

# Snímanie obrazu a jeho vlastnosti

Sonka, Hlavac, Boyle: Image Processing, Analysis and Machine vision,  
kapitola: The image, its representations and properties

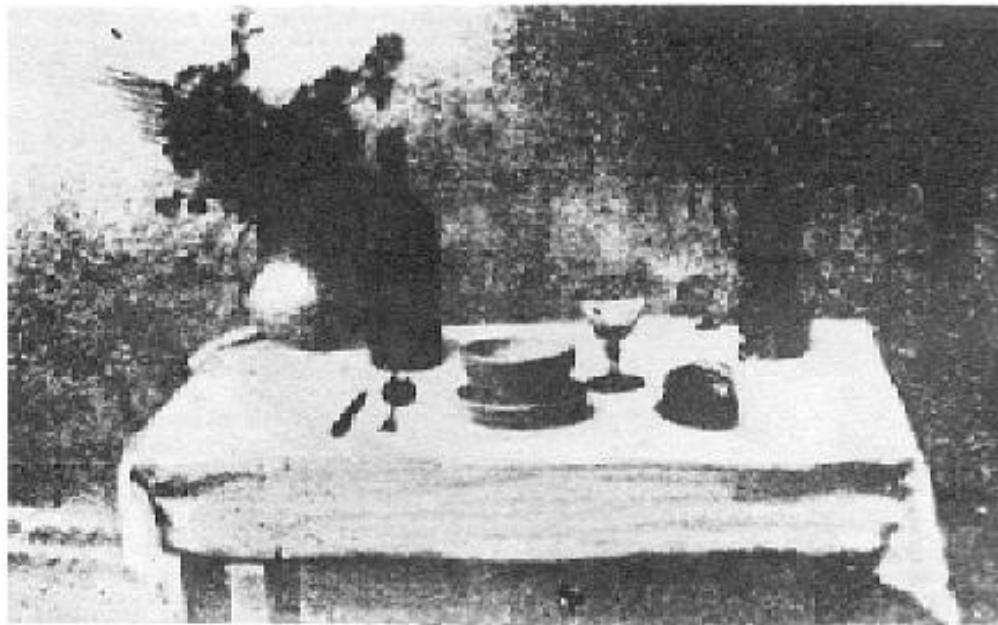
Gonzales, Woods: Digital Image Processing  
kapitola: Digital image fundamentals

Shapiro : Computer Vision

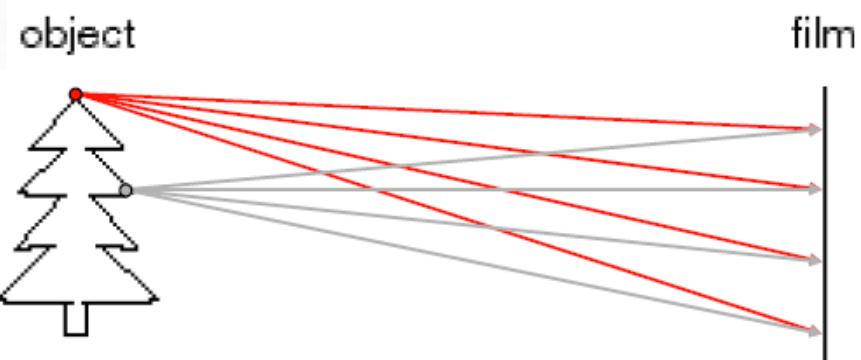
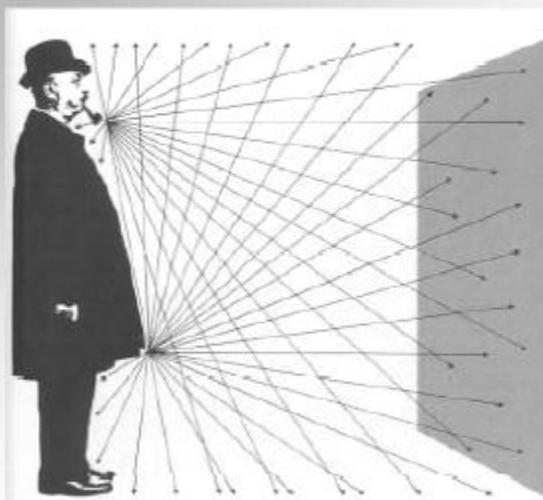
# Kamera a snímanie obrazu

## camera obscura (tmavá komora)

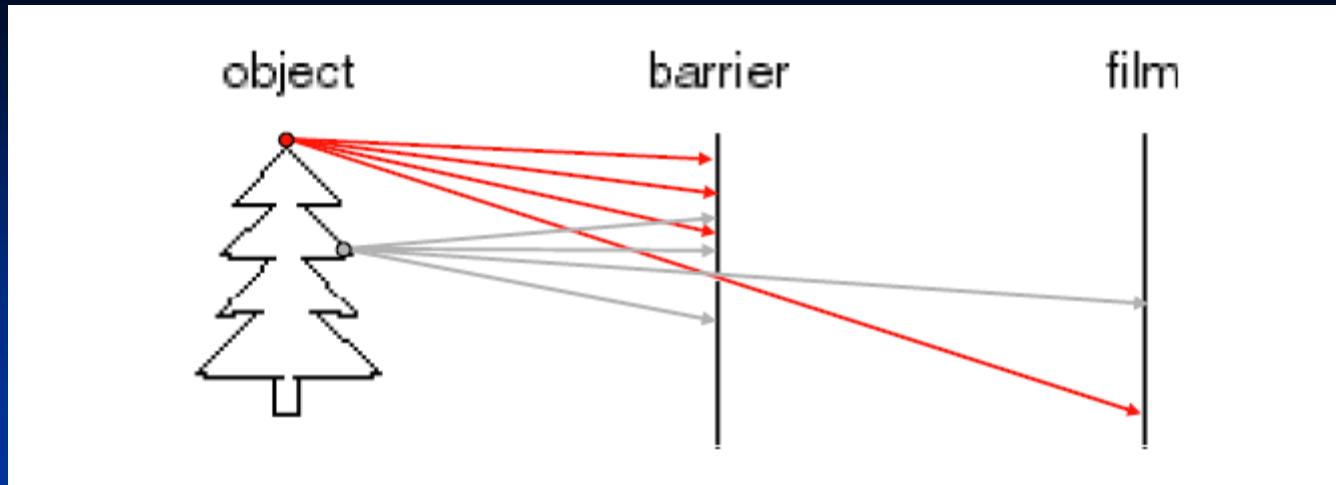
- First photograph due to Niepce (1816)
- First on record - shown below (1822)
- Basic abstraction is the pinhole camera



Light is all around us!

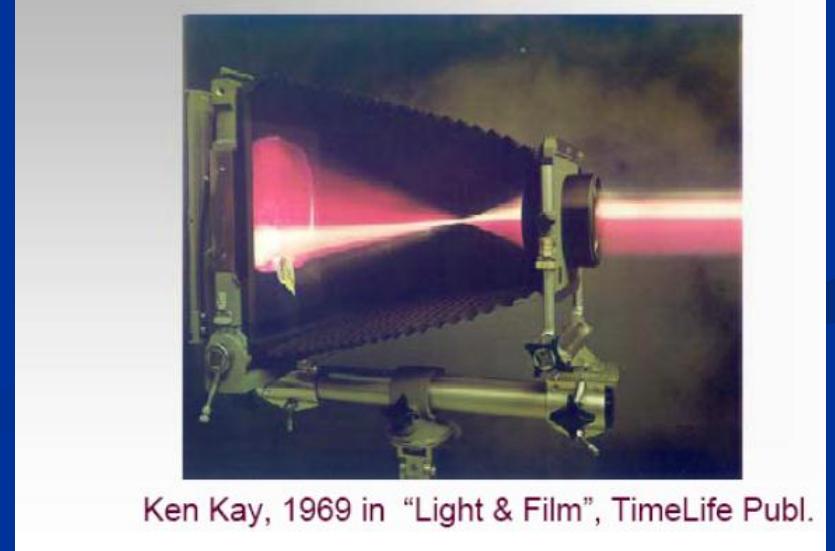


- Ak dáme film pred objekt nedostaneme zmysluplný obraz

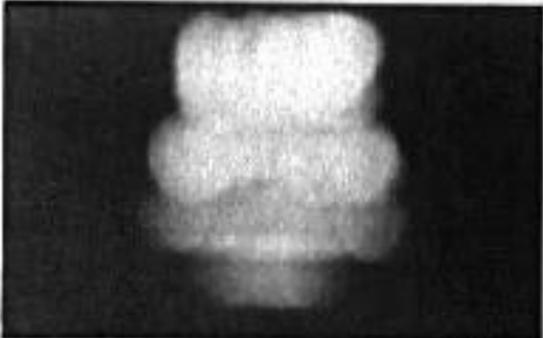


- Bariéra blokuje väčšinu svetla
- Redukuje blurring

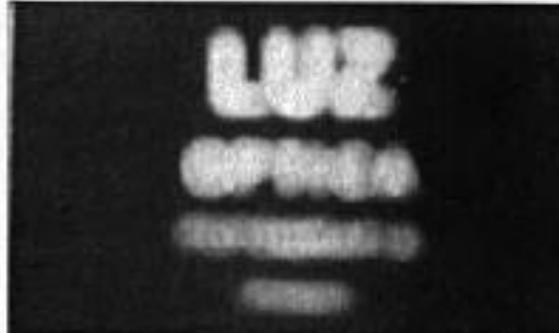
Conventional camera design ...



Ken Kay, 1969 in "Light & Film", TimeLife Publ.



