180206081104P2009H

图像处理

第一讲 (I): 绪论：图像与视觉

基本概念 + 课程简介

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内容提纲

- 什么是图像?
- 什么是图像处理?
- 课程内容概要
- 课程安排与要求
- 人类视觉机理
- 一些与课程有关的重要实用信息

- 什么是图像?
- 什么是图像处理?
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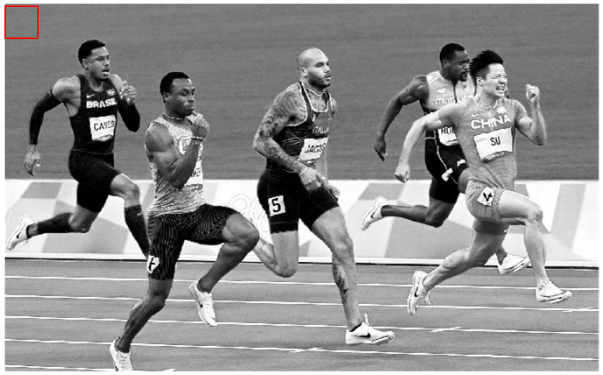
什么是图像？(I)

图像中包含哪些信息?

- ? ?
- ? ?
- ? ?

什么是图像？(II)

什么是图像？(III)

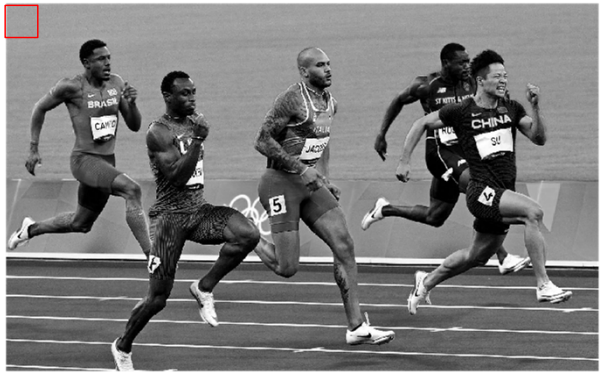


```
>> image(1:10, 1:10, 1)

ans =

  10×10 uint8 矩阵

   127   133   126   130   120   130   126   128   125   128
   132   136   128   130   120   130   126   128   130   132
   134   136   126   128   118   130   127   130   126   127
   132   134   123   125   117   130   128   131   123   124
   135   136   124   126   118   131   127   129   130   130
   140   140   129   131   123   134   127   127   128   130
   137   139   130   135   128   139   130   128   124   128
   130   134   127   135   131   142   133   130   130   134
   126   132   129   127   131   130   129   134   131   131
   126   131   128   125   128   126   124   130   124   125
```



```
>> image(1:10, 1:10, 2)

ans =

  10×10 uint8 矩阵

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   164   168   160   162   152   162   158   160   162   164
   167   169   159   161   151   163   160   163   159   160
   165   167   156   158   150   163   161   164   156   157
   168   169   157   159   151   164   160   162   163   163
   173   173   162   164   156   167   160   160   161   163
   170   172   163   168   161   172   163   161   157   161
   163   167   160   168   164   175   166   163   163   167
   160   166   163   161   165   164   163   168   165   165
   160   165   162   159   162   160   158   164   158   159
```
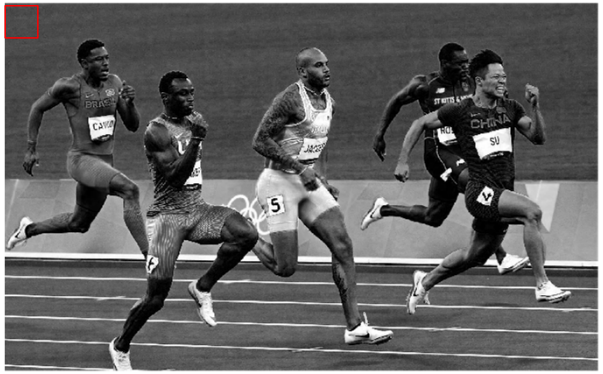



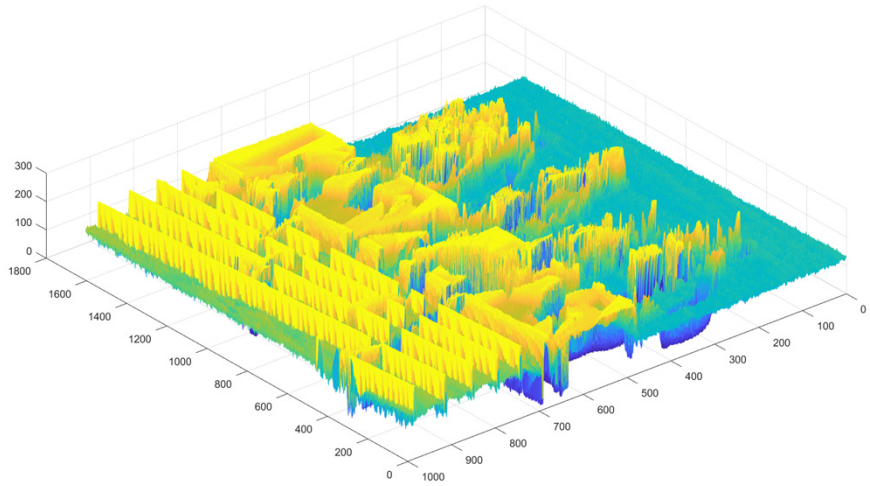
```
>> image(1:10, 1:10, 3)

ans =

  10×10 uint8 矩阵

    83    89    82    86    76    86    82    84    81    84
    88    92    84    86    76    86    82    84    86    88
    88    90    80    82    72    84    81    84    80    81
    86    88    77    79    71    84    82    85    77    78
    89    90    78    80    72    85    81    83    84    84
    94    94    83    85    77    88    81    81    82    84
    89    91    82    87    80    91    82    80    76    80
    82    86    79    87    83    94    85    82    82    86
    76    82    79    77    81    80    79    84    81    81
    76    81    78    75    78    76    74    80    74    75
```

什么是图像？(IV)

- 一幅二维图像是一个像素阵列。

- 一幅二维图像是一个矩阵。
  → 数学工具: 线性代数, 神经网络

- 一幅二维图像是一个曲面 (经平滑处理)。
  → 数学工具: 微积分，微分几何…



什么是图像？(IV)

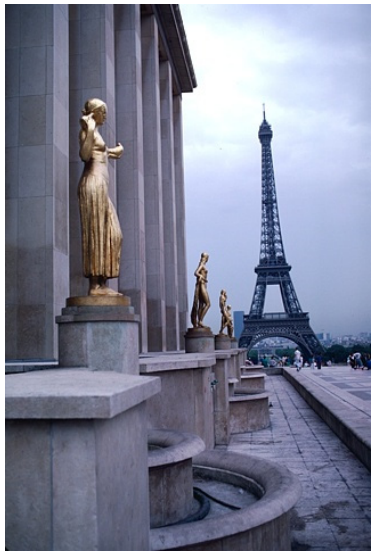
自然场景图像

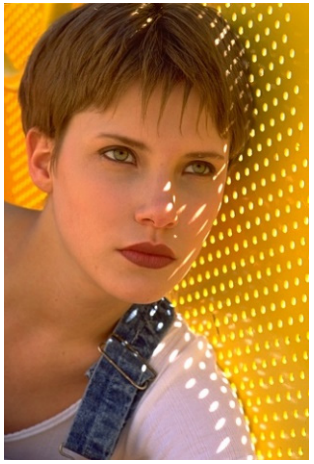
Berkeley Segmentation Data Set 500
https://www2.eecs.berkeley.edu/Research/Projects/CS/vision/bsds/

