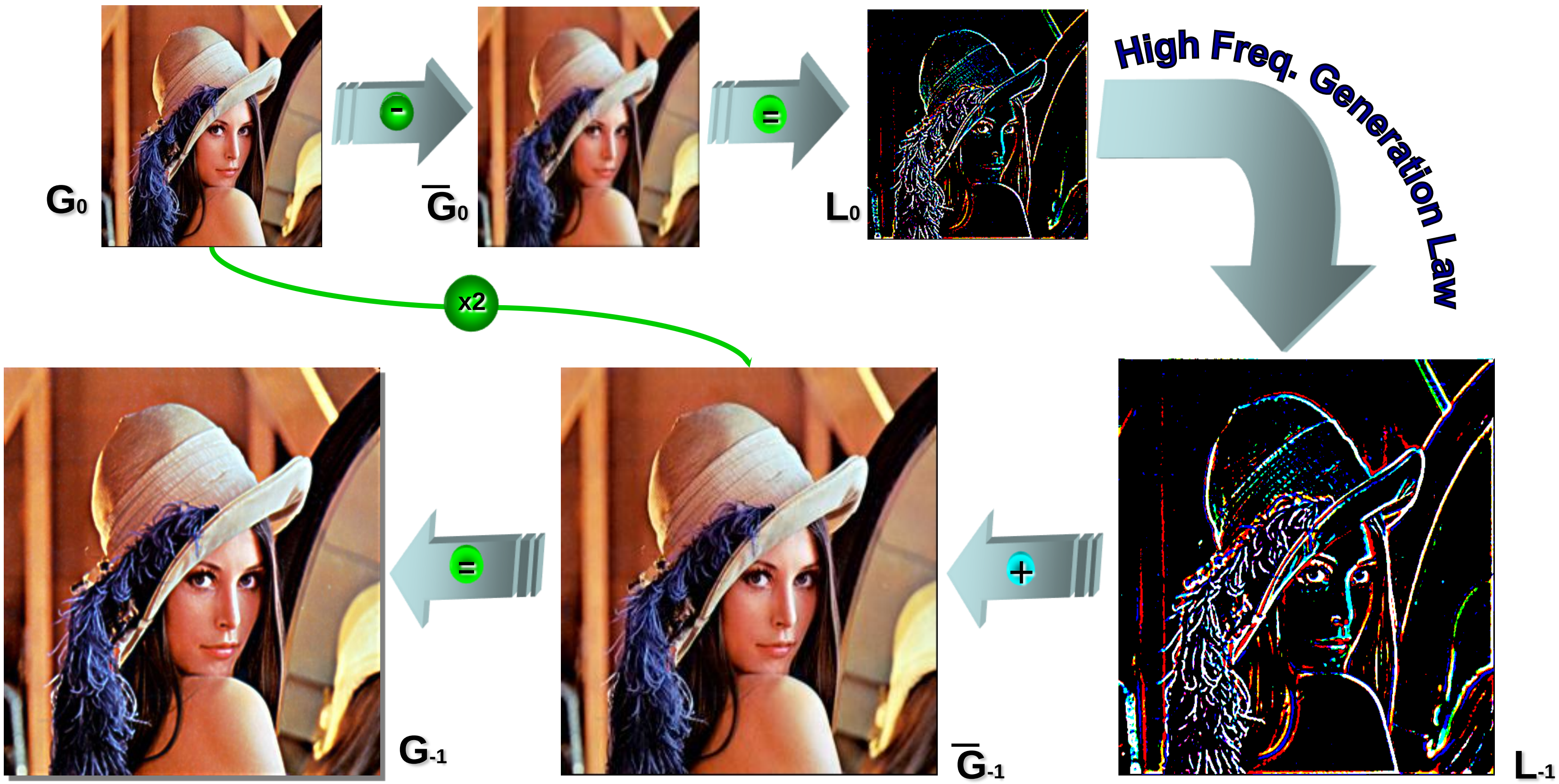




Single-Frame R.E.ST

- **Description:**
  - **Edges contain relevant details for Human Visual System;**
  - **Zooming operators introduce Blurring in Enlarged Images and cause Edges Expansion;**
  - **Efficient Edges Reconstruction is needed;**
  - **High Frequencies (edges) have to be Enhanced.**

Single-Frame R.E.ST



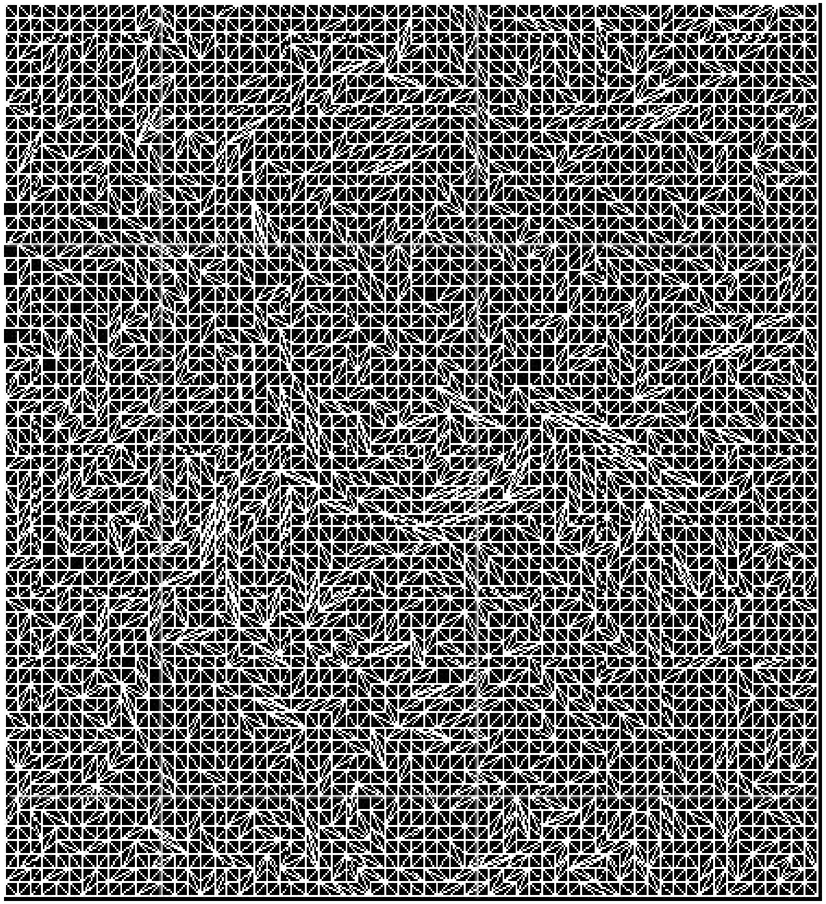
✓ **Merging of Enhanced High Frequencies (L_{-1}) with Double Size Image ($\overline{G}_{-1}$) results in High Resolution Image (G_{-1}).**

Single-Frame R.E.ST

High Frequencies Enhancement First Solution:

- Top Laplacian Pyramid Level (L_0) Enlargement (L_{-1}) by using suitable zooming algorithm;
- Different Edges Enhancement techniques have been applied:
  - Directional Filtering;
  - Ramp Edge Algorithm;
  - Adaptive Thresholding.

Data Dependent Triangulation



Data Dependent Triangulation converts raster image into a set of small triangles.

The Triangles set is Resolution Independent. This means that the representation of the images is *“about continuous”*.