2 mm



1 mm



0.6mm



0.35 mm

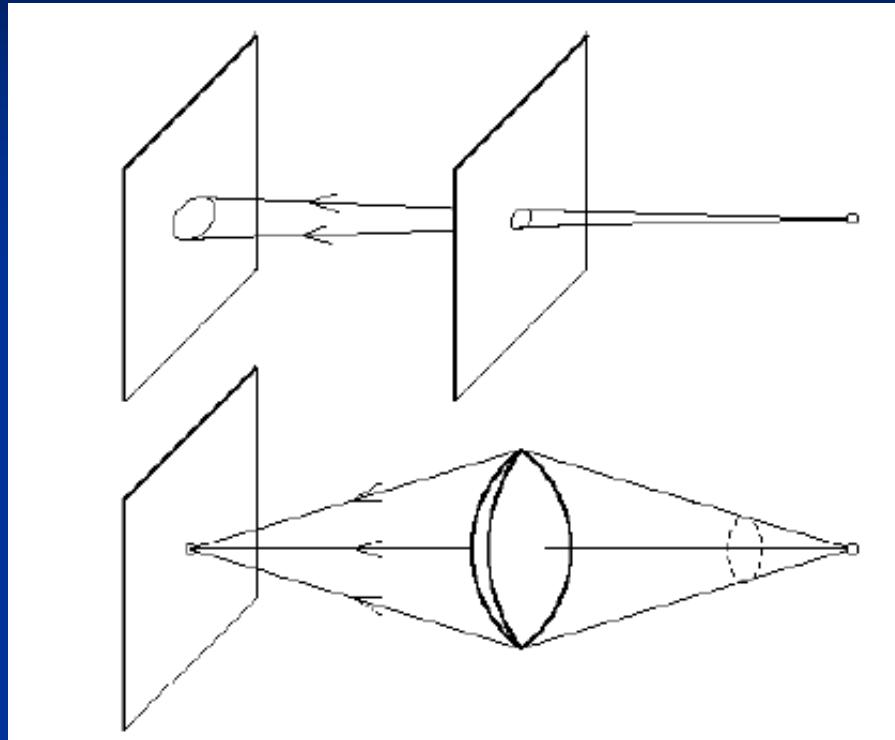


0.15 mm

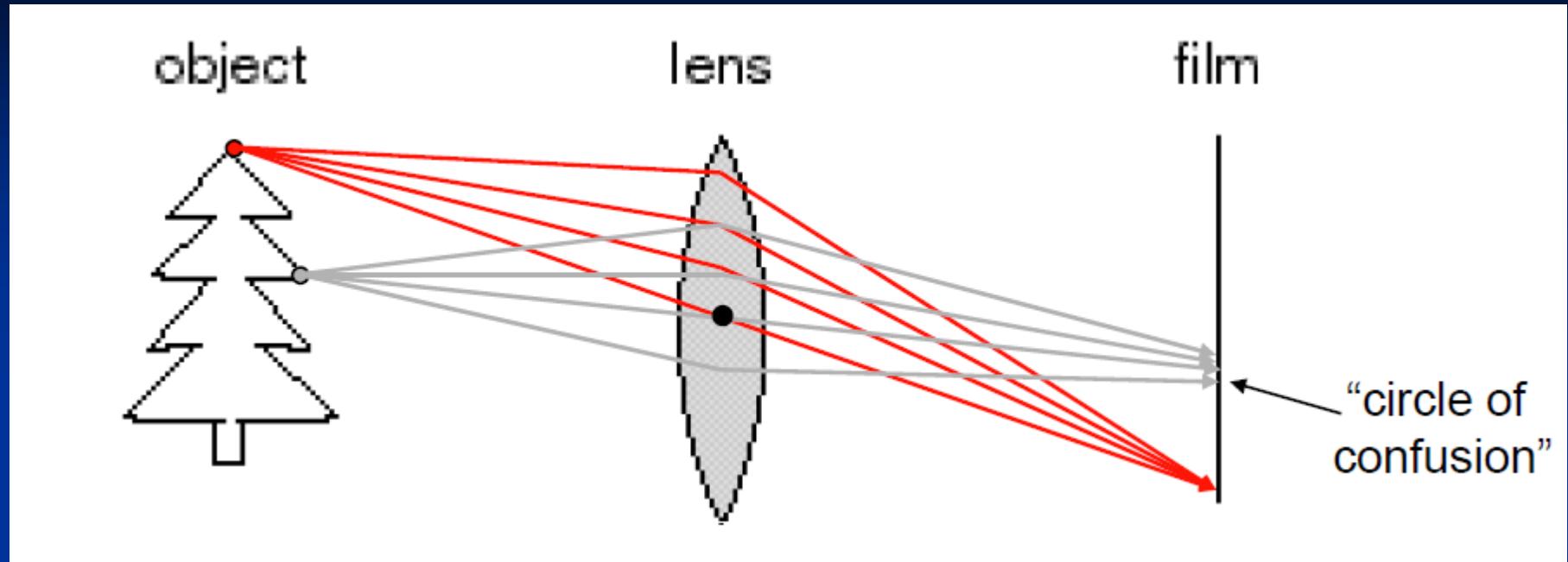


0.07 mm

# Šošovky



- Sústredujú viac svetelných lúčov z každého bodu scény



- Iba objekty v správnej vzdialenosť sa zobrazia na film zaostrené (in focus)
- Iné objekty sa zobrazia do tzv. circle of confusion nezaostrený bod
- Zmenou tvaru šošovky meníme vzdialosť zaostrenia (focus)

# Proces snímania obrazu

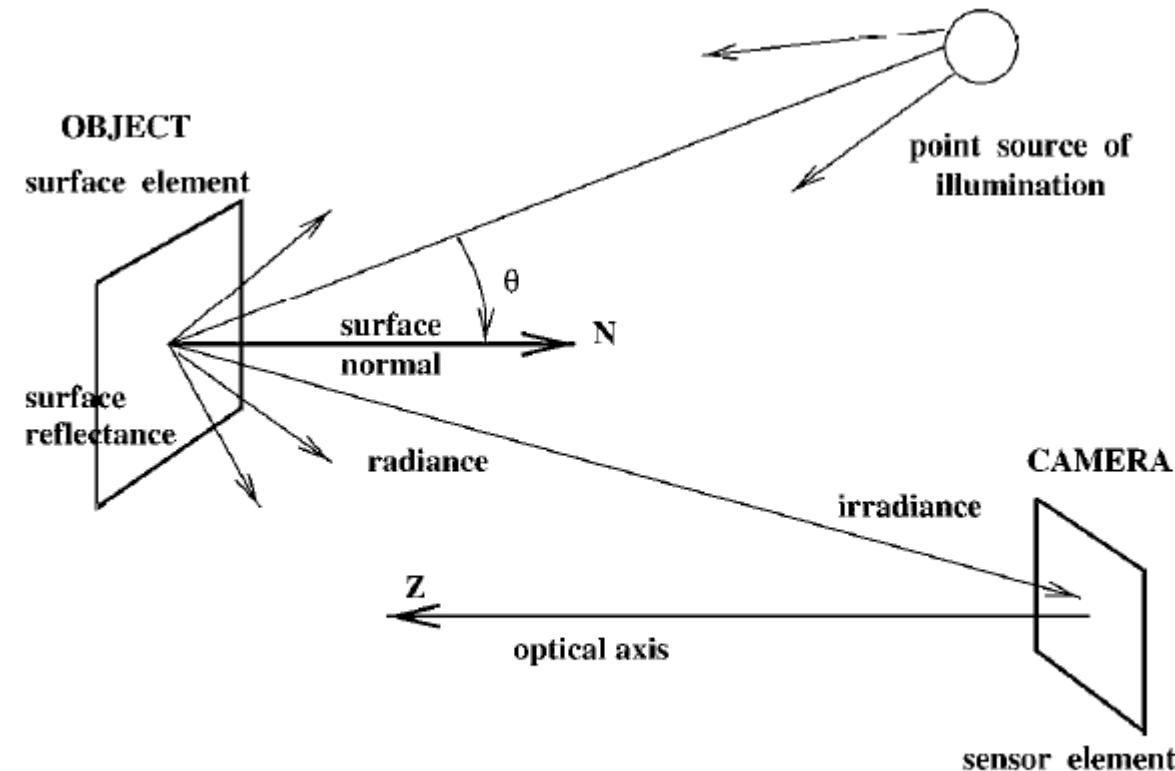
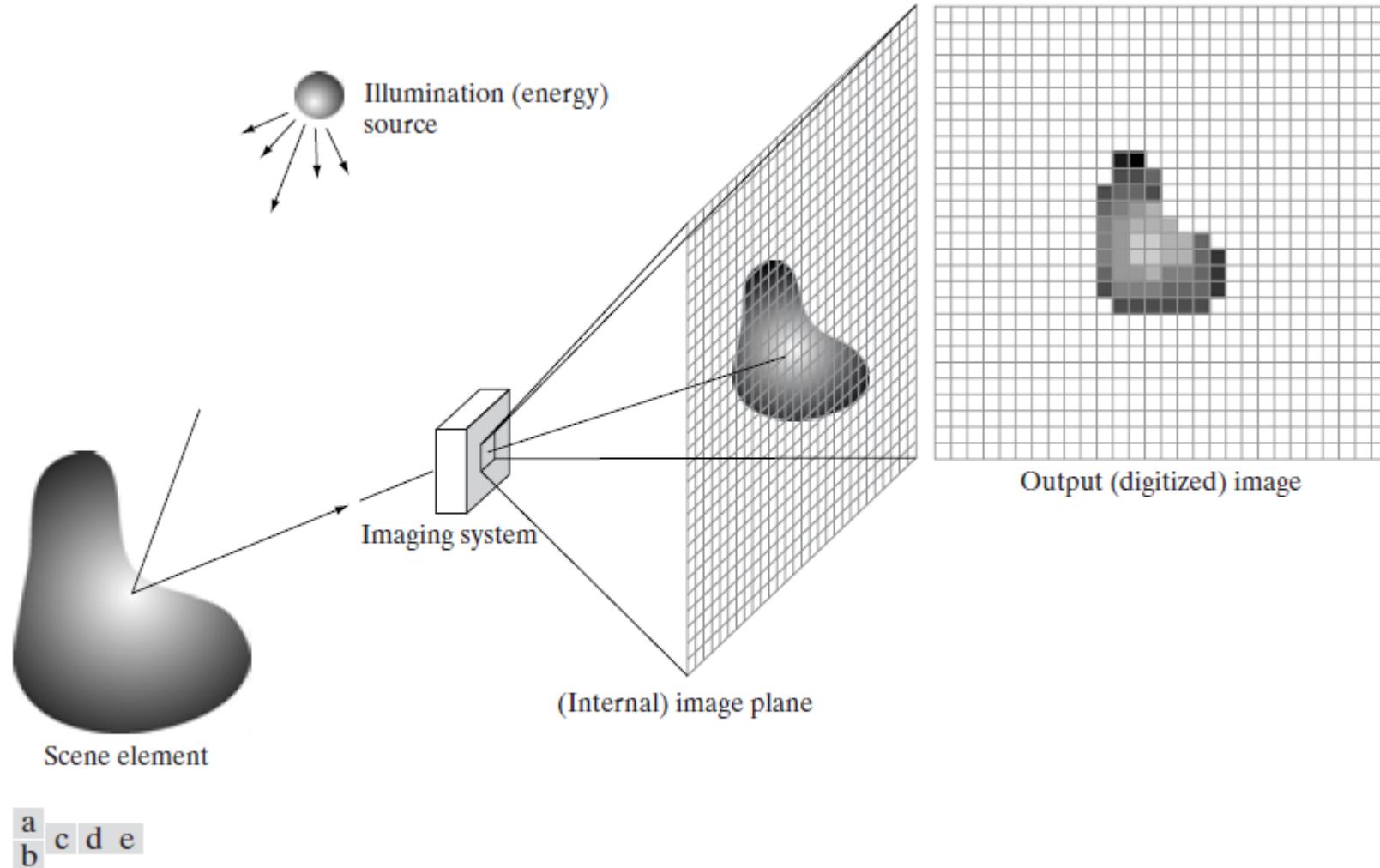


Figure 2.1: Reflection of radiation received from a single source of illumination.

# kamery

- Každá bunka v poli je fotosenzitívna dioda, ktorá konvertuje fotóny na elektróny
- Fotosenzitívna jednotka
  - CCD charge-coupled device
  - CMOS complementary metal oxide semiconductor
- Zachytávajú intenzitu svetla monochromatického obrazu



**FIGURE 2.15** An example of the digital image acquisition process. (a) Energy (“illumination”) source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

# CCD kamera

- Posuvný register
- Zachytáva elektróny počas expozičného času
- elektróny transferuje postupne na okraj – výstupného zosilovača
- Konvertované z analógového signálu na digitálny
- Má iba 1 výstup

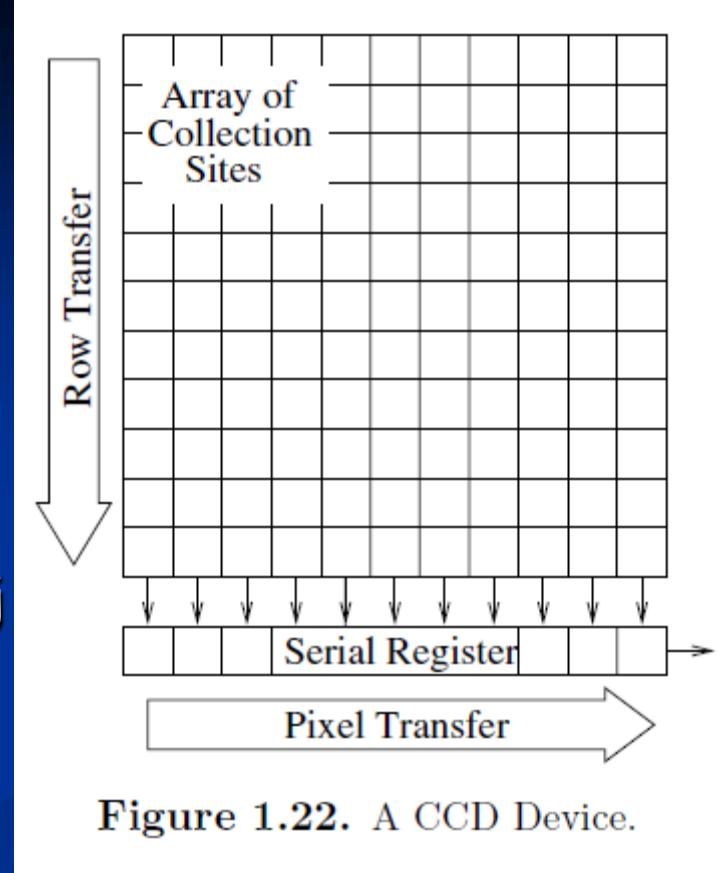
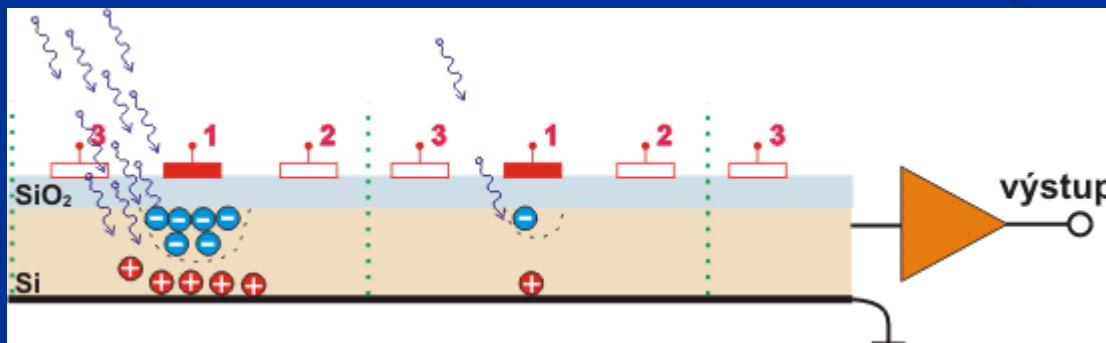


Figure 1.22. A CCD Device.