社会场景图像



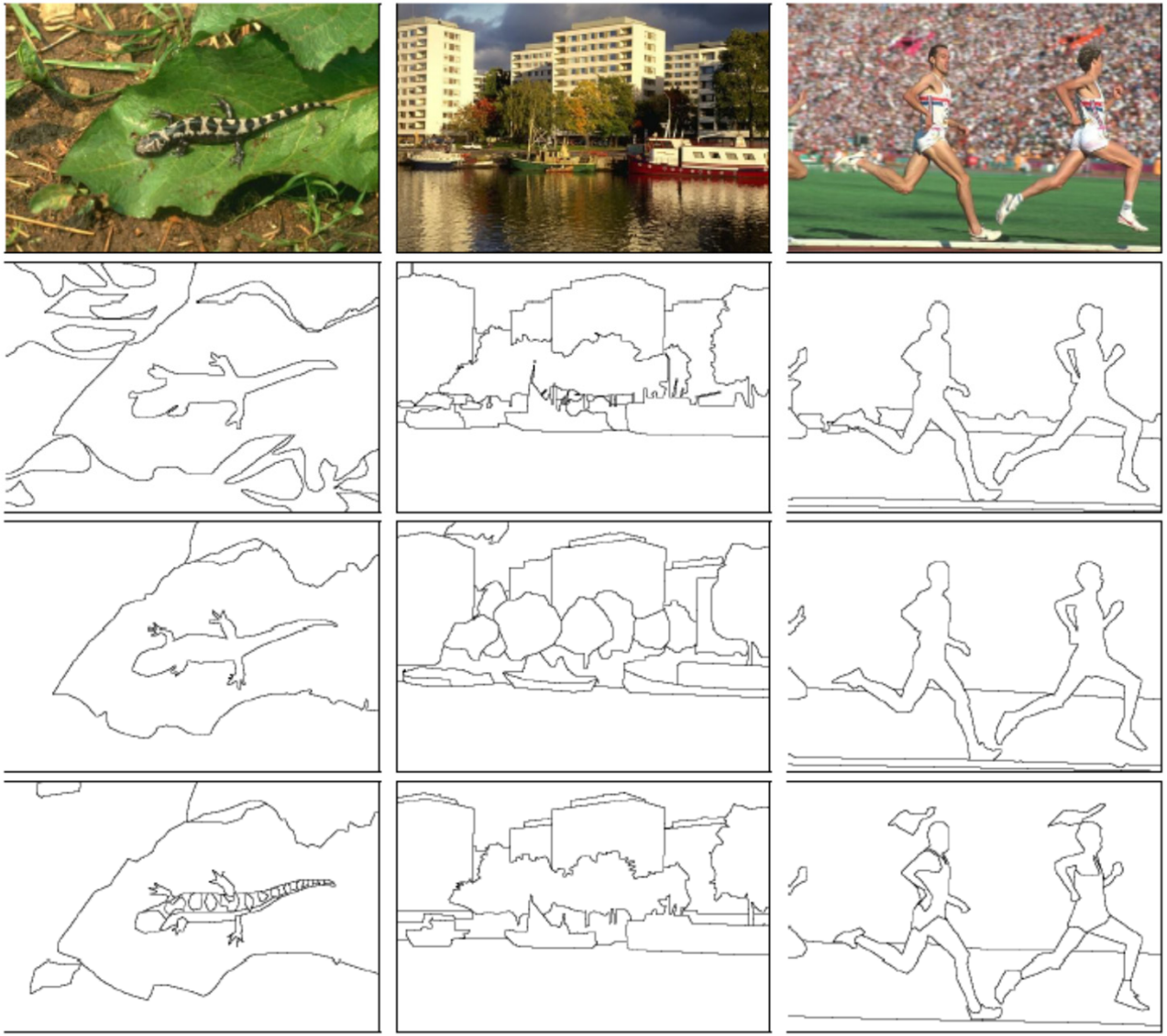




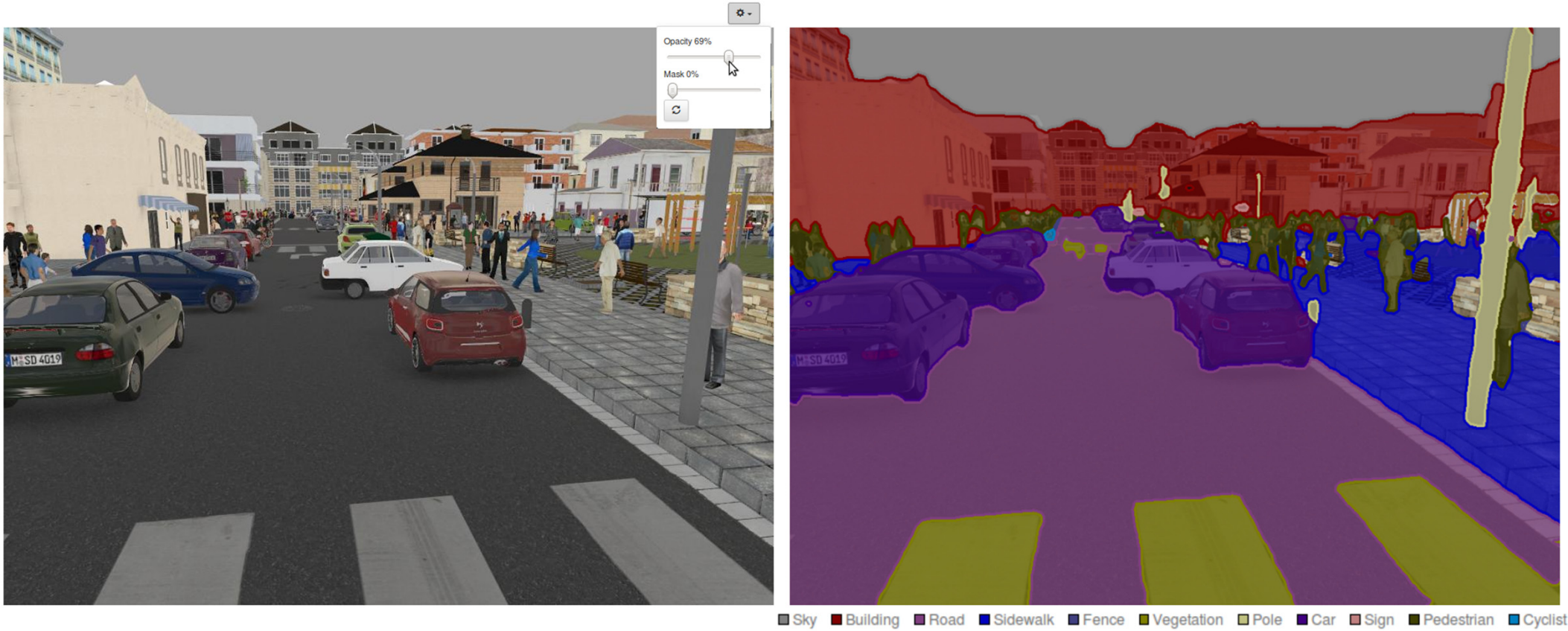

Berkeley Segmentation Data Set 500
https://www2.eecs.berkeley.edu/Research/Projects/CS/vision/bsds/

图像分割示例 (I)



Arbelaez et al, PAMI, 2010

图像分割示例 (II)



https://devblogs.nvidia.com/image-segmentation-using-digits-5/

遥感图像示例

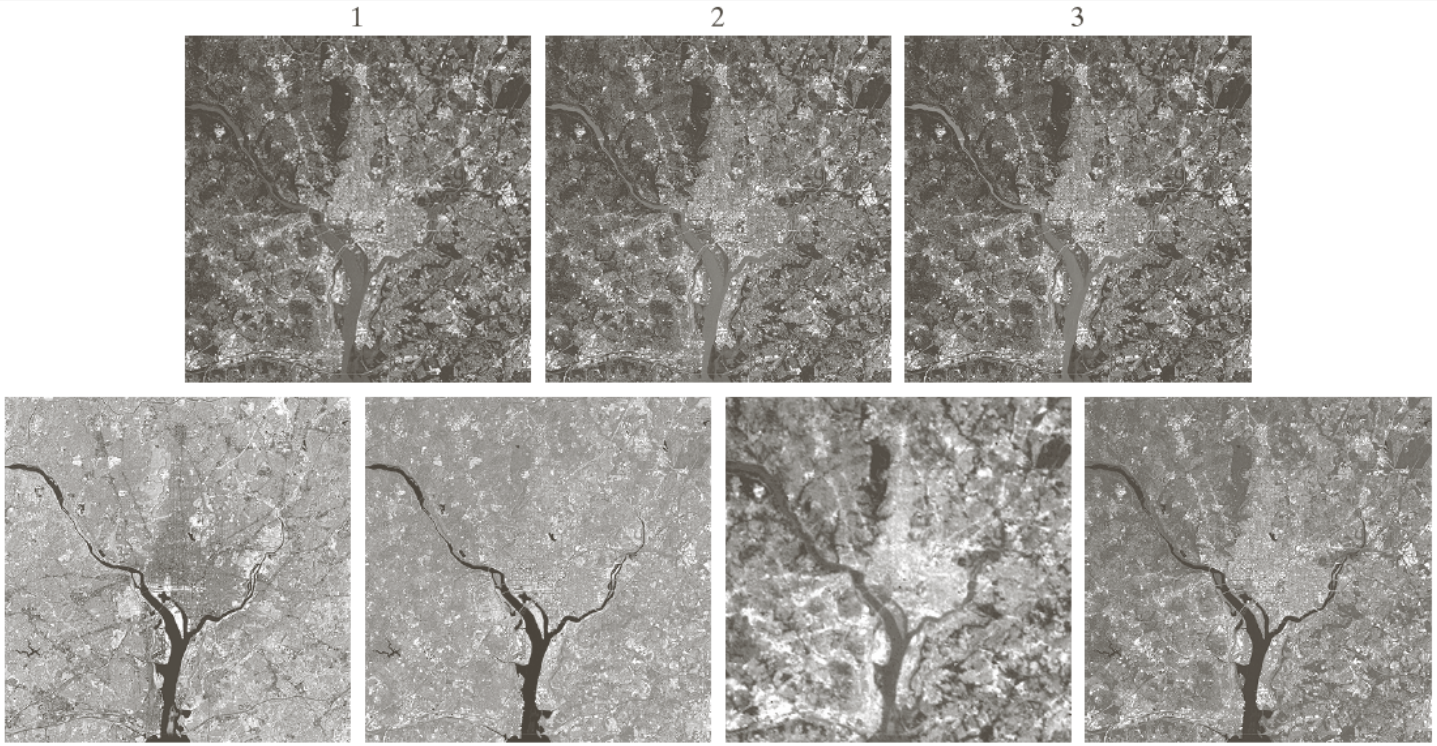
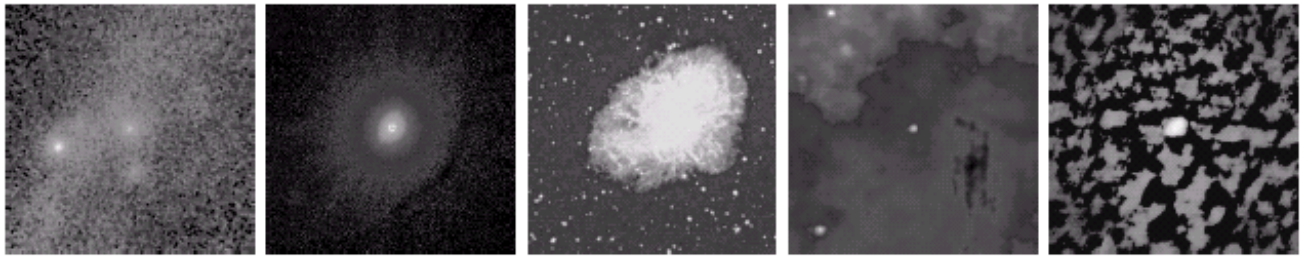


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

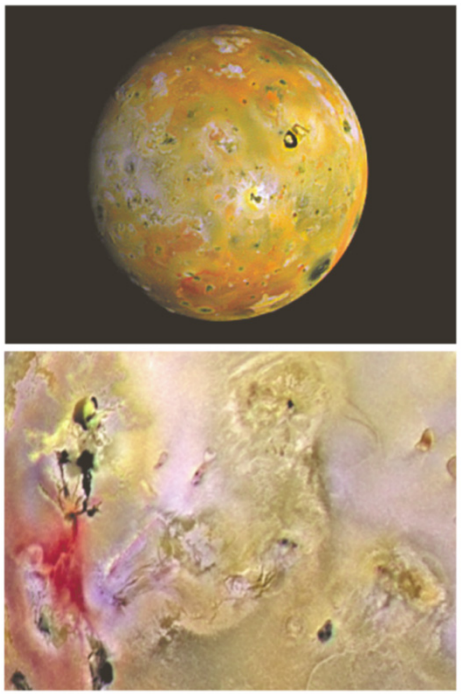
Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture 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

空间应用图像示例



Gamma X-ray Optical Infrared Radio

FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)



a
b

FIGURE 6.28
(a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)

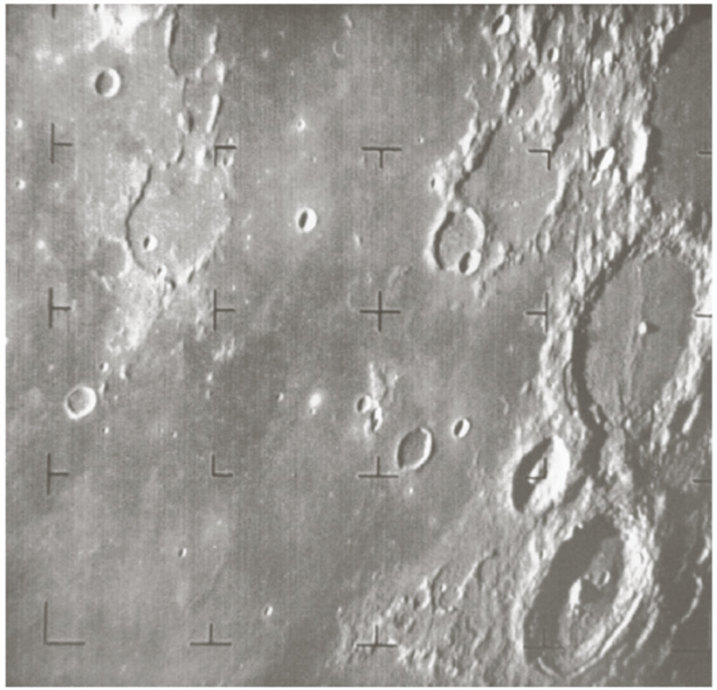
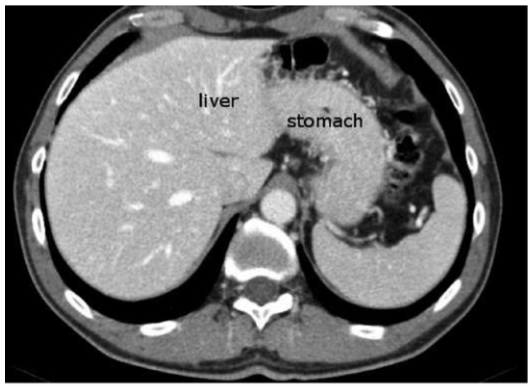
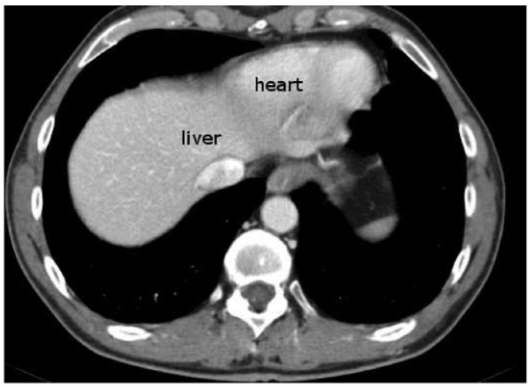


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

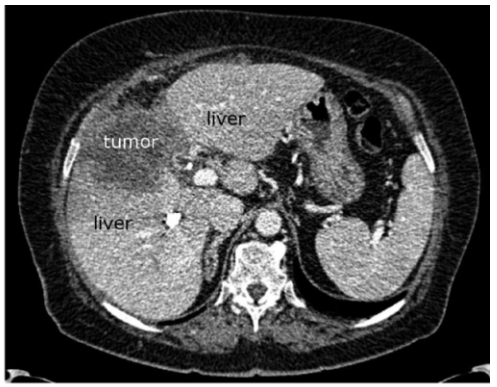
医学图像示例



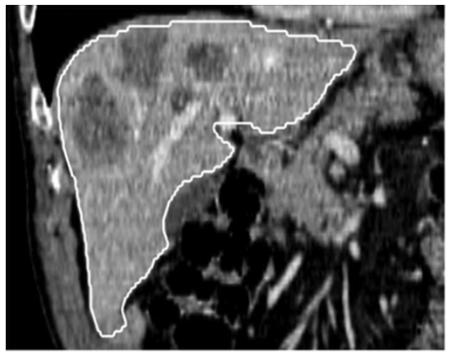
(a)



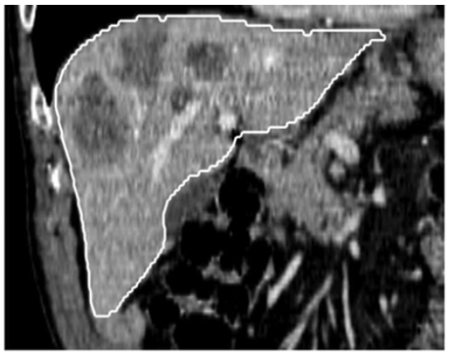
(b)



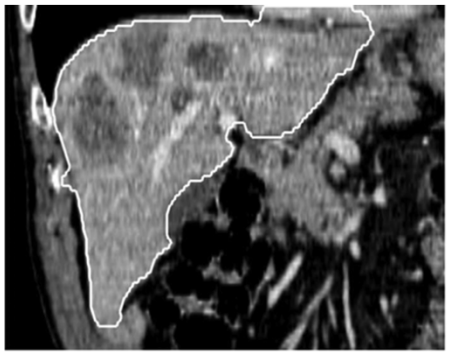
(c)



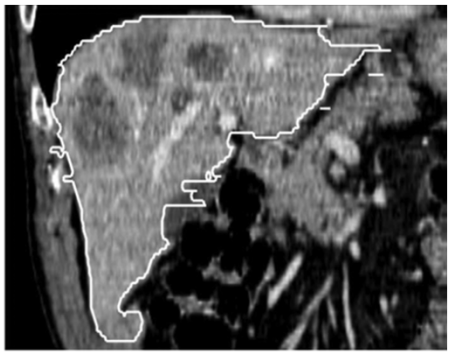
(a)



(b)



(c)



(d)

Heimann et al, Comparison and Evaluation of Methods for Liver Segmentation From CT Datasets, *IEEE Trans. Medical Imaging*, vol. 28, no. 8, 1251-1265, 2009.

