IMAGE PROCESSING

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Assessment

- Mid-term: %19.5
- Project grade: %45.5
- Final: %35

- IEEE Trans. on Image Processing
- IEEE Trans. on Circuits and Systems for Video Techology
- IET Image Processing
- IEEE Trans. on Consumer Electronics
- Signal Processing: Image Communication
- http://ieeexplore.ieee.org/
- www.sciencedirect.com

Course Content

- Basic concepts
- MATLAB
- File types and basic operations
- Image enhancement
- Image quantization (Lloyd Max)
- Pixel neighbor operations
- Image segmentation
- Color image processing
- Morphological image processing
- Frequency domain processing
- Image compression

Textbook

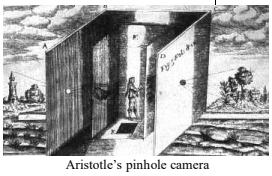
- Digital Image Processing (2nd Edition)
  Rafael C. Gonzalez, Richard E. Woods , 2002
- Digital Image Processing Using MATLAB(R)
  Rafael C. Gonzalez , 2003
- Image Processing Handbook The: Second Edition
  John C. Russ , 2006

IMAGE PROCESSING Lecture-1

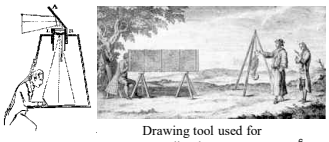
Basic Concepts

Camera Obscura: A Pinhole Camera

- History
  - Chinese philosopher Mo-Ti (5th century BC) was the earliest to report such a device
  - Aristotle (384-322 BC) understood the optical principle of pinhole projection
  - 11th century, Al-Haytham wrote a book on optics
  - 1490 Leonardo Da Vinci gave a well defined description
  - Lenses were used in 16th century allowing more light
  - Common use as a drawing t in 17th century



Aristotle's pinhole camera



Drawing tool used for recording human anatomy

First photograph

- Inspired by the newly-invented art of lithography (a printing technique), after several years of work Joseph Nicéphore Niépce succeded in recording an image captured by a camera obscura (1826)

1952 reproduction with touchups

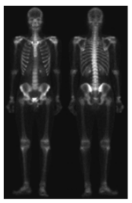
History of photograph

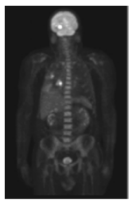
- The word photography was first used in the year 1839, "the year the invention of the photographic process was made public".
- Eastman Kodak establishes his company (at age 24) in 1880. After roll film is introduced in 1889 Photographic process becomes widely-used.
- Louis Lumiere invents the first motion picture camera (Cinematographe) in 1895
- 1936: development of Kodachrome, the first color multi-layered color film.
- In 1971 C-41 color negative process introduced
- 199X- Digital age

- Digital Image Processing:
  İmgeyi iyileştirmek, dönüştürmek ya da bilgi çıkartmak
- Computer Vision:
  İmgeleri işleyerek gerçek dünya ile ilgili bilgi çıkartmak.

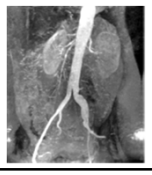
Applications

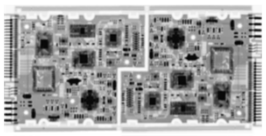
Gamma-ray imaging:





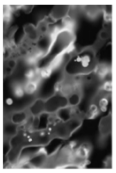
X-ray imaging:

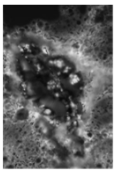


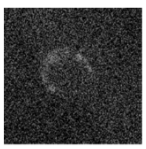


Applications

UV imaging:



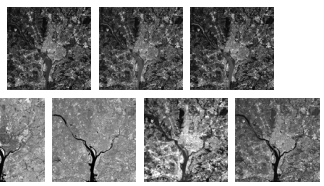




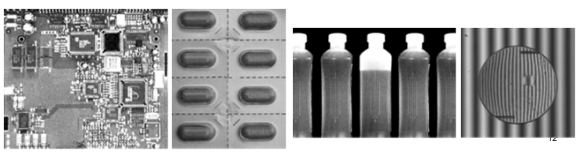
Visible and IR imaging:

