IMAGE PROCESSING

KULIS Kocaeli University Laboratory of Image and Signal Processing
Kocaeli Üniversitesi İşaret ve Görüntü İşleme Laboratuvarı

(Prof. Dr. Sarp ERTÜRK)

Conent

- Basic Concepts
- File Types and Basic Operations
- Image Enhancement
- Image Quantization
- Neighborhood Operations
- Image Segmentation
- Color Images
- Morphological Operations
- Image Frequency Space
- Image Compression

Sources

- 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

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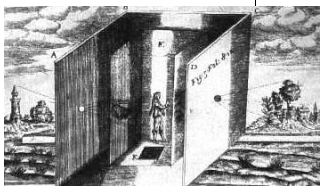
(Prof. Dr. Sarp ERTÜRK)

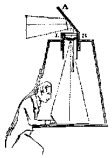
Hazırlayan: M. Kemal GÜLLÜ

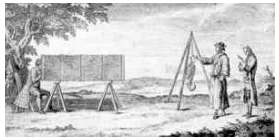
Camera Obscura: A Pinhole Camera

- 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 tool 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

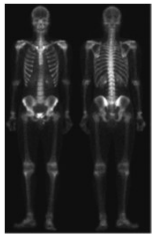
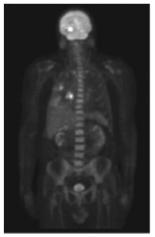
History of Photography

- 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 (Sayısal İmge İşleme):
  Image enhancement, transformation or information extraction
- Computer Vision (Bilgisayarla Görü):
  Processing images to extract real-world information.

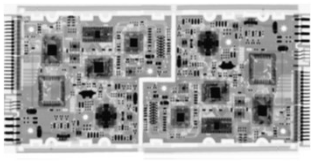
Example Application Fields

Gamma ray vision:

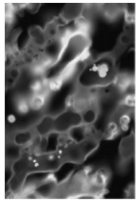
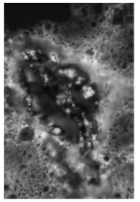
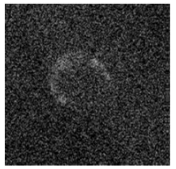
X ray vision:





Example Application Fields

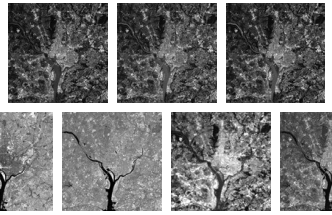
Ultra-violet vision:

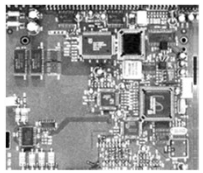
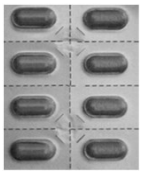
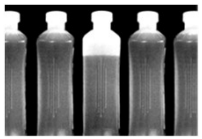
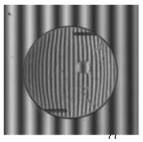
Visible and Infrared vision:


Example Application Fields

Multi-band vision:

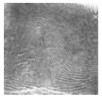


Quality Control:

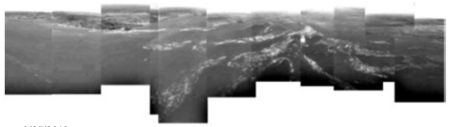
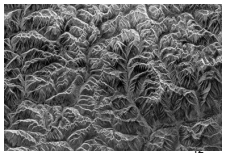
Example Application Fields

Pattern Recognition:

