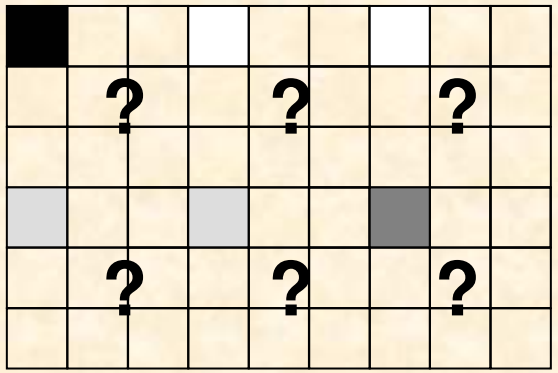
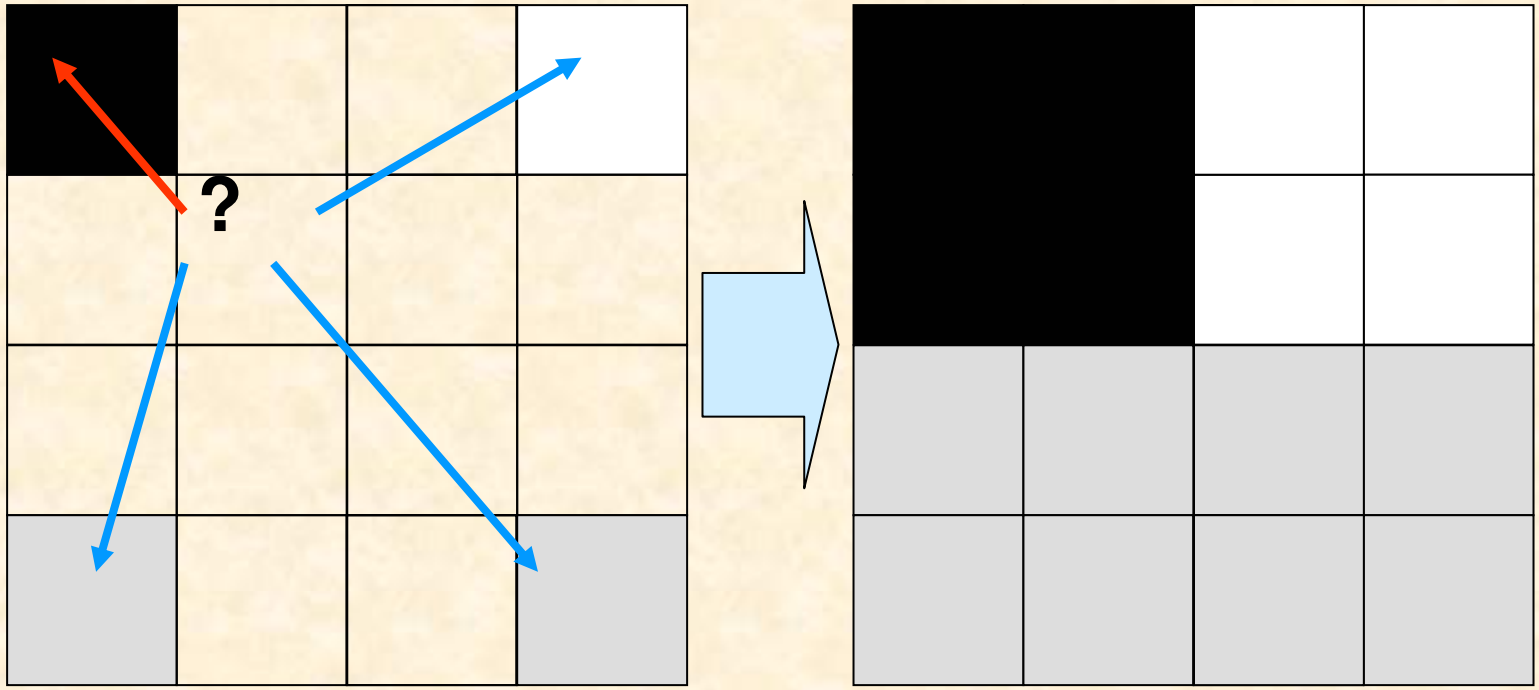
Image enlargement