生物图像示例 (I)

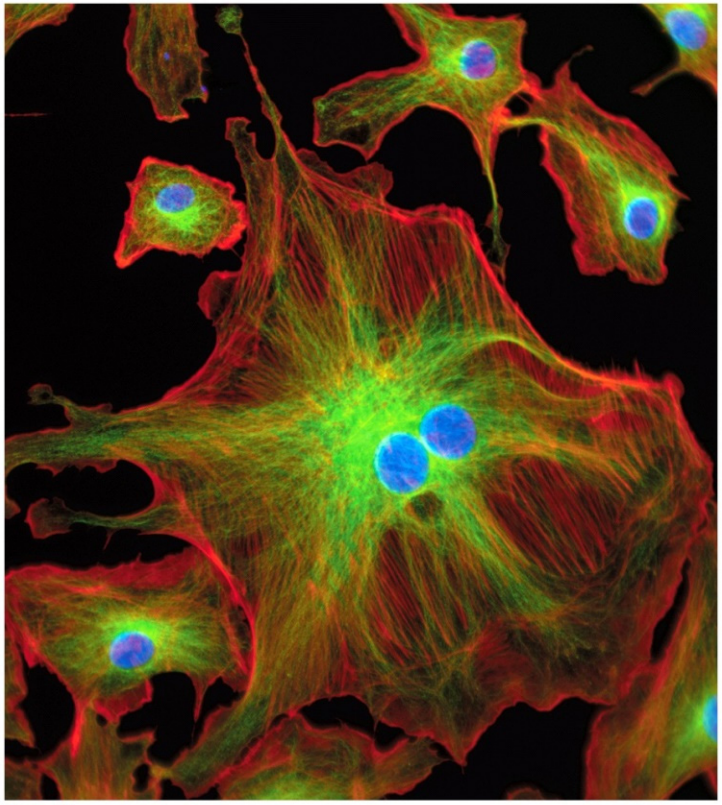
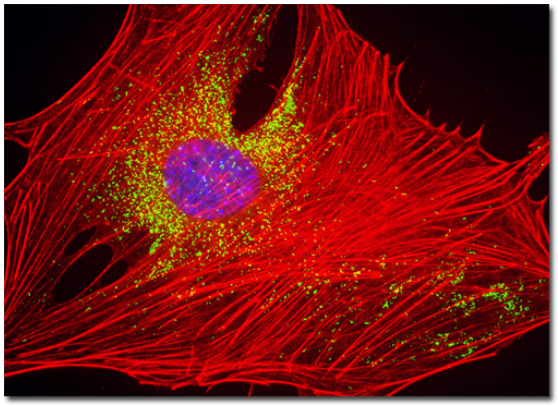
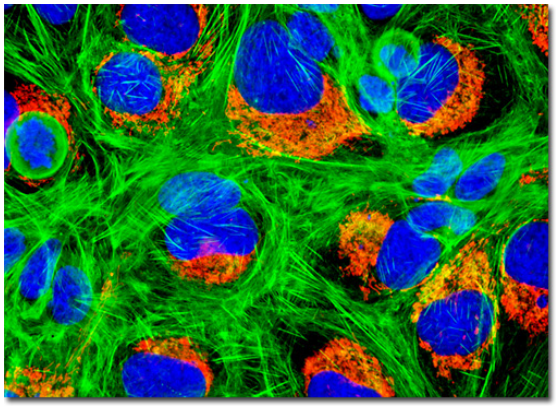


Figure 1-9a
Lehninger Principles of Biochemistry, Sixth Edition



Embryonic Swiss Mouse Fibroblast Cells (3T3)



Human Bone Osteosarcoma Cells (U-2 OS)

http://micro.magnet.fsu.edu/primer/techniques/fluorescence/gallery/cells/3t3/3t3cellslarge.html

生物图像示例 (II)

a
b

FIGURE 6.51
Color image compression. (a) Original RGB image. (b) Result of compressing and decompressing the image in (a).

按照光子能量排列的电磁波谱

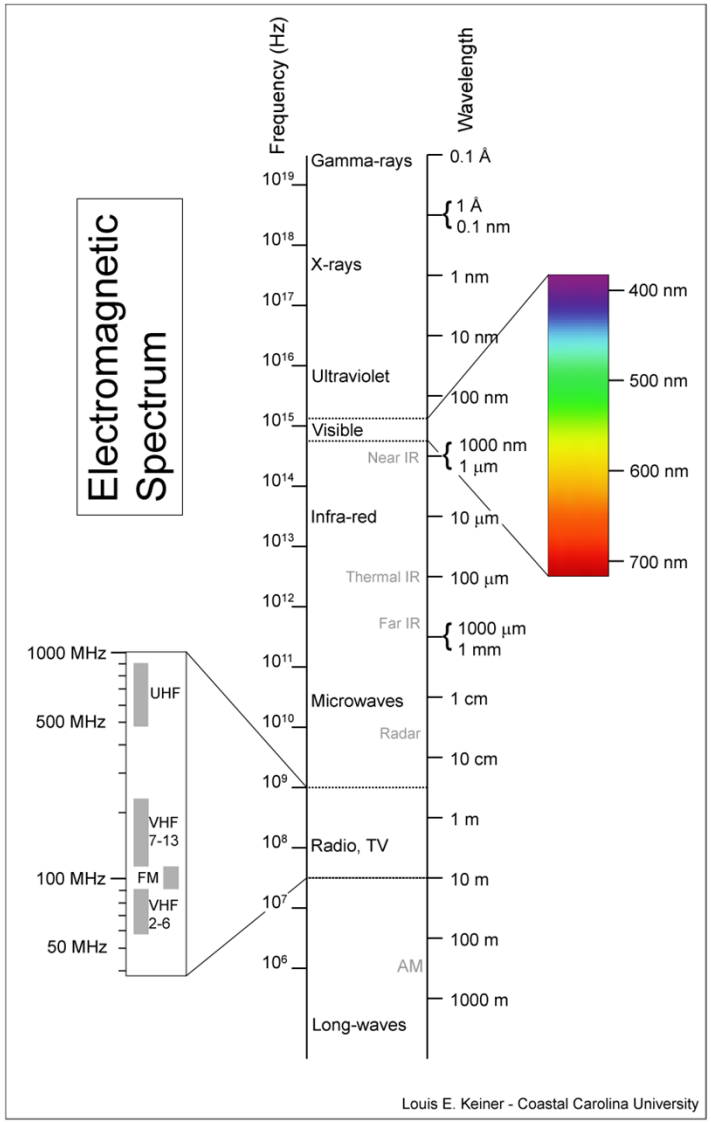
- 光子能量的普朗克定律：

$$E = h\nu = h\frac{c}{\lambda}$$

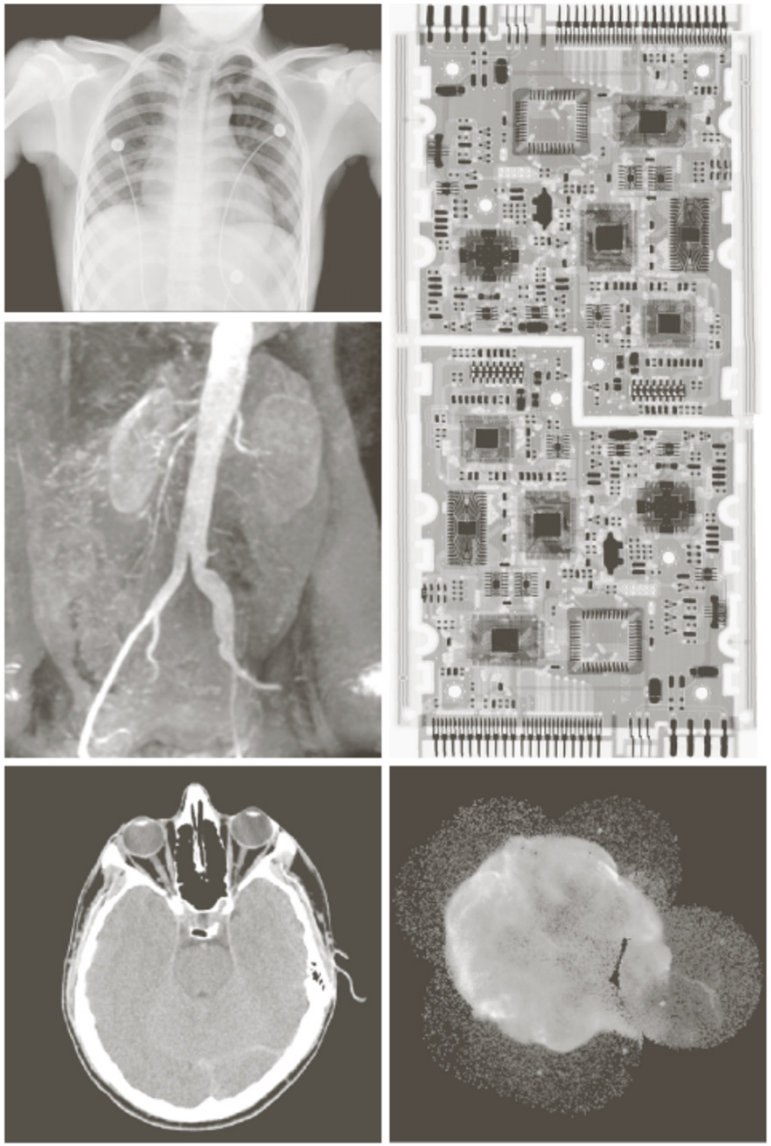
h: 普朗克常数; 6.626×10^{-34}J·s
v: 光频率;
λ: 光波长
c: 光速

光子能量 =
3.973×10^{-19}J at 500nm

- 光波长越短光子能量越高。



X射线成像



a d
b
c e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

总结：图像数据

- 视觉是人类感知的最高级形式，图像在人类认知中起最为重要的作用。
- 一幅二维图像可以定义为一个函数 I(x,y), 其中 (x,y) 为像素在图像坐标系中的坐标，I(x,y)为像素灰度。
- 图像数据在众多应用领域具有重要价值与意义。
- 不同应用领域在图像信息提取方面有共性也有不同。

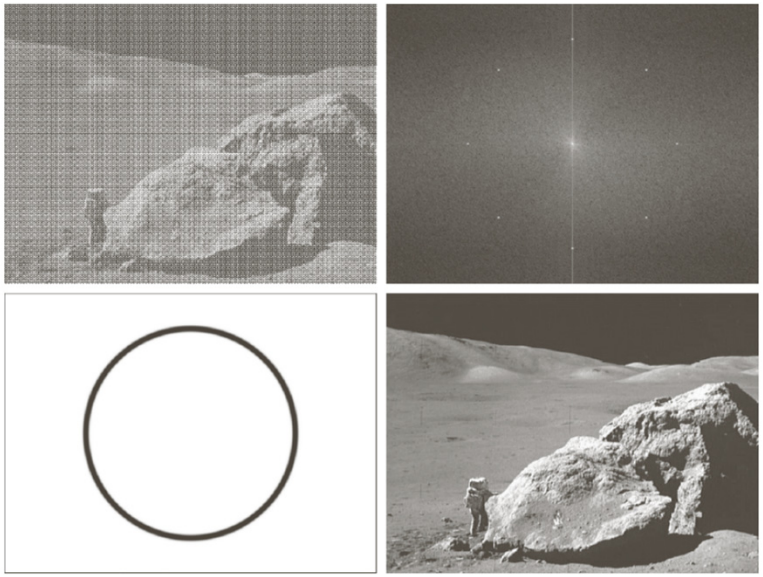
- 什么是图像?
- **什么是图像处理?**
- 课程安排与要求
- 人类视觉机理
- 一些与课程有关的重要实用信息

图像处理的重要性 (I)

- 改善图像信息以改善视觉效果，便于人们进行理解

a b
c d

FIGURE 5.16
(a) Image corrupted by sinusoidal noise. (b) Spectrum of (a). (c) Butterworth bandreject filter (white represents 1). (d) Result of filtering. (Original image courtesy of NASA.)