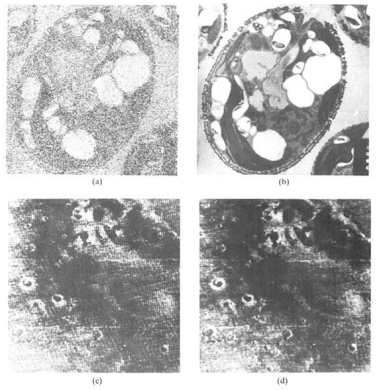




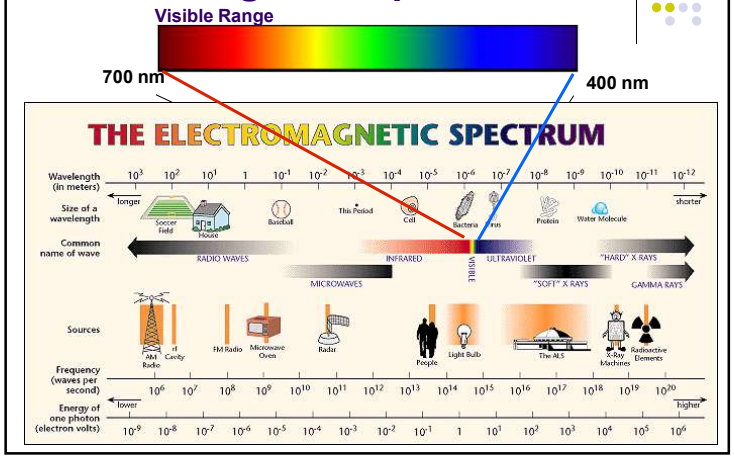
Radar Systems:

Enhancement Example

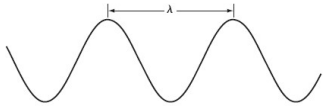


Elektromagnetic Spectrum



Light and Electromagnetic Spectrum

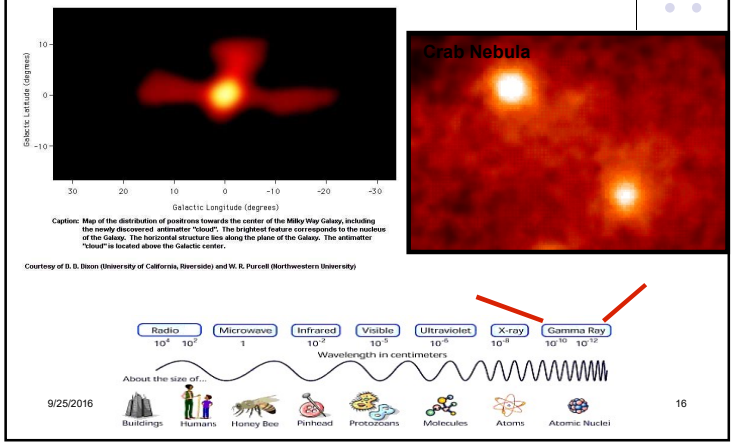
- Isaac Newton-1666: White light is dispered into color spectrum using a prism



Wavelength:

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

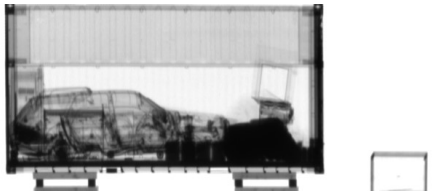
Across the EM Spectrum



Across the EM Spectrum

Cargo inspection using Gamma Rays

Mobile Vehicle and Cargo Inspection System (VACIS®)



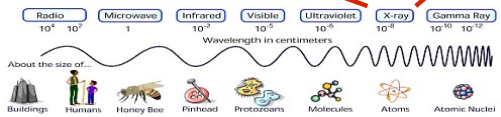
Gamma rays are typically waves of frequencies greater than 10^{19} Hz

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

Courtesy: Science Applications International Corporation (SAIC)