Previous Art

Triangulation Definition:

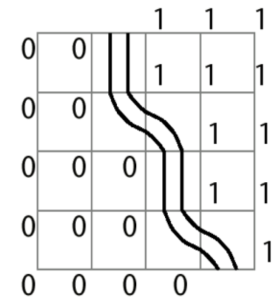
Ω : polygonal area in the x-y plane

V : a set $\{(x_i,y_i)\}_{i=1,2,..,N}$ (distinct points in Ω)

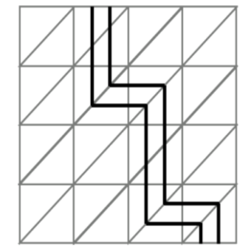
f : binary function defined in Ω but unknown

$$f(x,y): \Omega \Rightarrow \Re$$

$$f(x_i,y_i) = F_i, \quad i=1,2,\ldots,N$$



Interp. With Bilinear Triangulation

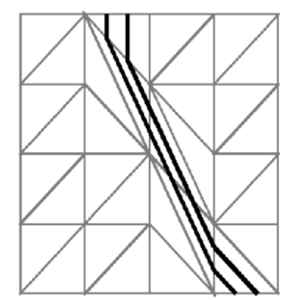


Interp. With Delaunay Triangulation

A Triangulation on Ω is a set $T=\{T_i\}_{i=1,2,..,q}$ of non degenerate triangles such that:

- Every triangle vertex is an element of V, and every element of V is a triangle vertex;
- Every edge of a triangle in T contains exactly two points on V.
- T is a partition of Ω:

$$\Omega = \cup_{\forall T_i \in T} (T_i); \quad T_i \cap T_j = \varnothing; \quad \forall T_i, T_j \in T : i \neq j$$



Data Dependent Triangulation

Example of DDZ 1/2

Original 

Perceived results are very impressive in Data Dependent Zooming output images.

ReST

DDZ

Bicubic

Example of DDZ 2/2

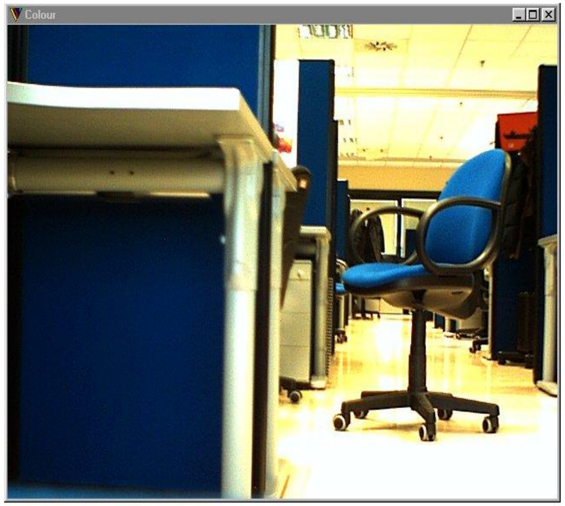
- Triangulation of a very small image and Zooming by a factor of 10.

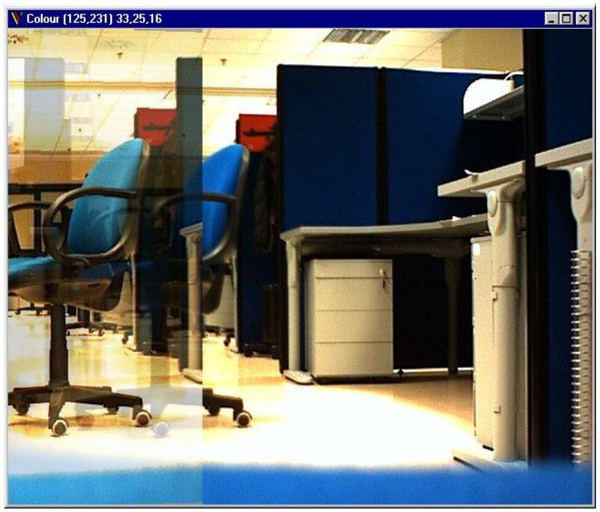
Original

Data Dependent Triangulation

Interpolated Triangulation

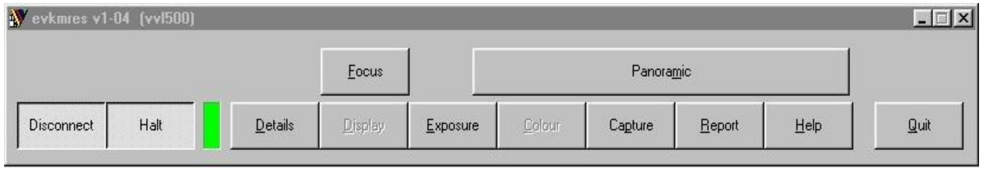
Panoramic

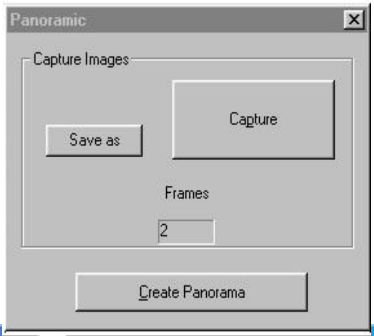




Perspective Correction

Blending



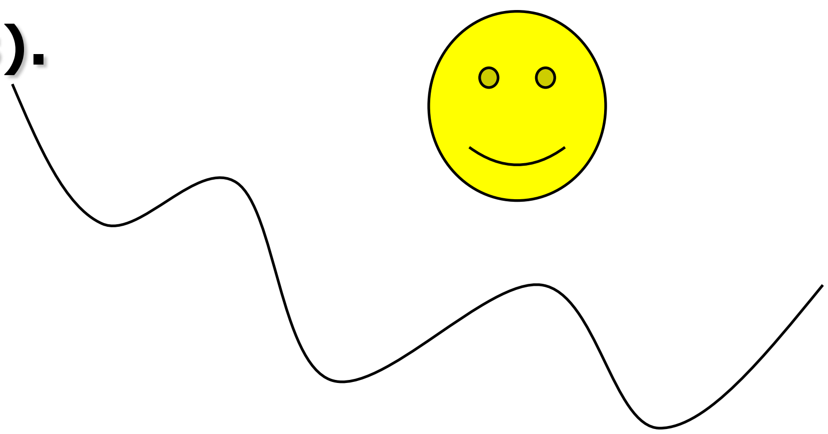


Panoramic

Example

SVG Introduction

- **SVG is a language for describing two-dimensional graphics in *XML*.**
- **SVG uses three types of graphic objects:**
  - ***Vector graphic shapes* (e.g., paths consisting of straight lines and curves),**
  - ***Images*;**
  - ***Text* (also called glyphs).**

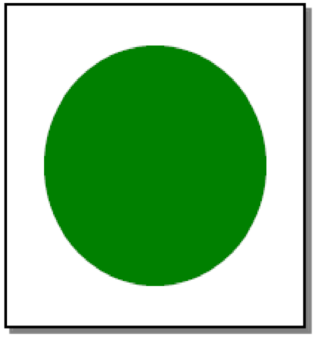


Standards

- **SVG 1.0 is a Web standard (W3C Recommendation).**
- **Standardization works on modular SVG 1.1/1.2 and Mobile SVG profiles.**
- **Powerful portability (display resolution independence)**