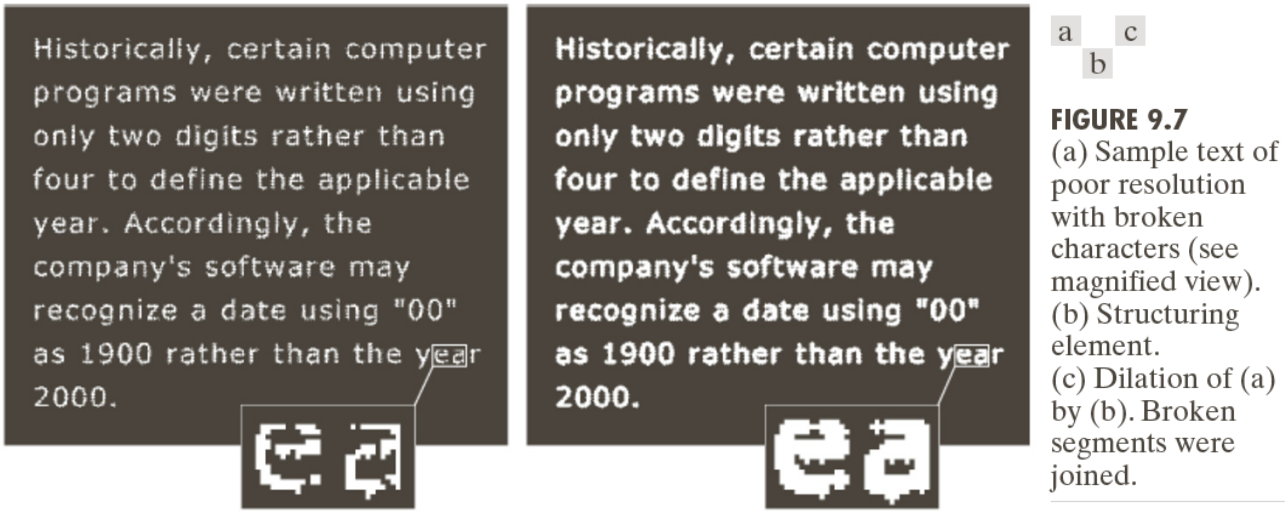


a b c

FIGURE 5.30 Results of constrained least squares filtering. Compare (a), (b), and (c) with the Wiener filtering results in Figs. 5.29(c), (f), and (i), respectively.

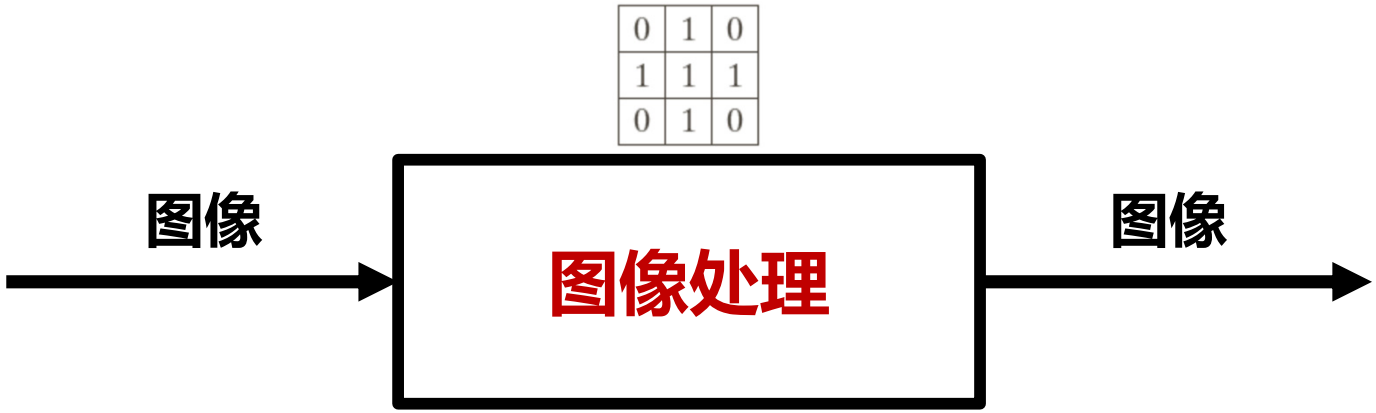
图像处理的重要性 (II)

- 为存储，传输和表示而对于图像进行处理，以便于机器自动理解。

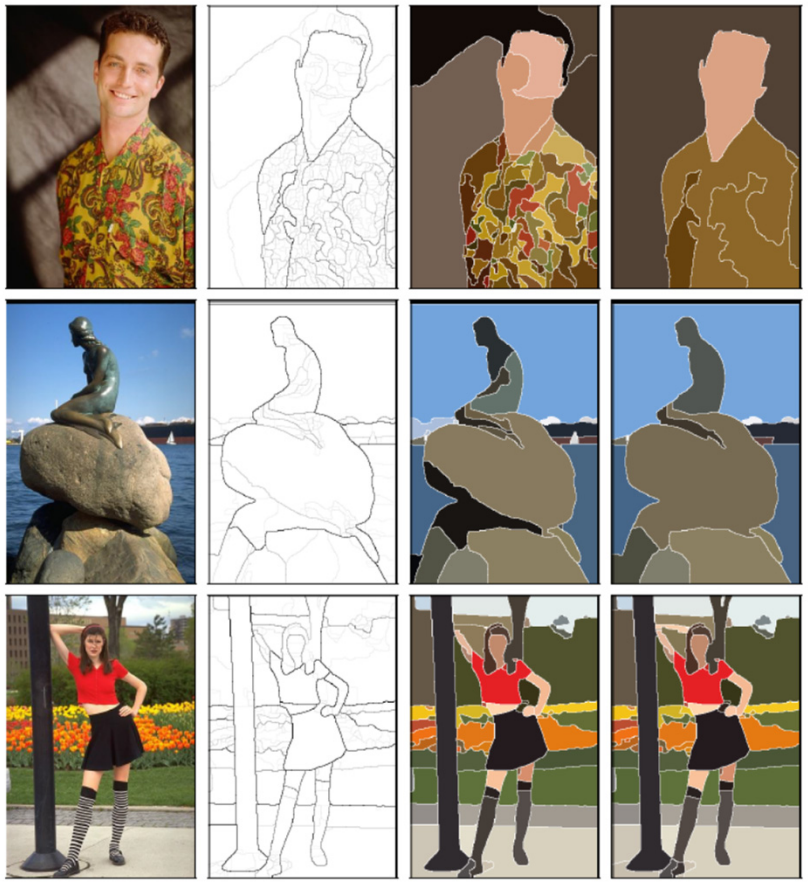


a c
b

FIGURE 9.7
(a) Sample text of poor resolution with broken characters (see magnified view). (b) Structuring element. (c) Dilation of (a) by (b). Broken segments were joined.



图像处理的重要性 (III)



Arbelaez et al, PAMI, 2010

图像处理的不同层次

- 低级处理
  - 图像降噪，对比度增强，图像锐化
  - 输入输出均为图像
- 中级处理 (计算机视觉，人工智能)
  - 图像属性提取
  - 输入为图像，输出为图像属性，例如区域分割
- 高级处理 (计算机视觉，人工智能)
  - 图像理解

图像处理与计算机视觉/人工智能的关系

- 图像处理通常作为计算机视觉的前处理，是后者的基础。
- 计算机视觉与图像处理的主要区别在于计算机视觉的目的是对于图像的理解。
- 对于视觉信息的进一步认知推理属于人工智能的范畴。
- 这些区分是概念性的，不是绝对的。

图像处理的简单历史回顾

- 真正意义上的图像处理起源于20世纪60年代初期，空间应用。
  - 计算能力与存储能力

- 20世纪60年代末70年代初开始用于医学成像，遥感及天文学等领域。

The Nobel Prize in Physiology or Medicine 1979

Photo from the Nobel Foundation archive.
Allan M. Cormack
Prize share: 1/2

Photo from the Nobel Foundation archive.
Godfrey N. Hounsfield
Prize share: 1/2

The Nobel Prize in Physiology or Medicine 1979 was awarded jointly to Allan M. Cormack and Godfrey N. Hounsfield "for the development of computer assisted tomography."

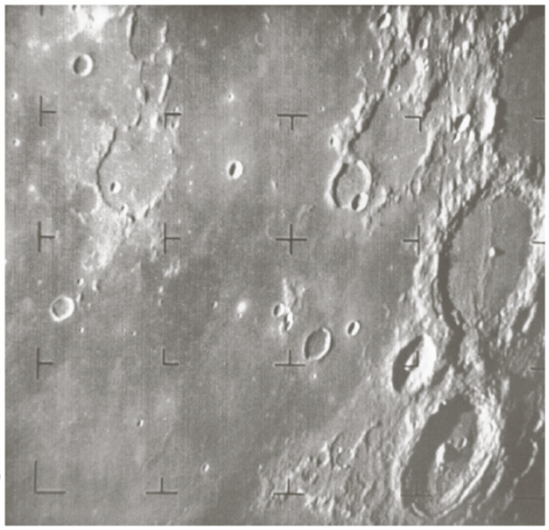


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

通用图像处理系统的组成

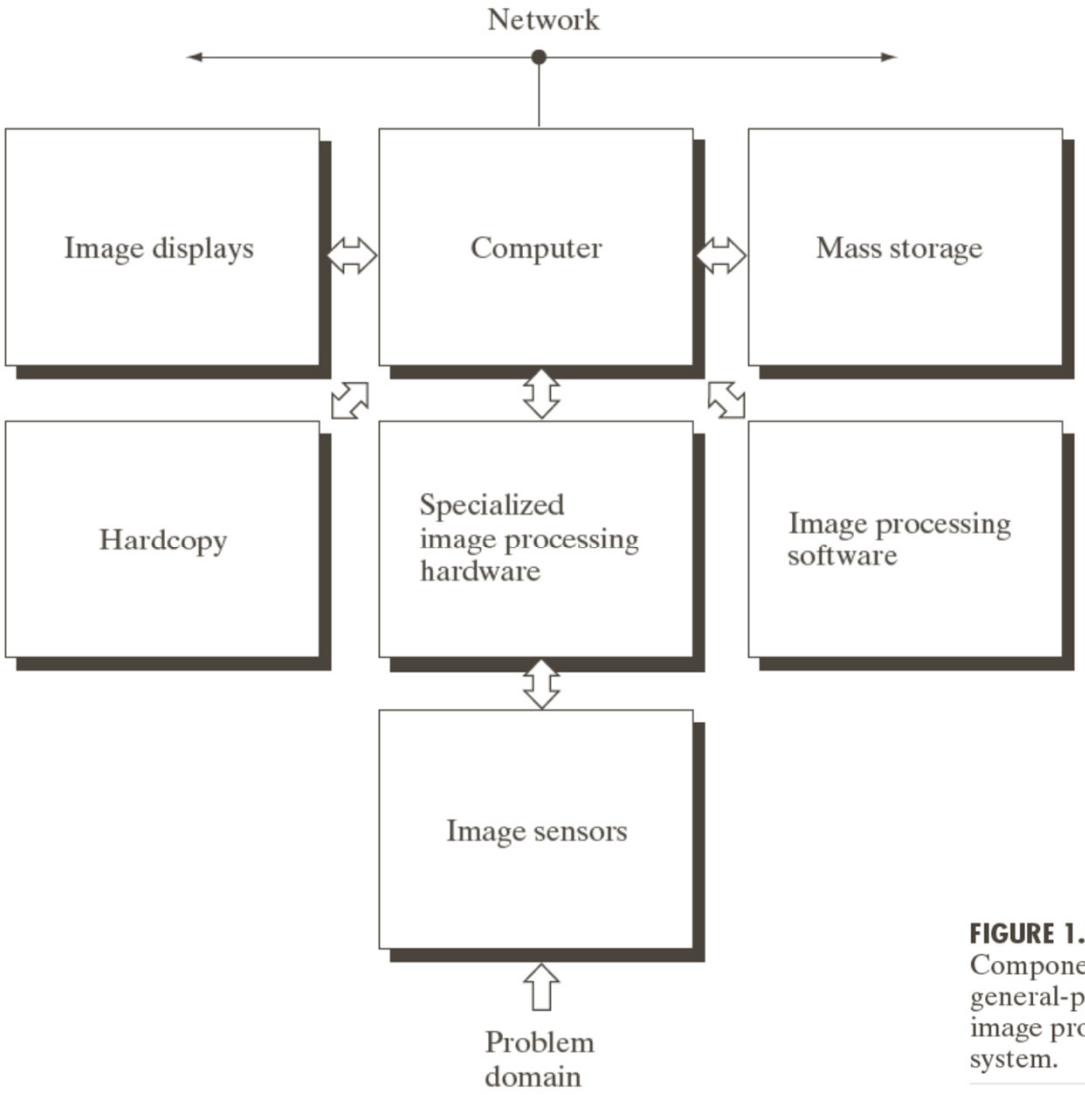


FIGURE 1.24
Components of a general-purpose image processing system.