Uygulama Alanları

Multi-spectral imaging:

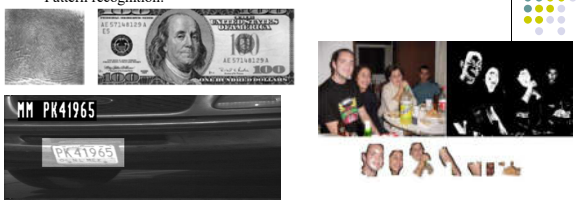


Quality control:

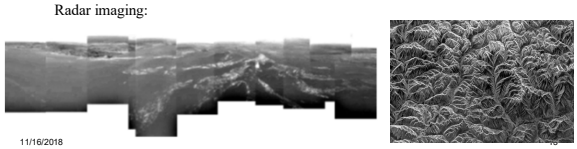


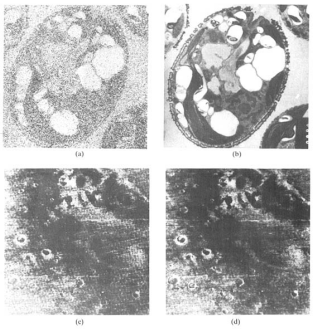
Applications

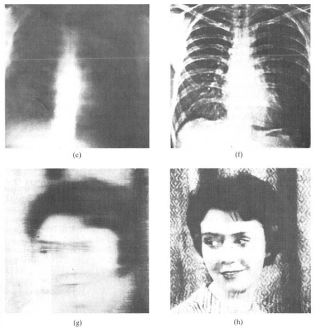
Pattern recognition:



Radar imaging:





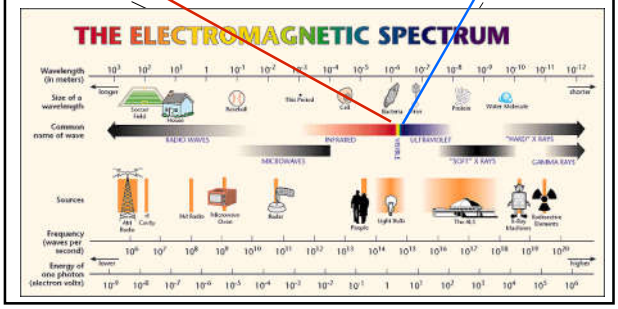


Electromagnetic Spectrum

Visible range

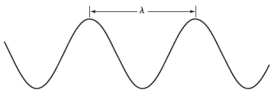
700 nm

400 nm



Light and EM Spectrum

- Cam prizmadan geçirilen güneş ışığının sürekli renk spektrumu oluşturduğunu kim bulmuştur?
  (Isaac Newton-1666)



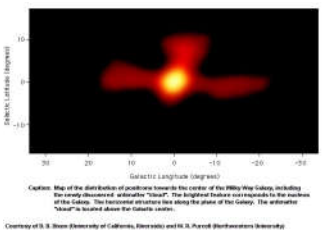
Wavelength:

$$\lambda = \frac{c}{f}, \mathrm{c} = 2.998 \times 10^8 m/s$$

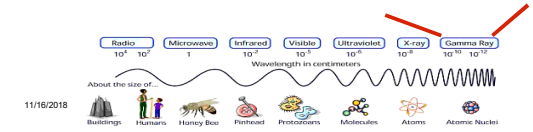
Energy:

$$E = hv,\ h: \text{plank sabiti}$$

Across the EM Spectrum



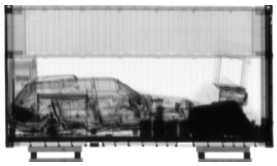
Crab Nebula



Across the EM Spectrum

Cargo inspection using Gamma Rays

Mobile Vehicle and Cargo Inspection System (VACIS®)



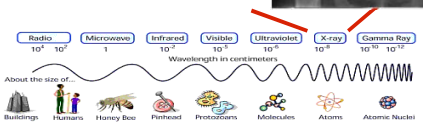
Gamma rays are typically waves of frequencies greater than 10^{19} Hz