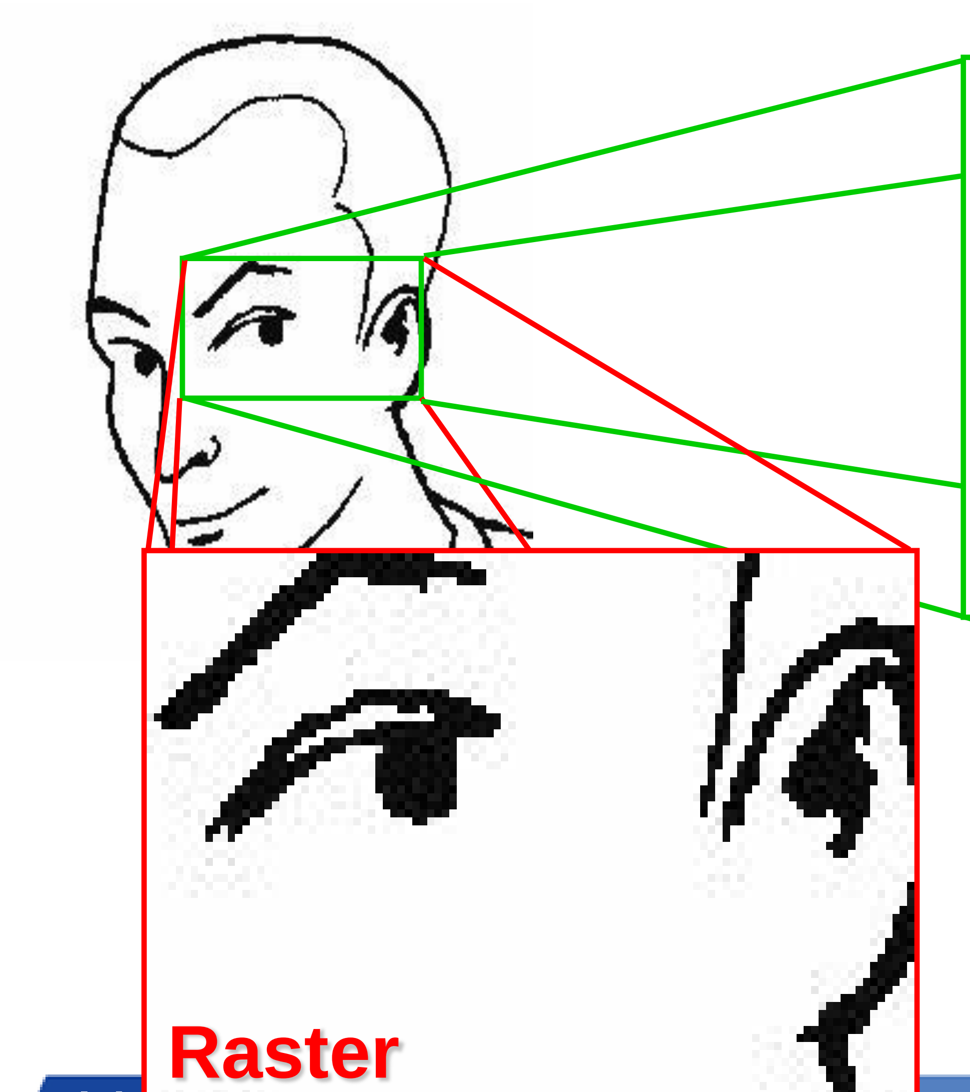
SVG Example 1

```
<?xml version="1.0"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.0//EN"
"http://www.w3.org/TR/2001/REC-SVG-20010904/DTD/svg10.dtd">
<svg width="200" height="200" xmlns="http://www.w3.org/2000/svg">
    <desc>All SVG documents should have a description</desc>
    <defs>
        <!-- Items can be defined for later use -->
    </defs>
    <g>
        <circle cx="100" cy="100" r="75" fill="green"/>
    </g>
</svg>
```



Output

Raster vs. Vectorial 1/2

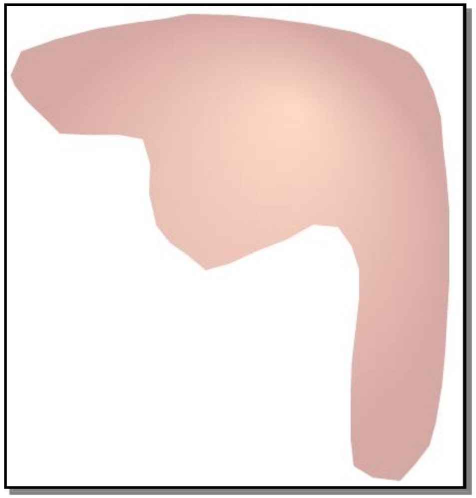


Comparison between raster image and vectorial image.

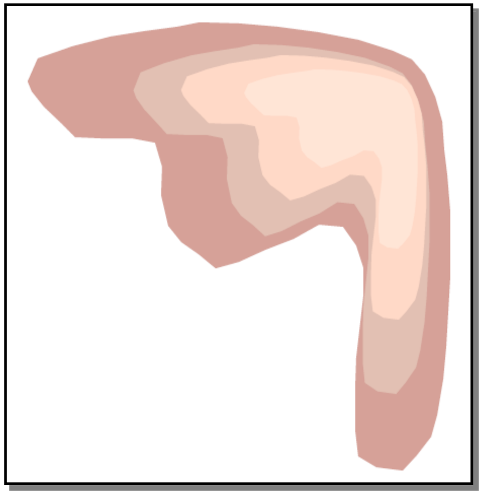
Raster vs. Vectorial 2/2

Comparison between raster image and vectorial image.

Possible Optimization



With gradient

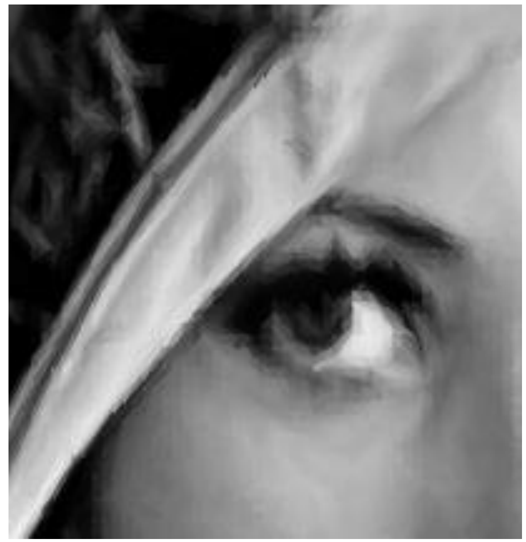


With Multiple Surfaces

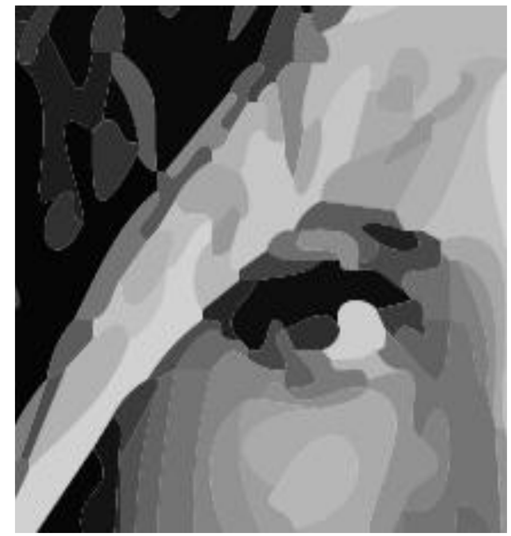
- Use of pattern gradient detection instead of multiple color surfaces;
- Better edge detection;
- Antialiasing Optimizations;

Experiments 1/2

Bicubic Zooming Algorithm



SVG representation
of Data Dep. Triangulation



Commercial Vector-Eye ©
SVG output

- Comparison of DDT/SVG with an enlargement and a Vector-Eye©, commercial SVG converter, result. The triangulation has been achieved by using ***Simple conversion***.