https://snapshot.canon-asia.com/article/en/canon-announces-the-eos-m50-new-digic-8-image-processor-4k-movie-shooting

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数字图像处理的基本步骤

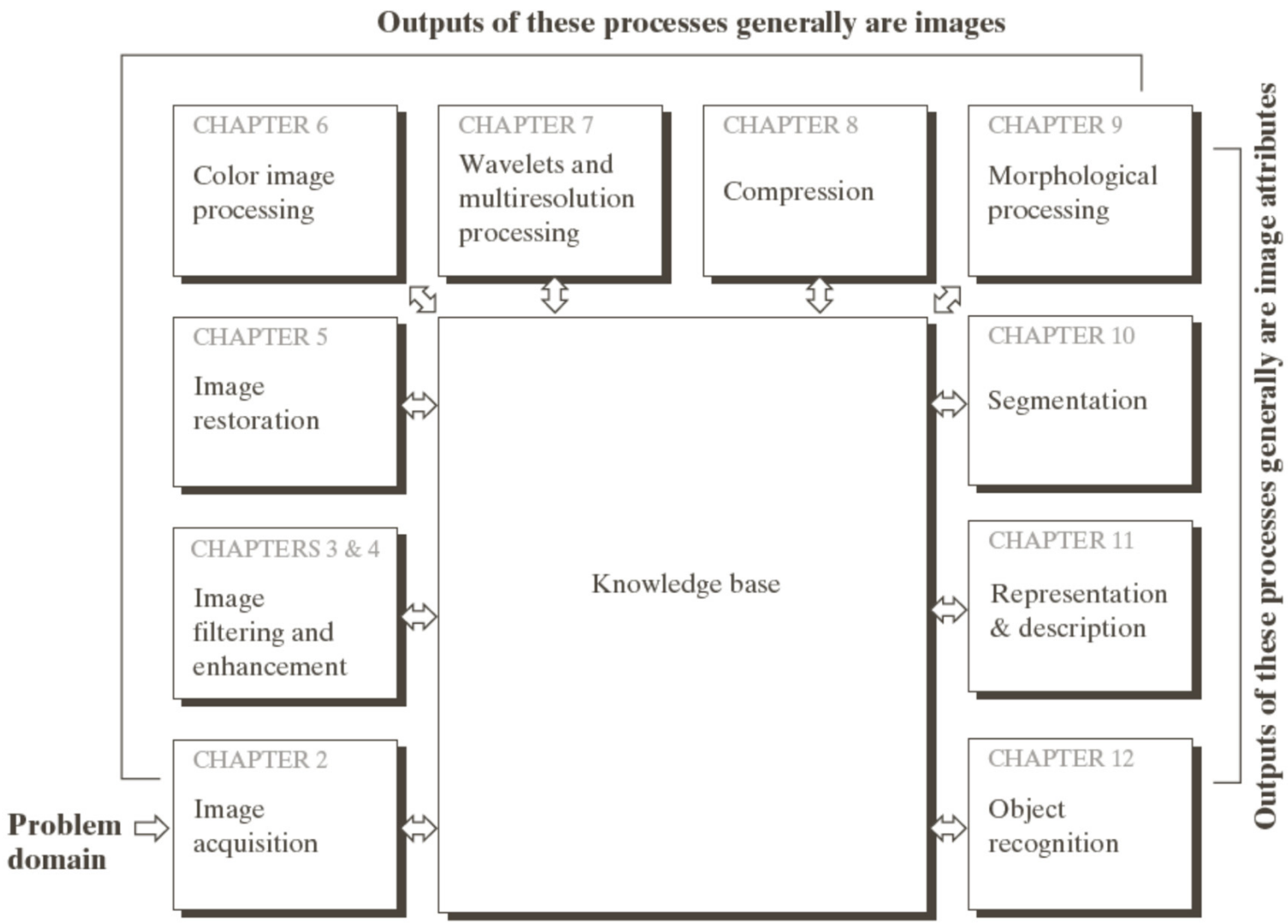

FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.

课程内容 （I）

1. 视觉与图像 （5 学时）
2. 数字图像的基本概念 （4学时）
3. 图像变换与滤波 + 深度学习简介（6学时）
4. 图像的统计描述 （3学时）
5. 图像增强 （3学时）
6. 图像的形态学处理 （3学时）
7. 图像分割与边缘检测 （6学时）
8. 小波变换初步及应用（3学时）
9. 图像复原与重建 （6学时）

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教学方式 (I)

- 课堂授课
  首席授课教师：杨戈
  共同授课教师：高伟

- 教师助教
  刘子文

- 平时作业
  - 平均每2-3周一次编程作业，共4次作业

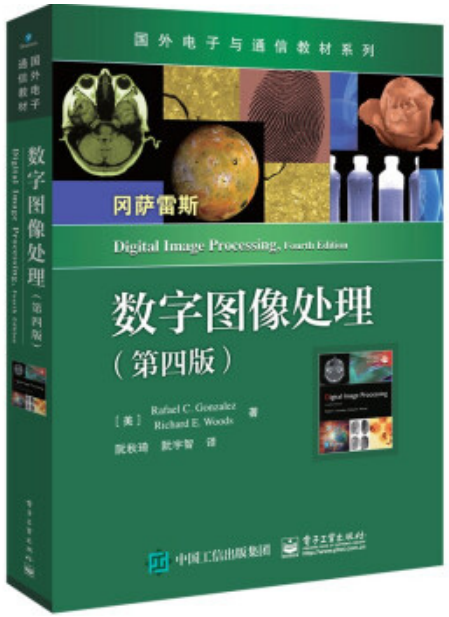
- 平时作业 （~70%）+ 闭卷考试（~30%）

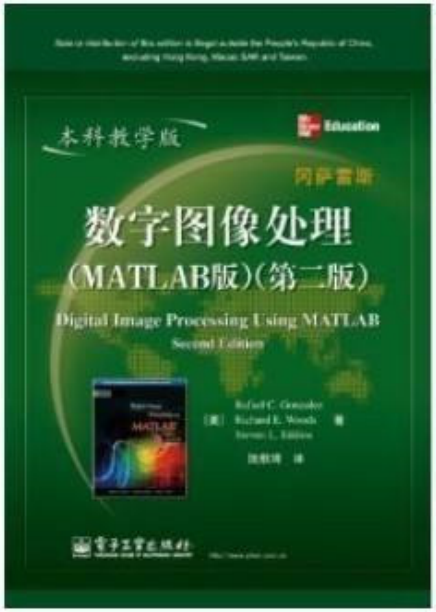
教学方式 (II)

- 推荐教材

-冈萨雷斯，伍兹著， 数字图像处理（第4版), 电子工业出版社，2020.

-冈萨雷斯，伍兹著， 数字图像处理 (MATLAB版), 电子工业出版社，2014.



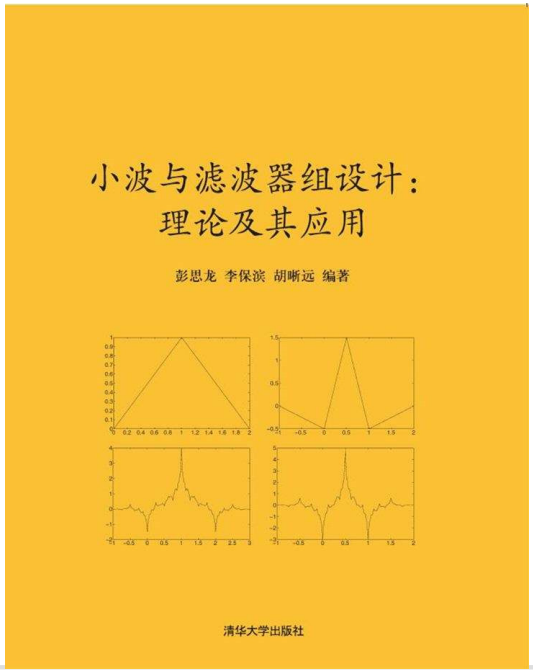


教学方式 (II)

- 参考书

- 彼得鲁著，赖剑煌译，数字图像处理疑难解析——计算机科学丛书 ，机械工业出版社，2005.

- 彭思龙，李宝滨，胡晰远著，小波与滤波器组设计：理论及其应用，清华大学出版社，2017.



- 什么是图像?
- 图像处理简介
- 课程内容概要
- 课程安排与要求
- **人类视觉机理**
- 一些与课程有关的重要实用信息

人眼的结构 (I)

- 人眼由三层膜包裹
  - 角膜(cornea)与巩膜(sclera)
  - 脉络膜 (choroid)
  - 视网膜 (retina)
- 脉络膜负责供血与营养
- 虹膜(iris) 负责控制入光量
  - 2~8mm
- 睫状体(ciliary body)，睫状肌(ciliary muscle)和晶状体(lens)负责光学调节

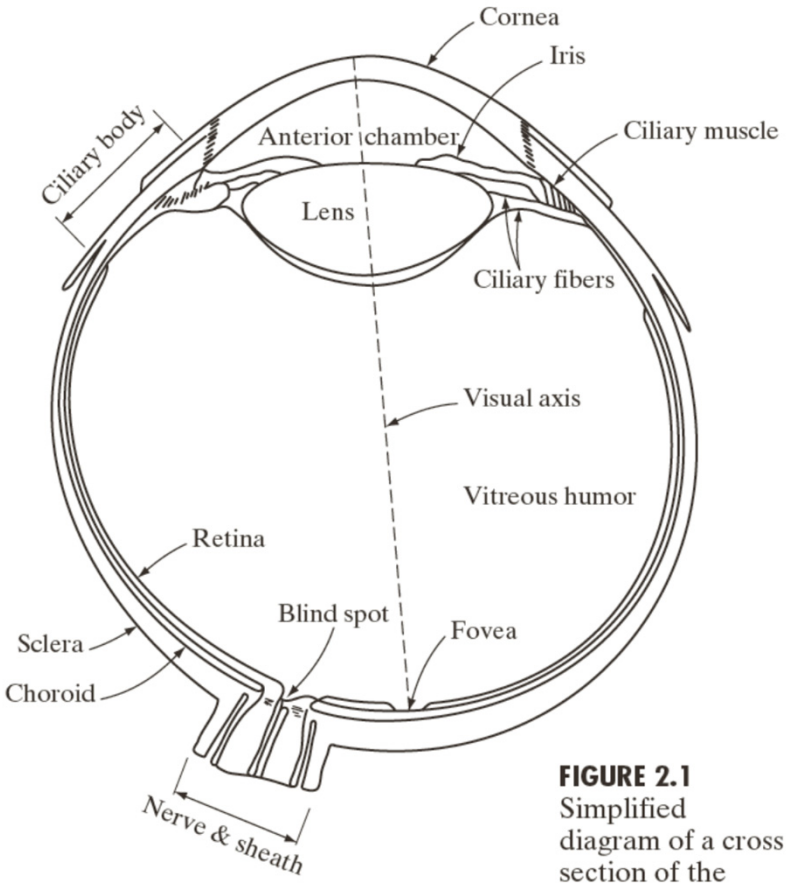


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

人眼的结构 (II)

- 视网膜：光感受器

- 锥状体(cones)
  - 600~700万个
  - 对颜色高度敏感
  - 负责亮视觉
  - 感兴趣的物体落在中央凹(fovea)