3x

3x

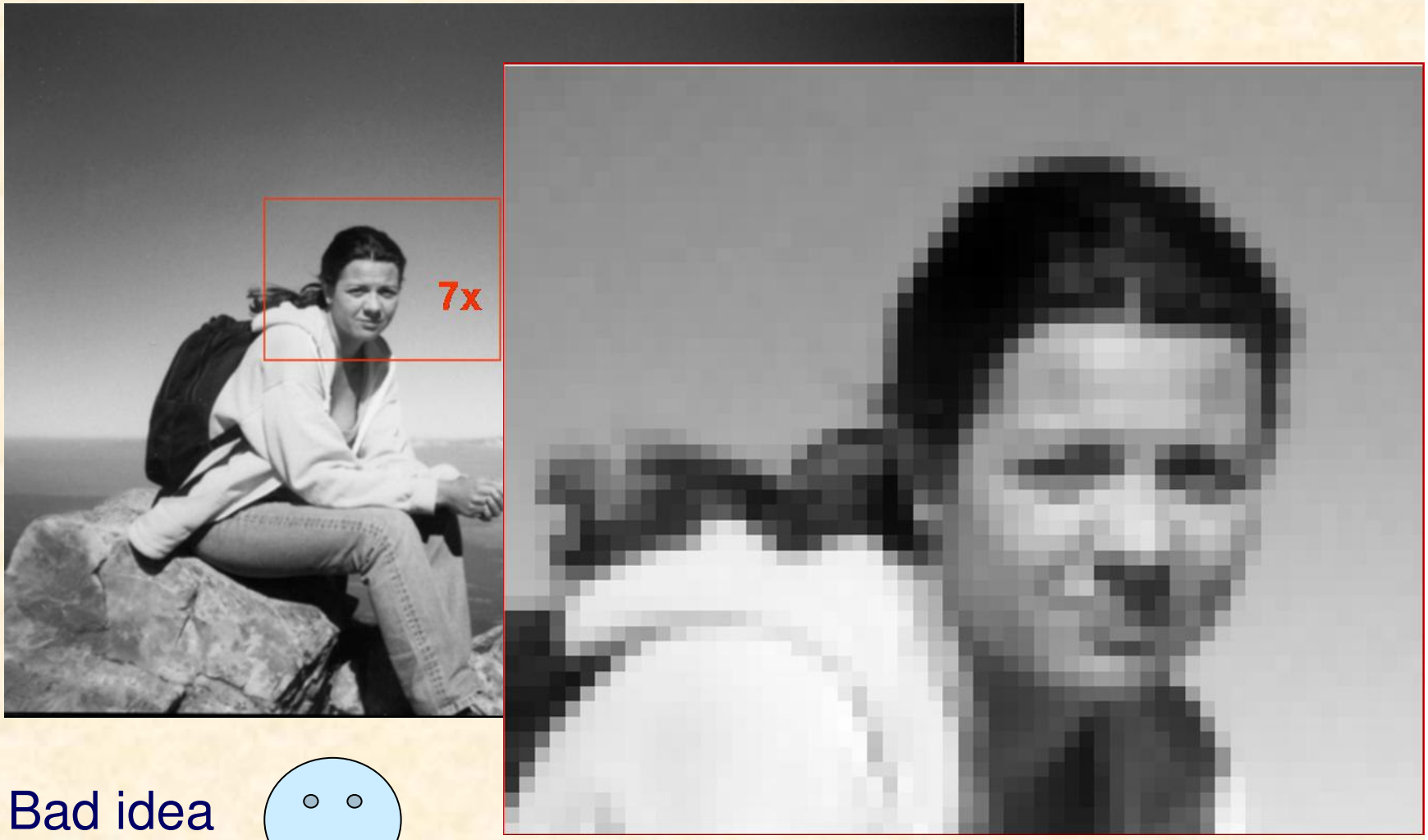


Nearest neighbour pixel replication



Zero-order interpolation

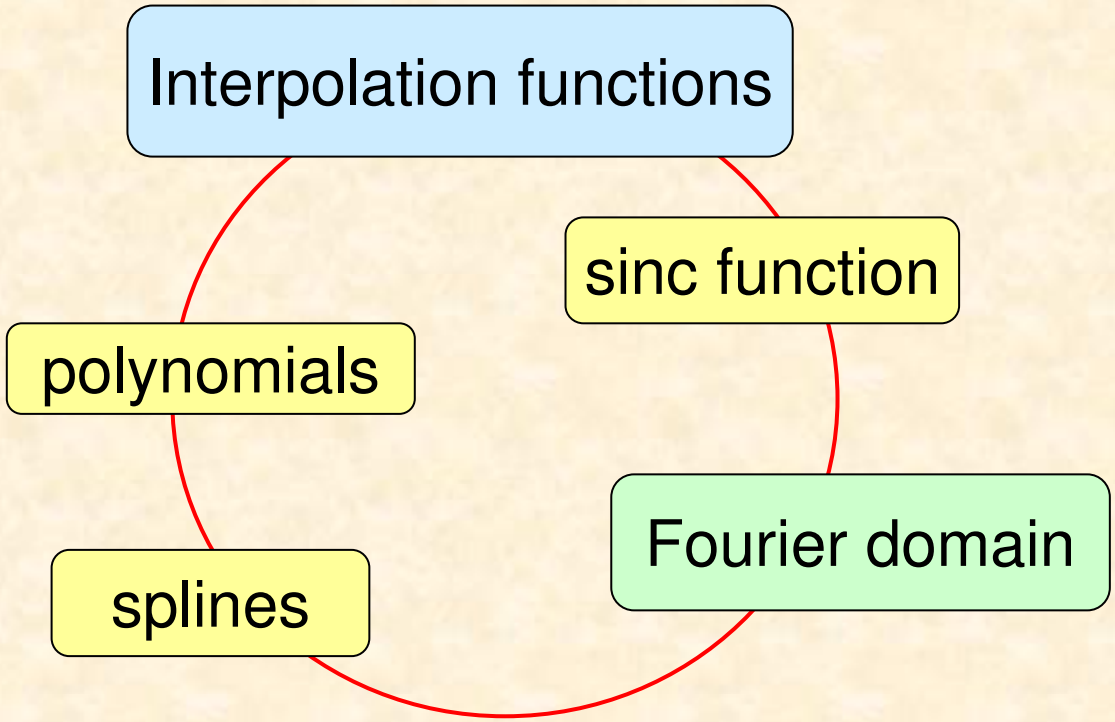
Pixel replication - example



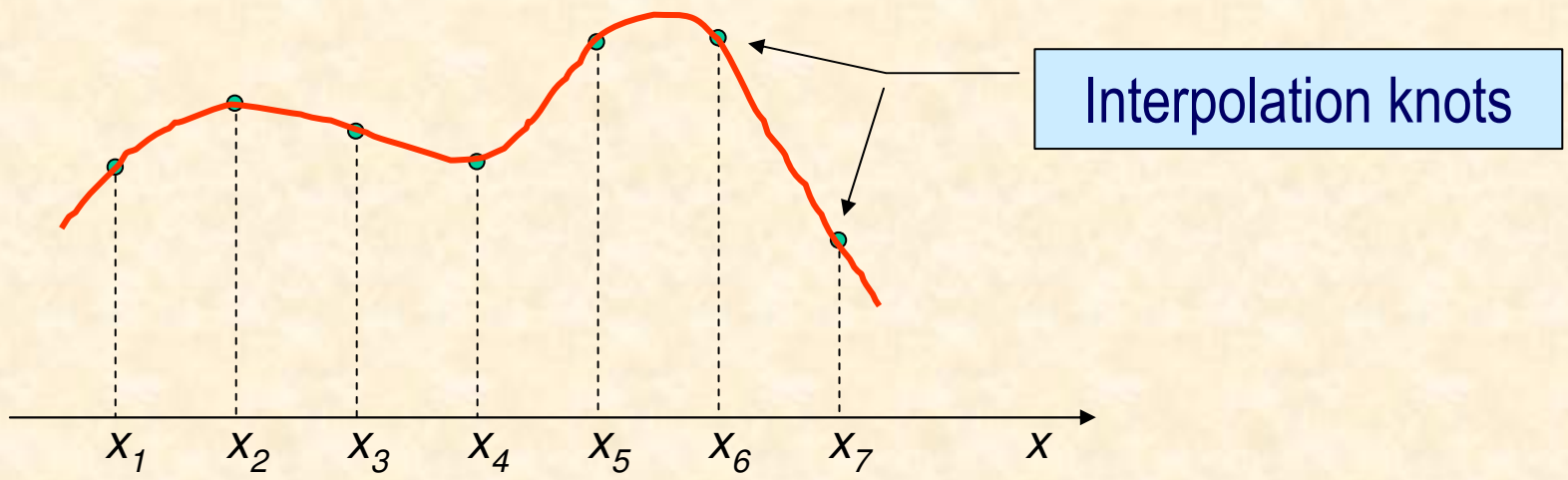
Bad idea

Image enlargement

Interpolation – estimation of a function on the basis of its discrete samples (knots)
Image interpolation is also used in geometric transformations of images.



Polynomial interpolation



$$W(x)=a_n x^n+a_{n-1}x^{n-1}+\ldots+a_1 x+a_0$$