Experiments 2/2

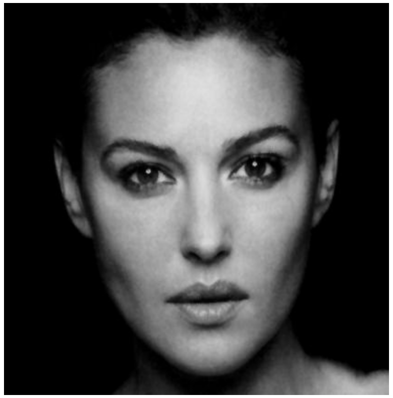
Original Input Image

SVG representation
of Data Dep. Triangulation

Commercial Vector-Eye ©
SVG output

- Comparison of original low resolution image with an x4 DDT/SVG enlargement and the Vector-Eye©, commercial SVG converter, result. The triangulation has been achieved by using ***Simple conversion***.

Applications



Pure SVG Transformation

SVG For High-Resolution Prints

Down Sampling

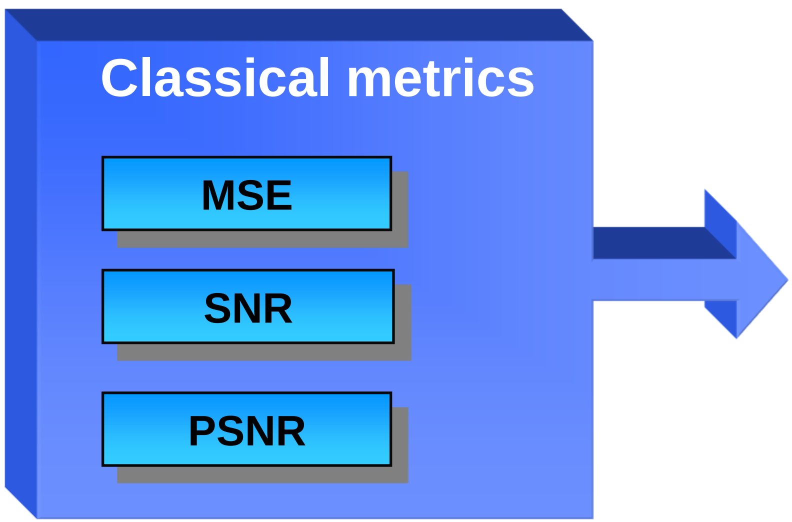
Phone Embed Dithering

SVG For Low-Resolution Displays

By Using an Adaptive Pipeline it is possible to achieve the better results for the selected device.

Image Quality Metrics

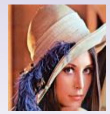
Subjective	Objective
IQ metrics are based on a sufficiently large number of observers (e.g. Visual Quality Expert Group)	Asses IQ using mathematical differences. Could not be able to measure some visual noticeable artifacts.



- ✓ easy to compute
- ✓ not correlate well with perceived quality measurements
- ✓ the perceived quality of images with the same PSNR can be very different

Quality Metrics and HVS

Computation

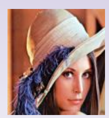


Objective metric using subjective informations

Quality Score Q1

Q1 ∈ [1,2,3,4,5,6,7,8,9,10]

Testing

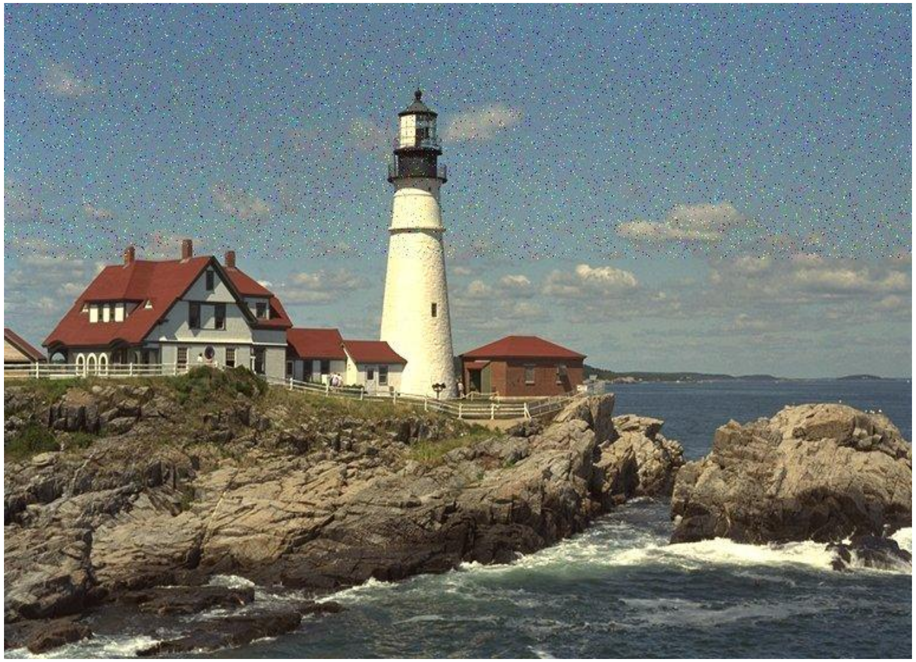


Quality Score Q2

Q2 ∈ [1,2,3,4,5,6,7,8,9,10]

If Q1≅Q2 then the metric is well correlated with the perceptive quality

Example



The same amount of noise has been added to rectangular areas at the top (left) and at the bottom (right). The two images have similar PSNR but their perceived quality is very different.

Reference Metrics

✓ Most of the proposed image quality assessment approaches require the original image as reference