- 杆状体(rods)
  - 7500~15000万个
  - 没有彩色感觉
  - 负责暗视觉/微光视觉

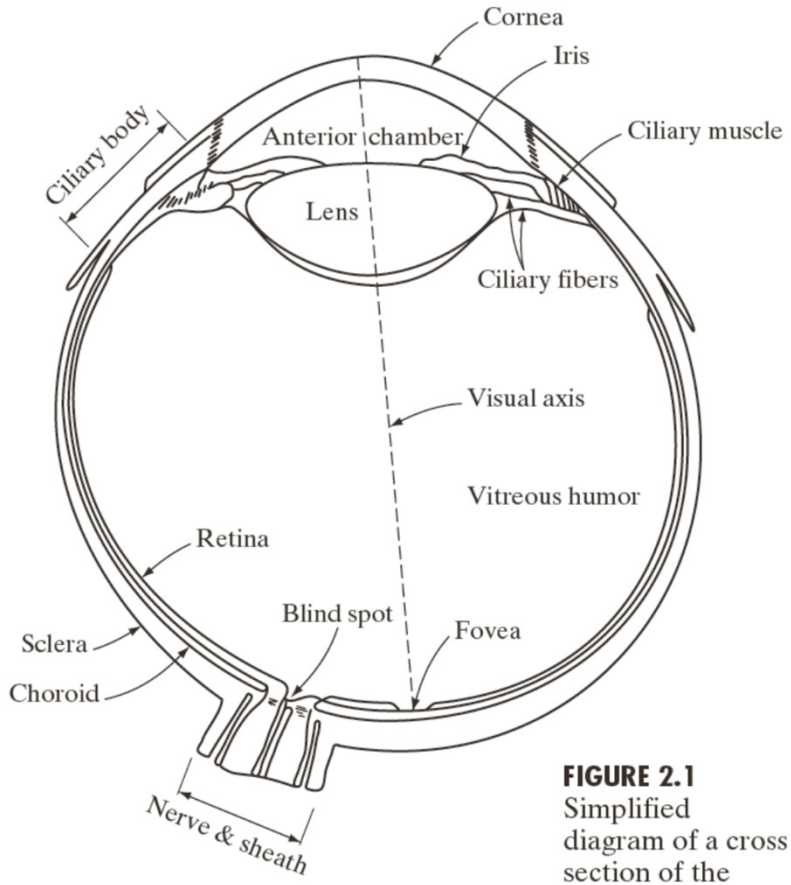


FIGURE 2.1 Simplified diagram of a cross section of the human eye.

视网膜中锥状体和杆状体的分布

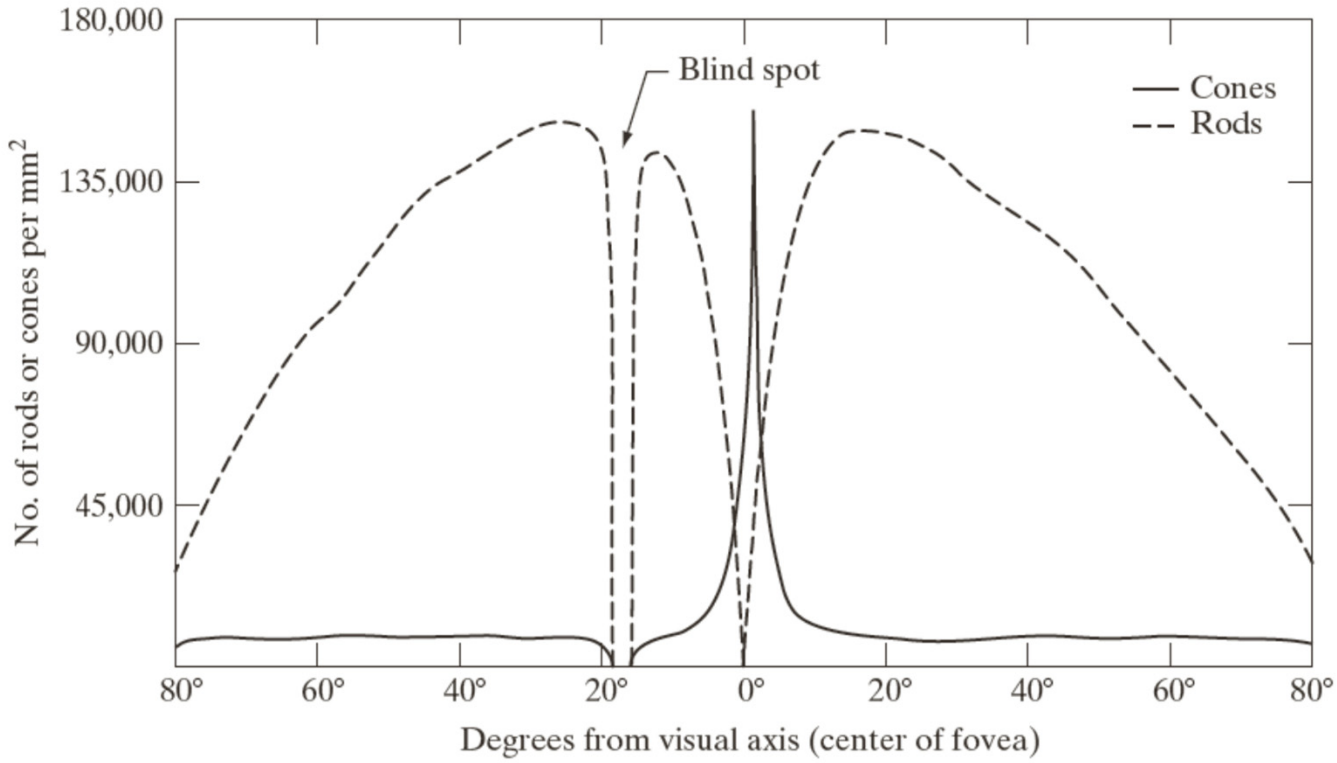


FIGURE 2.2
Distribution of rods and cones in the retina.

人眼的结构 (III)

- 中央凹是直径大约1.5mm的圆形凹坑
- 如果把中央凹近似为一个1.5mmX1.5mm的矩形，锥状体的密度大约为每平方毫米15万个。
- 典型的CCD芯片的尺寸是25mmX16mm, 以中央凹的密度，相当于共有60M像素。

眼睛中图像的形成

- 焦距： 14~17mm

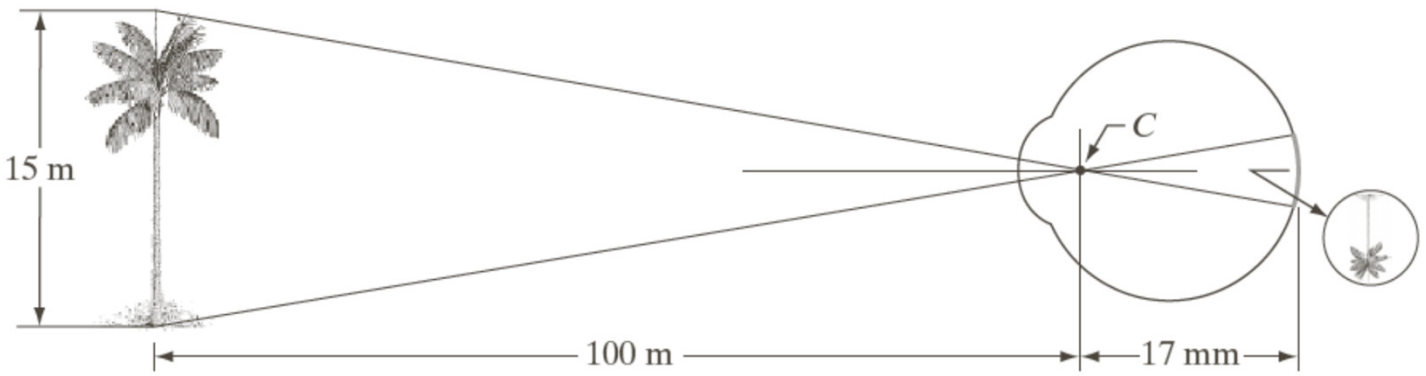


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

主观亮度与实际光强的关系

- 主观亮度是光强的对数函数
- 人眼在暗视觉(scotopic)条件下的敏感度低于亮视觉(photopic)条件下的敏感度

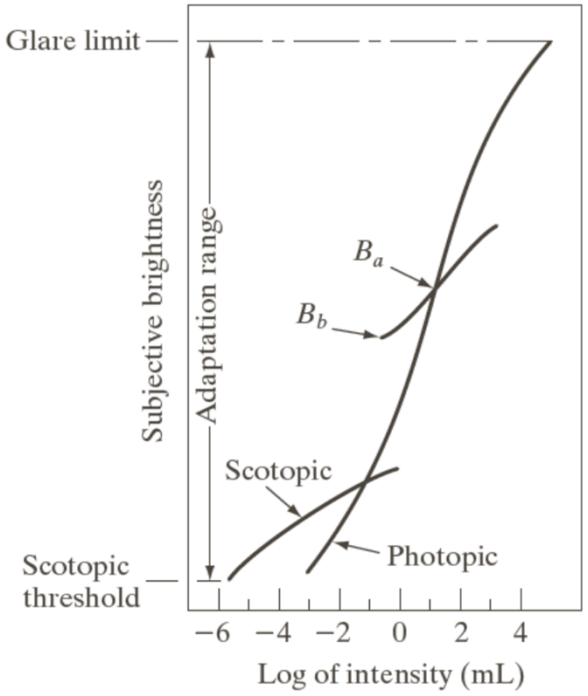


FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

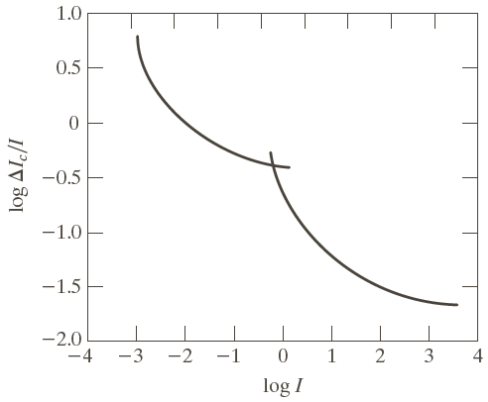
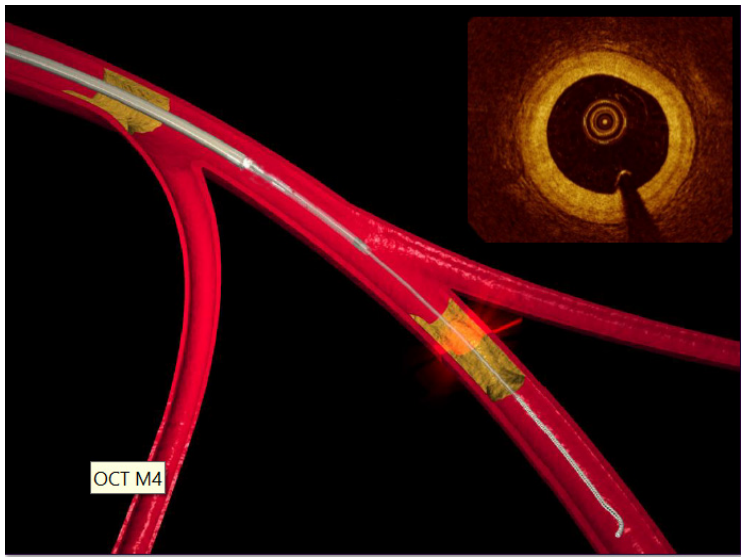


FIGURE 2.6 Typical Weber ratio as a function of intensity.

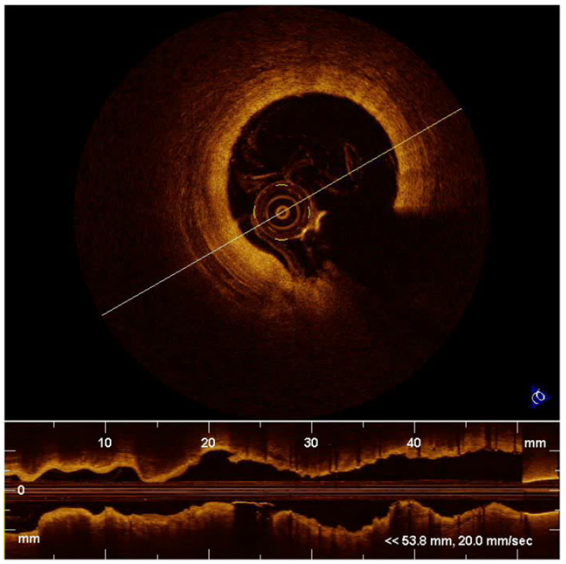
OCT成像



- 导管内光纤传输近红外光
- 光纤旋转：产生一系列的横截面图像
- 光纤回撤：生成一系列图像

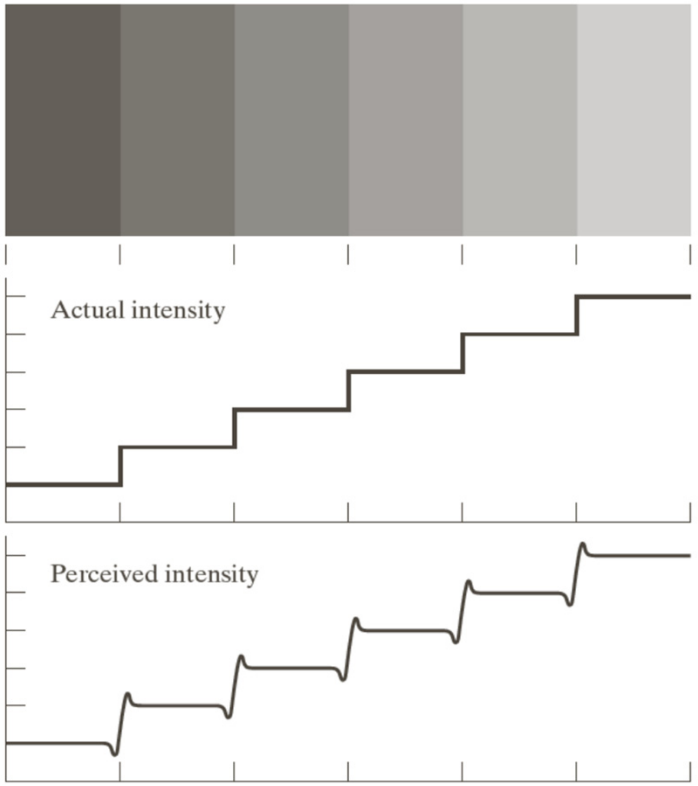
“B-Mode”
横截面视角

“L-Mode”
纵轴视角



- 一个轴线可有1024个像素（穿透组织深度2-3mm）
- 1帧图像有500条轴线
- 分辨率可达10-20um
- 可回撤扫描8cm的长度
- 1次回撤可产生270-540帧图像

人眼的马赫带效应



a
b
c

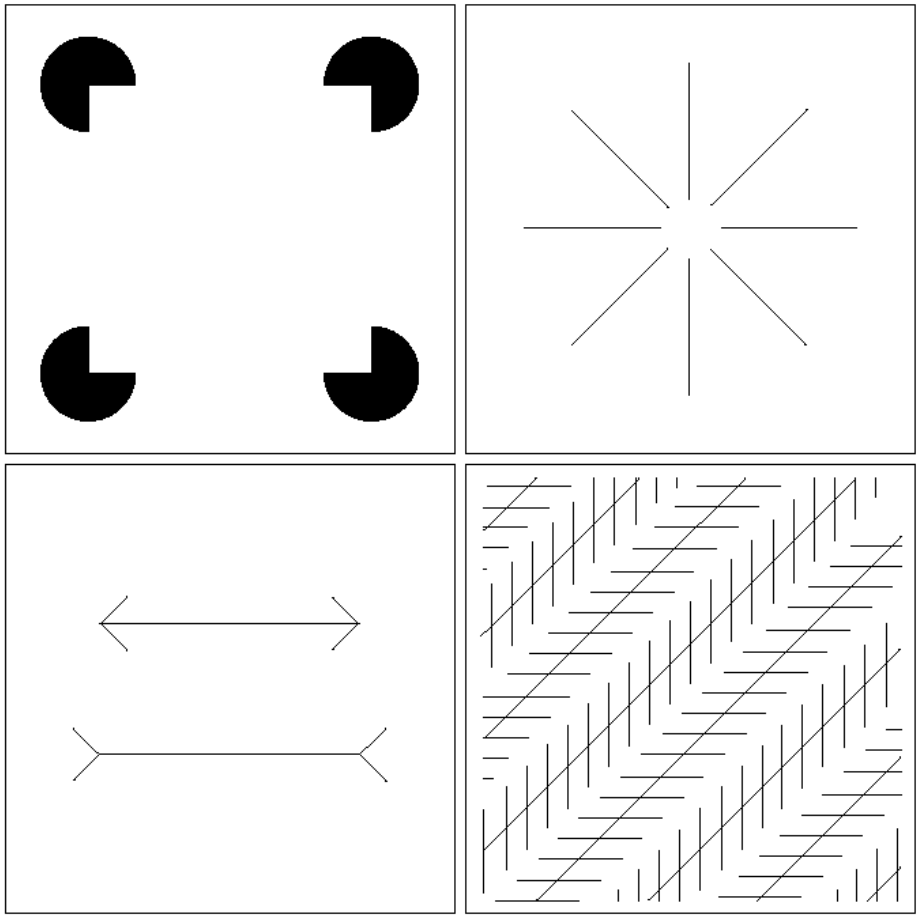
FIGURE 2.7
Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.

人眼的同时对比效应

a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

人眼的视错觉 (感知组织 Perceptual Organization)



a b
c d

FIGURE 2.9 Some well-known optical illusions.

参考文献

Image Formation in the Living Human Eye

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Annu. Rev. Vis. Sci. 2015. 1:1–17

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The *Annual Review of Vision Science* is online at vision.annualreviews.org

This article's doi: 10.1146/annurev-vision-082114-035905

Keywords

optics, retinal image, aberrations, intraocular scatter, spatial vision

Abstract

The human eye is a relatively simple optical instrument that imposes the first performance limits on the visual system. This review describes the main optical properties of the eye: geometric image formation, aberrations, and intraocular scattering. The article also discusses the sources of optical degradations and their impact on visual performance.

生成图像的电磁波谱

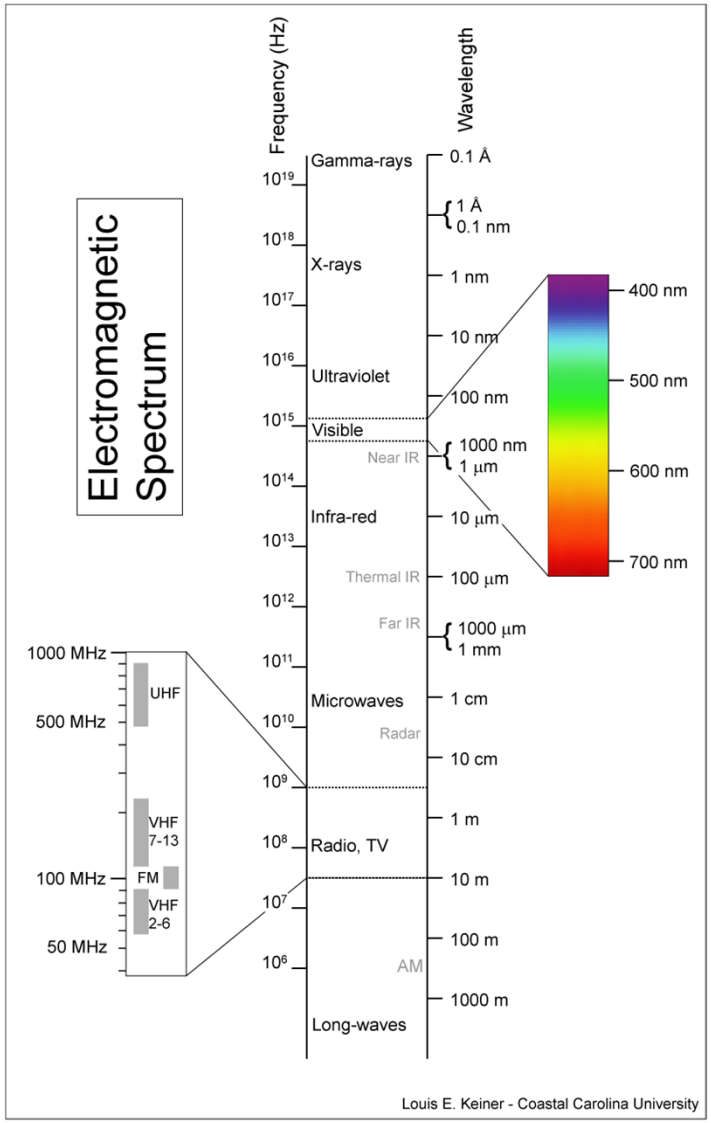
- 光子能量的普朗克定律：

$$E = h\nu = h\frac{c}{\lambda}$$

h: 普朗克常数; 6.626×10^{-34}J·s
v: 光频率;
λ: 光波长
c: 光速

光子能量 =
3.973×10^{-19}J at 500nm

- 光波长越短光子能量越高。



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本领域的重要国际会议

- http://conferences.visionbib.com/Iris-Conferences.html
- *IEEE CVPR*
- *ICCV, ECCV, ACCV*
- *NeurIPS， AAAI*
- Medical Image Computing and Computer Assisted Intervention Society Meeting (MICCAI)
- IEEE International Conference on Image Processing (ICIP)
- IEEE International Conference on Acoustics, Speech, and Signal (ICASSP)
- IEEE International Conference on Biomedical Imaging (ISBI)

本领域的重要专业杂志

- International Journal of Computer Vision (IJCV)
- IEEE Transactions on Pattern Analysis & Machine Intelligence (PAMI)
- IEEE Transactions on Image Processing
- IEEE Transactions on Medical Imaging

课程有关的网上资源

- 图像处理教科书网站

  http://www.imageprocessingplace.com/

  http://www.imageprocessingplace.com/root_files_V3/publications.htm

有关的网上课程

- Stanford University EE368/CS232 Digital Image Processing
  https://web.stanford.edu/class/ee368/index.html
- UC Berkeley
  http://inst.eecs.berkeley.edu/~ee225b/sp19/
- Purdue University
  https://engineering.purdue.edu/~bouman/ece637/
- Northwestern University
  https://www.mccormick.northwestern.edu/electrical-computer/courses/descriptions/420.html
- University of Waterloo
  https://ece.uwaterloo.ca/~ece417/index.html

Questions?

关于编程软件的说明

MATLAB Overview

- MATLAB stands for "matrix laboratory“, a product of MathWorks Inc. (Natick, Massachusetts).

- It is both an interpreted language and a development and application environment.

- History of MATLAB

  - First developed in 1970's by Cleve Moler, coauthor of LINPACK & EISPACK

  - First written in FORTRAN; Later rewritten in C

  - Commercial development initiated by Jack Little
    - MathWorks was founded in 1984.

  - In 2000, rewritten based on LAPACK.

Sources:
http://www.mathworks.com/company/aboutus/founders/clevemoler.html
http://www.mathworks.com/company/aboutus/founders/jacklittle.html
http://www.mathworks.com/company/newsletters/news_notes/clevescorner/dec04.html

Advantages of MATLAB (I)

- MATLAB provides reliable and efficient numerical computation with friendly user interfaces.
  - Maple, Mathematica traditionally strong in symbolic computation (computer algebra)
- Examples of numerical computation issues
  - Precision; numerical stability
  - Underflow and overflow
  - Code quality (debugging, exception handling)
  - Code efficiency (optimization)
- Visit www.netlib.org for more information about different numerical packages.

Advantages of MATLAB (II)

- Fast prototyping: MATLAB is an interpreted language
- Extensive toolboxes
- Versatile graphics
- Cross-platform: Windows, Unix, Linux, Mac OS
- Support parallel computing
- Support object oriented programming
- Large groups of users

  MATLAB file exchange **(use with caution)**

  http://www.mathworks.com/matlabcentral/

MATLAB Toolboxes (I)

- A large collection of basic math functions are provided in the MATLAB base package.
- Function extensions are packaged as toolboxes.
- Signal & image processing; Computer vsion
  - Signal processing toolbox
  - Image processing toolbox
  - Computer vision toolbox
  - Statistics and machine learning toolbox
  - Neural network toolbox (for deep learning)
- Math and optimization
  - Optimization toolbox
  - PDE toolbox

MATLAB Toolboxes (II)

- Statistics & data analysis
  - Curve fitting toolbox
- Third party toolboxes
  - Pattern recognition toolbox: www.prtools.org
  - Wavelet toolbox: http://www-stat.stanford.edu/~wavelab/

Limitations of MATLAB

- Operation details are hidden.
- Limited efficiency: MATLAB is an interpreted language.
  - Compiler also available
  - Can use MEX (MATLAB executable) to call DLL implemented in C
- Lack of properties to support large scale software development
  - E.g. Implicit & dynamic data type
- MATLAB is widely used in image processing and computer vision.
- MATLAB is the required implementation language for this class.