For given n knots and $f(x_i)$ for these knots, a polynomial $W(x)$ of order no larger than n is searched for so that:

$$W(x_i) = f(x_i).$$

Spline interpolation

Function S_m given on $x_0<x_1<x_2<\ldots<x_{n-1}<x_n$ is a spline of order m if:

- it is a polynomial of order m or lower for each sub-range $<x_i, x_{i+1}>$
- S_m is of class C^{m-1} ,i.e. it is continuous with its derivatives in x_i (left and right hand-side limits are equal)

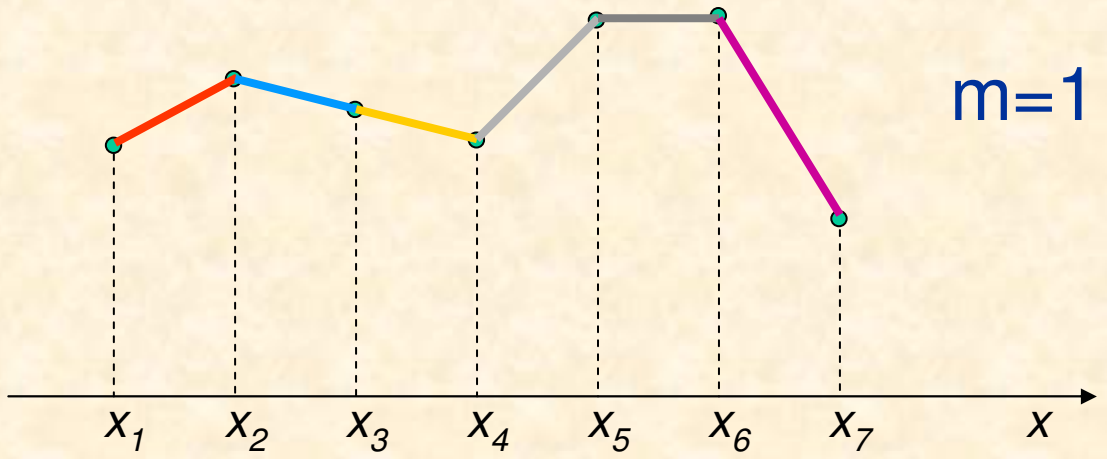
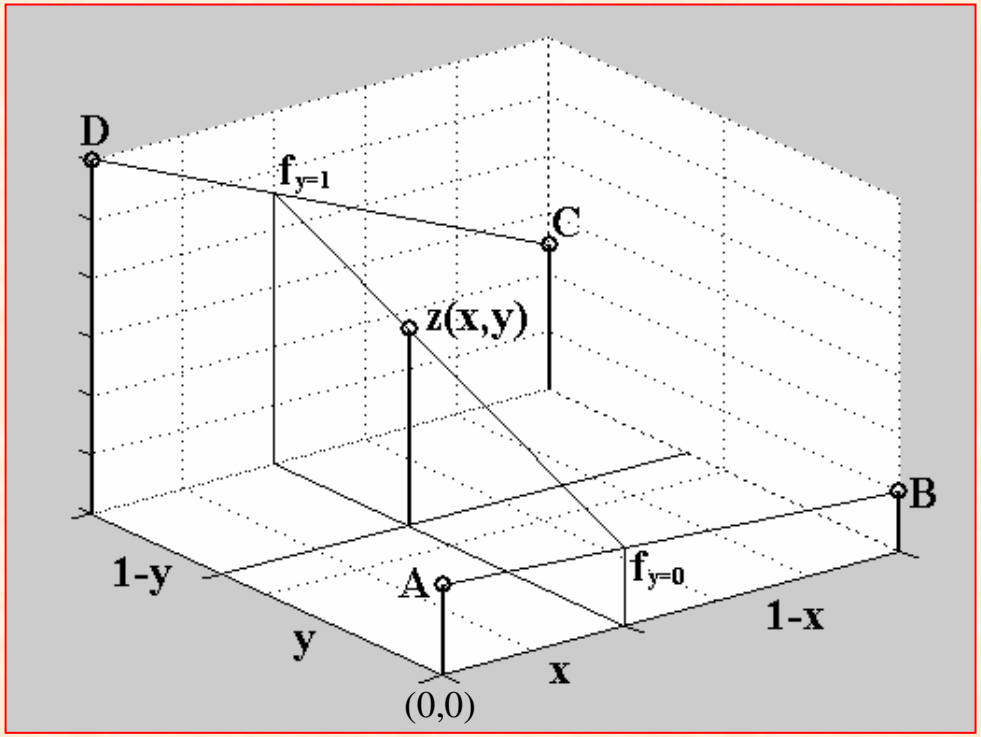