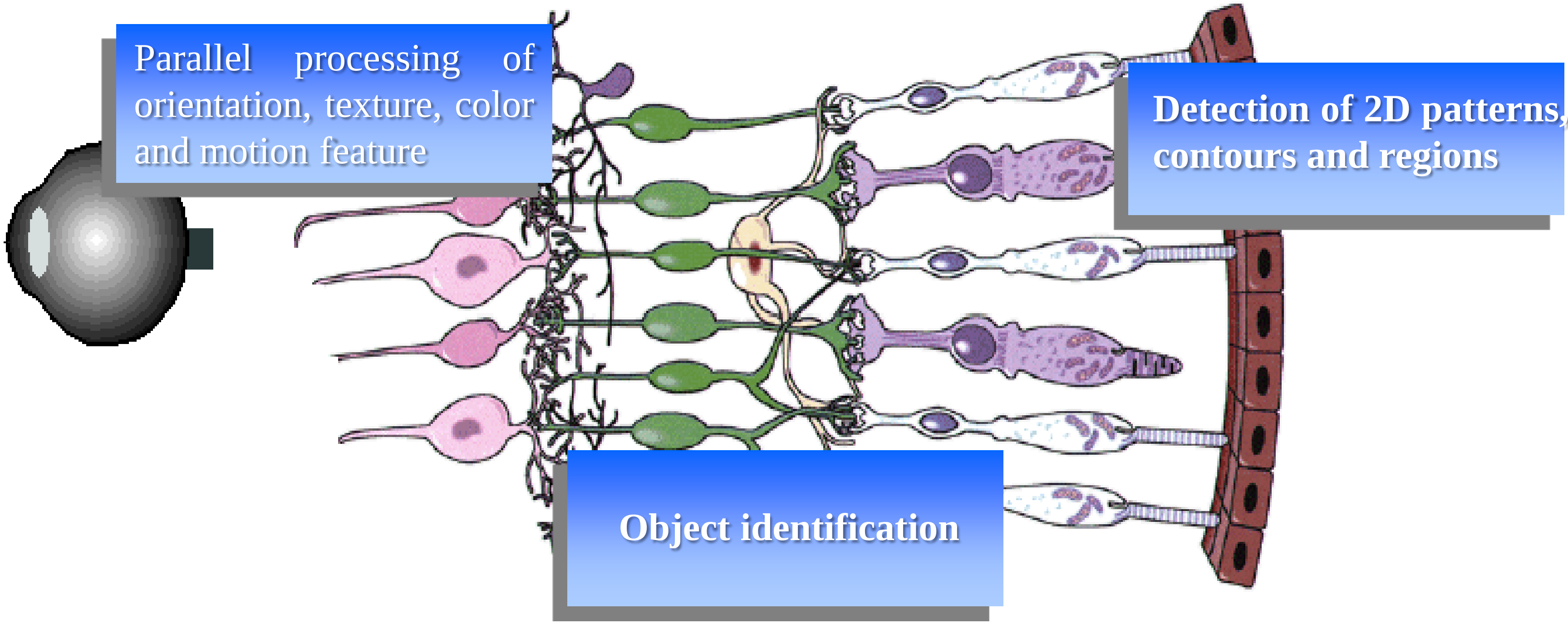
Original Image

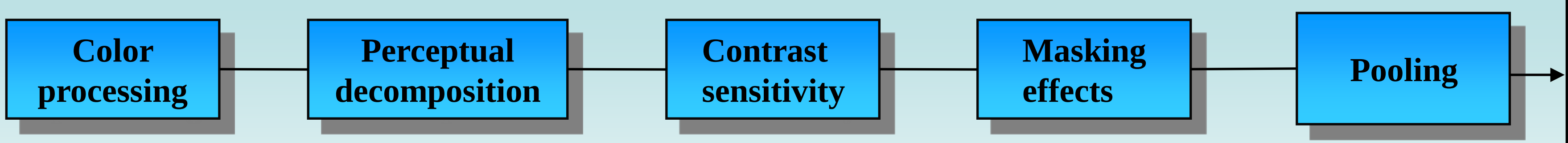
Distorted Image

No Reference Metrics

- ✓ Understand what “quality” means to the viewer
- ✓ To assess the quality of distorted images without using any reference image