Gamma rays can penetrate nearly all materials and are therefore difficult to detect

Courtesy:Science Applications International Corporation (SAIC);

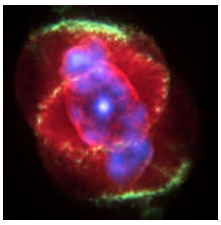
Across the EM Spectrum

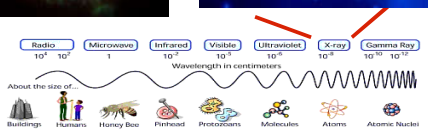
- Medical X-Rays



Across the EM Spectrum

- Chandra X-Ray Satellite

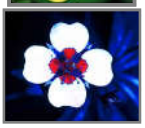


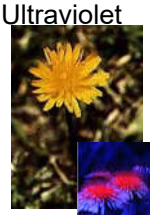


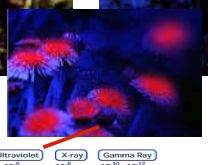
Across the EM Spectrum

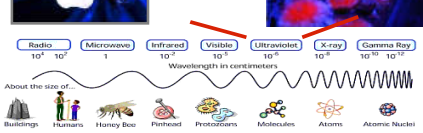
- Flower Patterns in Ultraviolet

Potentilla



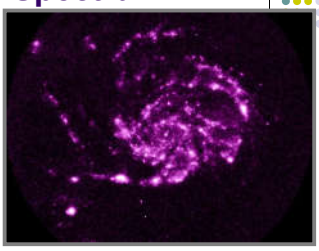


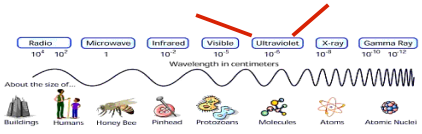




Across the EM Spectrum

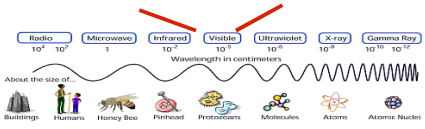
- Messier 101 in Ultraviolet





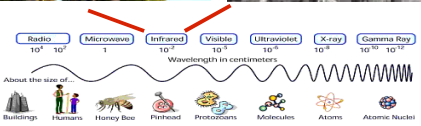
Across the EM Spectrum

- Traditional images



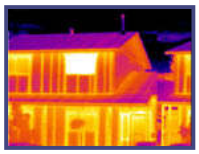
Across the EM Spectrum

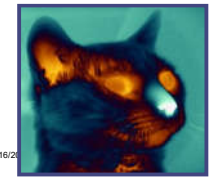
- IR: **Near**, Medium, Far (~heat)



Across the EM Spectrum

- IR: Near, Medium, **Far (~heat)**



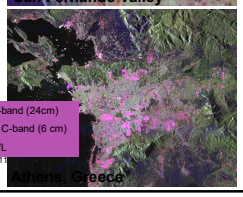


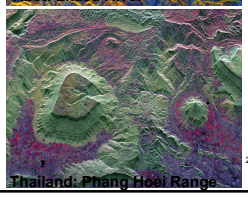
Across the EM Spectrum

- IR: Finding chlorophyll -the green coloring matter of plants that functions in photosynthesis

Across the EM Spectrum

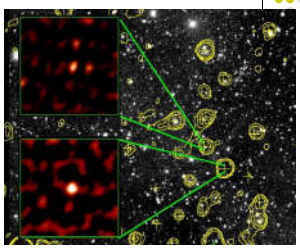
- Microwave Imaging: Synthetic Aperture

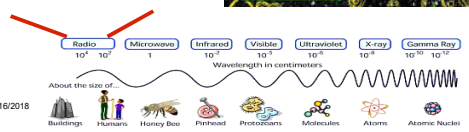




Across the EM Spectrum

- Radio Waves (images of cosmos from radio telescopes)





Dalgaboyları

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

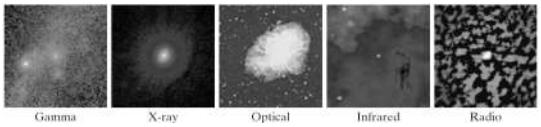


Image Processing and Related Fields

- Image Processing: image to image
- Computer Vision: Image to model
- Computer Graphics: model to image

All three are interrelated!