Image enlargement by bilinear interpolation

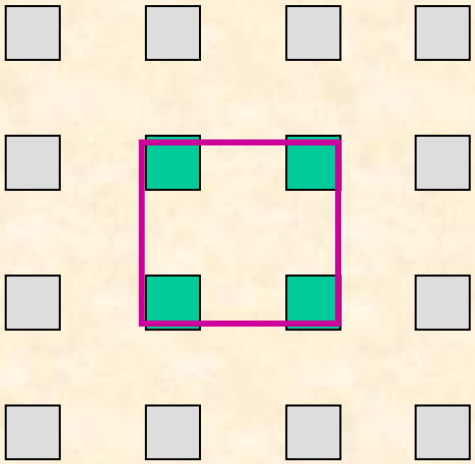


$x \in [0,1],\ y \in [0,1]$

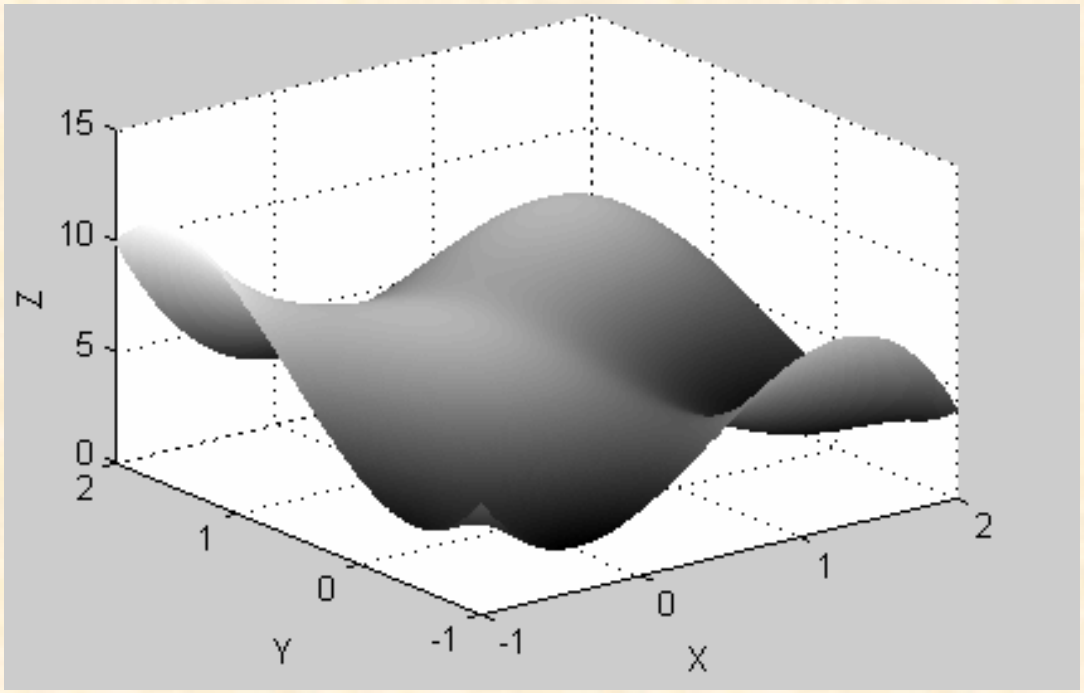
$$z(x,y) = A(1-x)(1-y) + B(x)(1-y) + C(x)(y) + D(1-x)(y)$$

Bilinear interpolation - example

Bicubic polynomial interpolation



Four 3-rd order polynomials
(16 coefficients)



$$z = b_3y^3+b_2y^2+b_1y+b_0$$

Bicubic interpolation - example

Image interpolation - comparison

***P**eak*
***S**ignal to*
***N**oise*
***R**atio*

$$PSNR = 10\log_{10}\left[\frac{255^2 MN}{\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j) - f_{INT}(i,j)]^2}\right]$$

Interpolation method	***PSNR* [dB]**
pixel replication	31.6371
bilinear	35.0411
bicubic	35.5752
cubic B-spline	35.7082