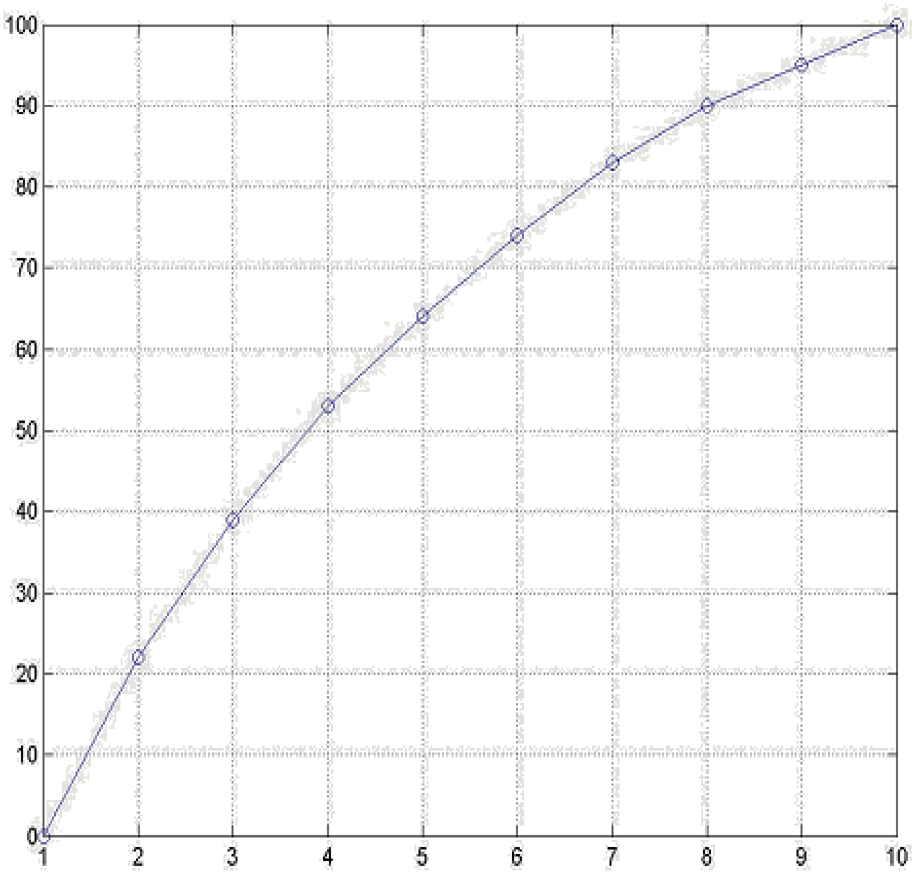
IQ and HVS





General structure of computational model of the human visual system

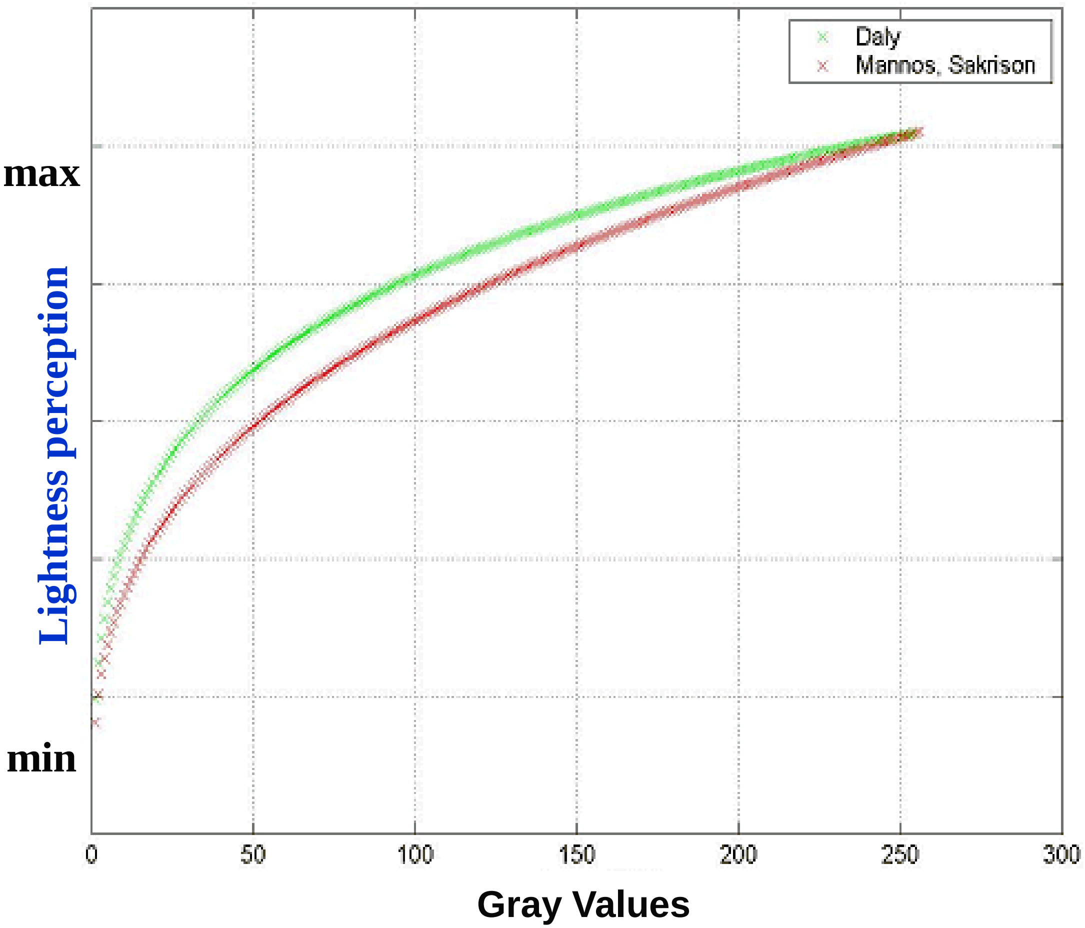
Lightness Perception 1



Tone Card

- ✓ The perception of lightness is not linearly related to the real luminance of an object
- ✓ In an experiment observers were supplied with about 100 tone-cards of a different gray color. They were asked to select 10 of them, so that they span the range between black and white in an equidistant manner. If the sensation associated with a tone is taken to be the number of steps from black, then the curve of steps-number versus luminance is showed in figure.

Lightness Perception 2

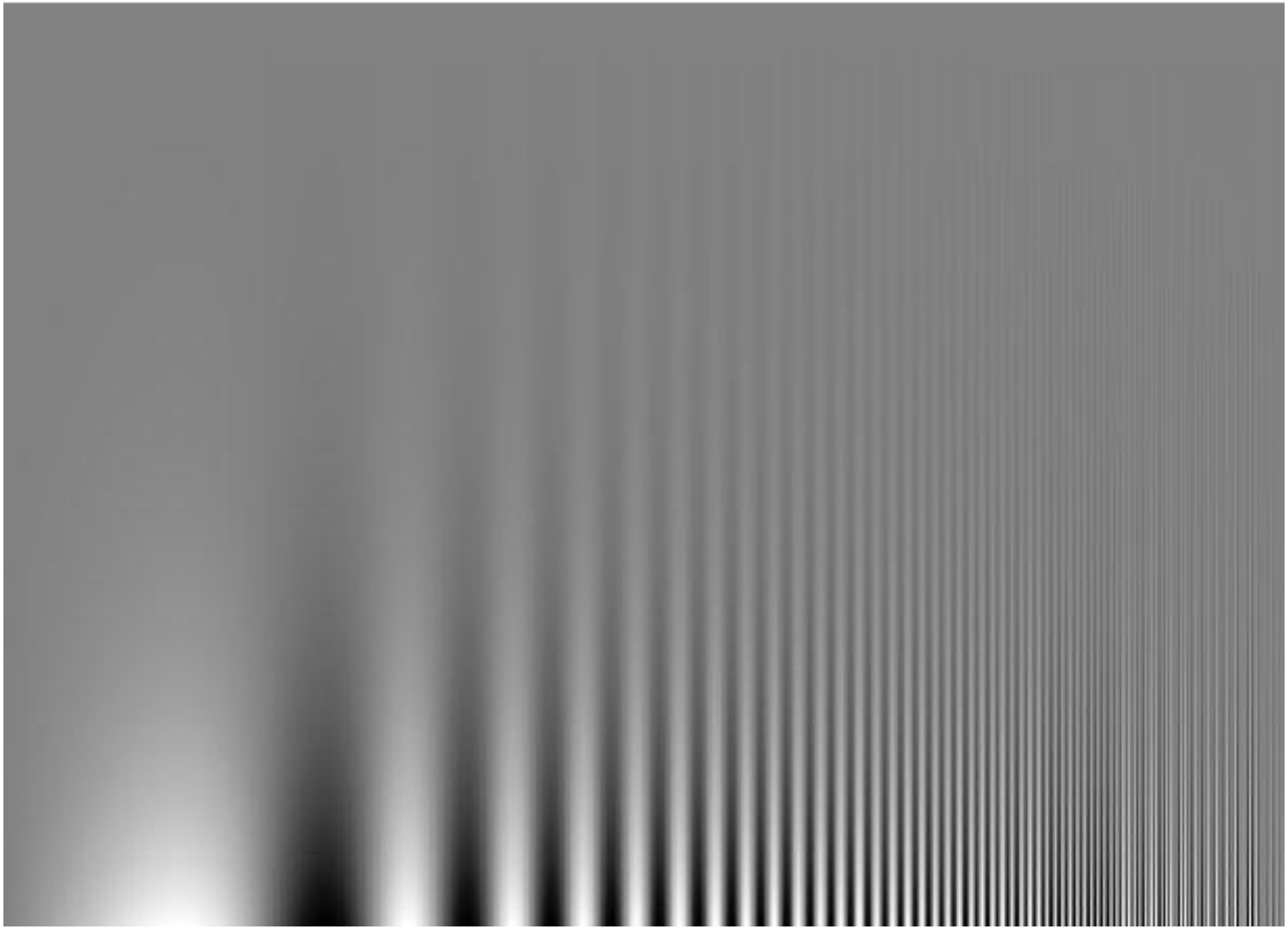


- ✓ **Daly and Mannos-Sakrison has proposed the following relationships:**

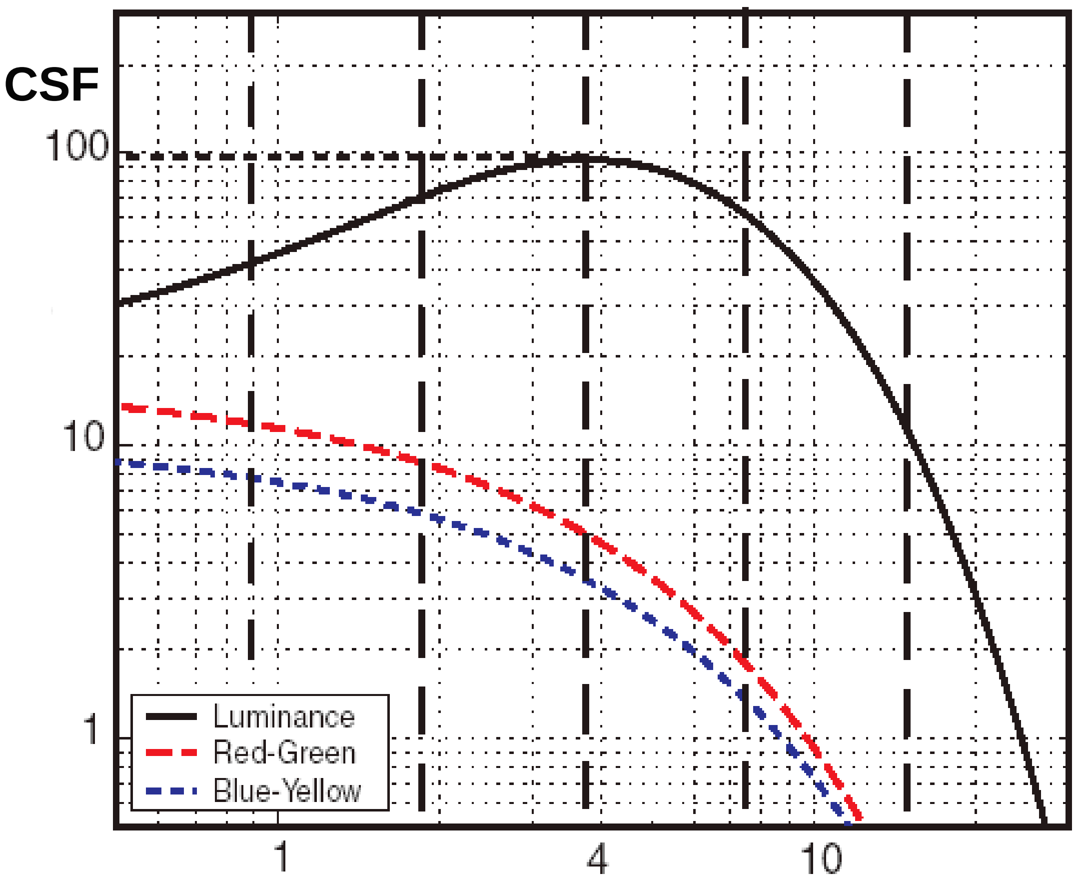
$$L' = L/\left(1 + 12.6L^{0.63}\right)$$