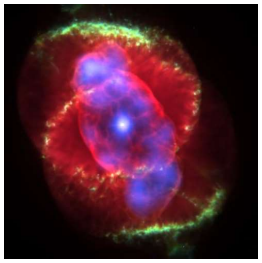
Across the EM Spectrum

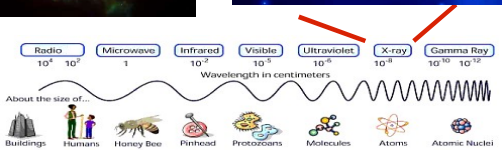
- Medical X-Rays



Across the EM Spectrum

- Chandra X-Ray Satellite

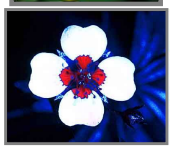


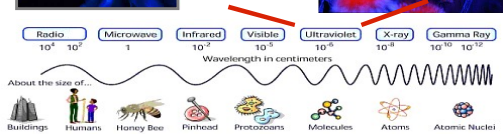


Across the EM Spectrum

- Flower Patterns in Ultraviolet

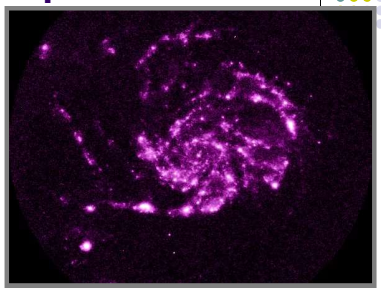
Potentilla

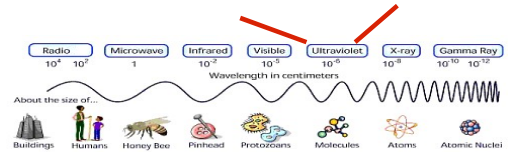




Across the EM Spectrum

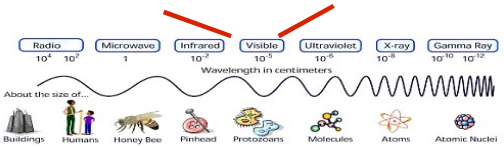
- Messier 101 in Ultraviolet





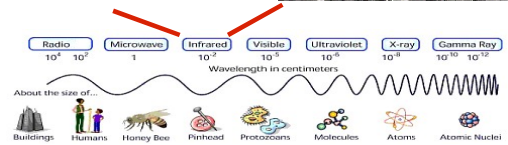
Across the EM Spectrum

- Traditional images



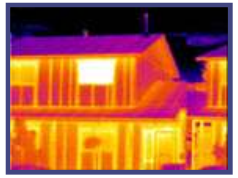
Across the EM Spectrum

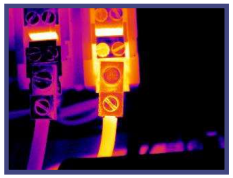
- IR: **Near**, Medium, Far (~heat)

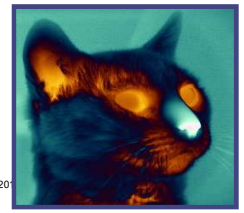


Across the EM Spectrum

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





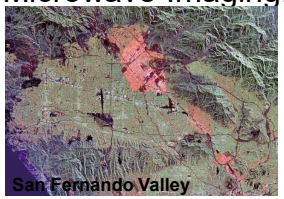


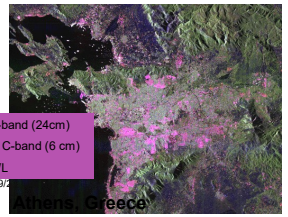
Across the EM Spectrum

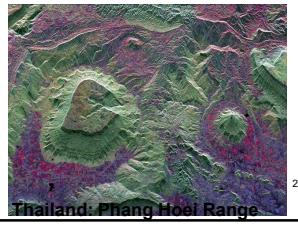
- IR: Finding chlorophyll -the green coloring matter of plants that functions in photosynthesis

Across the EM Spectrum

- Microwave Imaging: Synthetic Aperture

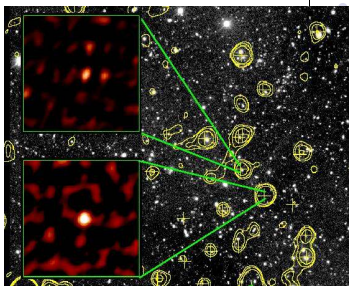


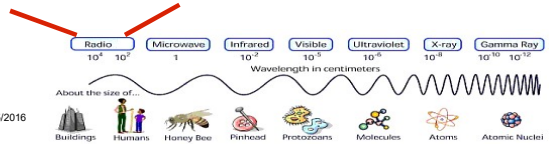




Across the EM Spectrum

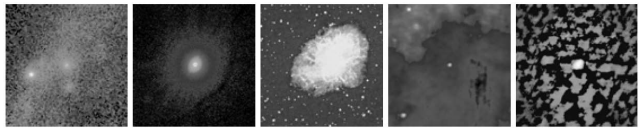
- Radio Waves (images of cosmos from radio telescopes)





Wavelengths

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



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

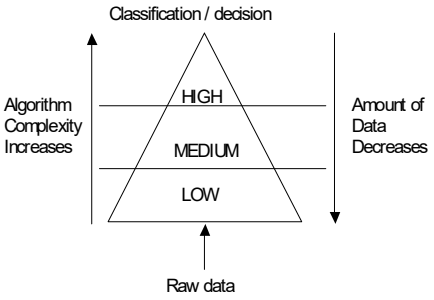
- Physics: basics
- Mathematics: basics
- Computer Science: programming skills