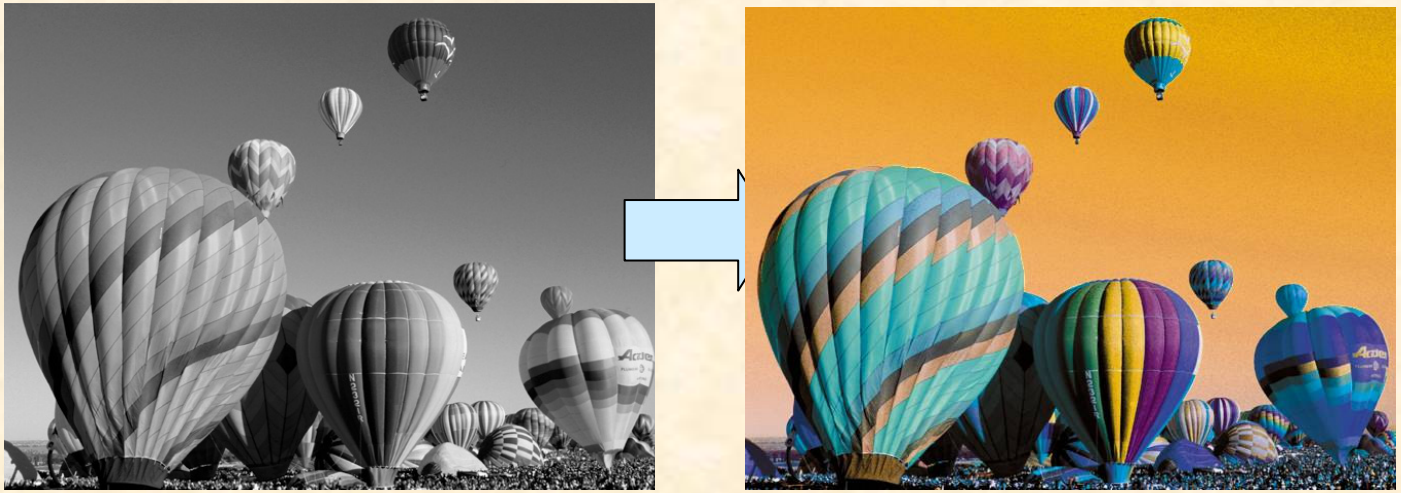
Image enhancement by pseudocoloring

Selected gray level range is replaced by a colour predefined in the look-up-table

```
lut : array[0..L-1] of longint;
f :  array[0..N-1 ,0..N-1] of longint;

for i:=0 to N-1 do for j:=0 to N-1 do
        f[i,j]:=lut[f[i,j]];
```

Image pseudocoloring –application examples



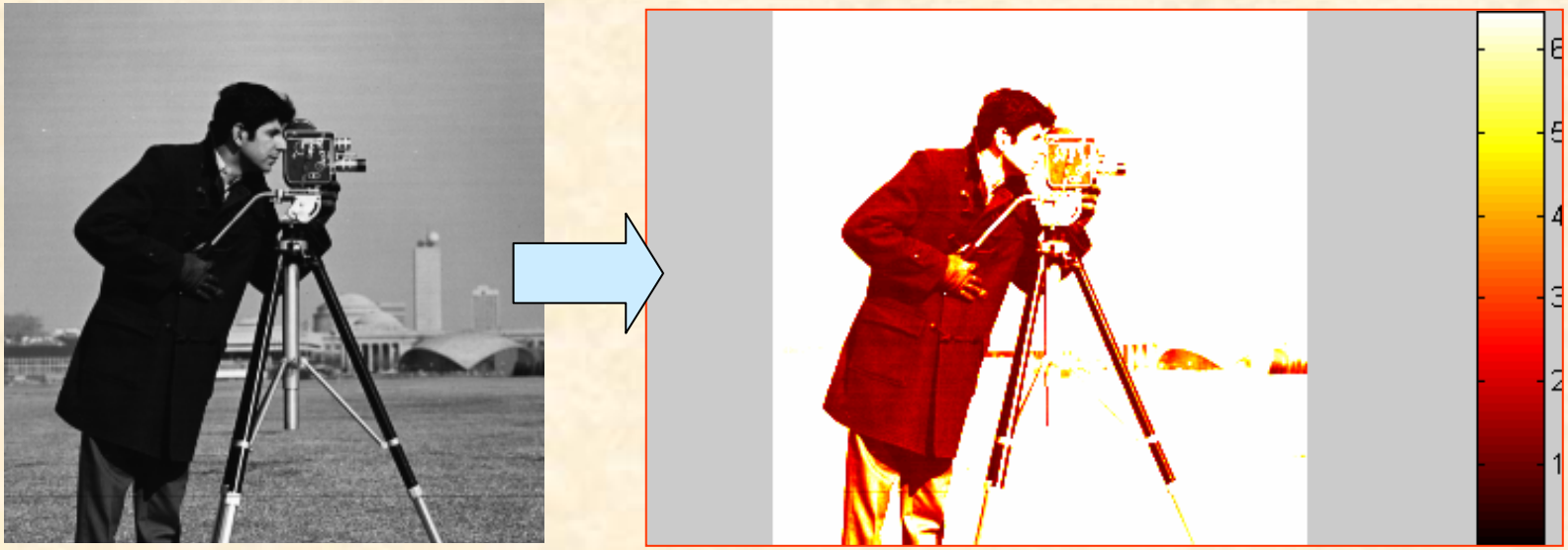
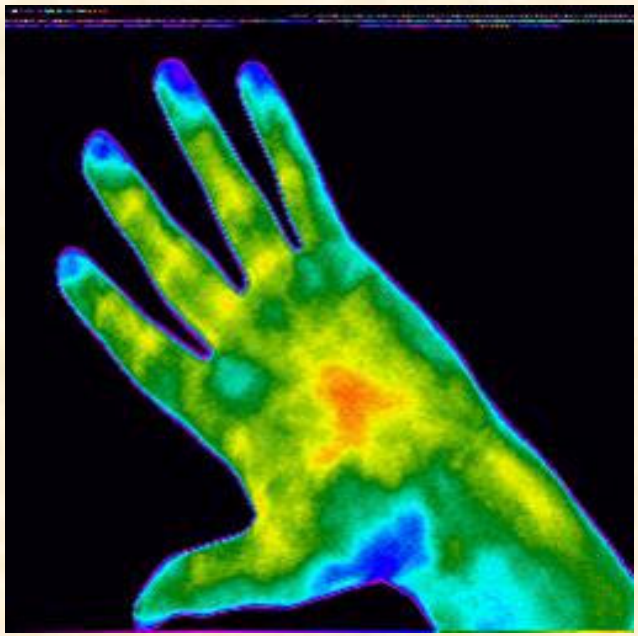
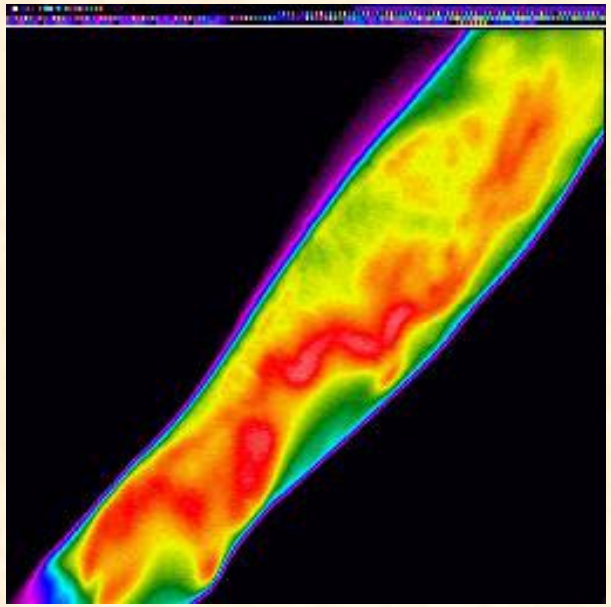