Learning MATLAB

- How to write a MATLAB function
  - Many videos are available

- Some references
  - There are many MATLAB tutorials online and books available.
  - Kermit Sigmon, MATLAB Primer, 3rd ed.
  - MATLAB User's Guide.

- Reminder: MATLAB computation results can be saved in .mat files and loaded back.

- Reminder: MAT files are exchangeable on different platforms.

Getting Help with MATLAB

- Read related references and practice first.
- For a specific function, it is often helpful to look in MATLAB online help.
- For a general question, it is often helpful to check related toolbox manuals.
- If none of these works, direct your questions to the instructor.

A Partial List of Resources

- A MATLAB Primer (3/e) by Kermit Sigmon
- Free video-based tutorials on MATLAB:
  http://www.mathworks.com/academia/student_center/tutorials/
- Plot gallery with source code (by clicking on the figures):
  http://www.mathworks.com/discovery/gallery.html
- 8th Edition MATLAB Primer:
  http://www.mathworks.com/support/books/book52873.html?category=17&language=1
- Free online book to learn MATLAB by Cleve Moler, creator of MATLAB:
  http://www.mathworks.com/moler/exm/chapters.html

Python Overview

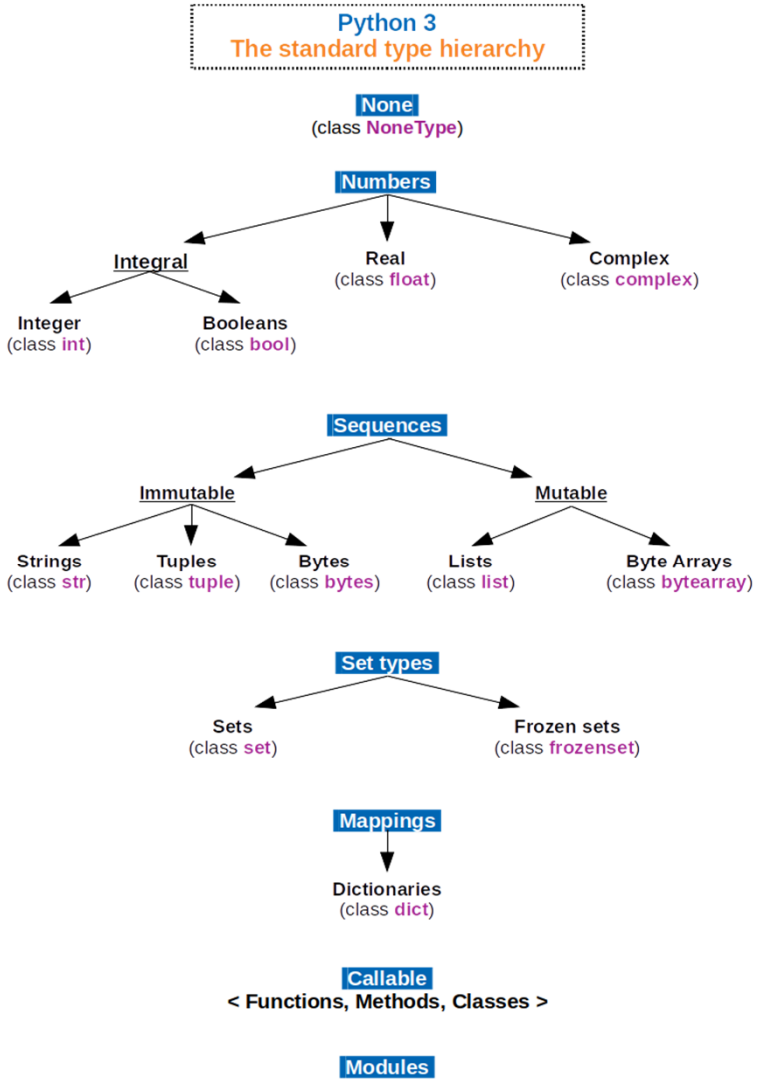
- An interpreted, high-level and general purpose programming language. (stable release 3.9.2)
- Many functions are provided in its standard library.
- First started by Guido van Rossum in late 1980's.
- One of the most popular languages for deep learning programming.

https://en.wikipedia.org/wiki/Python_(programming_language)

Design Philosophy

- Beautiful is better than ugly.
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- Readability counts.

Supported Standard Types

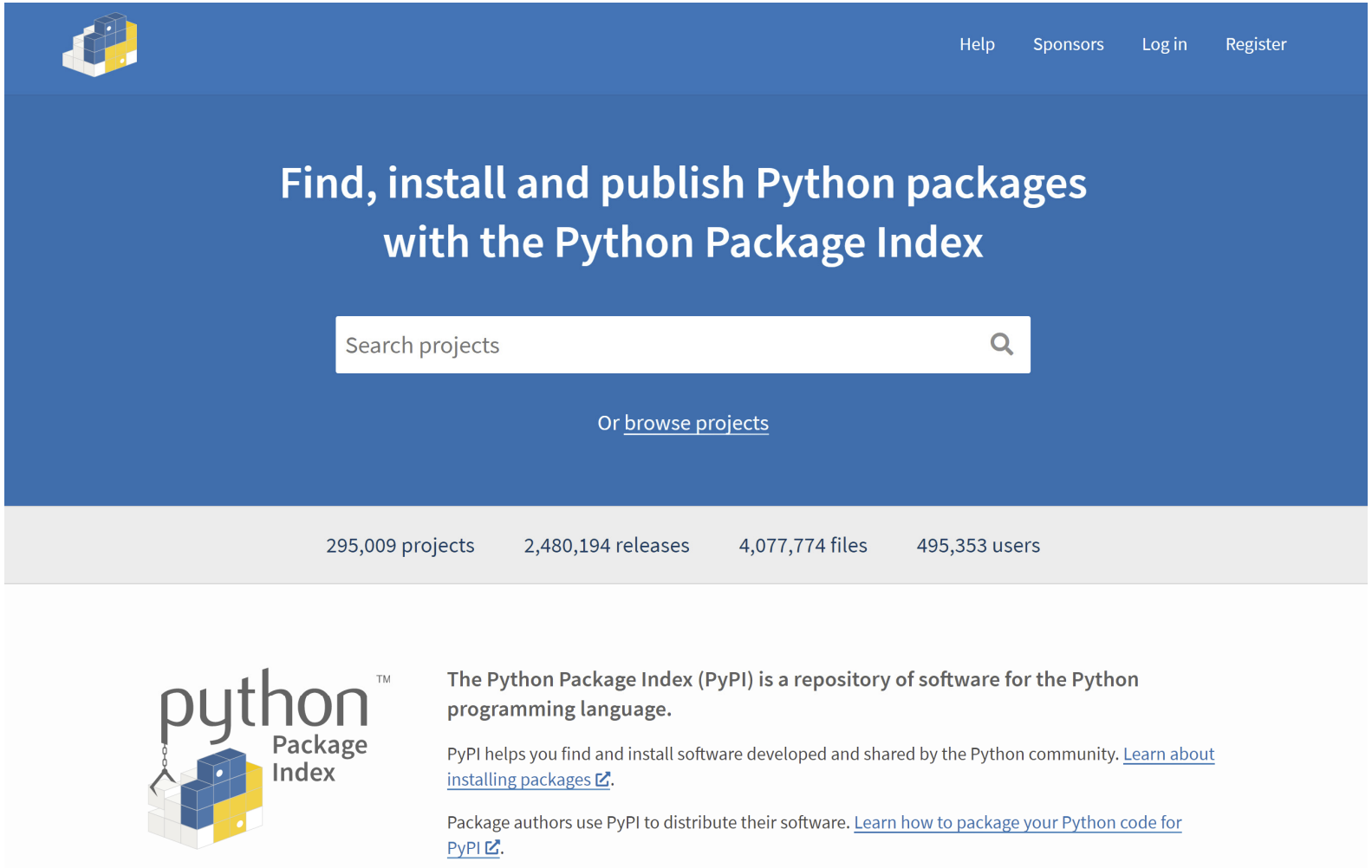


Standard Library and Third-Party Packages

- Python has a rather large standard library.

- Automation
- Data analytics
- Databases
- Documentation
- Graphical user interfaces
- Image processing
- Machine learning
- Mobile App
- Multimedia
- Computer Networking
- Scientific computing
- System administration
- Test frameworks
- Text processing
- Web frameworks
- Web scraping

Python Package Index (PyPI)



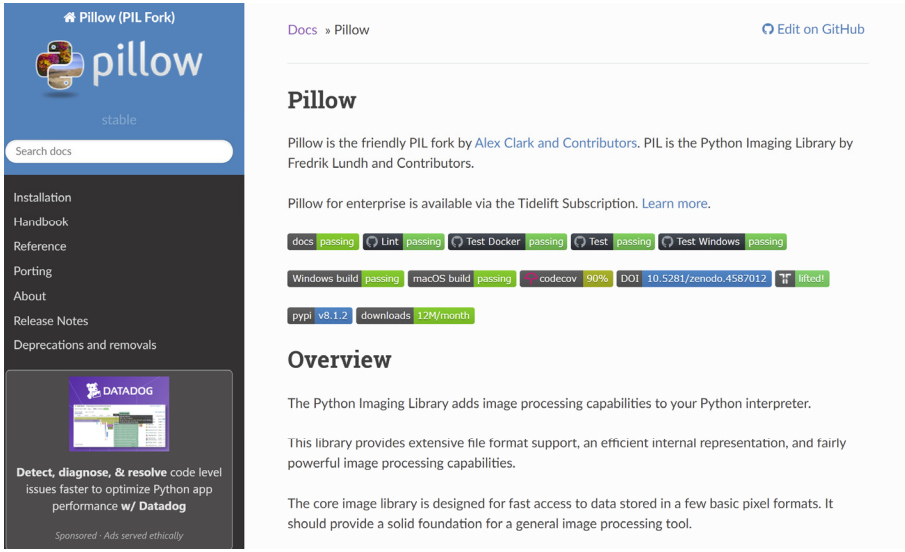
https://pypi.org/

Python Imaging Library

- PIL first released in 1995, last release in 2009, discontinued in 2011.
- Pillow is a new fork of PIL repository and serves as a replacement.

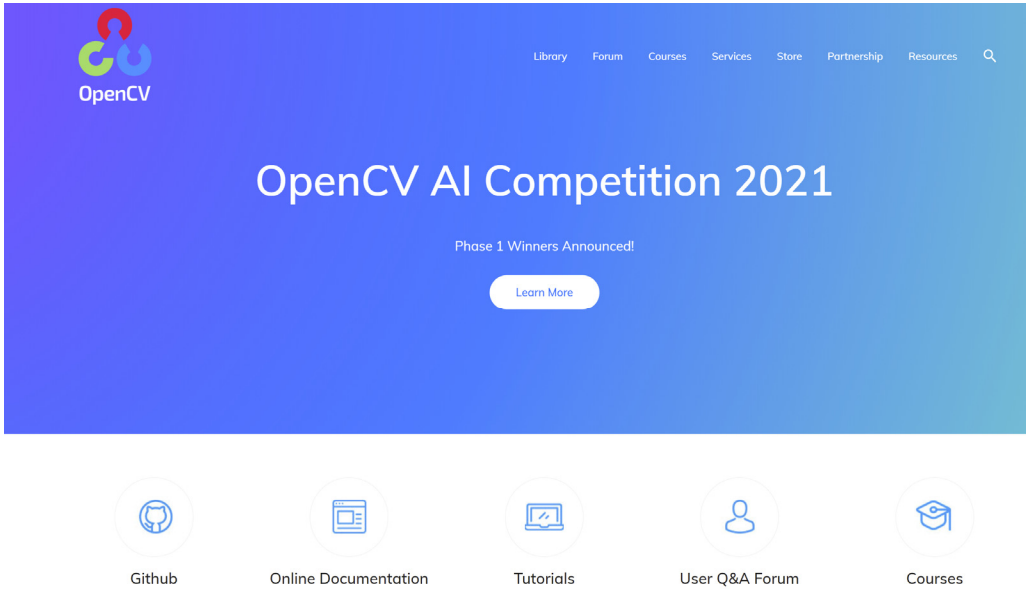
https://pillow.readthedocs.io/en/stable/#

https://github.com/python-pillow/Pillow



OpenCV

- First launched in 1999 as an Intel Research Initiative.
- Taken over by OpenCV.org in 2012.
- Intel came back in 2016.



https://opencv.org/

https://github.com/opencv/opencv