Fundamentals

Application Fields

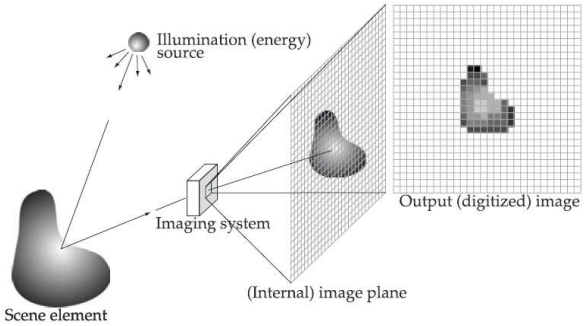
- Medicine & Biomedical
- Geographical
- Archeological
- Games
- Physics
- Space
- Defense
- Industrial
- Consumer
- Security
- Remote Sensing
- ….

Different Layers of Image Processing



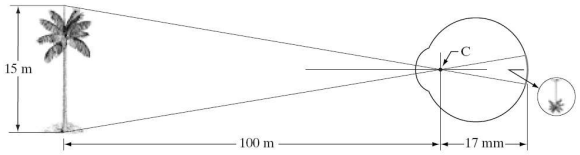
- Acquisition, preprocessing
  - no intelligence
- Extraction, edge joining
- Recognition, interpretation
  - intelligent

İmage Concepts

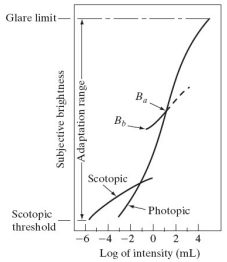


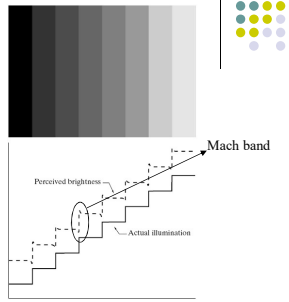
Visualization

- Vision System:

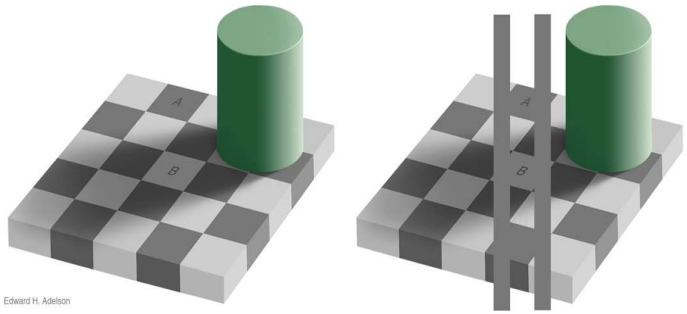


Visual Perception

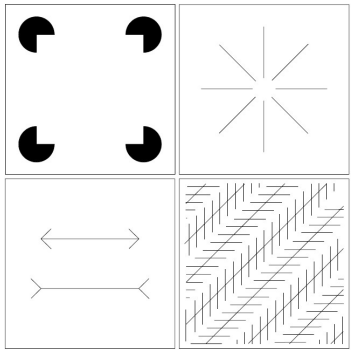




Perception

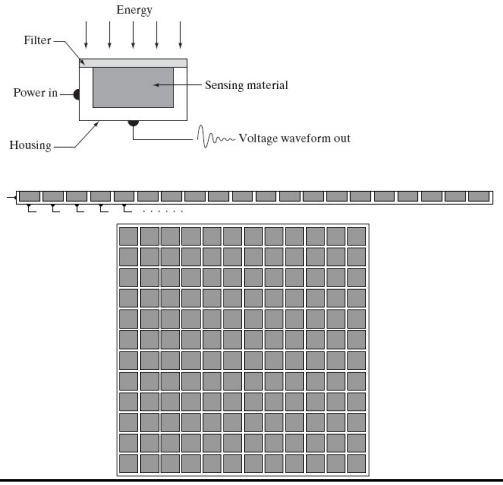


Perception



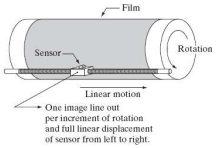
Perception

Detection

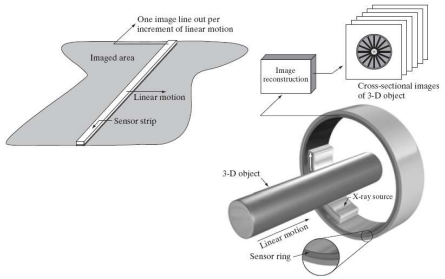


Detection

- Single Sensor:



- Multiple Sensors:



Acquisition

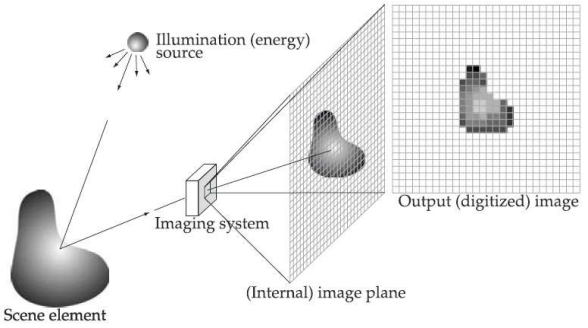


Image Model

- 2-D Function:

$$f(x,y)$$

$(x,y) \rightarrow$ yatay ve düşey konumları belirtir.

- Physically the brightness is related to reflected energy
- Therefore:

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

Image Representation

- *Illumination of light source*
- *Reflectance* from object surface

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

- Gray-Images:

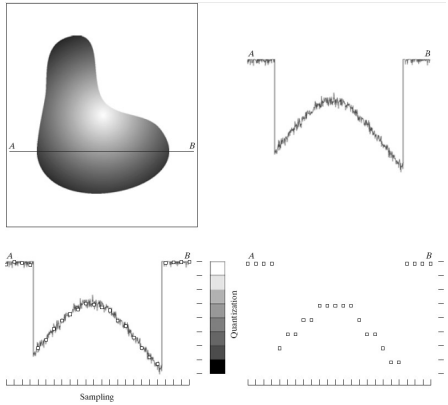
$$\ell = f(x,y)$$
$$L_{\min} < \ell < L_{\max}$$
$$L_{\min} = i_{\min} r_{\min} \approx 10$$
$$L_{\max} = i_{\max} r_{\max} \approx 1000$$

$[L_{\min}, L_{\max}]$: Gri ton aralığı.

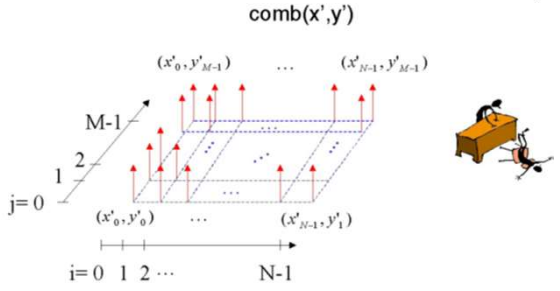
Pratikte: $L_{\min}$ = siyah, $L_{\max}$ = beyaz

Sampling and Quantization

- Sampling
- Quantization



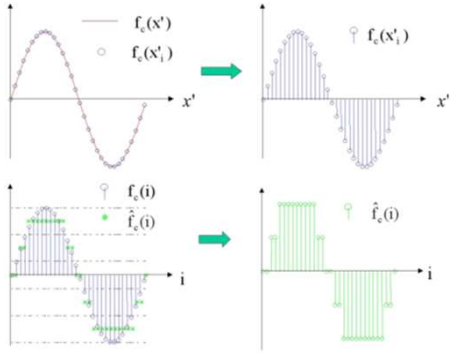
Sampling



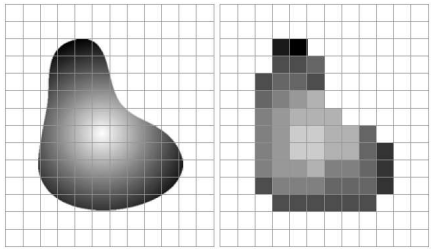
$$comb(x',y') = \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \delta(x' - i\Delta_x, y' - j\Delta_y)$$

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

In 1-D

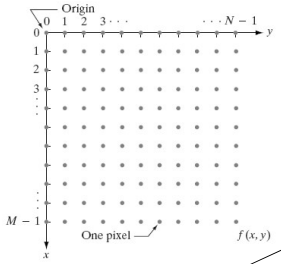


- Usually 8 bits -> 256 levels.



Digital Images

- $f(x,y)$



Resim elemanı
(piksel)

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

Digital Images

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

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

Digital Images

- No. of bits required for representation:

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

$M = N$:

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 Images

- Spatial Resolution

Digital Images

- Bit depth