Image pseudocoloring –application examples

[A. Weeks, Fundamentals of Electronic Image Processing, IEEE Press, 1996]

Image pseudocoloring –application examples

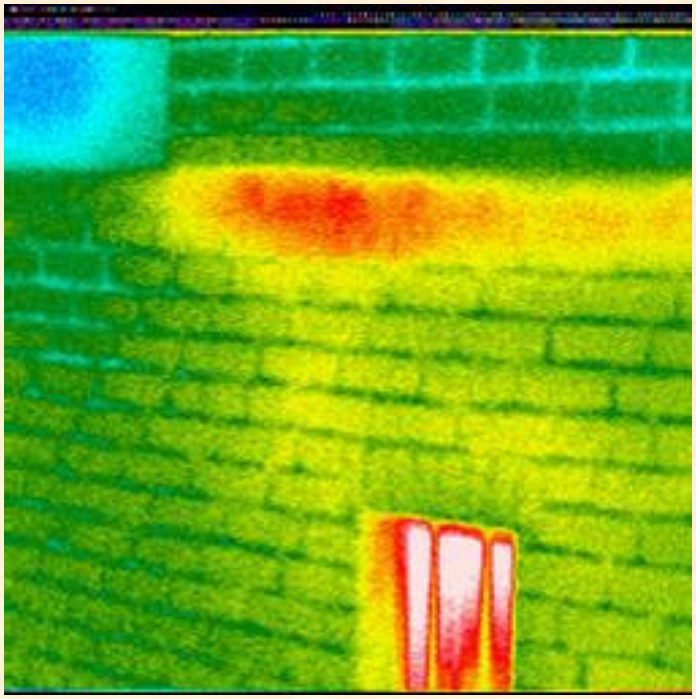


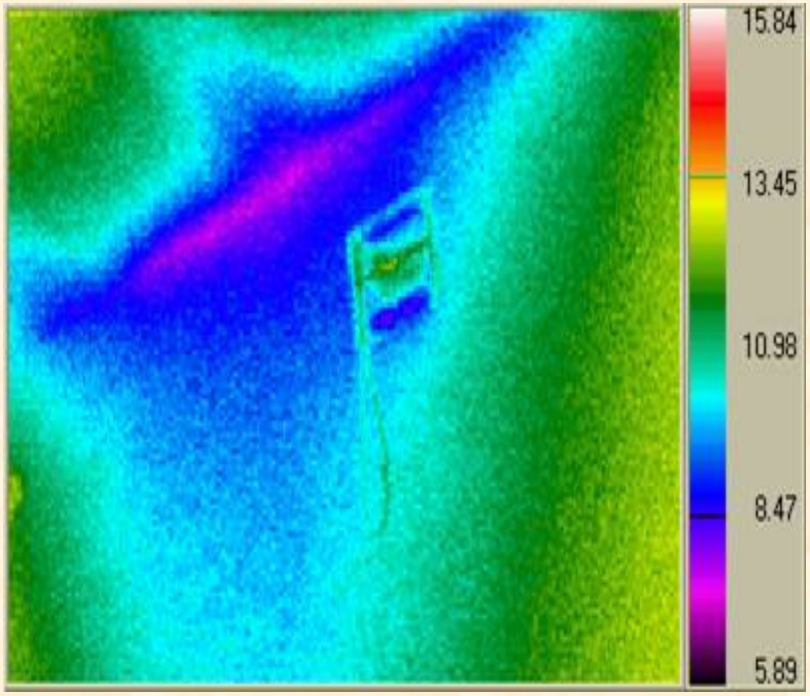


Allergy

[Pracownia Termografii, IE]