# CCD kamera

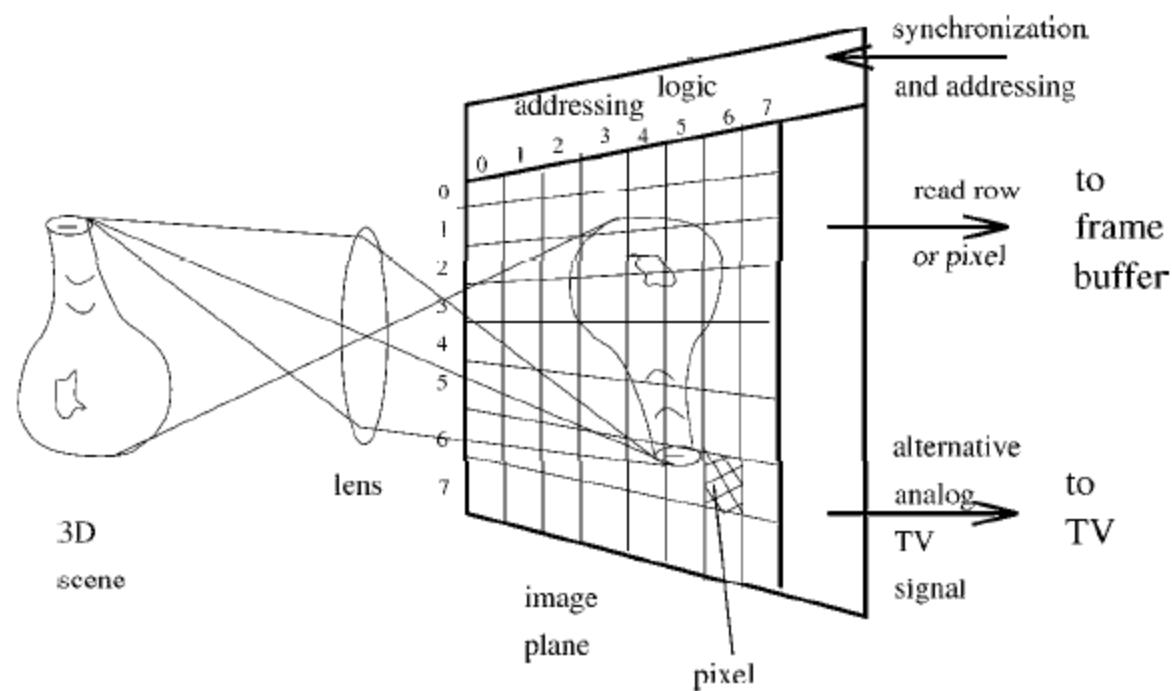
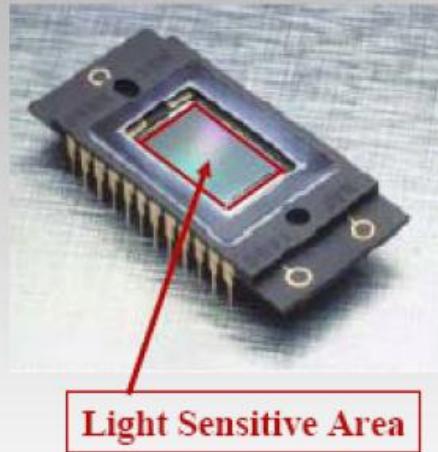
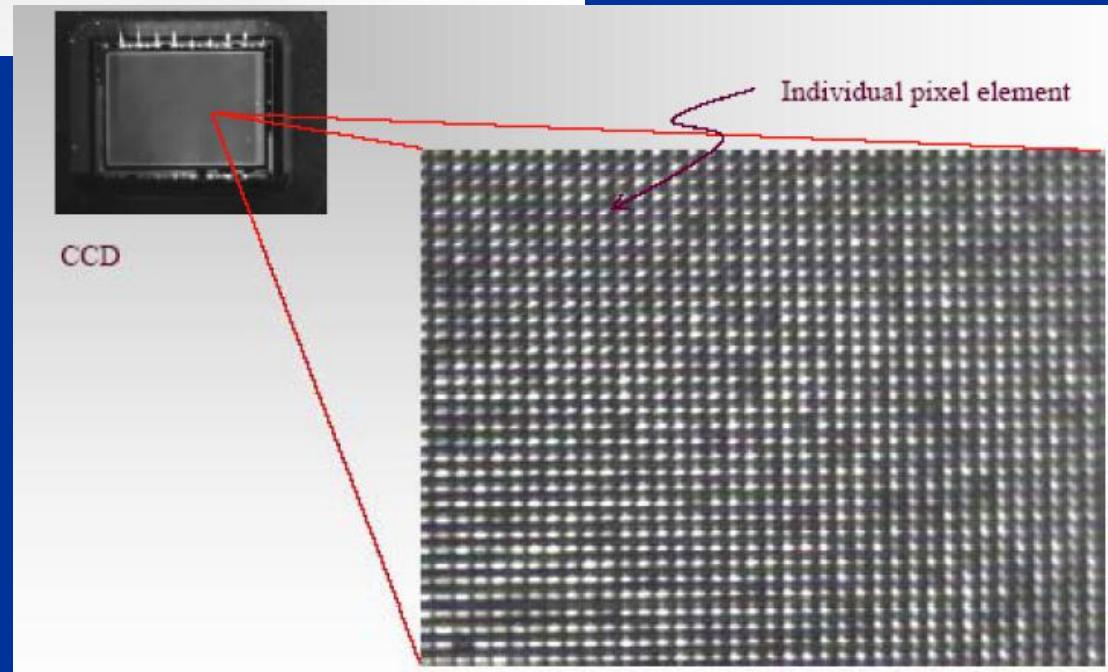


Figure 2.2: A CCD (charge-coupled device) camera imaging a vase; discrete cells convert light energy into electrical charges, which are represented as small numbers when input to a computer.

# CCD čip



- CCD replaces AgX film
- Based on *silicon chip*
- Disadvantages vs. AgX:
  - Difficulty/cost of CCD manufacture; large arrays are VERY expensive
  - "Young" technology; rapidly changing



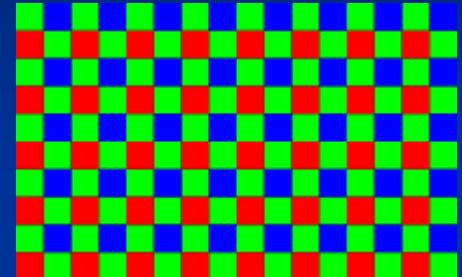
Close-up of a CCD Imaging Array

# Problémy CCD čipu

- Blooming
  - anti-blooming technology
- Nie je možné priamo pristupovať k jednotlivým pixelom
  - treba čítanie cez shift register

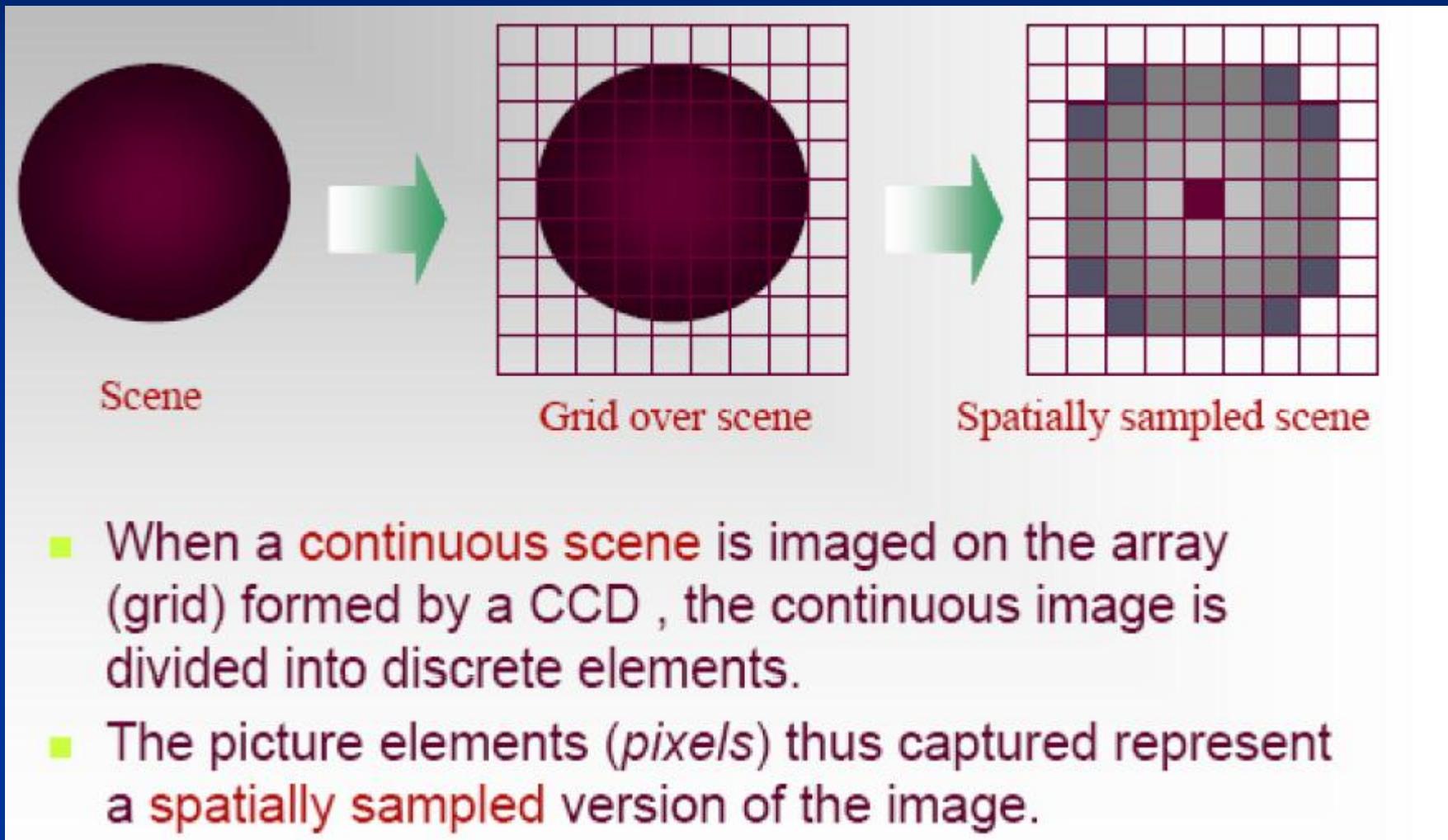
# Farebný obraz - CCD

- Jednočipové CCD
  - Farebné filtre – Bayerova maska
- Trojčipové CCD
  - 3 CCD snímače – jemná optika – drahšie
  - Lúč prechádza cez optickú sústavu, ktorá láme svetlo na jednotlivé spektra



# CMOS kamery

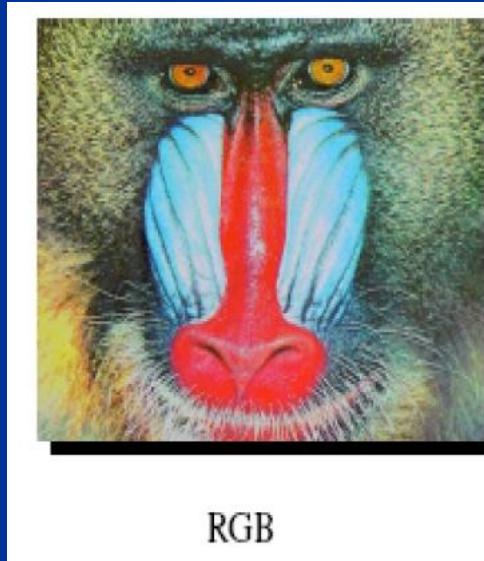
- Výhody oproti CCD
  - vyšší rozsah zachytených intenzít
  - Vysoká rýchlosť čítania
  - Random prístup k pixelom
- Nevýhoda
  - Vysoká úroveň šumu



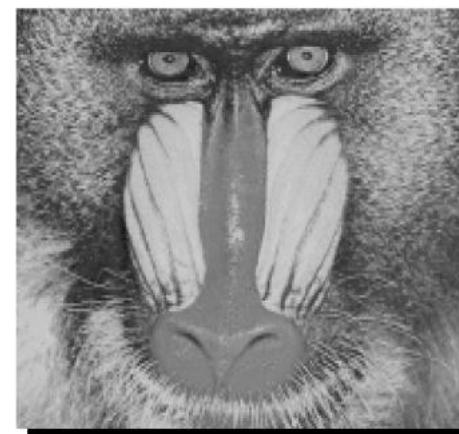
# Vlastnosti obrazu

- **Analógový obraz** je 2D obraz  $F(x,y)$  s nekonečnou presnosťou parametrov  $x$  a  $y$  a nekonečnú presnosť intenzity v každom bode  $(x,y)$
- **Digitálny obraz** je 2D obraz  $I[r,c]$  reprezentovaný diskrétnym 2D poľom vzoriek intenzít, kde každá je reprezentovaná limitovanou presnosťou

- **Šedotónový obraz** (grey scale image) je monochromatický obraz  $I[r,c]$  s jednou hodnotou intenzity pre každý pixel
- **Multispektrálny obraz** je 2D obraz  $M[x,y]$  s vektorom hodnôt pre každý bod obrazu (farebný obraz – 3 hodnoty)
- **Binárny obraz** je digitálny obraz s hodnotami v pixeloch 0 alebo 1



RGB

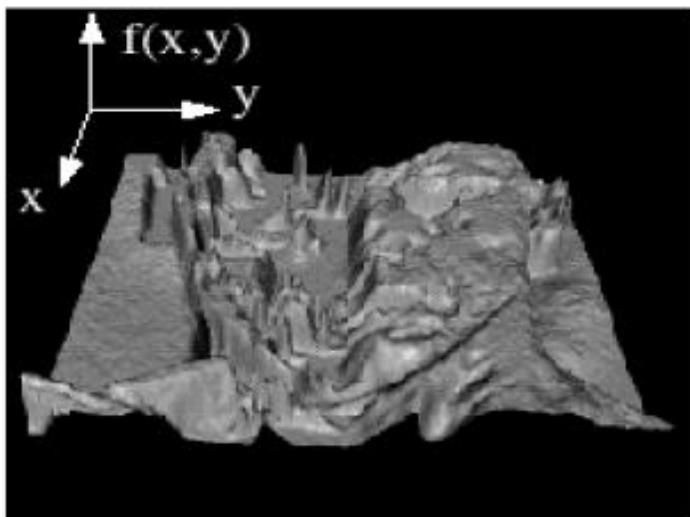
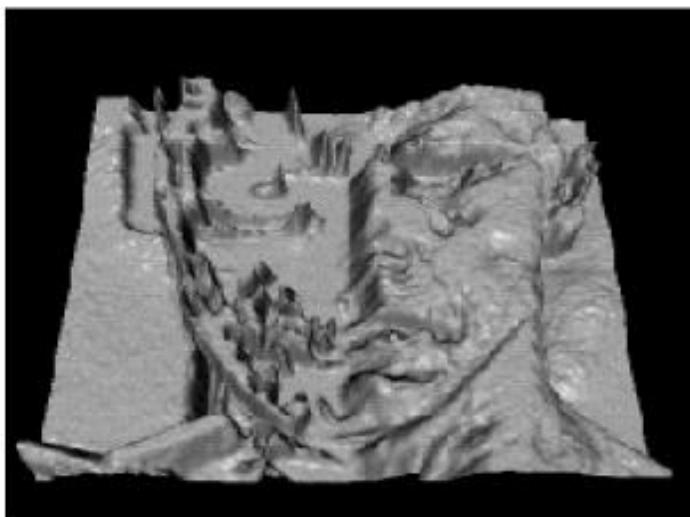


Greyscale



Binary

# Obraz ako funkcia

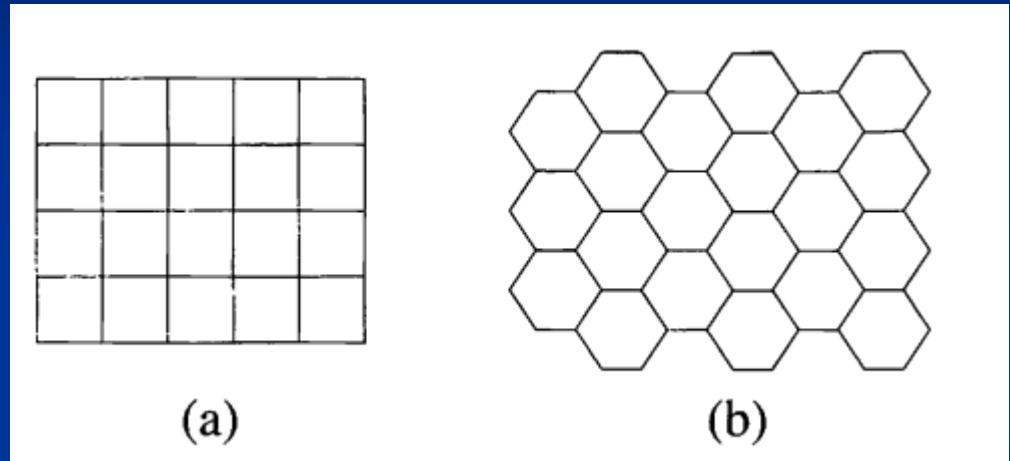


# Digitalizácia obrazu

- Digitalizácia obrazu je **navzorkovanie (sampling)** spojitého obrazu do mriežky
- Mriežka je zvyčajne pravidelného tvaru štvorcové a hexagonálne
- Ďalším aspektom vzorkovania je nastavenie vzdialosti medzi vzorkovanými bodmi
  - Čím menšia vzorkovacia vzdialosť tým väčšie rozlíšenie

# Typy mriežky

- 768x576 PAL
- 640x480 NTSC
- 1920x1080 HD



**Figure 2.2:** (a) Square grid. (b) Hexagonal grid.

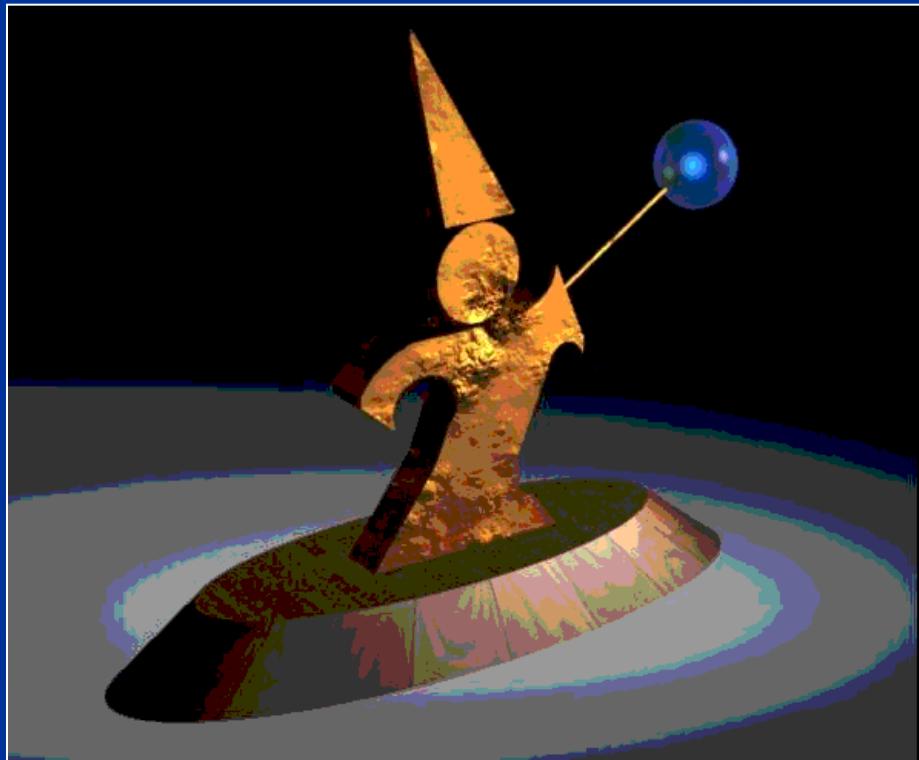
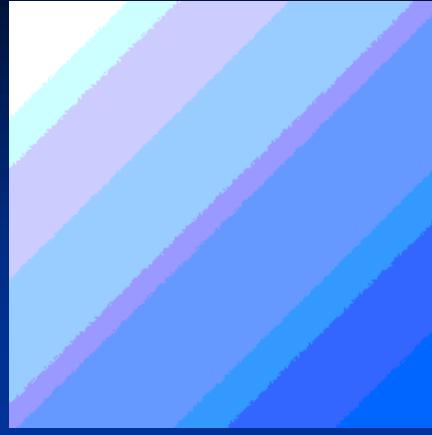
- Raster je mriežka na ktorej sú definované susednosti

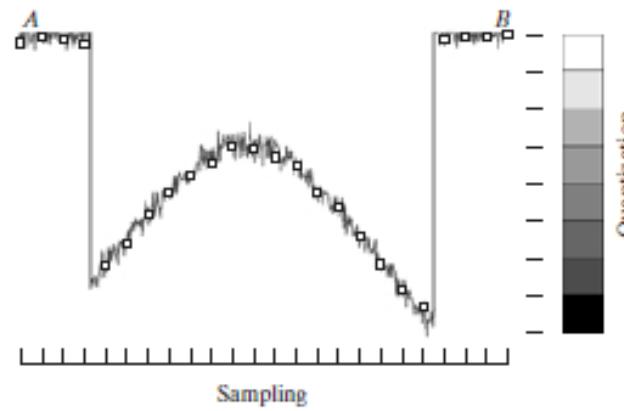
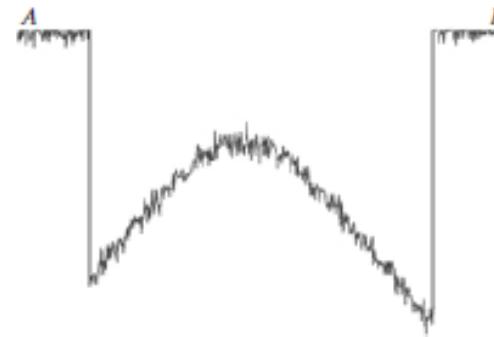
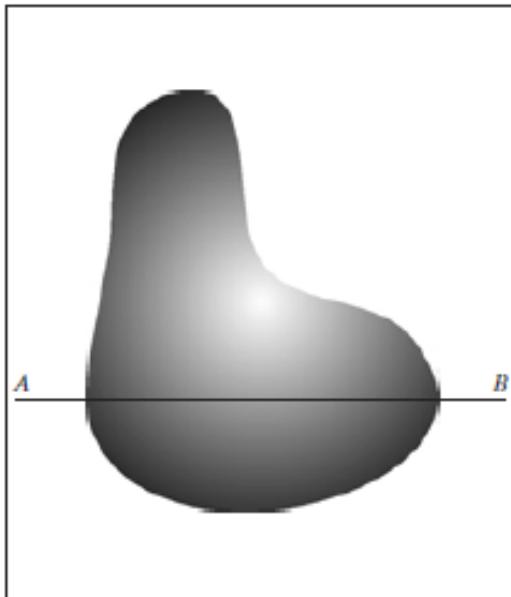
# Kvantizácia

- je prechod medzi spojitu hodnotou obrazovej funkcie a jej digitálnym ekvivalentom
- Kvantizácia na k rovnakých intervalov
- $k = 2^b$ , b je počet bitov
- Malé k – vznikajú nepravé kontúry

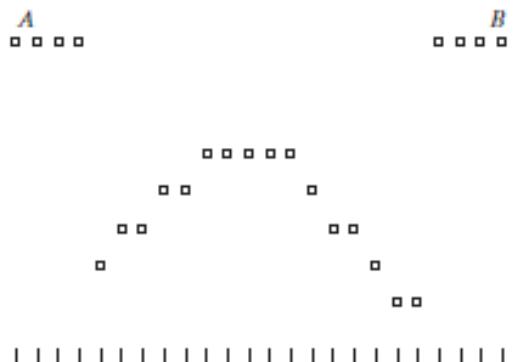
Riešenie :

- Aspoň 100 úrovní šedej
- Rozdelenie na k nepravidelných intervalov
- Človek je schopný rozpoznať asi 60 odtieňov šedej

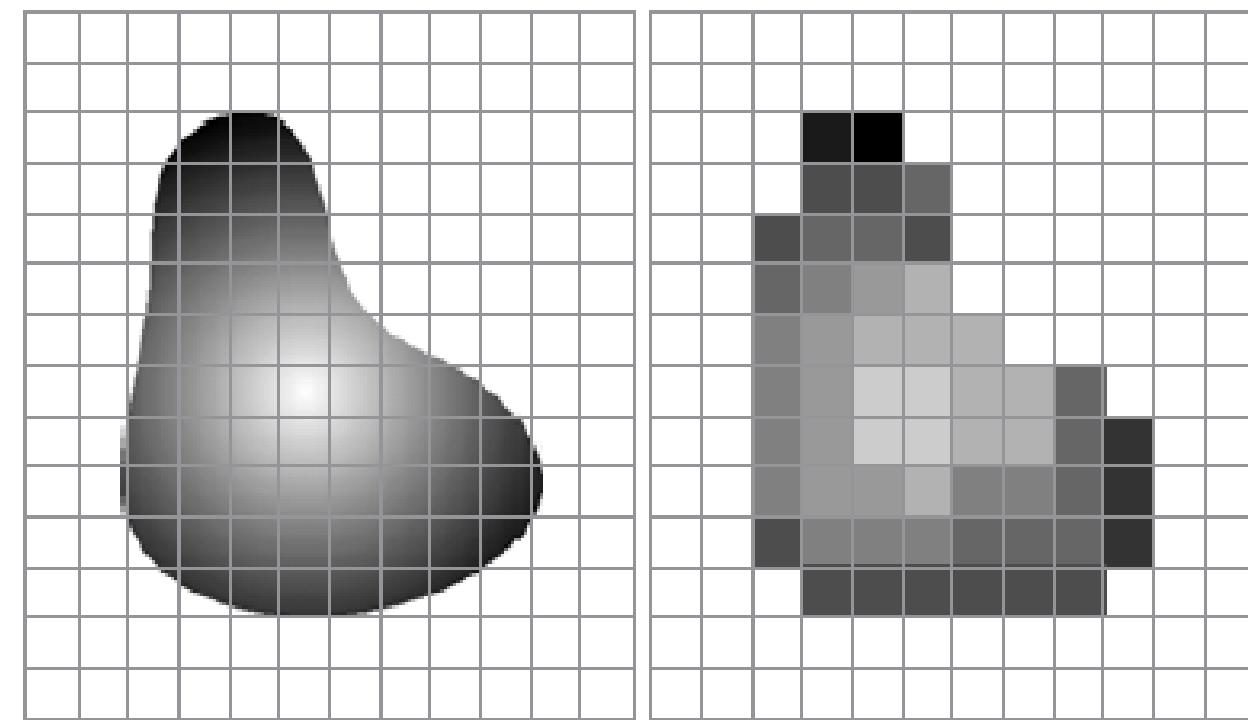




a b  
c d



**FIGURE 2.16** Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.



a b

**FIGURE 2.17** (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

# Problém priestorovej kvantizácie

0	0	0	0	0	0	0	0	0	0
0	8	0	0	0	0	8	8	0	0
0	0	0	0	0	0	8	8	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
8	8	8	8	8	8	8	8	8	8
0	0	0	0	0	0	0	0	0	0
8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8
0	0	0	0	0	0	0	0	0	0

(a)

2	0	0	4	0
0	0	0	4	0
4	4	4	4	4
4	4	4	4	4
4	4	4	4	4

(b)

0	0	0	0	0	0	0	0	0	0
0	8	0	0	0	0	8	8	0	0
0	0	0	0	0	0	8	8	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
8	8	8	8	8	8	8	8	8	8
0	0	0	0	0	0	0	0	0	0
8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	8	8
0	0	0	0	0	0	0	0	0	0

(c)

2	0	4	4
0	0	0	0
4	4	4	4
8	8	8	8

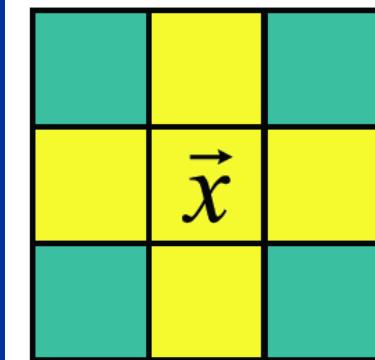
(d)

Figure 2.9: (a)  $10 \times 10$  field of tiles of brightness 0 or 8. (b) Intensities recorded in a  $5 \times 5$  image of precisely the brightness field at the left where each pixel senses the average brightness of a  $2 \times 2$  neighborhood of tiles. (c) Image sensed by shifted camera “one tile down and one tile to the right”. Note that the quantized brightness values depend on both the actual pixel size and position relative to the brightness field. (d) Intensities recorded from the shifted camera in the same manner as in (b). Interpretation of the actual scene features will be problematic with either image (b) or (d).

# Susednosť a spojitost' pixlov

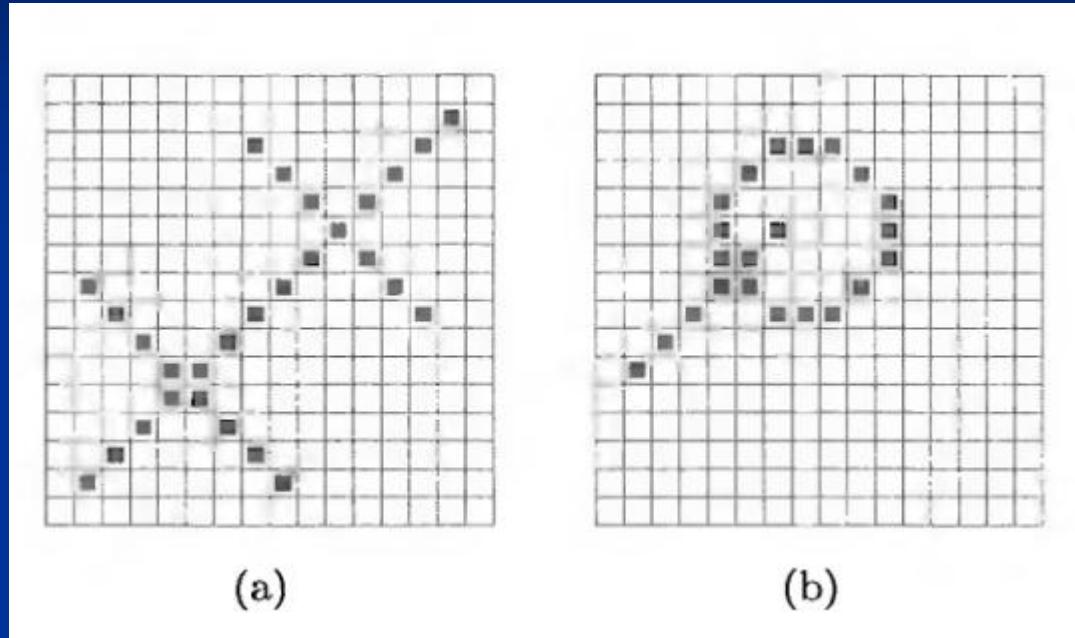
- 4-neighborhood
  - For pixel  $(i, j)$   
 $\{(i-1, j), (i+1, j), (i, j-1), (i, j+1)\}$
- 8-neighborhood
  - For pixel  $(i, j)$   
 $\{(i-1, j), (i+1, j), (i, j-1), (i, j+1), (i-1, j-1), (i+1, j+1), (i+1, j-1), (i-1, j+1)\}$

- Ak existuje cesta medzi ľubovoľným 2 obrazovými bodmi, tieto nazývame spojité



4-neighbourhood of  $\vec{x}$   
 8-neighbourhood of  $\vec{x}$

# Paradox pretínajúcej čiary



- Obr. a: ak uvažujeme 4-spojitost' čiary v ľavo nie sú spojité
- Obr. b: ak uvažujeme 8-spojitost': čiara nepretína kruh lebo nemaju spoločný bod

# Metriky

Euklidovská

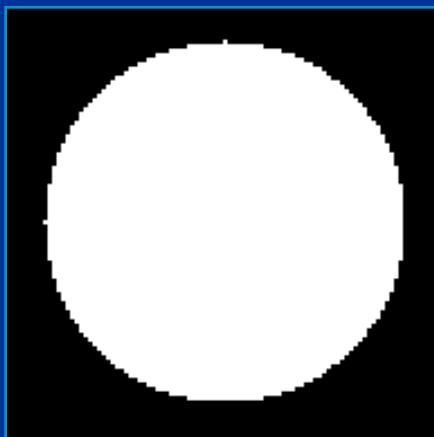
$$D_e(p_1, p_2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

City Block (Manhattan)

$$D_4(p_1, p_2) = |x_1 - x_2| + |y_1 - y_2|$$

Chessboard

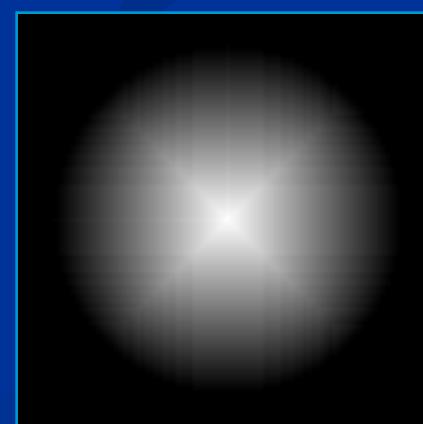
$$D_8(p_1, p_2) = \max(|x_1 - x_2|, |y_1 - y_2|)$$



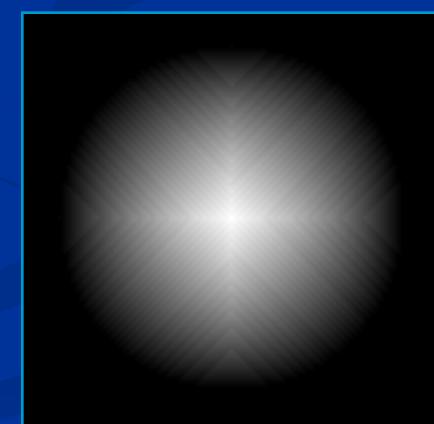
Original



Euklidovská

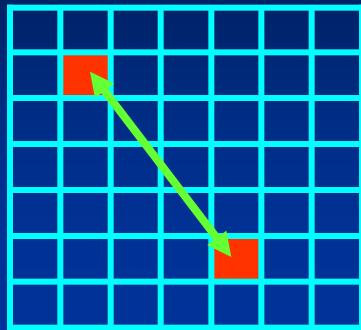


City block



Chessboard

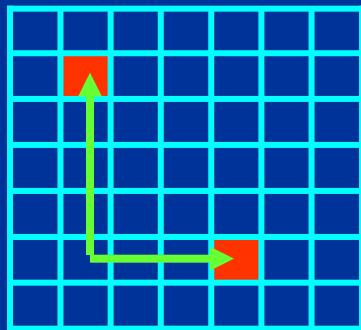
# Metriky



Euklidovská

$$d([i, j], [k, l]) = \sqrt{(i - k)^2 + (j - l)^2}$$

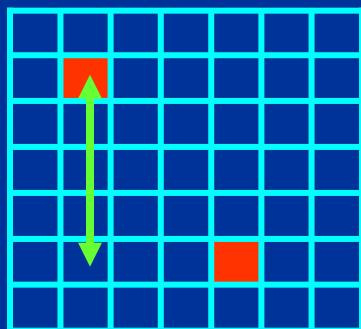
$$d = 5$$



Manhattan  
(City-block)

$$d([i, j], [k, l]) = | i - k | + | j - l |$$

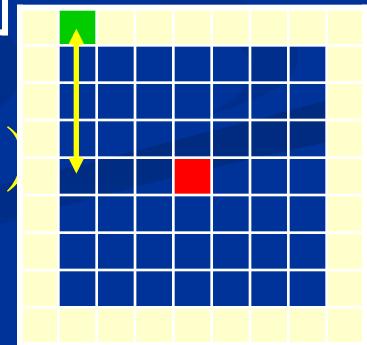
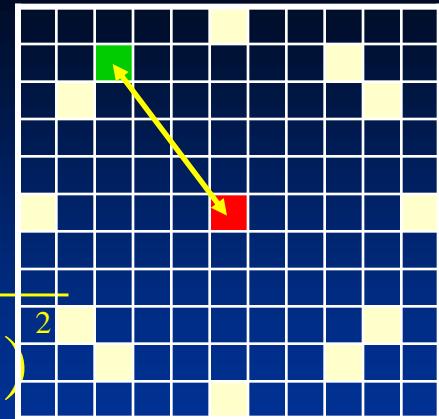
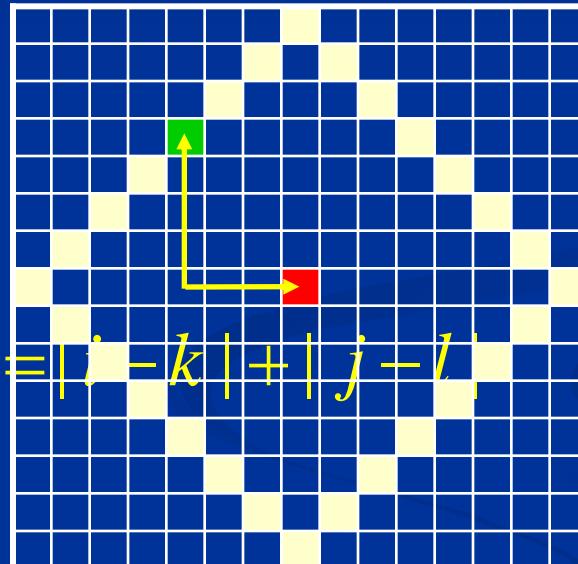
$$d = 7$$



Chessboard

$$d([i, j], [k, l]) = \max(| i - k |, | j - l |)$$

$$d = 4$$



# Distance Transform

Operátor aplikovaný na binárne obrazy

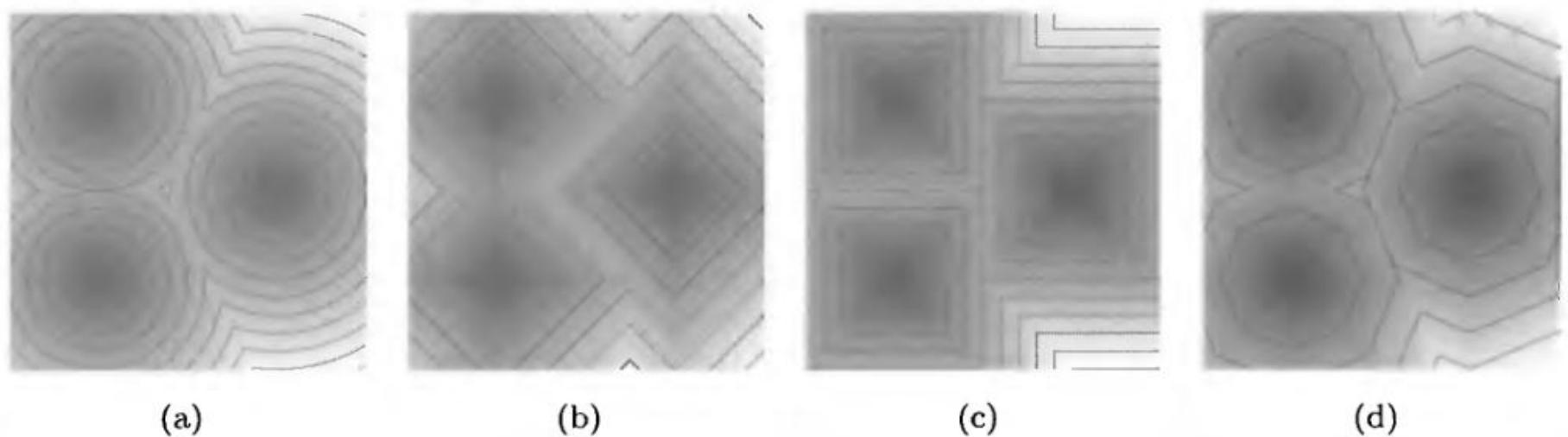
0	0	0	0	0	0	1	0
0	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0
0	1	1	0	0	0	1	0
0	1	0	0	0	0	0	1
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0

**Figure 2.8:** Input binary image. Gray pixels correspond to objects and white pixels to background.

5	4	4	3	2	1	0	1
4	3	3	2	1	0	1	2
3	2	2	2	1	0	1	2
2	1	1	2	1	0	1	2
1	0	0	1	2	1	0	1
1	0	1	2	3	2	1	0
1	0	1	2	3	3	2	1
1	0	1	2	3	4	3	2

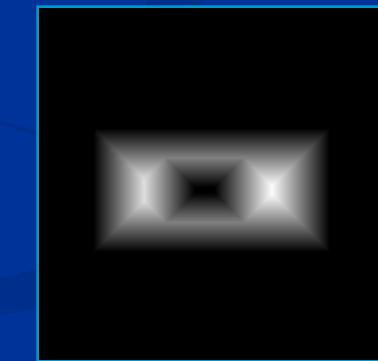
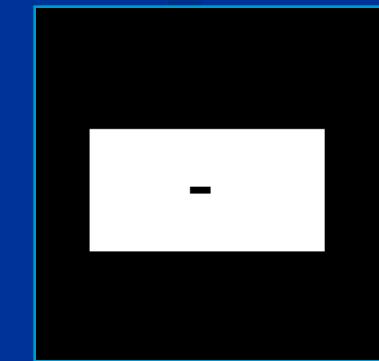
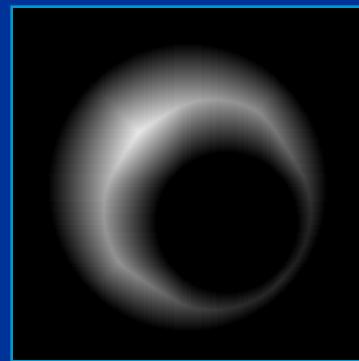
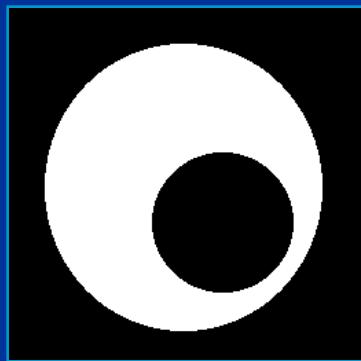
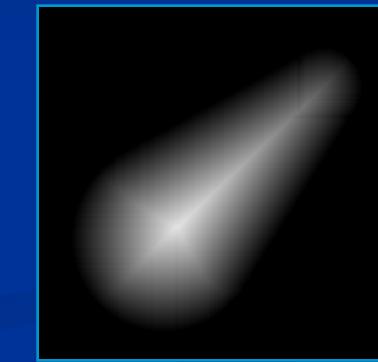
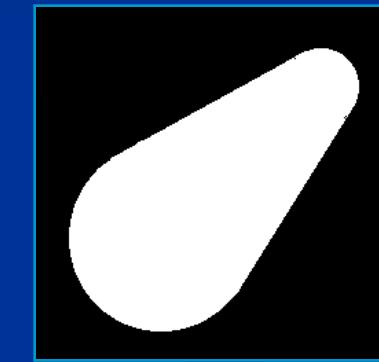
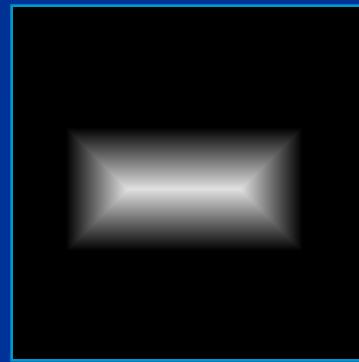
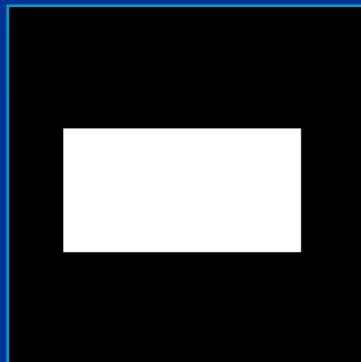
**Figure 2.9:** Result of the distance transform when the distance  $D_4$  is considered in calculations.

# Distance Transform



**Figure 2.11:** Illustration of four distances used often in distance transform calculations. The input image consists of three isolated ‘ones’. The output distance is visualized as the intensity, lighter values denote higher distances. Contour plots are superimposed for better visualization. (a) Euclidean distance  $D_E$ . (b) City block distance  $D_4$ . (c) Chessboard distance  $D_8$ . (d) Quasi-Euclidean distance  $D_{QE}$ .

# Distance Transform

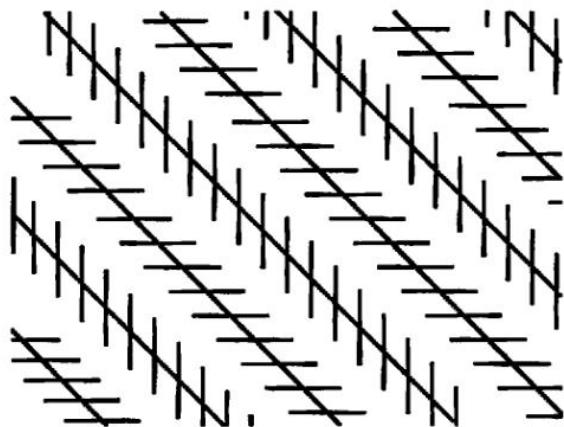


# Vnímanie obrazu - kontrast

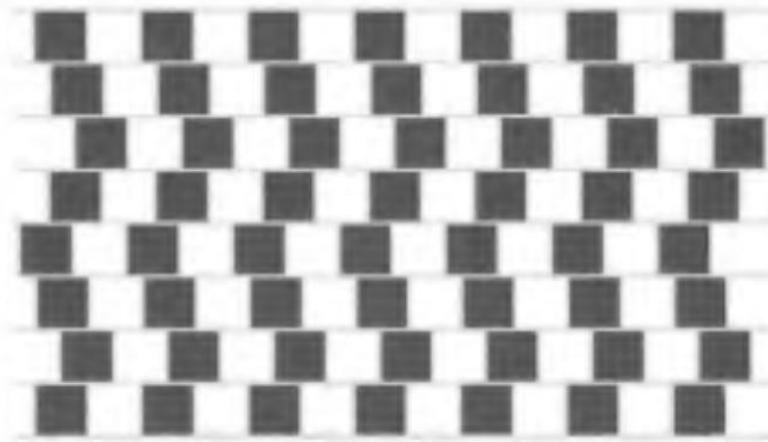


**Figure 2.17:** Conditional contrast effect. Circles inside squares have the same brightness and are perceived as having different brightness values.

# Vnímanie obrazu – vizuálne ilúzie

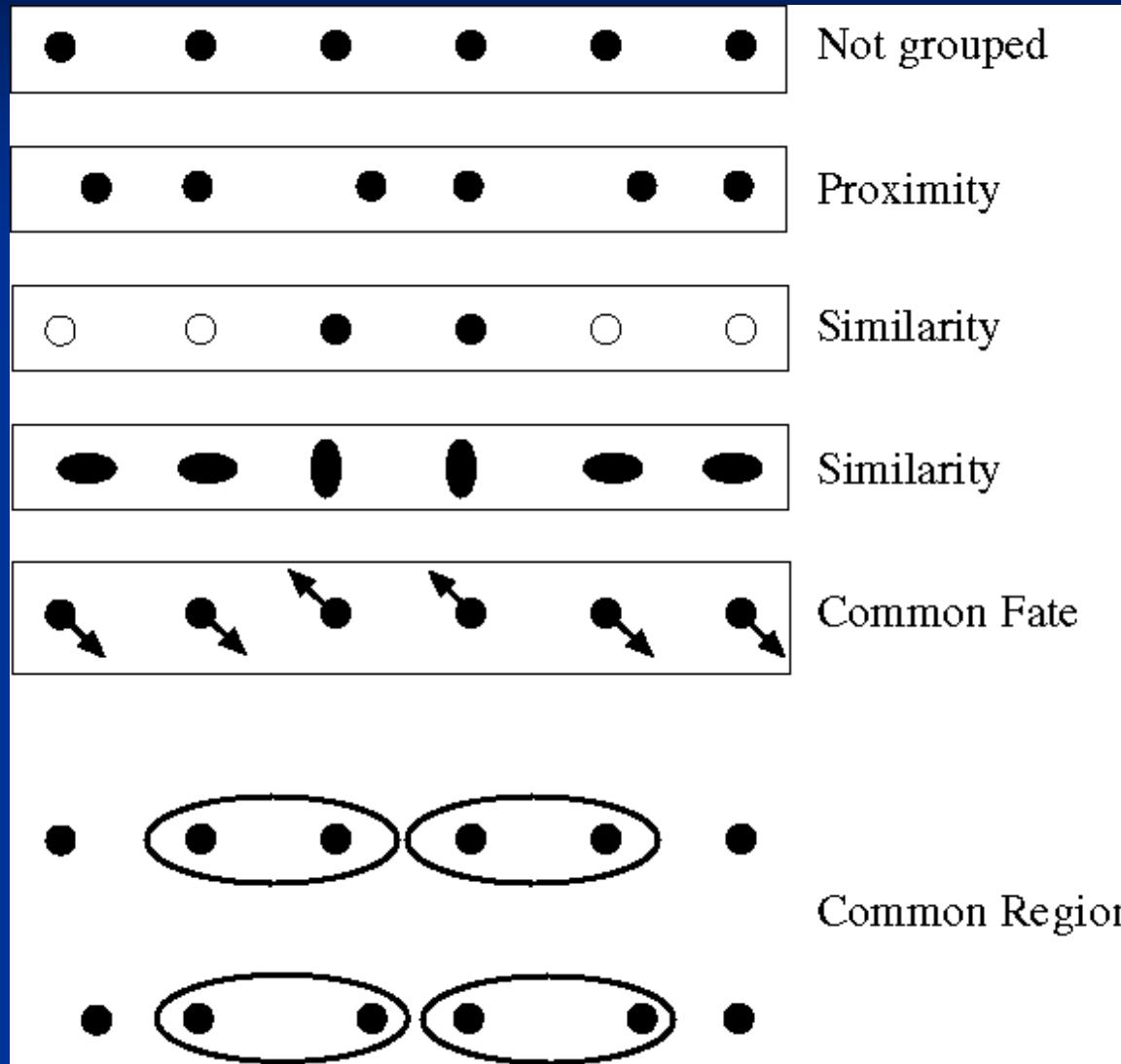


**Figure 2.19:** Disrupted parallel diagonal lines.



**Figure 2.20:** Horizontal lines are parallel, although not perceived as such.

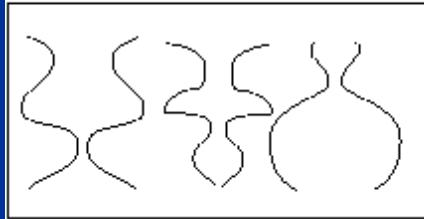
# Perceptual grouping - Gestalt laws



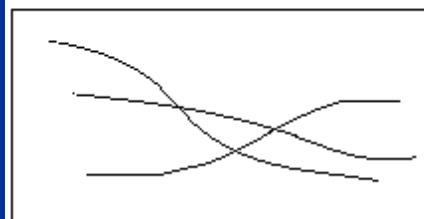
# Gestalt laws



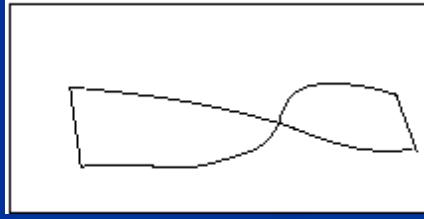
Parallelism



Symmetry



Continuity



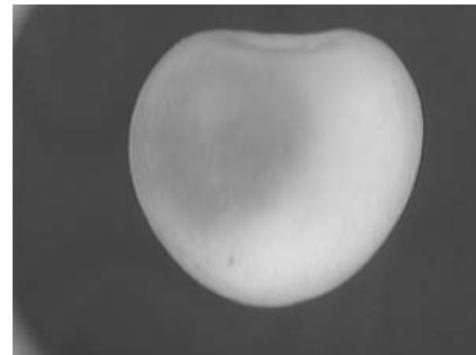
Closure

# Histogram

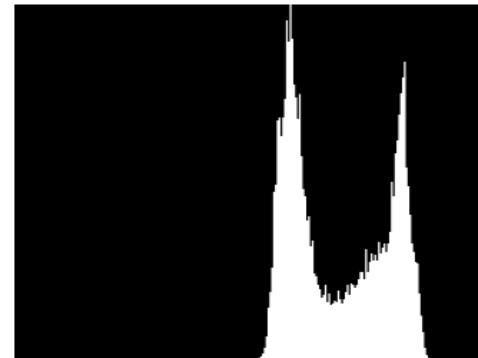
22 DEFINITION *The histogram  $h$  of gray-tone image  $I$  is defined by*

$$h(m) = |\{(r, c) \mid I(r, c) = m\}|,$$

*where  $m$  spans the gray-level values.*



a) Image of a bruised cherry



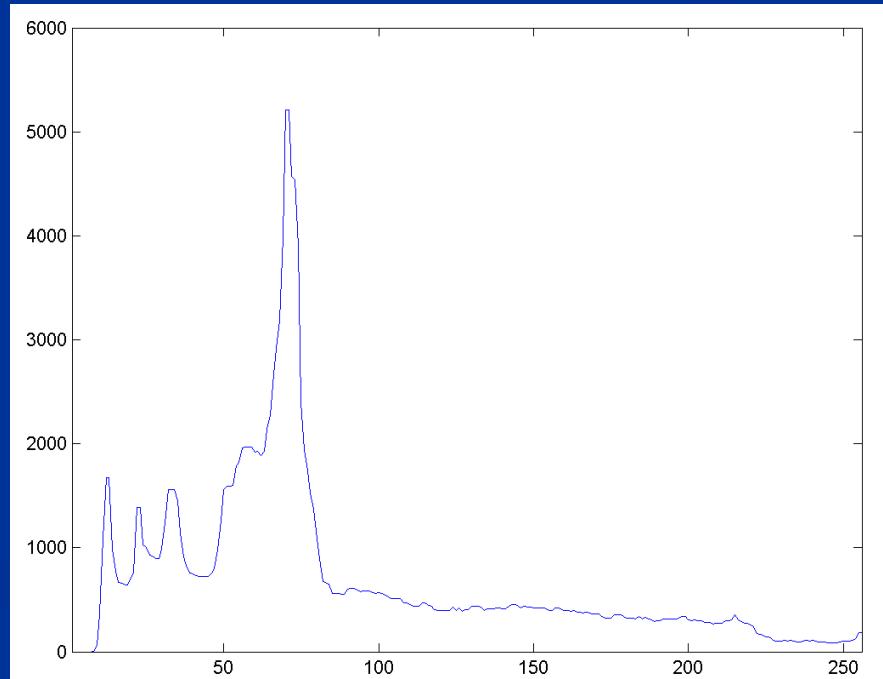
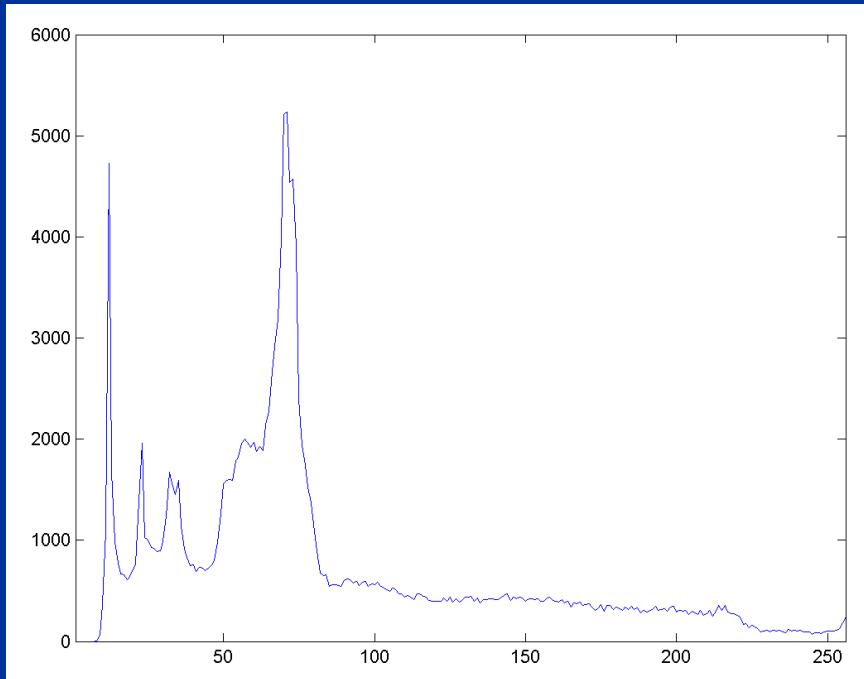
b) Histogram of the cherry image

Figure 3.22: Histogram of the image of a bruised cherry displaying two modes, one representing the bruised portion and the other the nonbruised portion. (Courtesy of Patchrawat Uthaisombut.)

# Histogram

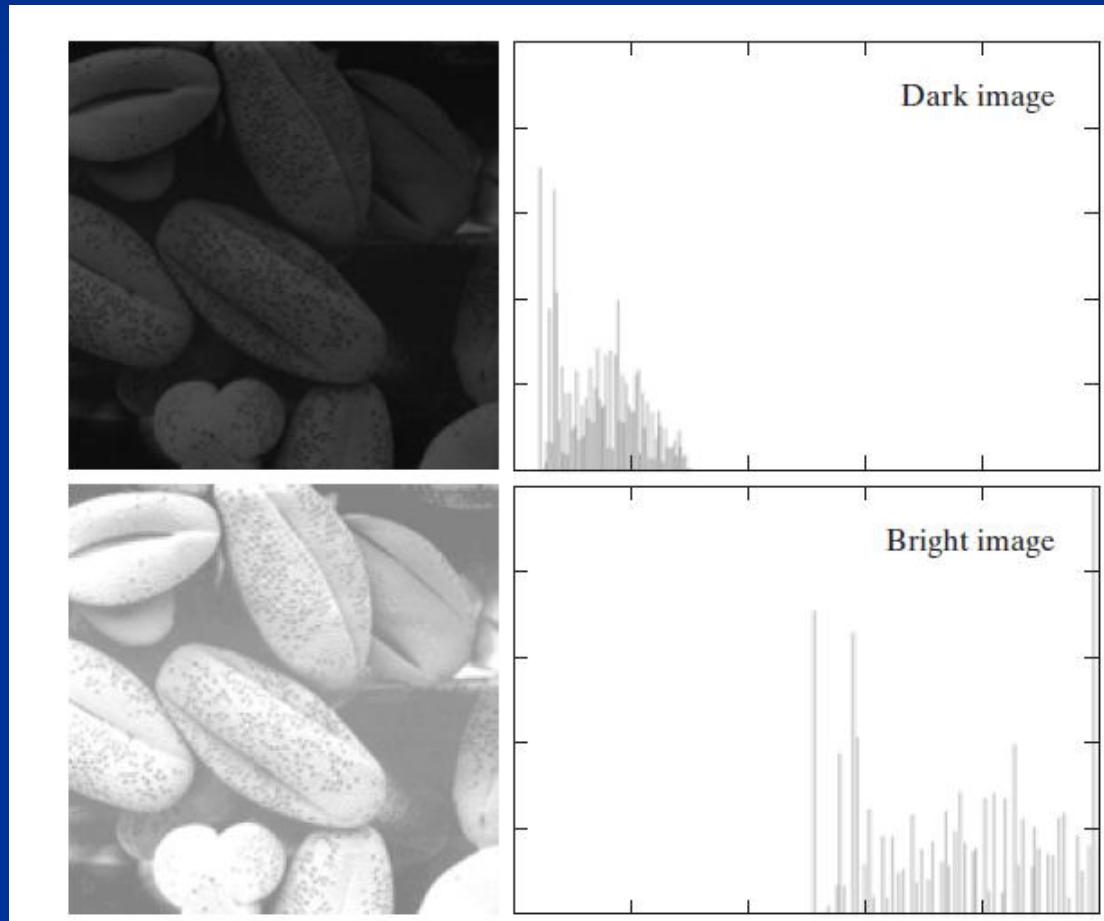
každej úrovni jasu priradí zodpovedajúcu početnosť v obrazu