- Pattern Recognition: image to class
  - image data mining/ video mining
- Artificial Intelligence: machine smarts

AI

Applications

- Photogrammetry: camera geometry, 3D reconstruction
- Medical Imaging: CAT, MRI, 3D reconstruction (2nd meaning)
- Video Coding: encoding/decoding, compression, transmission

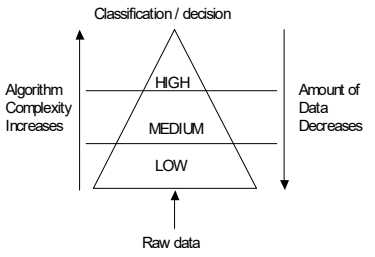
- Physics: basics
- Mathematics: basics
- Computer Science: programming skills

Fundamentals

Applications

- Tıp ve biyoloji (x-ışınları, biyomedikal görüntüler…)
- Coğrafi bilimler (hava ve uydu görüntülerinden hava tahmini)
- Eski, hasar görmüş fotoğrafların onarılması, GPR-mayın tarama, arkeolojik kalıntıların tespiti
- Oyun Programlama (bilgisayarda görü, 3-B modelleme)
- Fizik (spektrometreler, elektron mikroskobu görüntüleri)
- Uzay bilimleri (uydu, mikrodalga radar görüntüleri…)
- Savunma sanayi (gece görüş, akıllı roket sistemleri…)
- Endüstriyel uygulamalar (süreç, ürün denetimi…)
- Tüketici elektroniği (Video kayıt cihazları, cep telefonları…)
- Biyometrik tanıma ve güvenlik sistemleri (iris-parmak izi tanıma, güvenlik-kamera uygulamaları)
- Uzaktan algılama

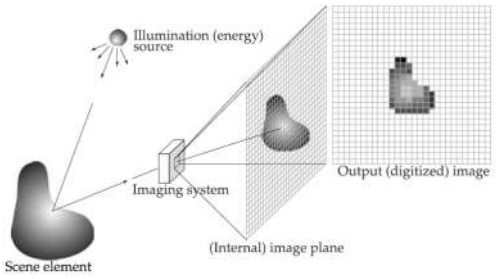
Different Layers of Image Processing



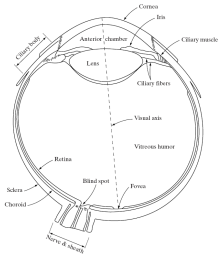
- Acquisition, preprocessing
  - no intelligence
- Extraction, edge joining
- Recognition, interpretation
  - intelligent

İmge Kavramı

- Sözlük anlamı: Işık etkisi veya optik mercek ile meydana gelen suret, hayal (3B→2B)



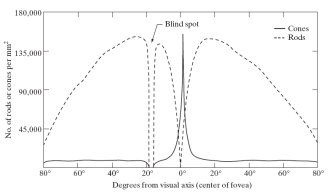
Visual perception elements



Gözün retina bölgesinde iki tip algılayıcı vardır:

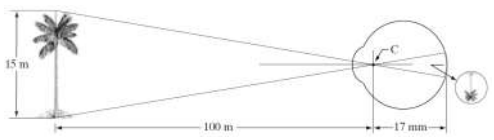
• Koni (6-7 milyon), renge duyarlı.

• Çubuk (75-150 milyon), ışığa duyarlı.



Visual perception elements

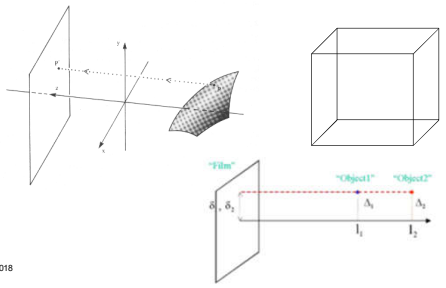
- İmgenin gözde oluşumu:



Gözde oluşan imgenin uzunluğu nedir?