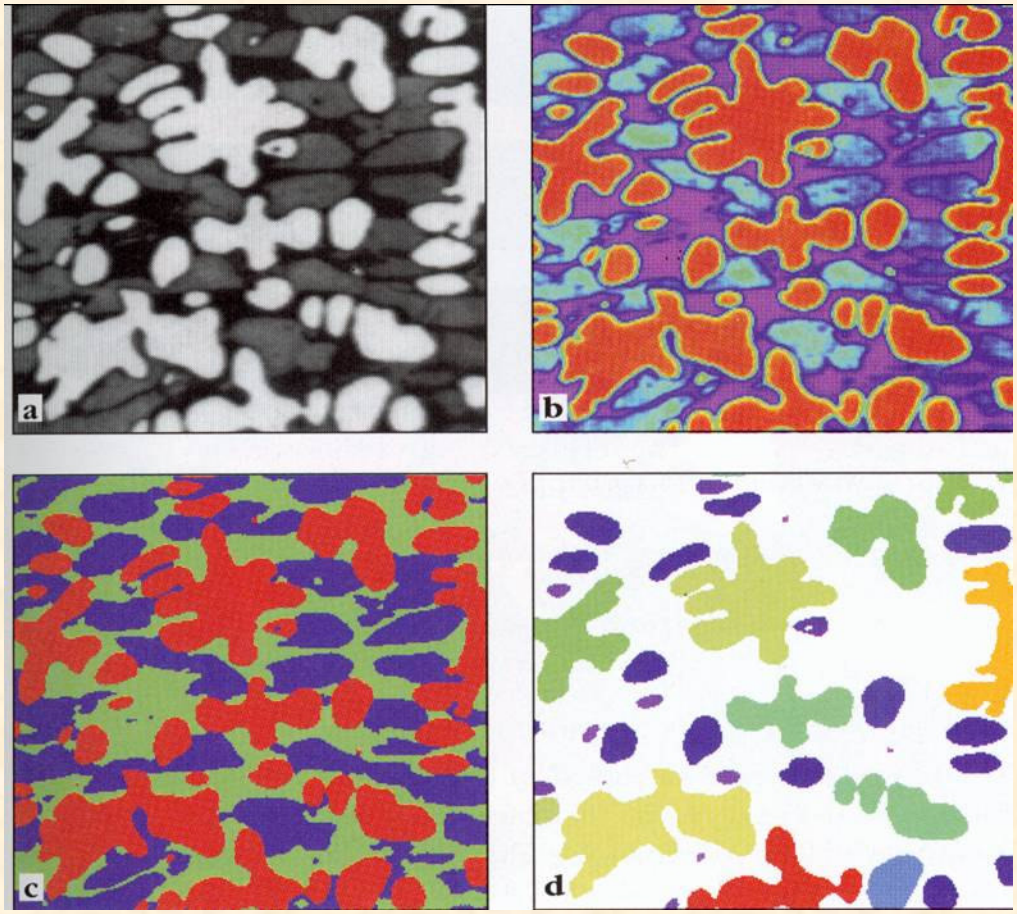
Image pseudocoloring –application examples





Infrared images of buildings (testing of thermal insulation quality)
[Pracownia Termografii, IE]

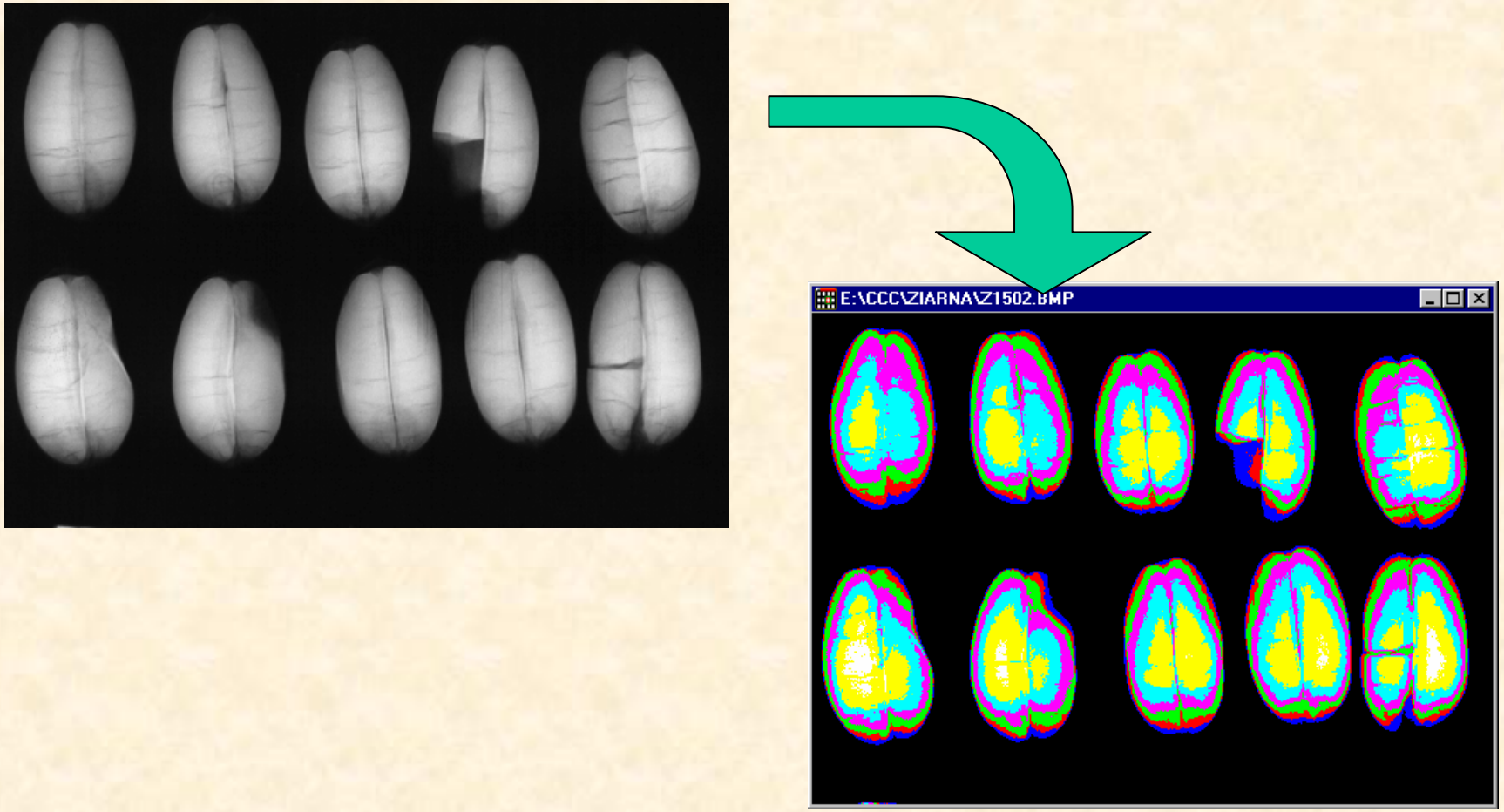
Image pseudocoloring –application examples