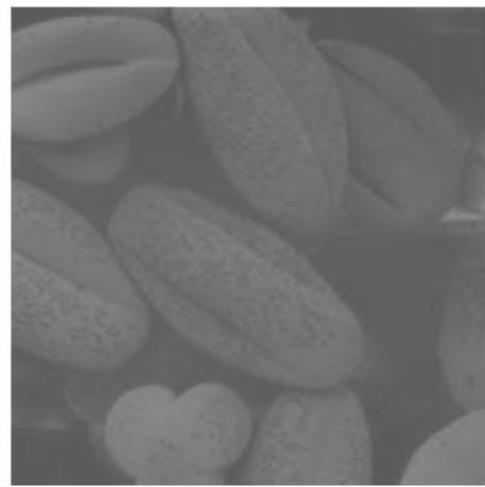
vyhľadenie histogramu



# Vlastnosti histogramu

- Jasový histogram je globálny deskriptor





Low-contrast image



High-contrast image

# Prahovanie histogramu

prahová (hraničná) hodnota:  $p(i)$ ,  $i=0,..n$

reprezentatívna farba:  $f(i)$ ,  $i=1,..n$  - voľba

$\forall$  body obrazu s intenzitou  $I(x,y)$

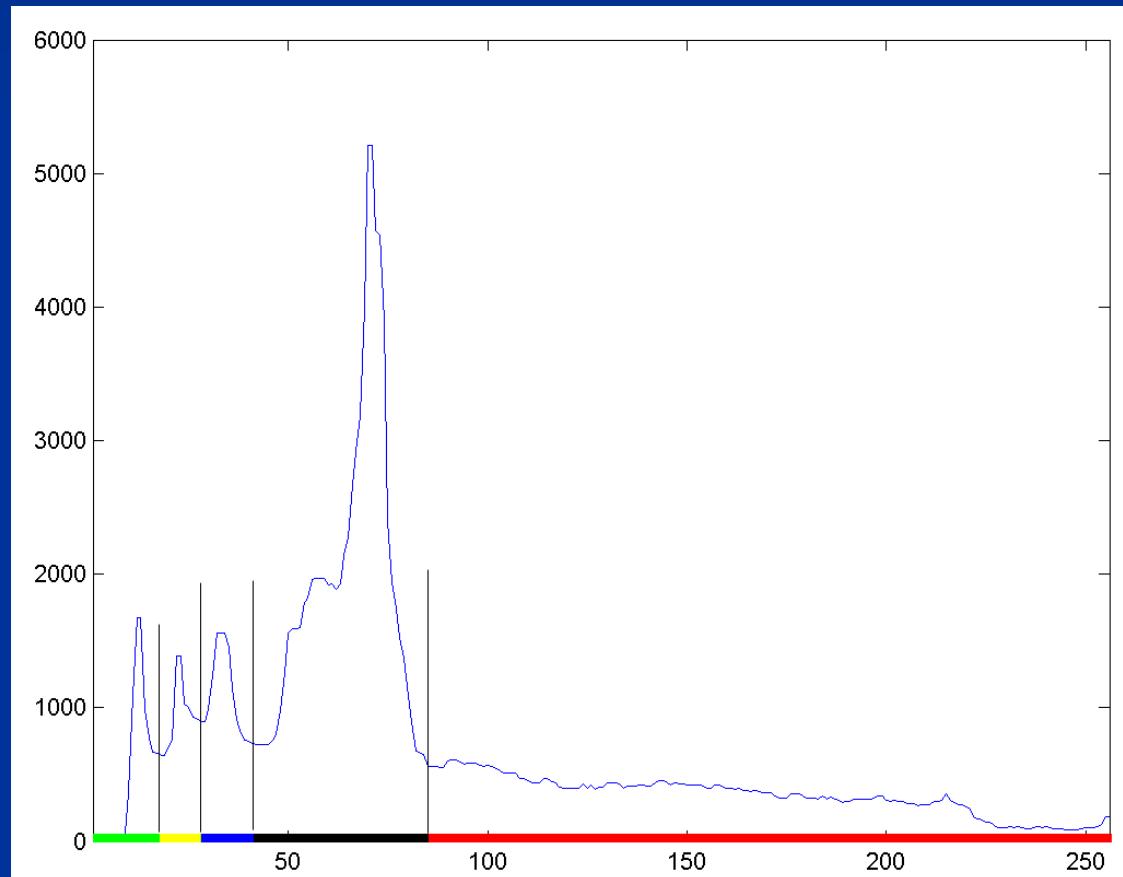
$\forall i=1,..n$

ak  $p(i-1) < I(x,y) \leq p(i)$  tak  $I(x,y) = f(i)$

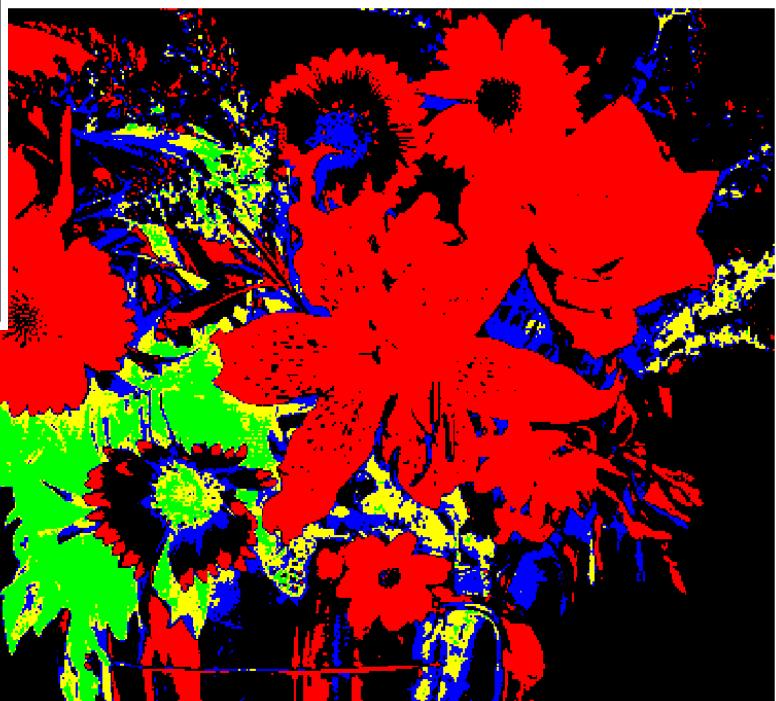
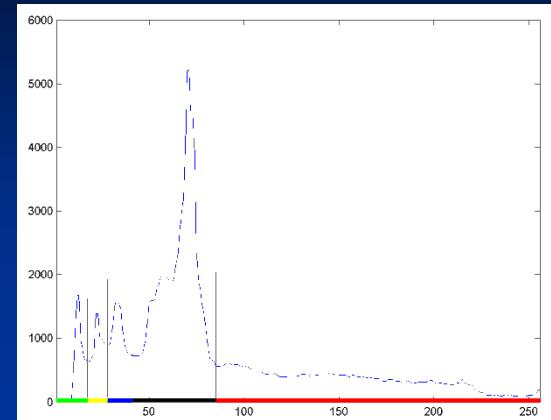


# Prahovanie

adaptívne – hľadáme lokálne minimá

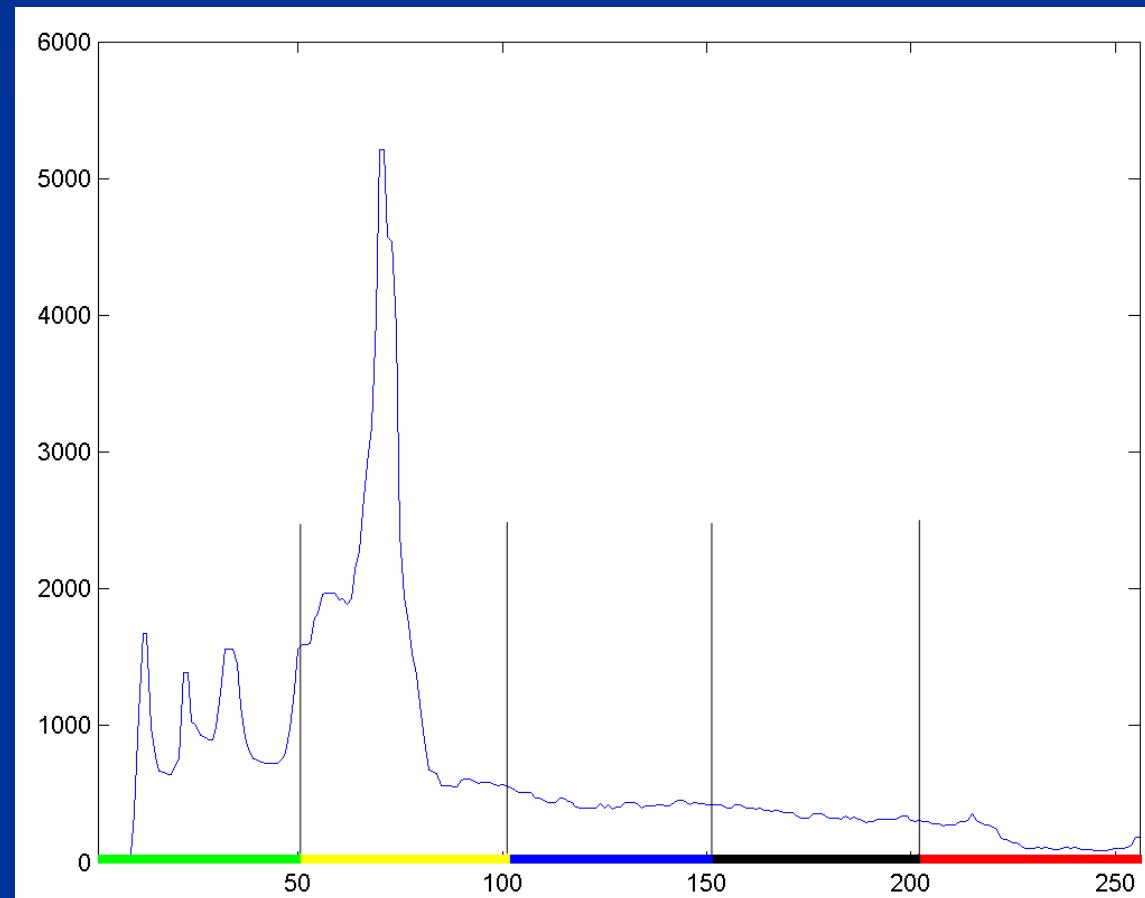


# Výsledok

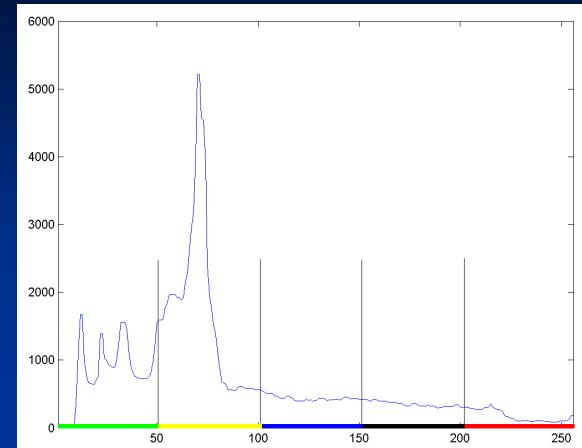


# Prahovanie

pevný prah – pravidelné intervaly



# Výsledok



# Porovnanie

adaptívne vs. pevné



účel použitia