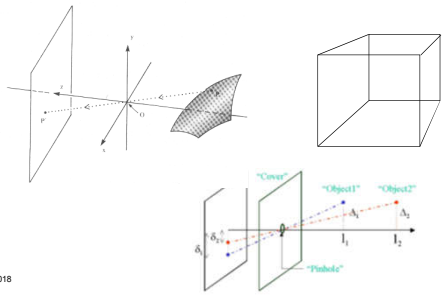
How image is constructed?

- Orthographic projection



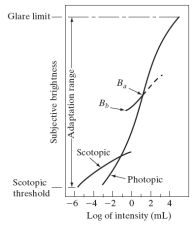
How image is constructed?

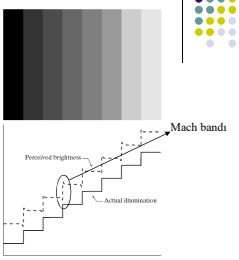
- Perspective projection



Visual perception elements

- Işıklılık uyumu ve ayrımsama:

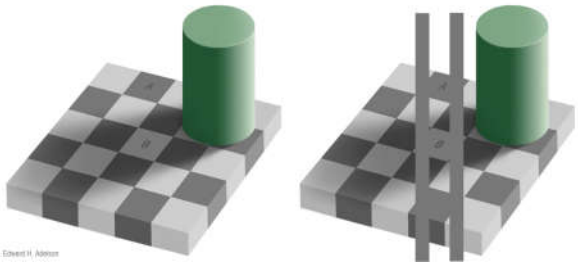




İnsan görme sistemi tarafından alınan ışık (öznel ışık), göze gelen ışık yoğunluğunun logaritmik bir fonksiyonudur.

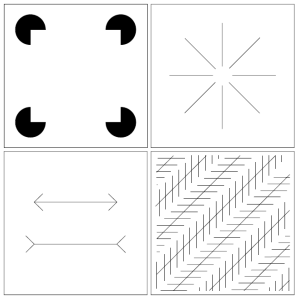
Eş zamanlı karşıtlık

Visual perception elements



Visual perception elements

- Optical illusions:



Visual perception elements

Image sensing and capturing

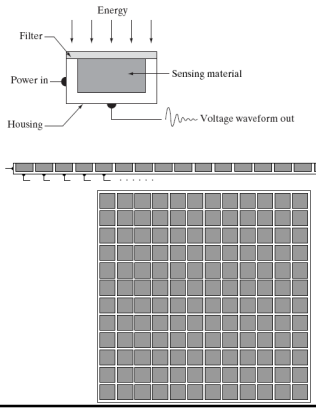
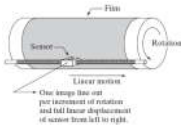


Image sensors

- Single element sensors:



- 1-D sensor array

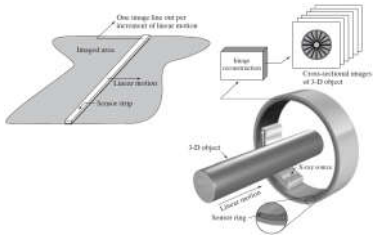


Image sensors

- Image capturing using 2D sensor arrays :

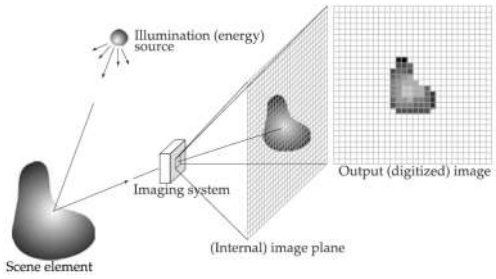


Image model

- Basically, an image can be represented by a two-dimensional function:

$$f(x,y)$$

$$(x,y) \rightarrow \text{horizontal and vectical positions.}$$

- and

$$0 < f(x,y) < \infty$$

Image model

- $f(x,y)$ function can be defined using two components:
- The first one is illumination source of the scene.
- The second one is reflectance of illumination source from the objects.