Metallographic images

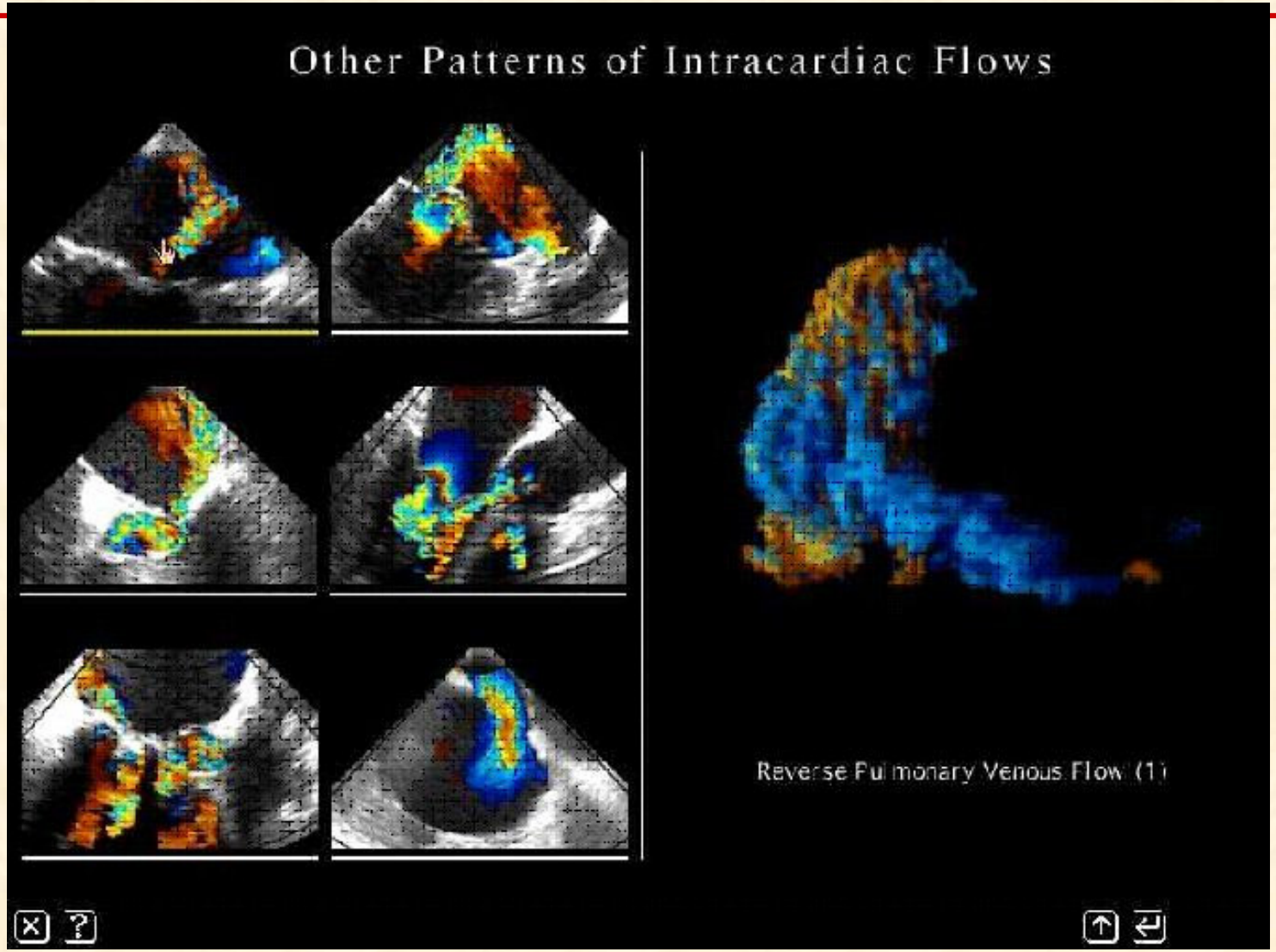
[J. Russ, The Image Processing of Handbook, CRC Press 1995]

Image pseudocoloring –application examples



X ray images of wheat grains [Instytut Agrotechniki PAN, Lublin]

Doppler ultrasonography



Cardiac images [Medical and Biological Informatics, GCRC, Heidelberg, Germany]