$$L'' = \left(L/L_m\right)^{0.333}$$

Contrast Sensitivity Function (CSF) 1

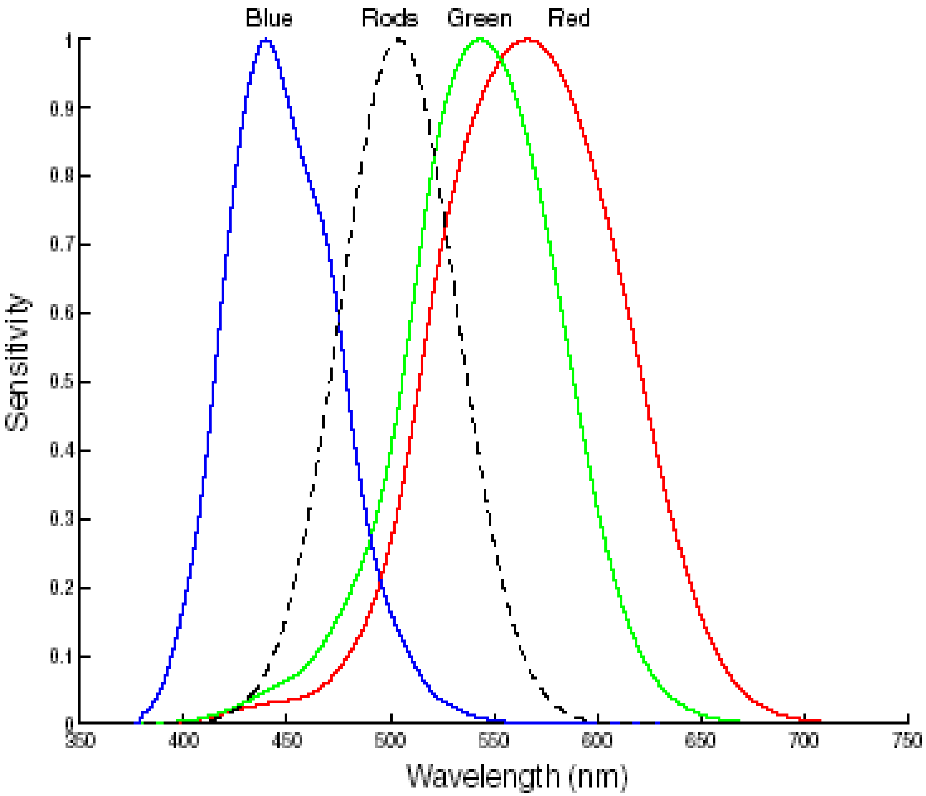


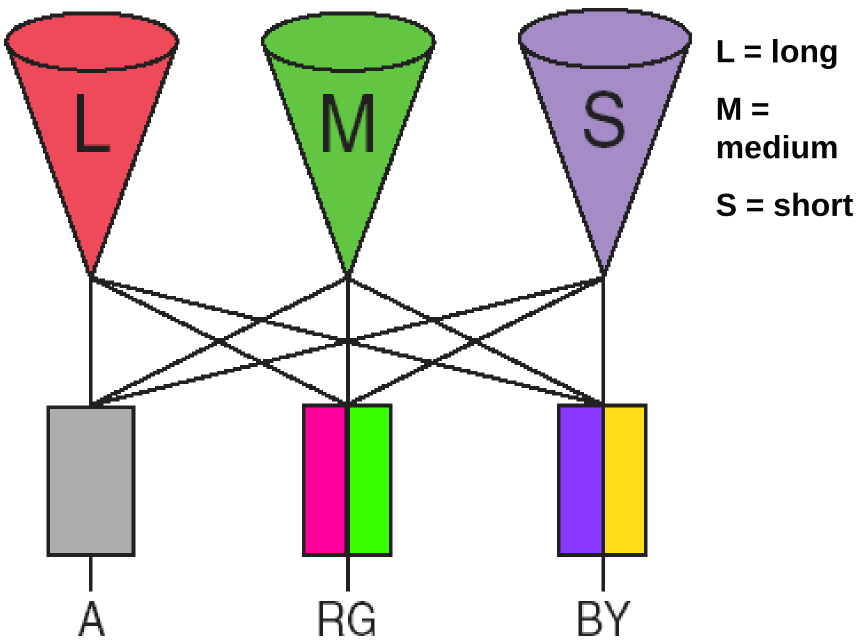
Contrast Sensitivity Function (CSF) 2



Spatial frequency in cycles per optical degree

Color Encoding

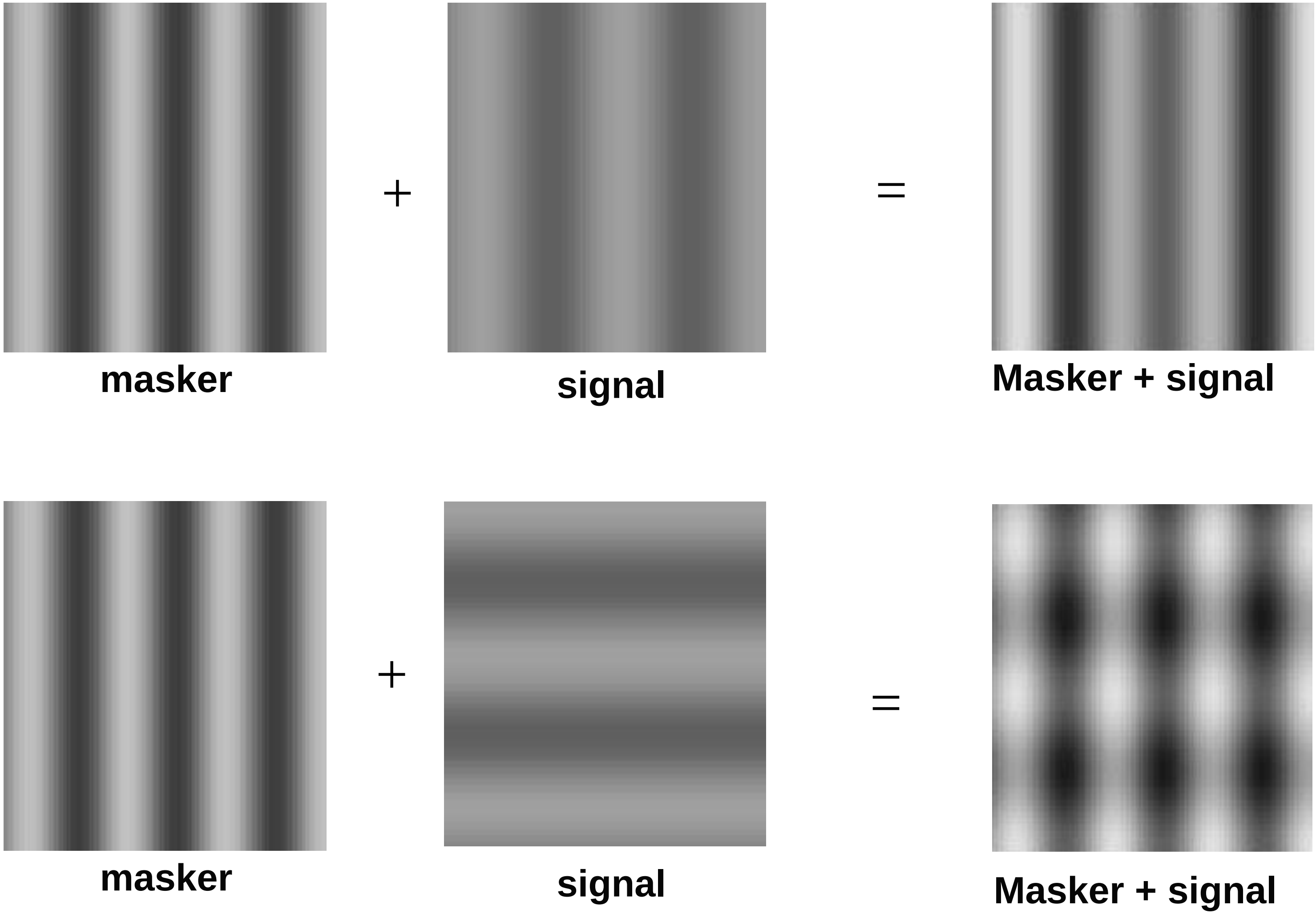




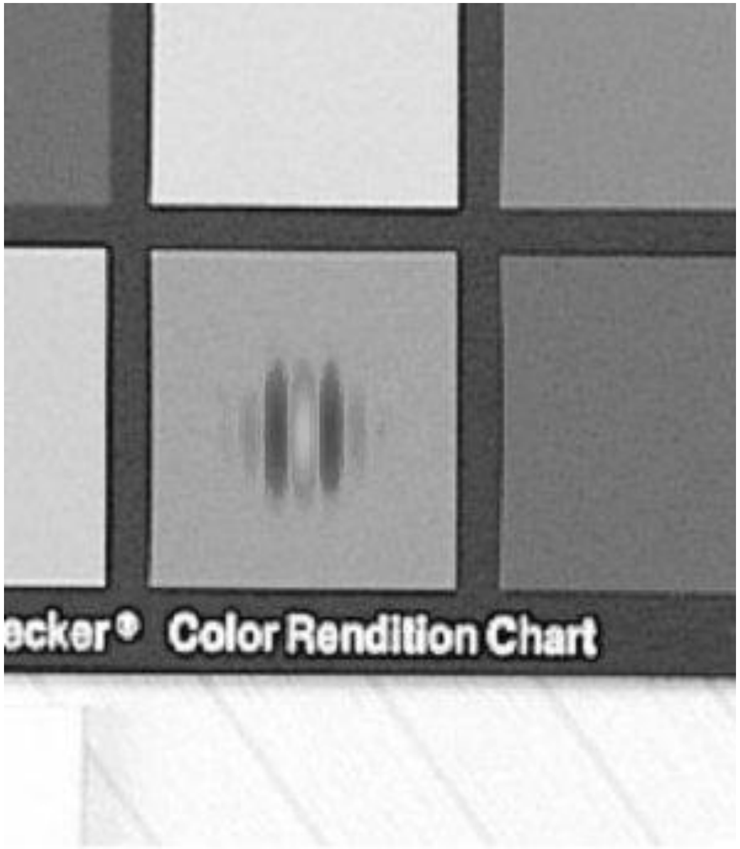
Normalized sensitivity curves for the different photoreceptors

Photo-receptors combined color information in one achromatic and two chromatic channels

Contrast Masking



Activity Masking



The local surround of the feather is very active and the HVS needs more time to pick up the distortion

Universal Image Quality (UIQ) Index

“ **The Human Visual System is highly sensitive to structural image information. A measurement of structural distortions should be a good approximation of perceived image distortions** ”

x → **reference image**

y → **target image**

means:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

variances:

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})^2 \qquad \sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N} (y_i - \bar{y})^2$$

covariance:

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})$$

$$UIQ = \left(\frac{\sigma_{xy}}{\sigma_x \sigma_y}\right)\left(\frac{2\bar{x}\bar{y}}{\bar{x}^2 + \bar{y}^2}\right)\left(\frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2}\right)$$

Loss Of Correlation | Luminance Distortion | Contrast Distortion

Example 1 Universal Image Quality


reference


1°


2°


3°

From best to worst

Bibliography

- Adams, James E. "Interactions between color plane interpolation and other image processing functions in electronic photography" Proceedings of SPIE Vol. 2416 P.144-151
- Sakamoto,Tadashi. et.al., "Software pixel interpolation for digital still cameras suitable for a 32-bit MCU" IEEE Transactions on Consumer Electronics. Vol.44, No.4, P.1342-1352, November 1998
- Zen,Hidemori. et.al., "A New digital signal processor for progressive scan CCD" IEEE Transactions on Consumer Electronics. Vol.44, No.2, P.289-295, May 1998
- Parulski,Kenneth A. "Color Filters and Processing Alternatives for one-chip cameras" IEEE Transactions on Electron Devices. Vol.ED-32, NO.8, August 1985
- Chan,Wen-Hsin. et.al., "A Mega-Pixel resolution PC Digital Still Camera" Proceedings of SPIE Vol.2654. P.164-171
- Tsai, Y.Tim. et.al., "Optimized Image Processing Algorithms for a Single Sensor Camera" 1997 IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, Vol.2, P.1010-1013
- Adams,James E. et.al., "Design of practical color filter array interpolation algorithms for digital cameras" Proceedings of SPIE Vol.3028 P.117-125
- Chang, Ed. et.al., "Color Filter Array Recovery Using a Threshold-based Variable Number of Gradients" to be published in Proceedings of SPIE, January, 1999
- Keys, Robert.G. et.al., "Cubic Convolution Interpolation for Digital Image Processing" IEEE Transactions on Acoustic, Speech and Signal Processing, Vol ASSP-29, P1153-1160, 1981
- Simons, K.W. "Digital Image Reconstructon and Resampling for Geometric Manipulation" Proceedings of IEEE Symp. on Machine Processing of Remotely Sensed Data P.3A-1--3A-11,1975
- Mitchell, Don P. et.al., "Reconstruction Filters in Computer Graphics" Computer Graphics, (SIGGRAPH'88 Proceedings), Vol.22, No.4, P.221-228, August 1988
- Schreiber, William F. et.al., "Transformation between Continuous and Discrete Representations of Image: A Perceptual Approach" IEEE Transactions on Pattern Analysis and Machine Intelligence Vol.PAMI-7 No.2, P.178-186 March 1985