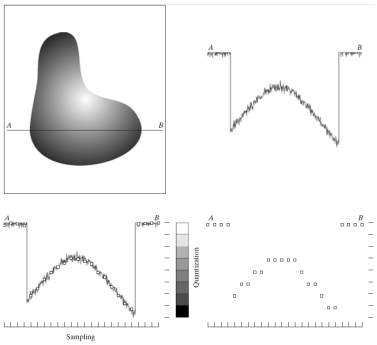
$$f(x,y) = i(x,y)\,r(x,y)$$
$$0 < i(x,y) < \infty$$
$$0 < r(x,y) < 1$$

- Pixel values in gray-scale images :

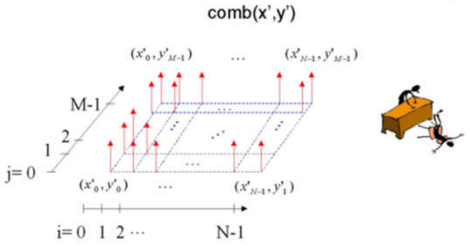
$$\ell = f(x,y)$$
$$L_{\min} < \ell < L_{\max} \qquad [L_{\min}, L_{\max}]: \text{ Gray-tone range.}$$
$$L_{\min} = i_{\min} r_{\min} \approx 10 \qquad \text{In practice: } L_{\min} = \text{black},\ L_{\max} = \textit{white}$$
$$L_{\max} = i_{\max} r_{\max} \approx 1000$$

Image Sampling and Quantization

- Koordinat değerlerini sayısallaştırma → *örnekleme.*
- Genlik değerlerini sayısallaştırma → *nicemleme.*

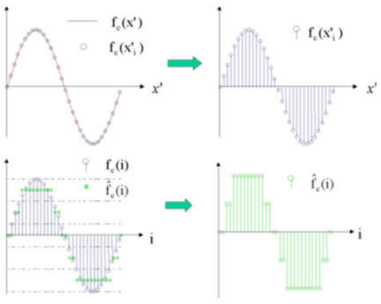


Sampling

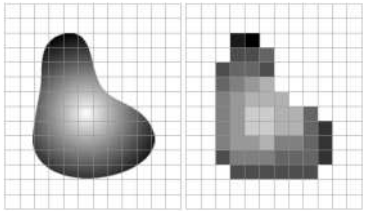


$$comb(x',y') = \sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\delta(x' - i\Delta_x, y' - j\Delta_y)$$

Örnekleme → $f_C(x',y') \times comb(x',y')$

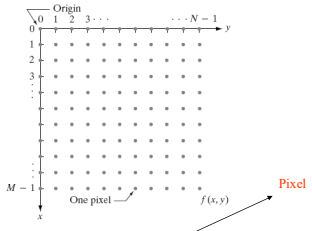


- In general P=2^8=256 and $\log_2(P)=\log_2(2^8)$=8 bit quantization.



Digital Image Representation

- $f(x,y)$ imgesi örneklendiğinde *M* satır ve *N* sütunluk bir sayısal imge oluşur.



$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

Digital Image Representation

- Another representation of digital images:

$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

$$a_{i,j} = f(x=i, y=j) = f(i,j)$$

- Sayısallaştırmda genellikle uzamsal boyutlar önemli değildir.
- Donanımsal açıdan asıl önemli olan, gri ton seviyesinin 2'nin kuvveti olmasıdır.

$$L = 2^k$$

$[0, L-1]$: imgenin dinamik aralığı (dynamic range).

Digital Image Representation

- Number of bits required to store an image :

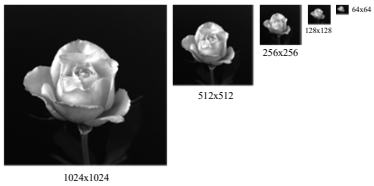
$$b = M \times N \times k$$

$M = N$:

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Digital Image

- Spatial resolution:



Digital Image

- Bit-depth: