图像与视觉计算
Image & Vision Computing

http://www.graphics.pku.edu.cn/chenyisong/lectures/Spring2008/cys_home.htm

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课程安排

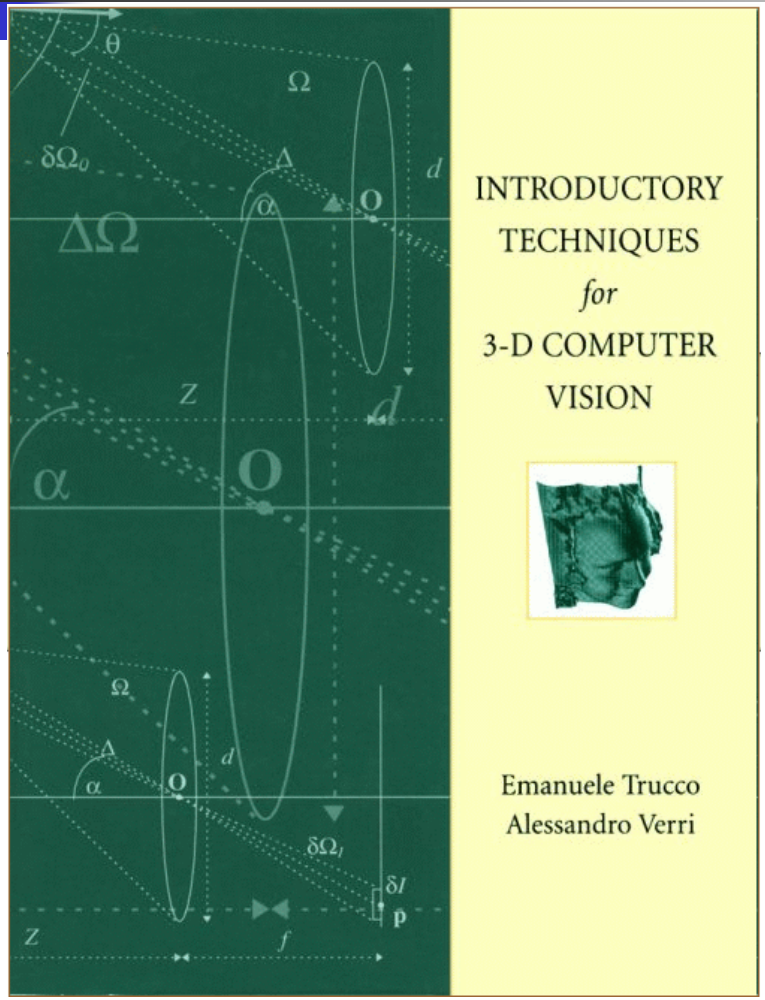
- 上课时间
  - 星期二 16:50 – 18:40
- 质量评估
  - 课堂表现 30%
  - 小作业 30%
  - 期末考试（大作业） 40%
- 编程工具
  - Matlab (推荐)
  - C (C++)

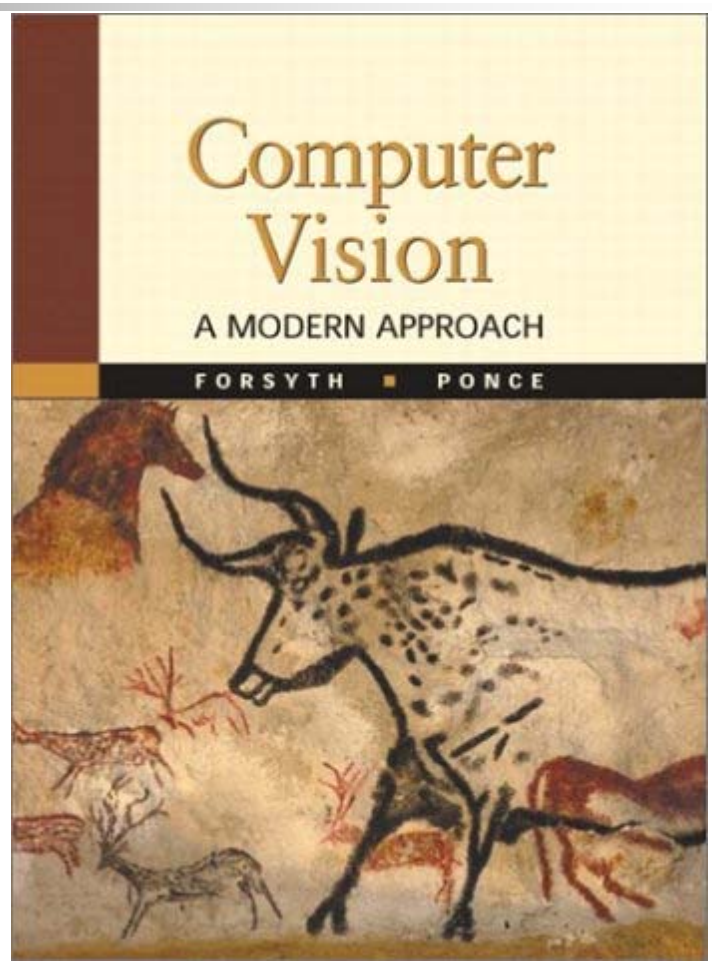
参考书目

- R. C. Gonzalez *et al.*, Digital image processing, Prenntica Hall
- Kenneth R. Castleman, Digital image processing, Prentice Hall
- David A. Forsyth and Jean Ponce, Computer Vision: A Modern Approach", Prentice Hall, 2003. *available online*.
- Emanuele Trucco, Alessandro Verri, Introductory Techniques for 3-D Computer Vision", Prentice Hall, 1998.
- R. O. Duda *et al.*, Pattern Classification, Wiley Interscience
- W.H. Press *et al.*, Numerical Recipes in C, The Art of Scientific Computing (2nd), Cambridge, 1999. *available online*.

- A. Blake, M. Isard, Active contours, Springer, London, 1998.
- M.F.Barnsley. Fractals Everywhere. Academic Press,San Diego, 1988.
- Applied multivariate analysis [electronic resource] / Neil H. Timm.
- ……

参考书目





Available on line

Important Academic References - Reference Journals

- International Journal of Computer Vision (IJCV)
- IEEE Trans. Pattern Analysis and Machine Intelligence (PAMI)
- IEEE Trans. Image Processing (IEEE IP)
- Computer Vision and Image Understanding (CVIU)
- Pattern Recognition (PR)
- Image and Vision Computing (IVC)
- Machine Vision and Applications (MVA)
- ……

Important Academic References – Conferences

- IEEE International Conference on Computer Vision (ICCV)
- IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)
- International Conference on Machine Learning (ICML)
- European Conference on computer vision (ECCV)
- British Machine Vision Conference (BMVC)
- International Conference on Pattern Recognition (ICPR)
- International Conference on Image Processing (ICIP)
- International Conference on Data Mining (ICDM)
- ……

相关学科（计算机，数学）

- 数字图像处理
- 计算机视觉
- 计算机图形学
- 模式识别和人工智能

- 线性代数
- 概率统计
- 计算方法
- 射影几何
- ……

课程内容

- 图像计算
  - 图像编码（各种编码策略，小波和分形编码，JPEG/JPEG2000.....）
  - 图像分析（图像滤波，特征抽取和匹配，图像分割.....）
  - 图像理解（图像配准，图像编辑，目标检测和识别，光流计算.....）
- 视觉计算
  - 相机原理和射影几何初步
  - 静态场景分析（2D/3D 测量，重构）
  - 动态场景分析 （2D/3D 运动跟踪 ）
  - 多视几何及应用
- 模式识别
  - 统计初步
  - 多变量分析
  - 数据挖掘及应用

Course webpage

http://www.graphics.pku.edu.cn/chenyisong/lectures/Spring2008/cys_home.htm

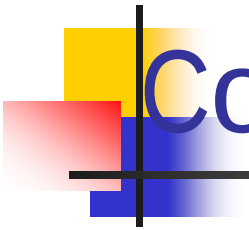
- Home
- Schedule
- Assignments
- Additional
- Bulletin

Course webpage - Home

- Course Summary
- Announcements
- References
- Grading Policy

Course webpage - Schedule

- Date
- Topic (Course note download)
- Readings
- Assignments



Course webpage - assignments

- Assignments/Requirement
- Projects/Requirement
- Reference topics

Course webpage - Resources

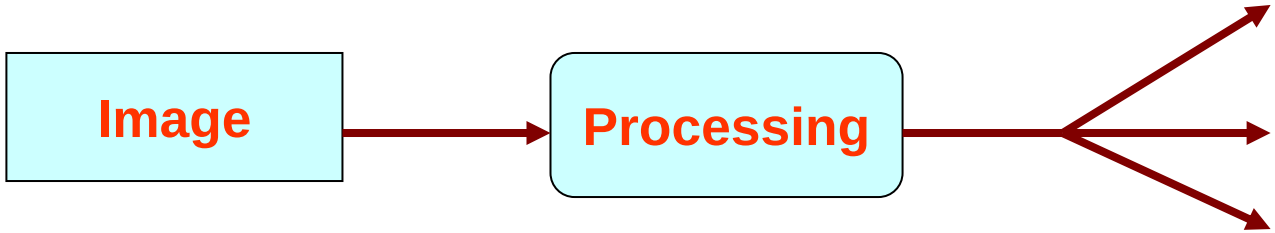
- Matlab resources
- Conferences
- Journals
- Related courses
- Useful links

Course webpage - Bulletin

- Students feedback
- Assignments presentation
- Any suggestions ?

Image Processing, What Is It?

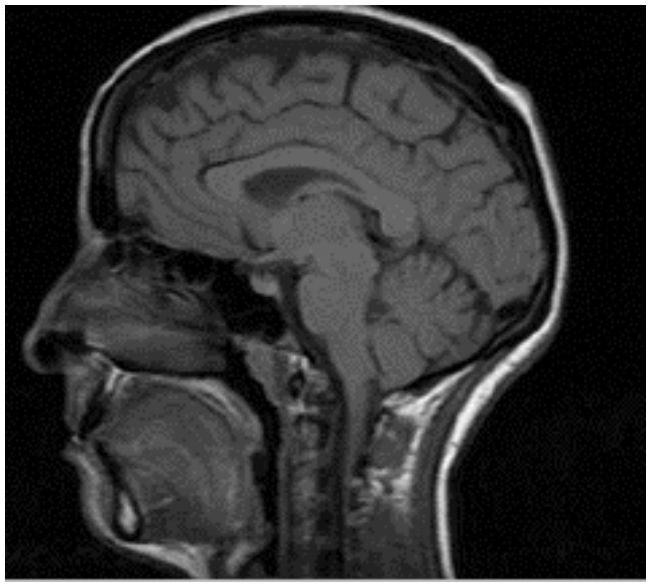
- A set of algorithms for manipulating digital images
- A preprocessing step necessary for image understanding
- Techniques to transform an image into a meaningful signal



General Questions:

- What input images are required for a particular algorithm
- What are feasible outputs
- Most Importantly: What does the “processing” box contain?

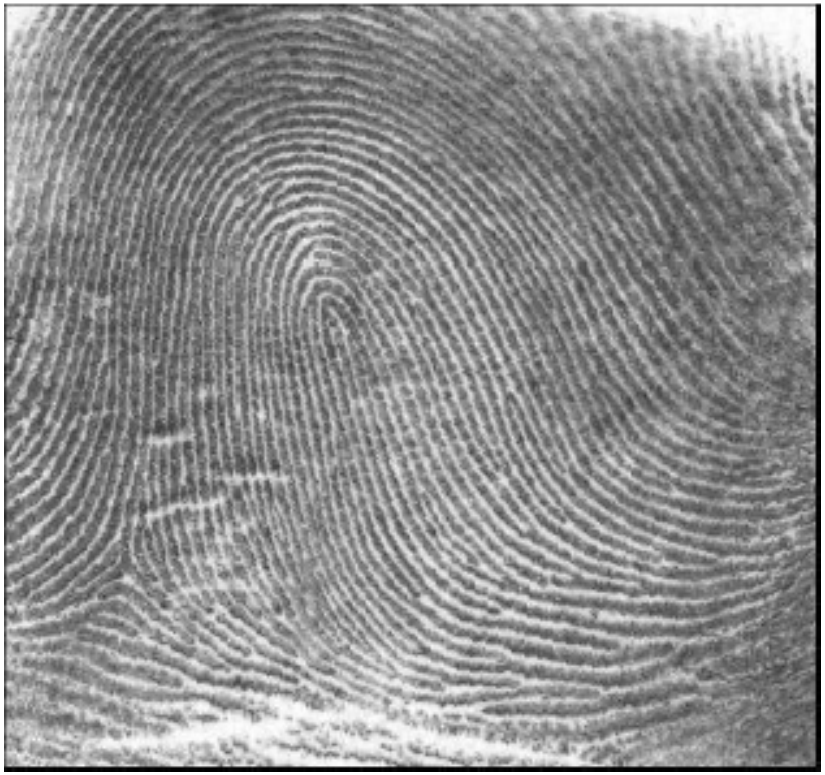
Some Representative Images



Enhanced MRI scan, Human Head

CT Image, Human Torso

Some Representative Images



fingerprint image

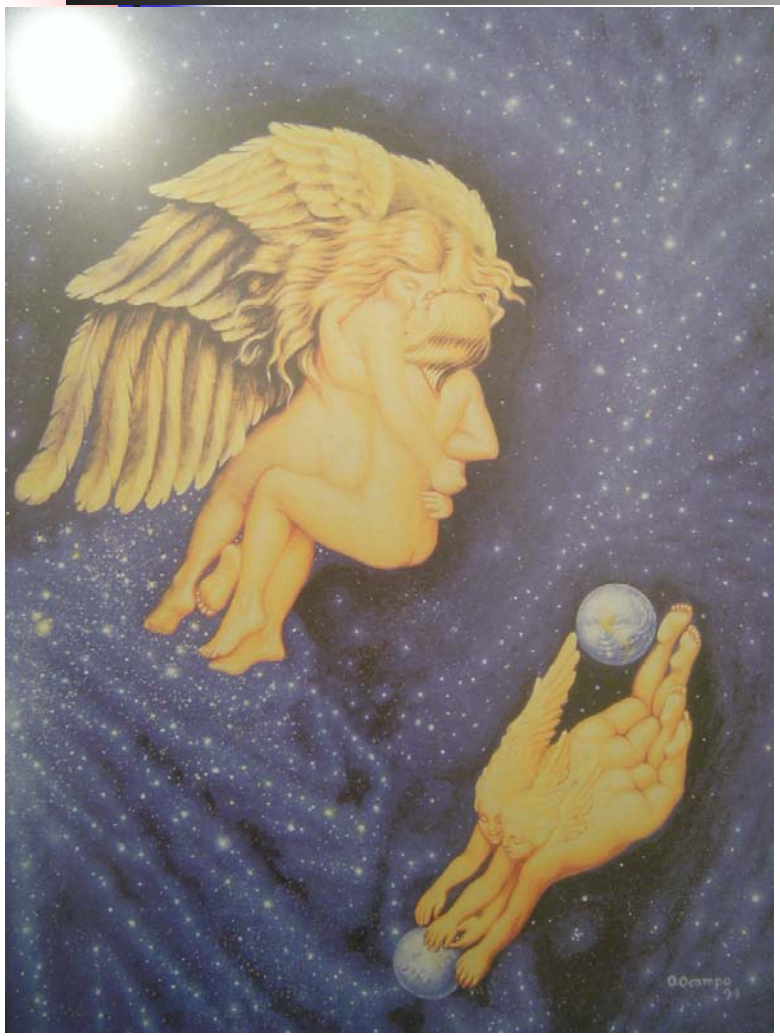
Some Representative Images

Image from video

Some Representative Images

License Plate reader

Image fun



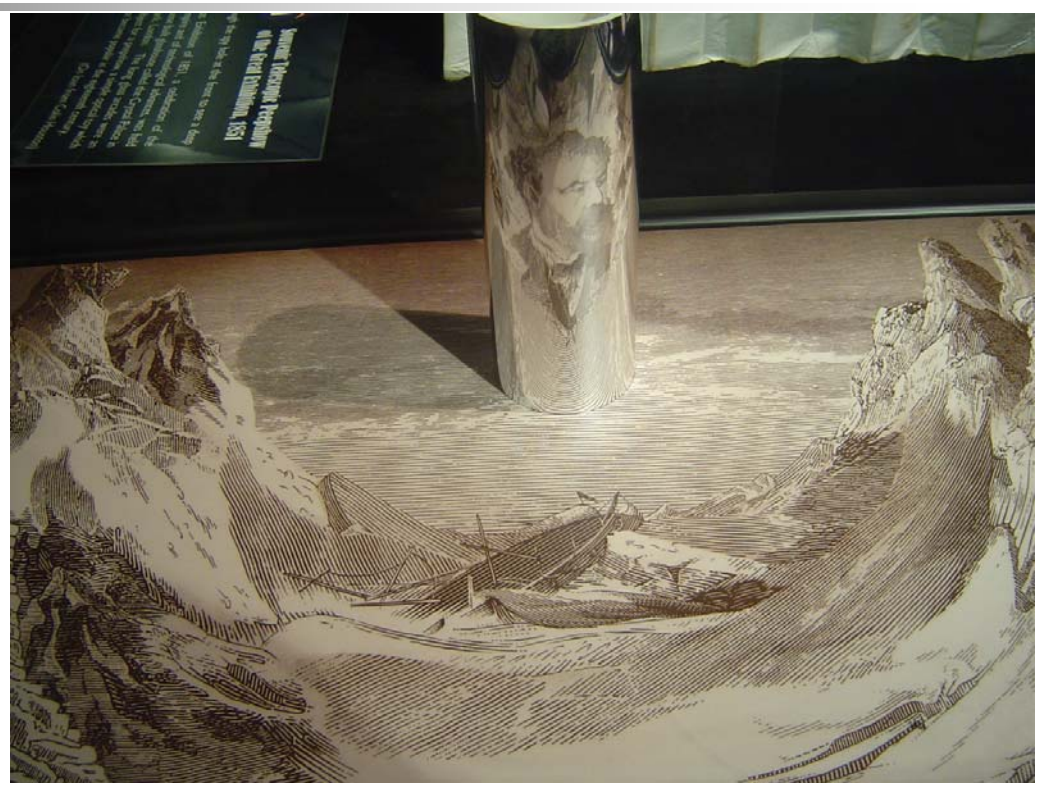
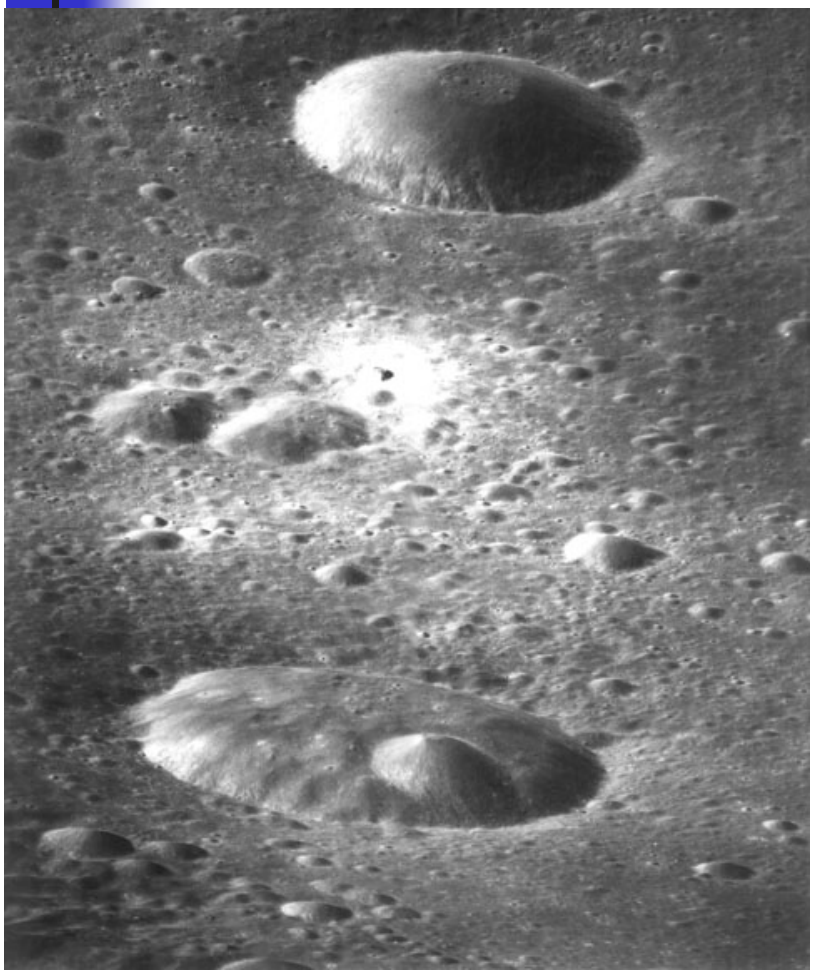
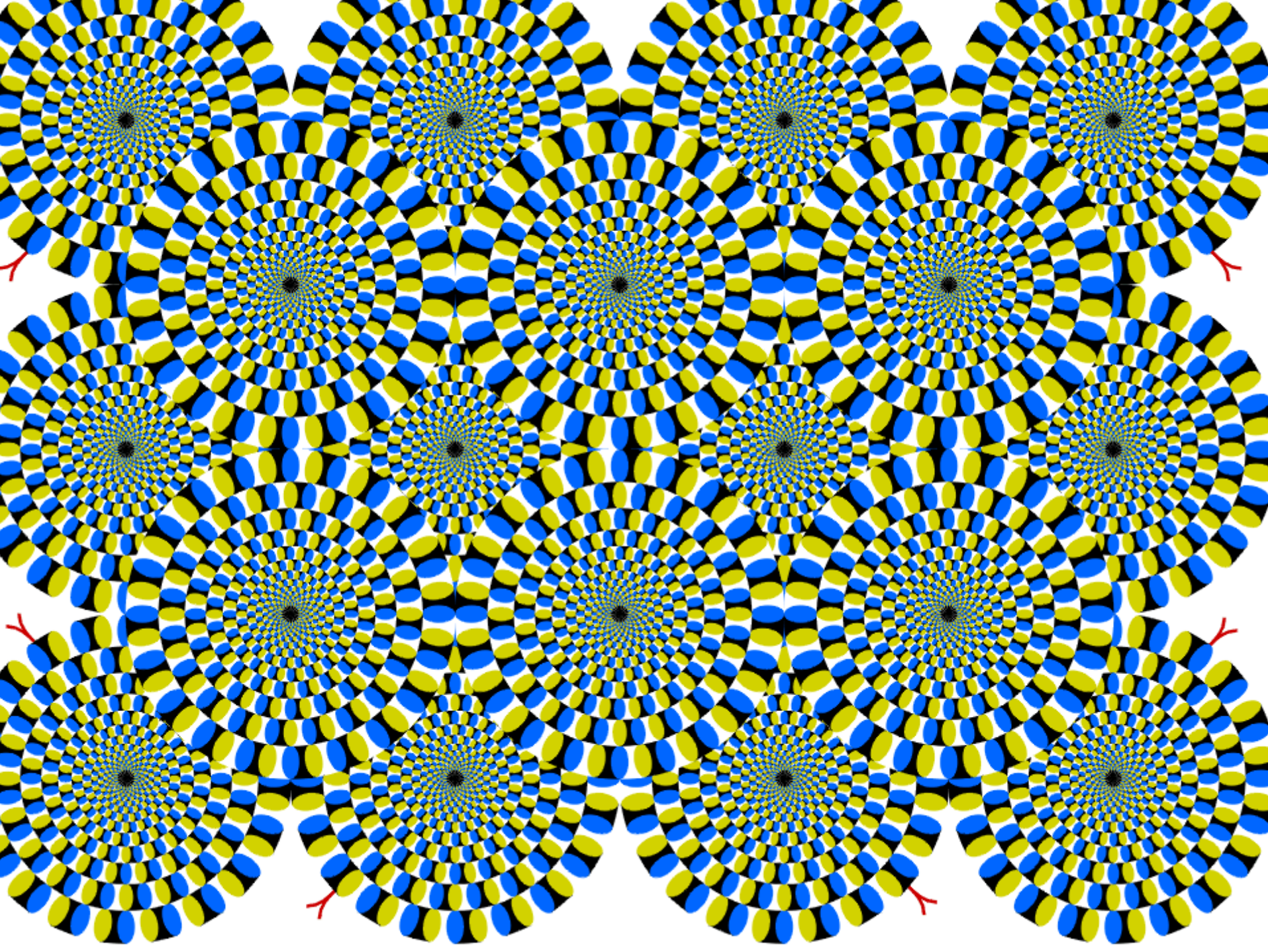
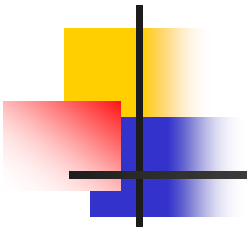


Image fun







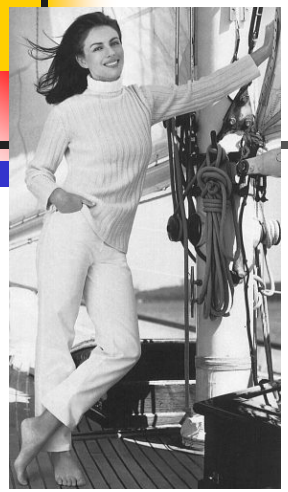
Example

Finding People in images

Problem 1: Given an image I

Question: Does I contain an image of a person?

“Yes” Instances



Phil Noble / AP


Mike Hewitt / Allsport


Patrick Gardin / AP


Andy Barron / Reno Gazette-Journal


Sydney Morning Herald

“No” Instances

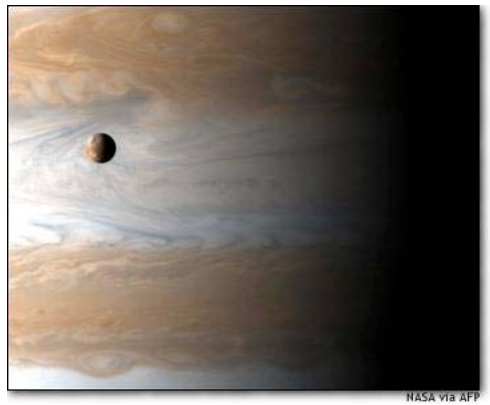

Eric Miller / Reuters


Mark Garkfinkel / The Boston Herald

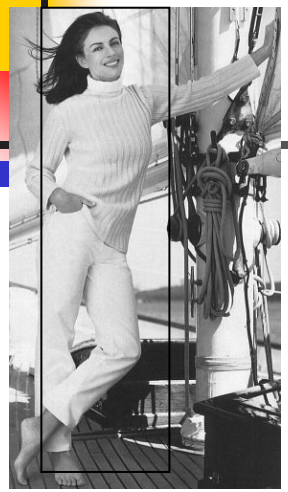
Jeff J. Mitchell / Reuters

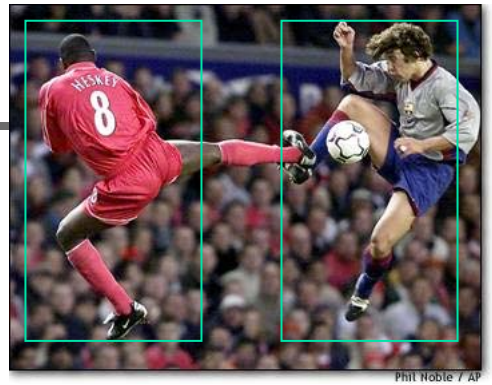

Monroe County Sheriffs Department / Newsmakers

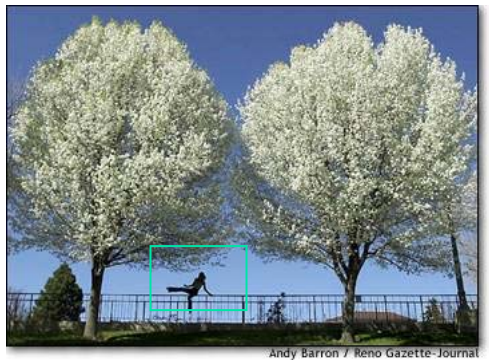

Uno Andersson / AP


NASA via AFP

High Level Vision

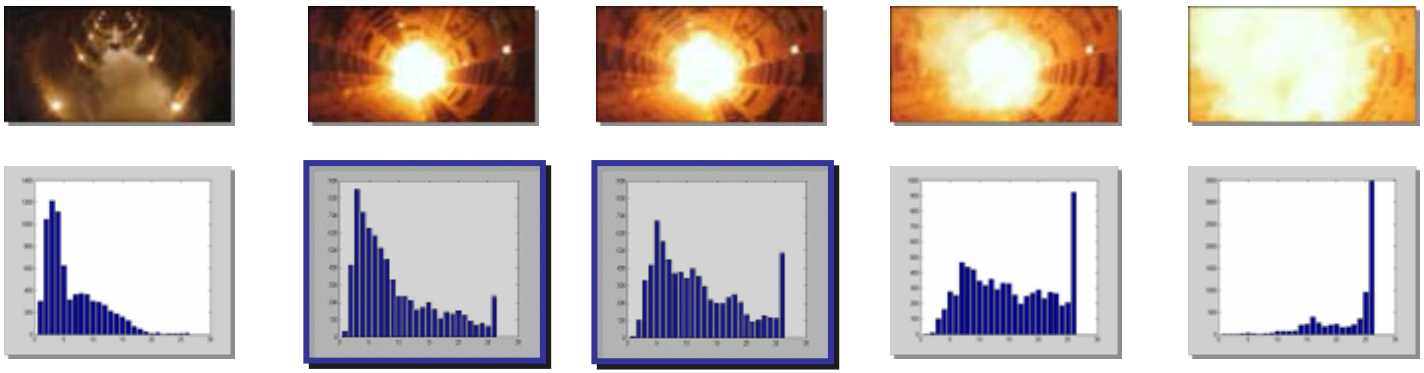






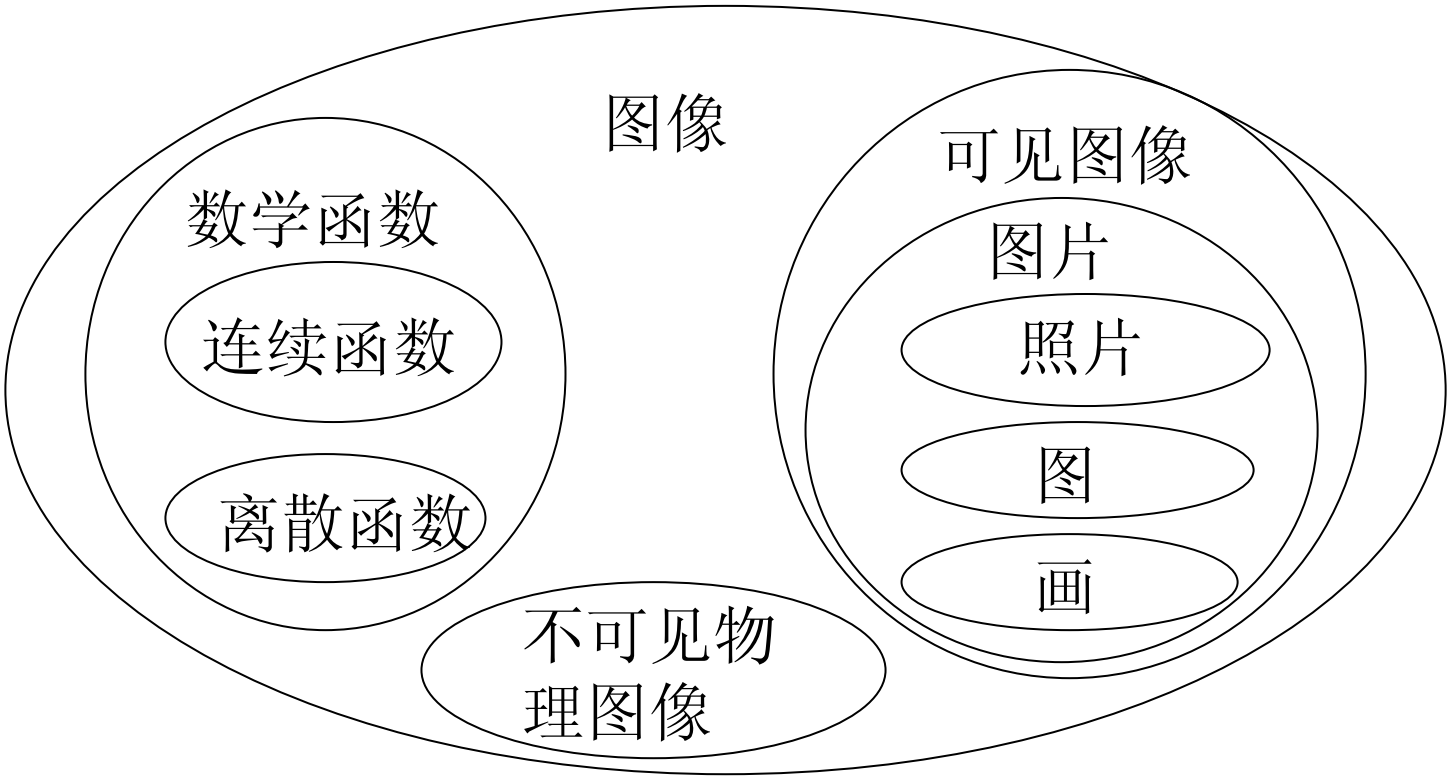
Example 2

Explosion/fire Detection



图像与视觉计算

- 什么是图像



图像与视觉计算

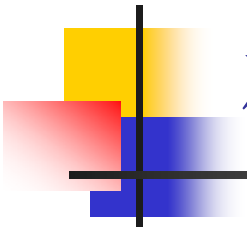
- 数字图像处理
  - 定义:对一个物体的数字表示施加一系列的操作,以得到所期望的结果
  - 一个图像到图像的过程
- 数字图像分析
  - 一幅图像转化为非图像的表示
  - 例:若一个数字图像包含多个物体,图像分析可通过分析后抽取这些物体的测度

图像与视觉计算

- 计算机图形学
  - 定义:使用计算机将由概念或数学描述所表示的物体进行处理和显示的过程。
  - 侧重点在于根据给定的物体描述模型、光照及摄像机的成像几何，生成一幅图像的过程。
- 计算机视觉
  - 目的是发展出能理解自然景物的系统
  - 在机器人领域，计算机视觉为机器人提供眼睛

图像处理的内容

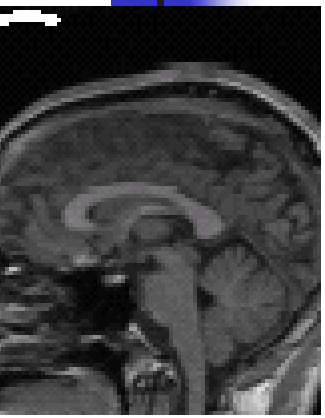
- 图像采集和数字化
- 图像存储和传输
- 计算机处理和展示
- 视觉计算

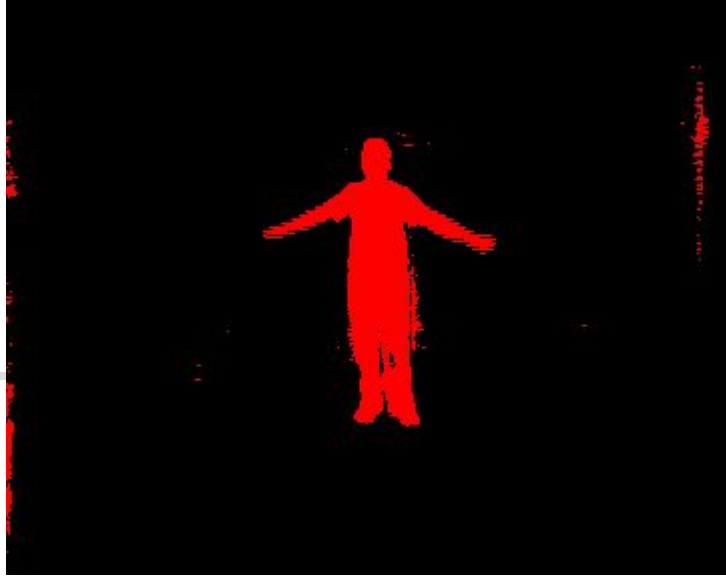


相关硬件

- 输入设备（扫描仪/摄像机/采集卡...)
- 处理设备（CPU/GPU...）
- 输出设备（显示器/打印机/投影仪...)

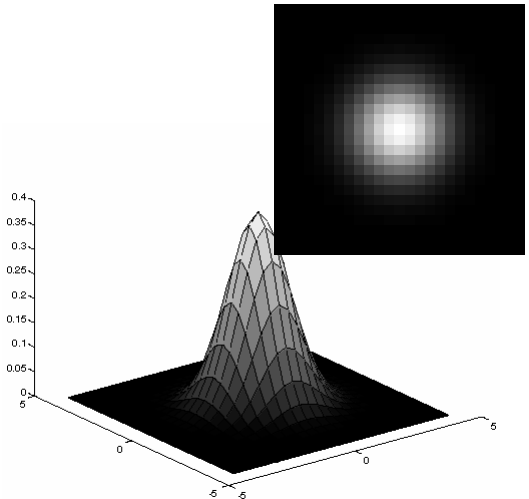
数字图像的表示





像素值的含义

- 物体表面的亮度(颜色)
- 生物体的吸收特性，如X光片
- 区域的温度，如红外照相
- 深度信息
- 任意二维函数的值



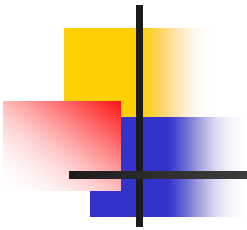
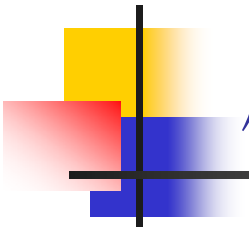


Image Formats

- TIFF
- JPEG
- PGM, PPM
- GIF
- BMP
- PNG
- Video formats...

计算机处理

- 图像变换
- 图像增强
- 图像复原
- 图像编码
- 图像分析

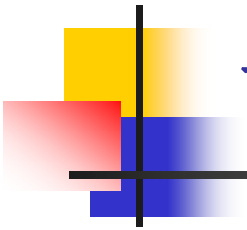


应用

- 医学图像处理（成像，处理，重建）
- 遥感图像处理
- 艺术创作
- Web
- 人机交互
- 广播与娱乐

图像处理

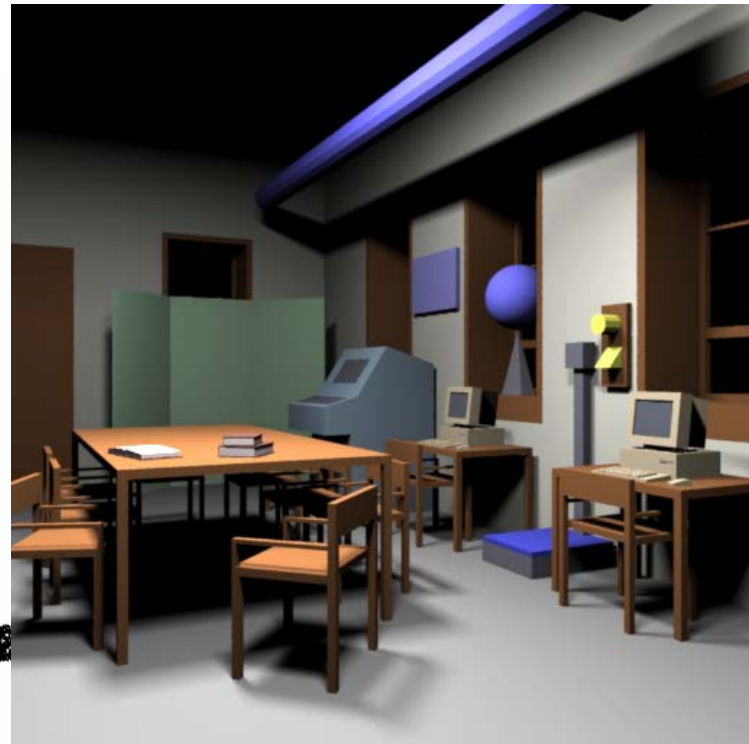
- 对一幅连续图像取样、量化以产生数字图像，
- 如何滤去图像中的无用噪声
- 如何对数字图像做各种变换/滤波以方便处理
- 如何压缩图像数据以便存储和传输
- 图像边缘提取，特征增强和提取，图像分割...
- 图像内容识别、重构、跟踪...



计算机图形学

- 对2/3维，静/动态物体的建模和绘制
  - 数据从三维模型到二维展现的过程
  - 建模（**Modeling**）
  - 绘制（**Rendering**）

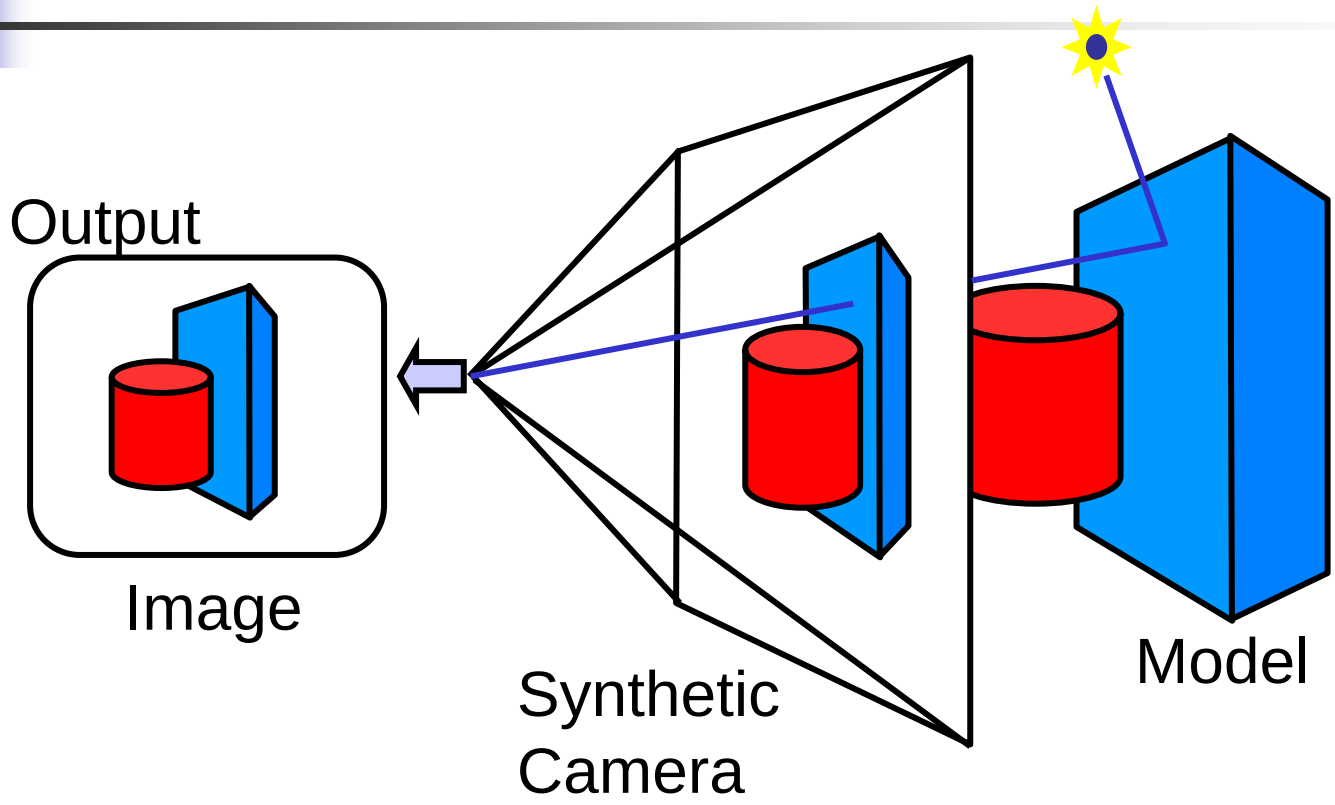
计算机图形学(示例)



计算机视觉和模式识别

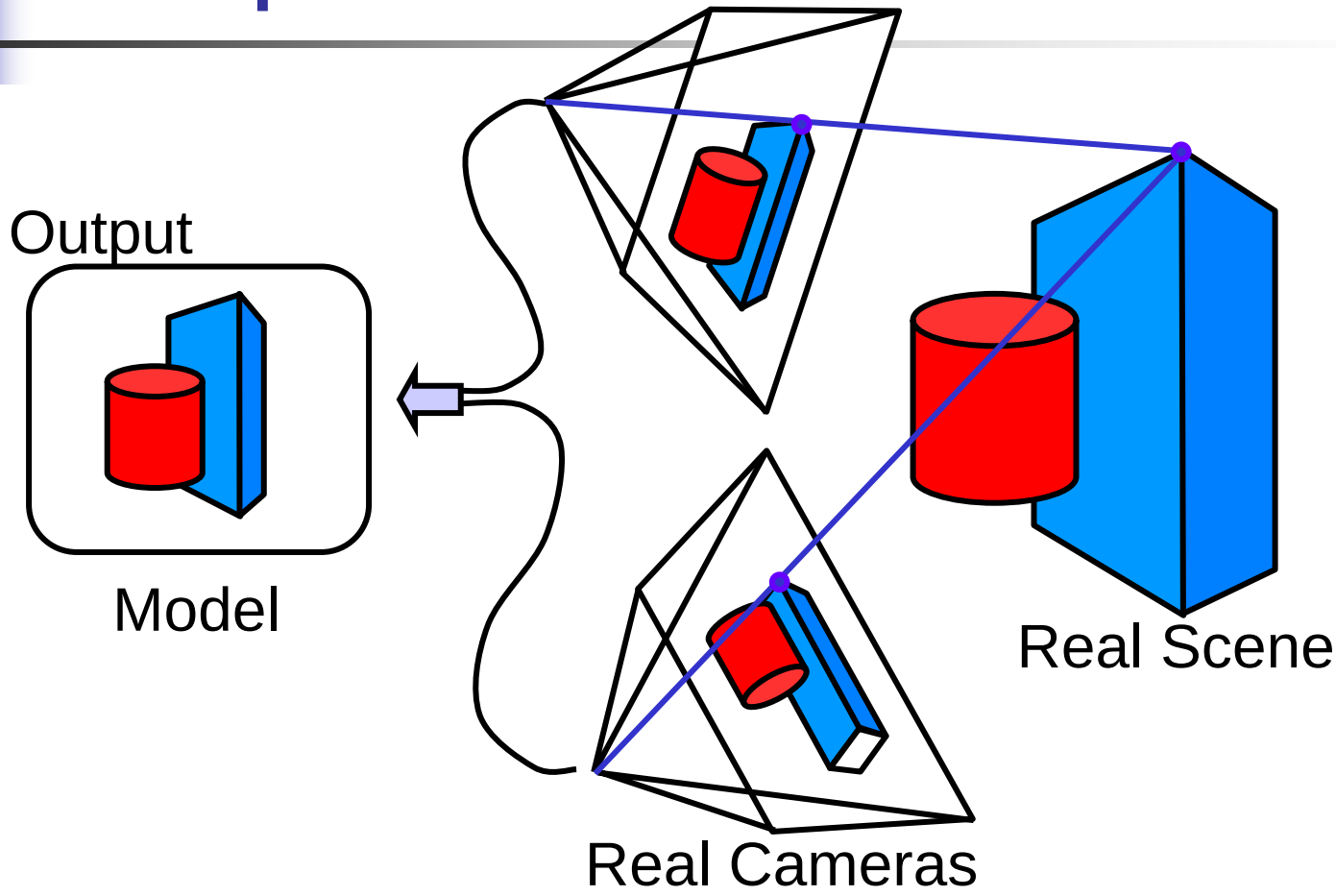
- 图形学的逆过程，分析和识别输入的图像并从中提取二维或三维的数据模型。
  - 图像分析
  - 视觉重构

Computer Graphics



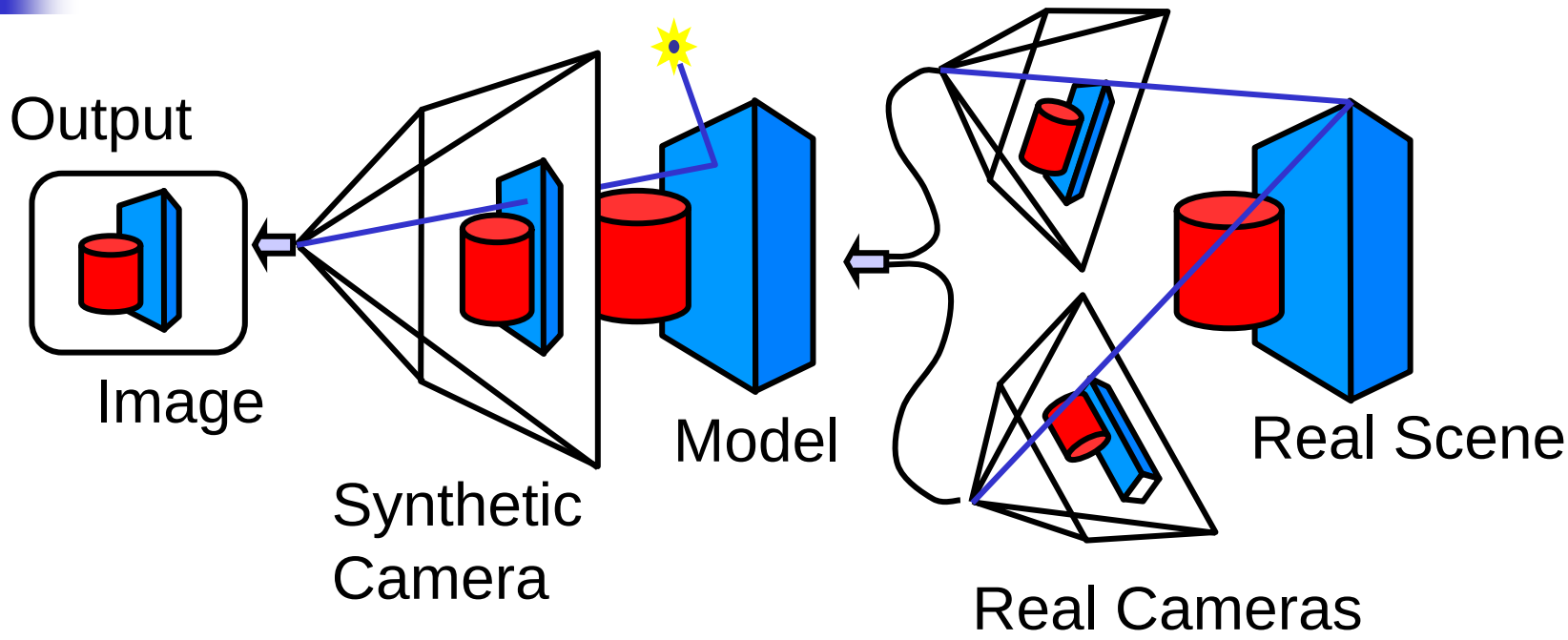
(slides courtesy of Michael Cohen)

Computer Vision



(slides courtesy of Michael Cohen)

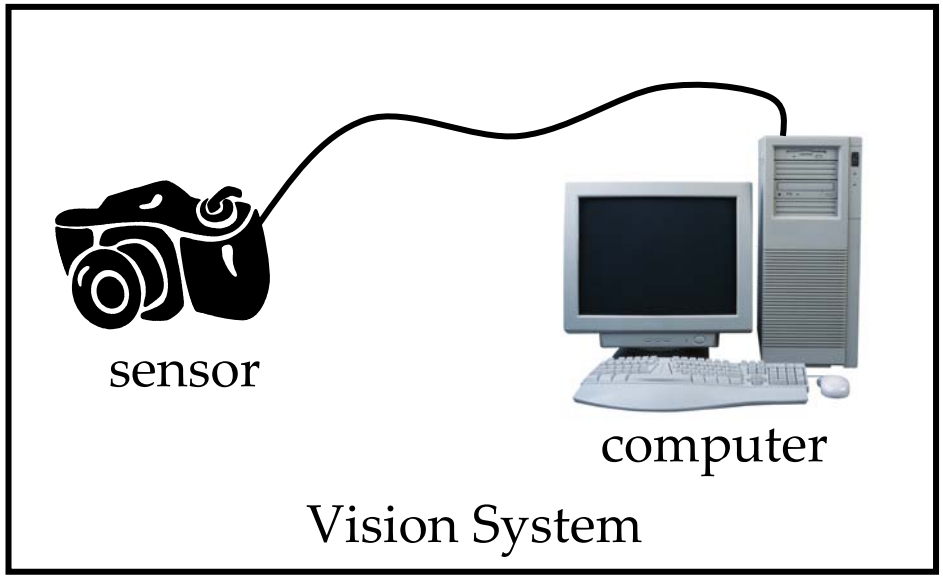
Combined



(slides courtesy of Michael Cohen)

What is Computer Vision?

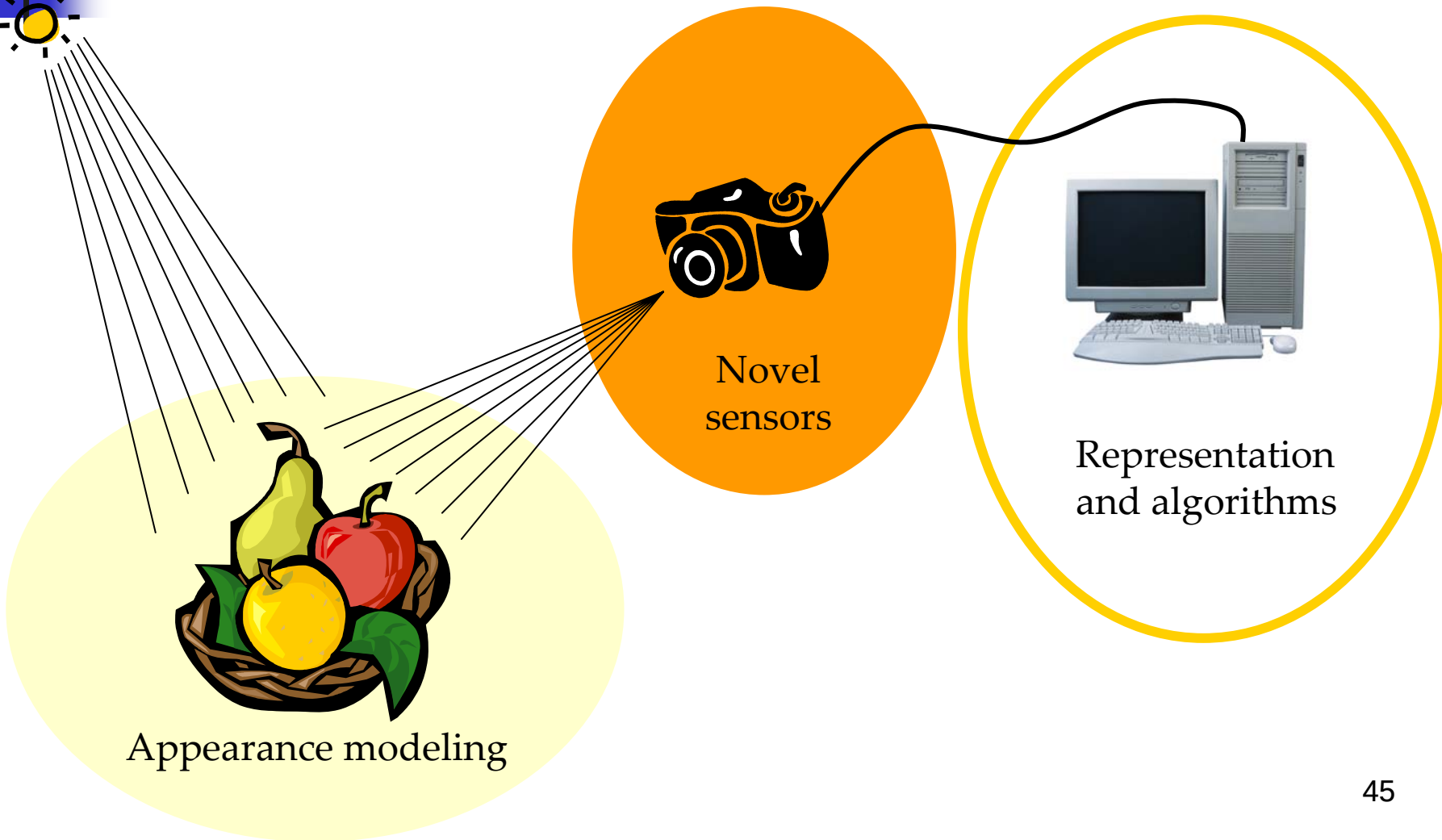
illumination



scene

Fruits
The red one is an apple
The pear is rotten

Research Areas in Computer Vision



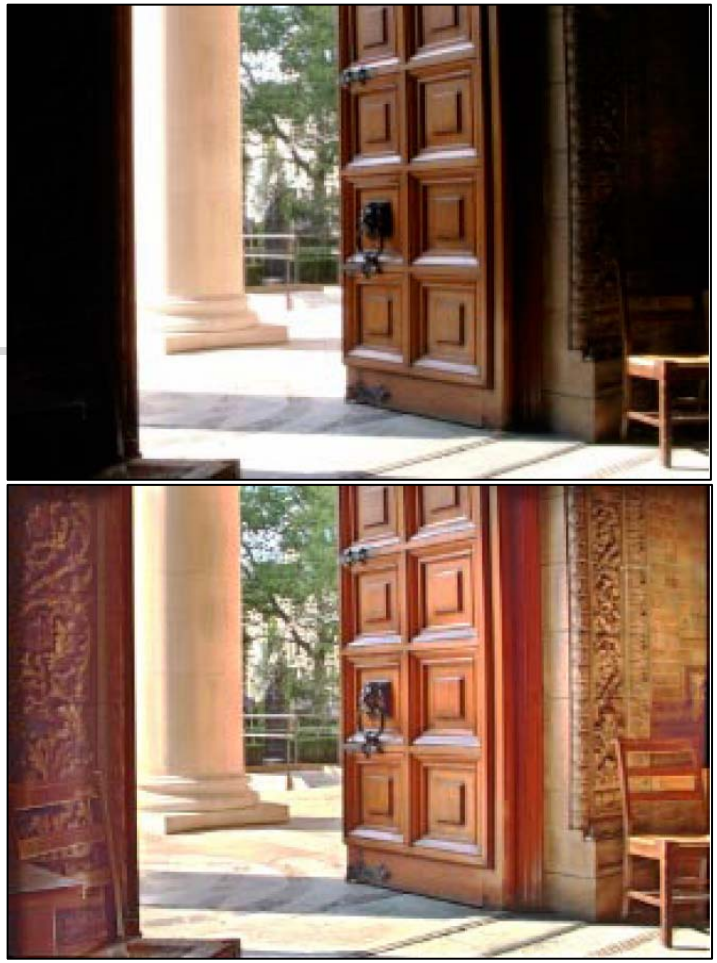
Low-level Processing

- Low-level Processing: Extract low-level queues
  - Corners, edges, regions
- Mid-level Processing: Recover physical entities
  - 3D shape, motion, lighting
- High-level Processing: Interpret the scene
  - Identify objects, people, action, style

How is it useful?

- Better images

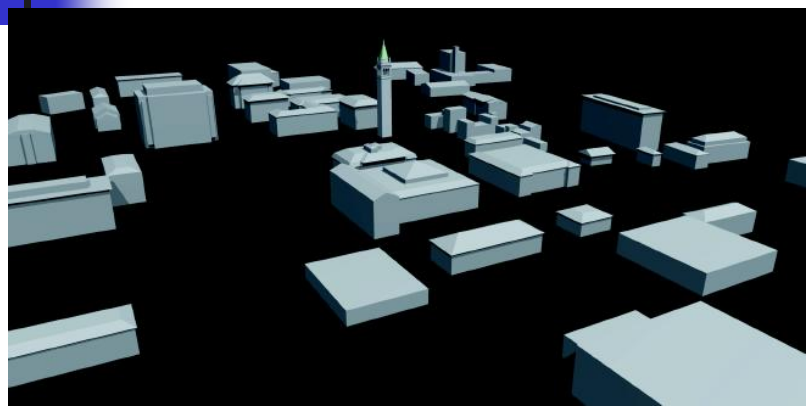
Image inpainting by M. Bertalmío et al.



HDR Imaging by S.K. Nayar et al.

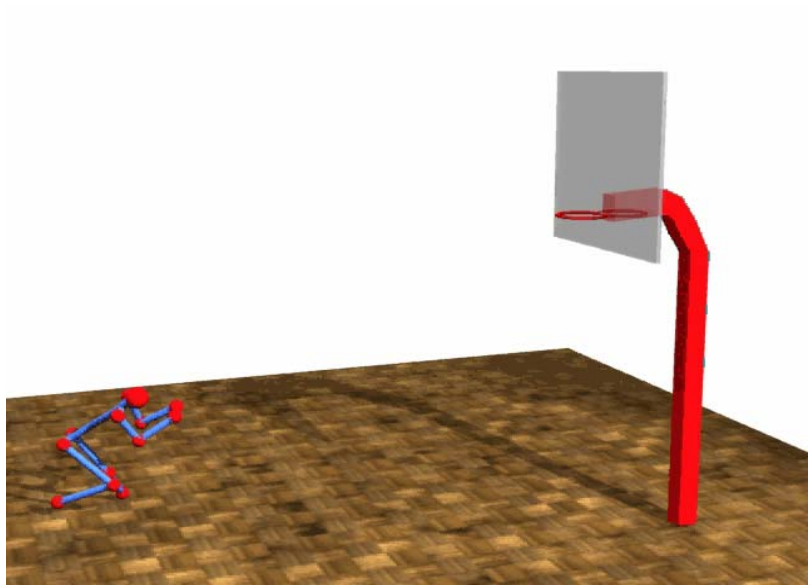
Instant dehazing by Y. Schechner et al.

Example 1: 3D Shape Reconstruction



Debevec, Taylor, and Malik, SIGGRAPH 1996

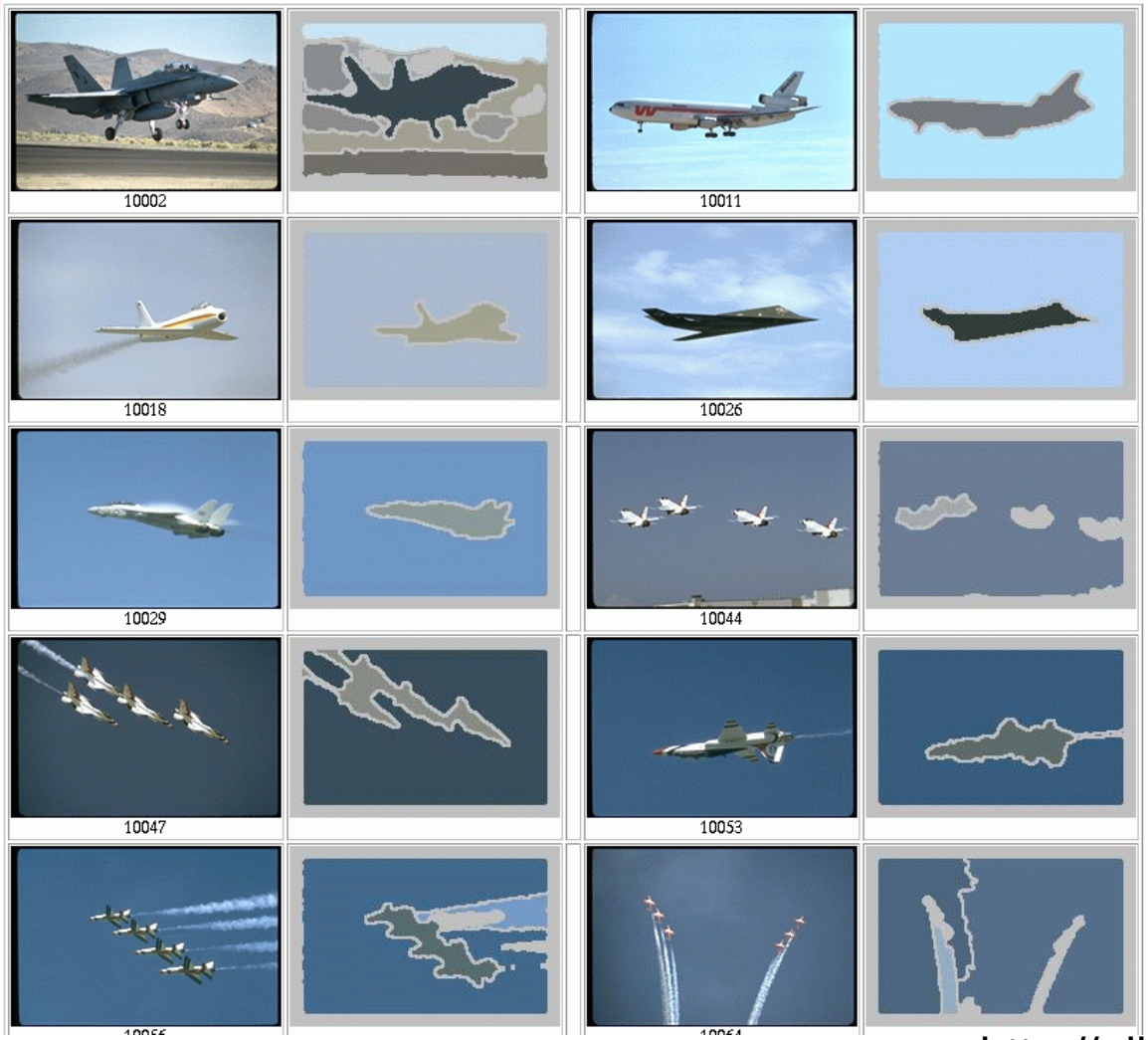
Example 2: 3D Modeling



http://www.photogrammetry.ethz.ch/research/cause/3dreconstruction3.html

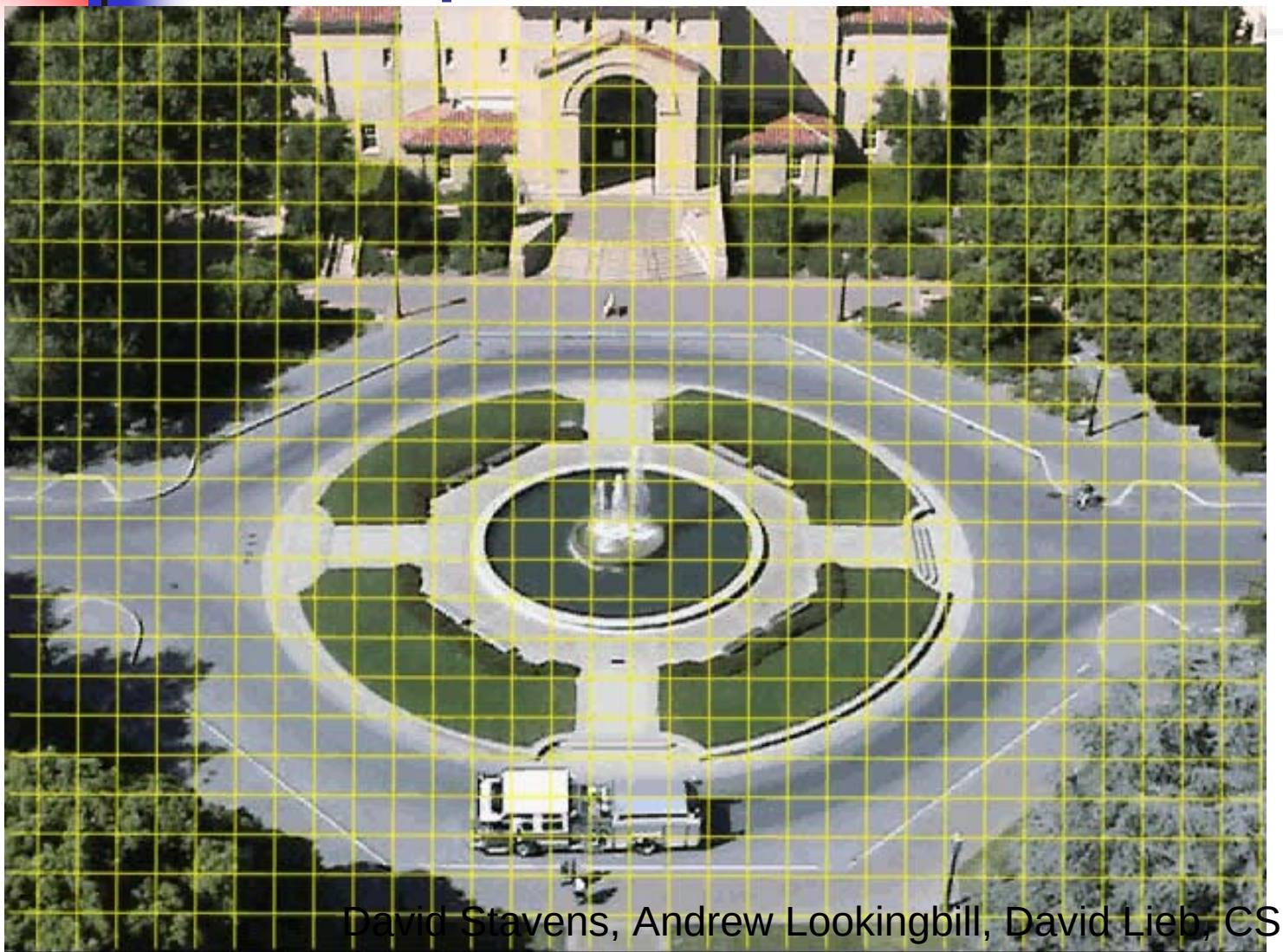
Face Modeling

Example 3: Segmentation

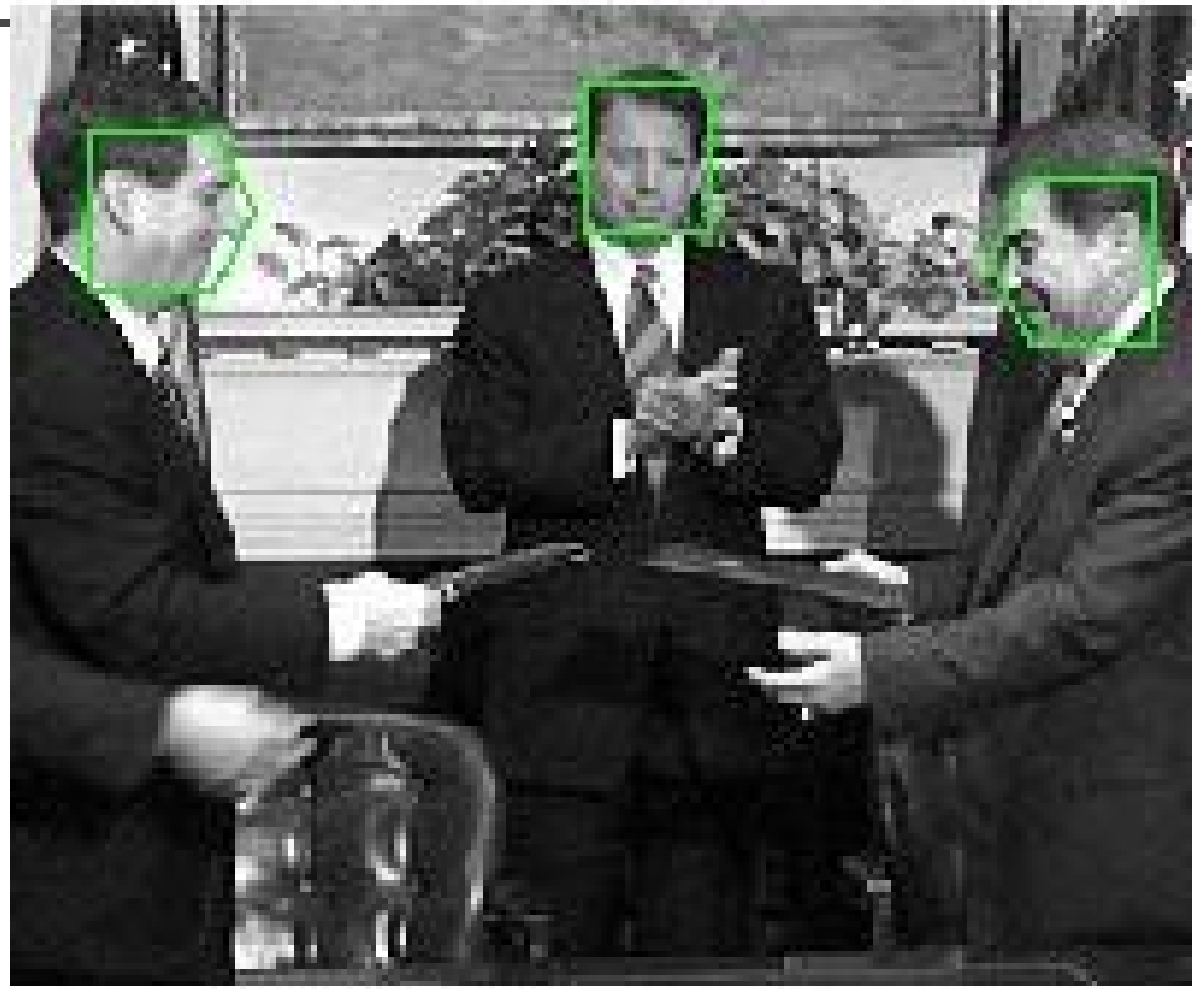


http://elib.cs.berkeley.edu/photos/classify/

Example 4: Detection

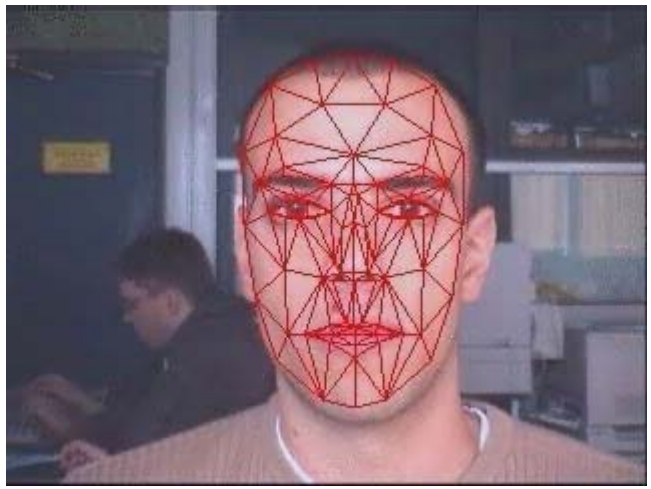


Face detection/Recognition

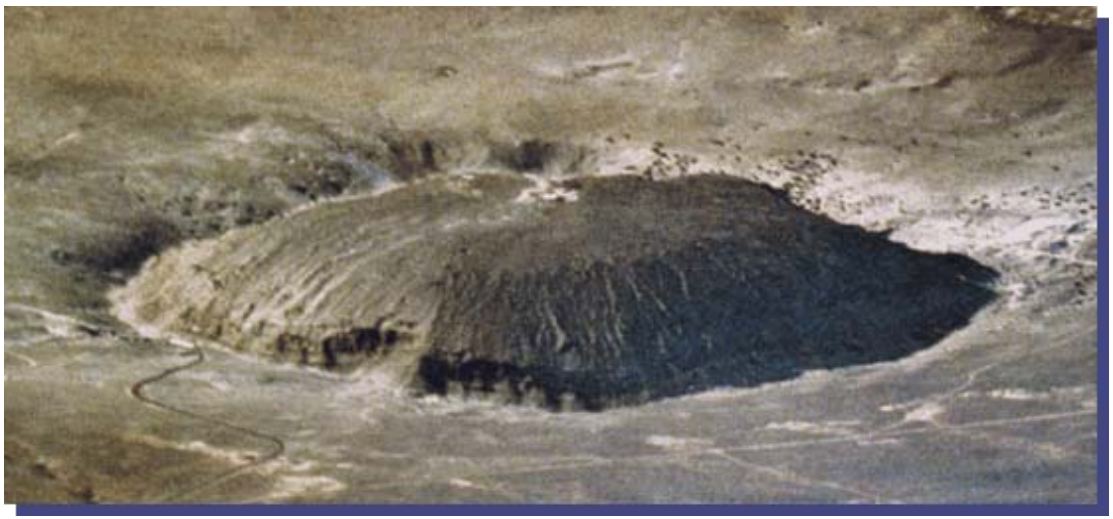


http://vasc.ri.cmu.edu/cgi-bin/demos/findface.cgi

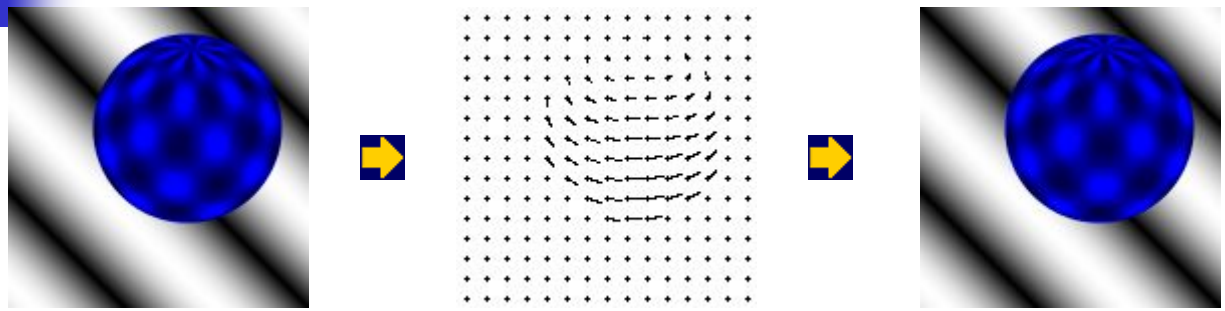
Example 5: Tracking

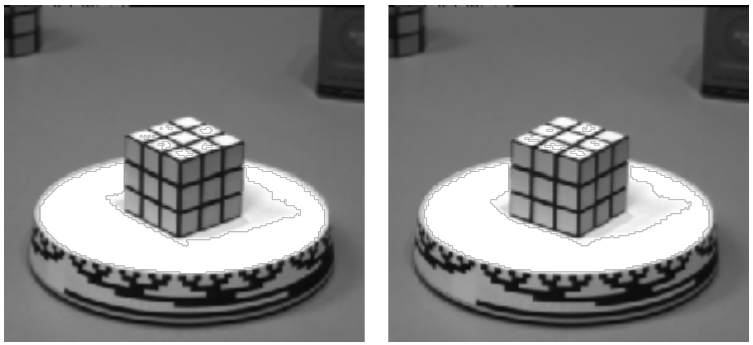


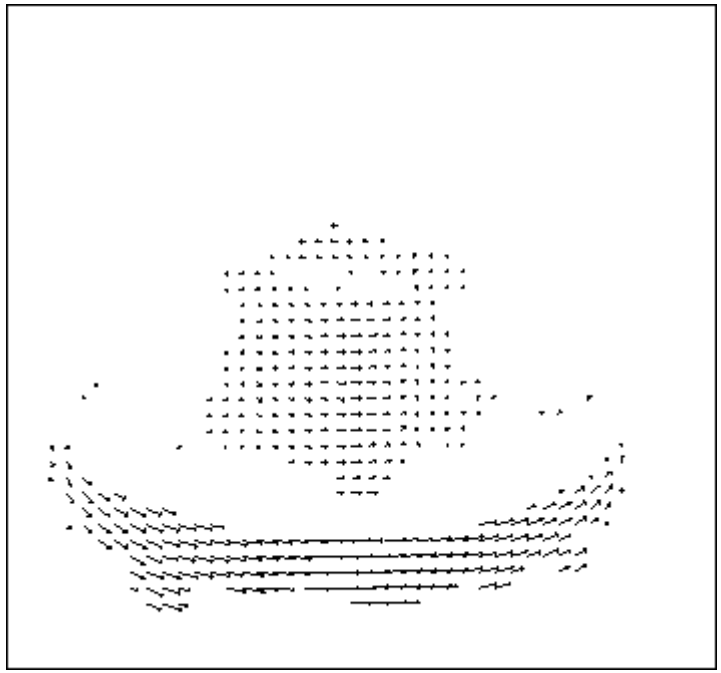
Example 6: Human Vision



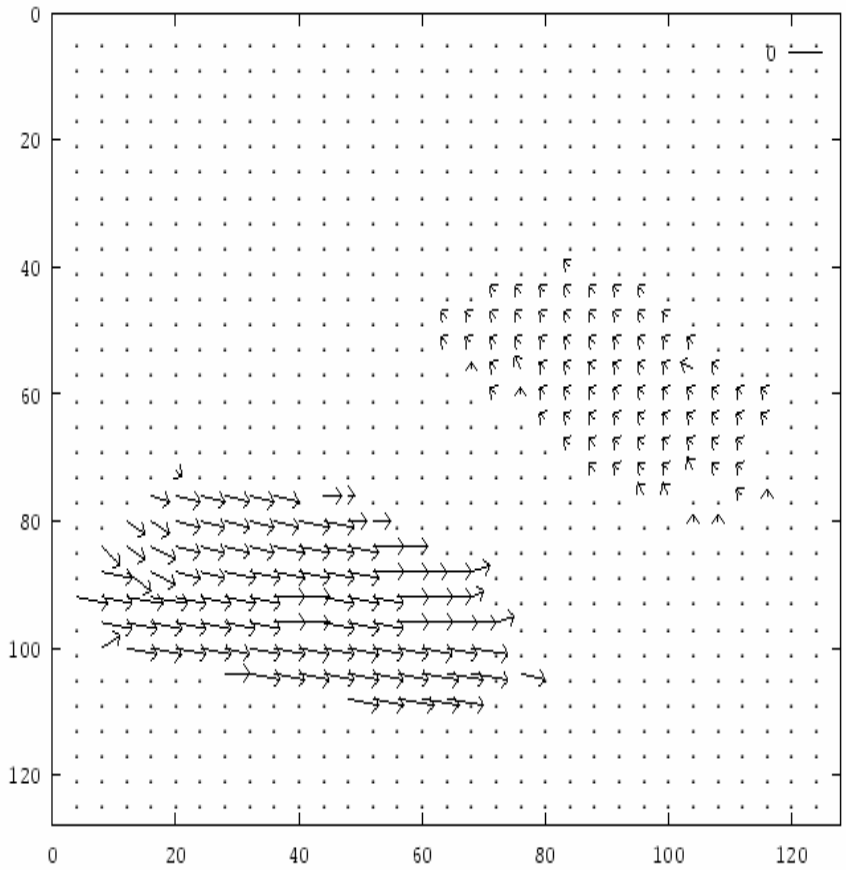
Example 7: Motion and optical flow





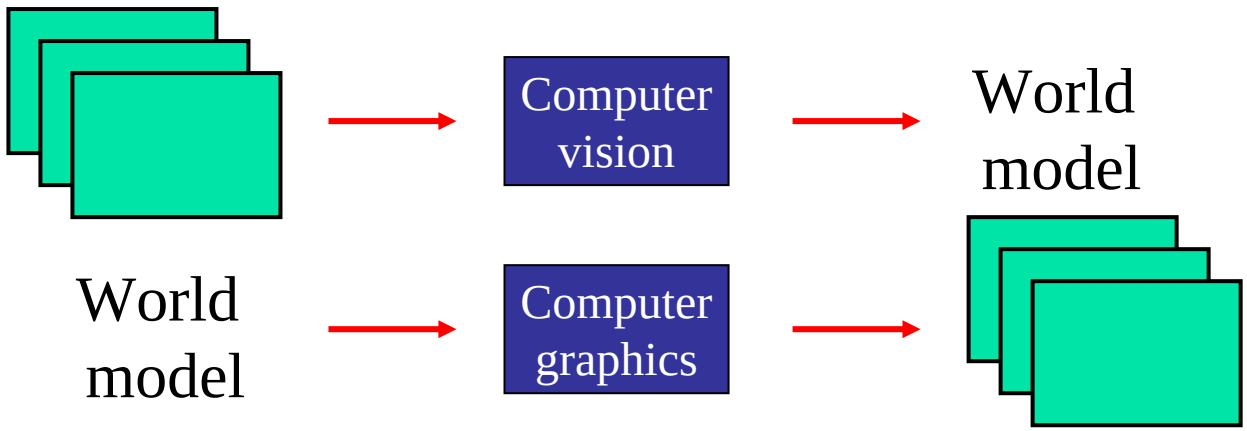


Example 7: Motion and optical flow

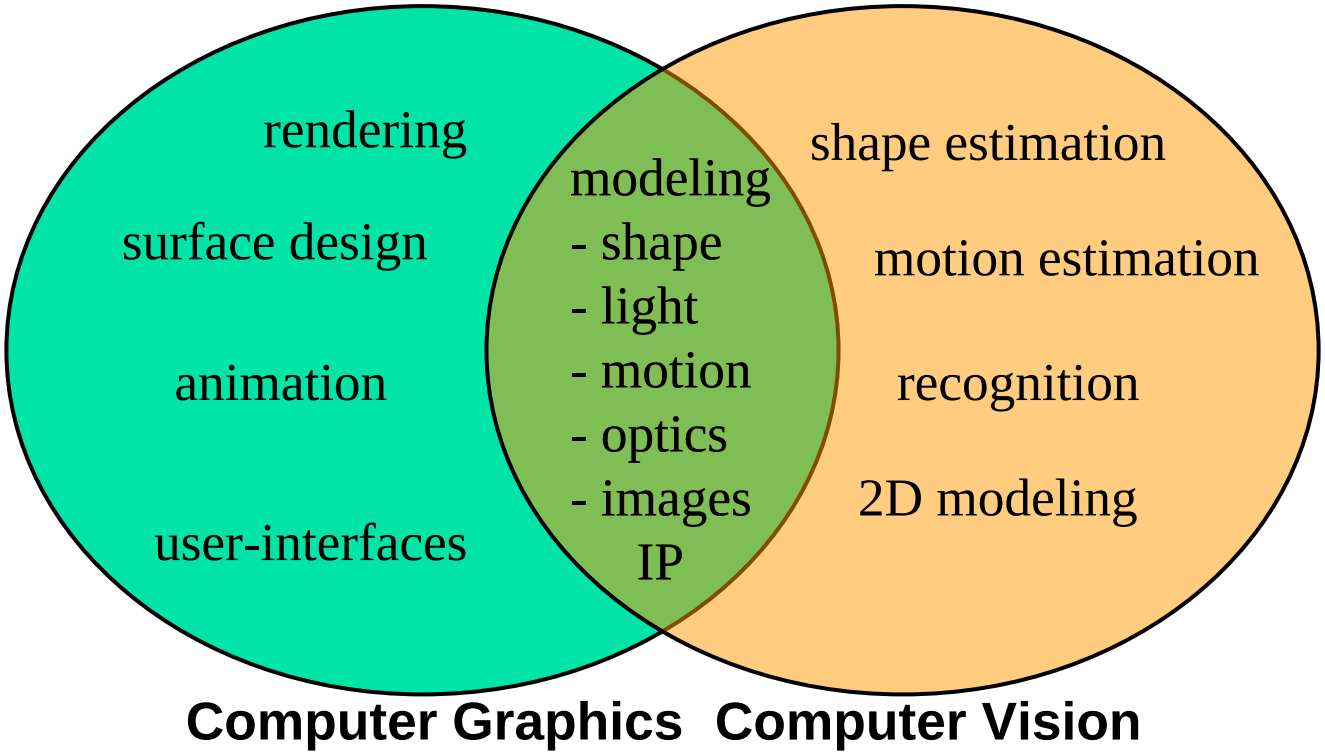


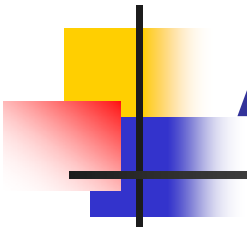
What is Computer Vision?

- Image Understanding (AI, behavior)
- A sensor modality for robotics
- Computer emulation of human vision
- Inverse of Computer Graphics



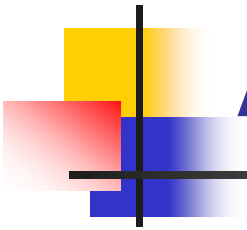
Intersection of Vision and Graphics





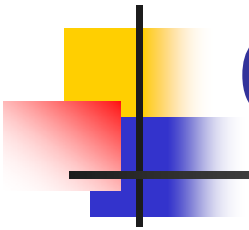
Applications

- Geometric reconstruction: modeling, forensics, special effects (ILM, RealVis,2D3)
- Image and video editing (Avid, Adobe)
- Webcasting and Indexing Digital Video (Virage)
- Scientific / medical applications (GE)



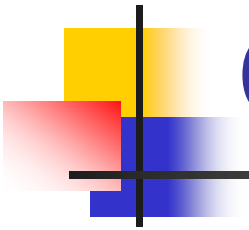
Applications

- Tracking and surveillance (Sarnoff)
- Fingerprint recognition (Digital Persona)
- Biometrics / iris scans (Iridian Technologies)
- Vehicle safety (MobilEye)
- Drowning people (VisionIQ Inc)
- Optical motion capture (Vicon)



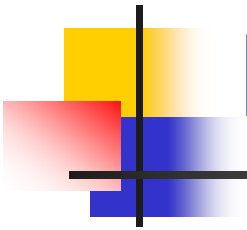
Computer Vision (Break)

- Image Analysis
  - Single frame
  - Image Understanding
- Video Analysis
  - Multiple frames, temporal information
  - Video Understanding



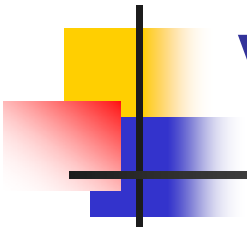
Generating an Image

- 3D Scene
  - Surface reflectance
  - Surface structure (shape)
- Light source
- Camera



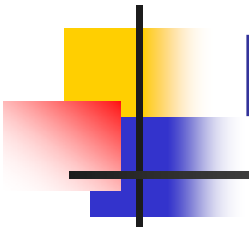
Discrete Domain Image

- Set of integer values in two dimensions
  - 0-255
- Gray level image (1 matrix
  - 0: Black 255: White
- Color image (3 matrices)
  - Red, Green, Blue
- Resolution
  - Number of rows, number of columns



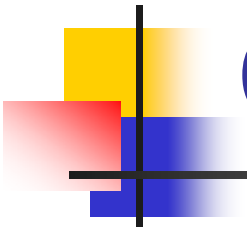
Video

- Sequence of image
  - Frames per second
  - Gray level video
  - Color video



Digitization

- Analog camera
  - Analog to Digital converter
  - Frame grabber
- Digital camera
  - Already digitized
  - MPEG or JPEG

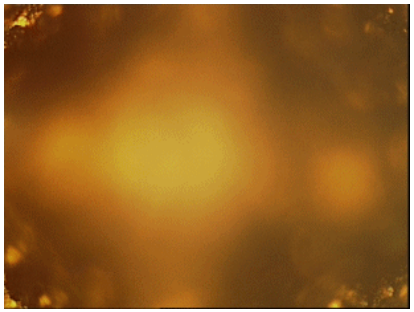


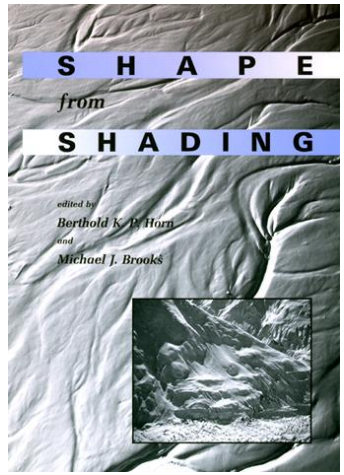
Computer Vision

- Shape From “X”
  - Shading (single image)
  - Texture (single image)
  - Stereo (two images)
  - Motion (multiple images)

Shape from ...

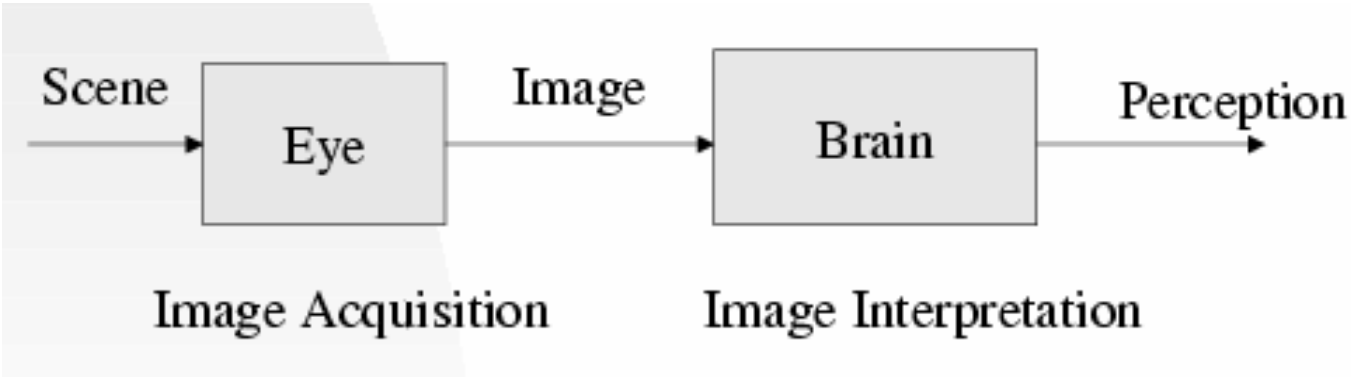
many different approaches/cues





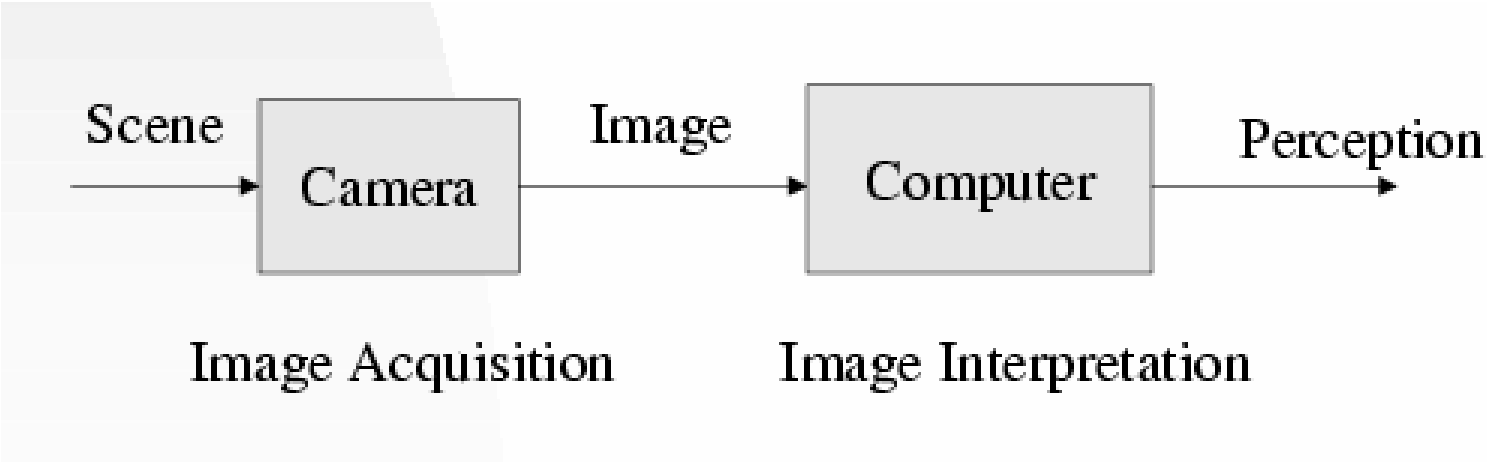
Vision

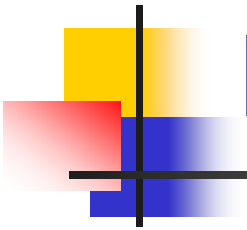
- Vision is the process of discovering what is present in the world and where it is by looking.



Computer Vision

- Computer Vision is the study of analysis of pictures and videos in order to achieve results similar to those as by men.





Main topics

- Shape (and motion) recovery

  “What is the 3D shape of what I see?”

- Segmentation

  “What belongs together?”

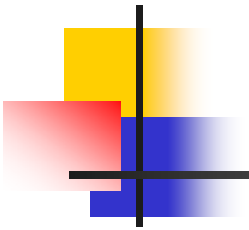
- Tracking

  “Where does something go?”

- Recognition

  “What is it that I see?”

Main topics

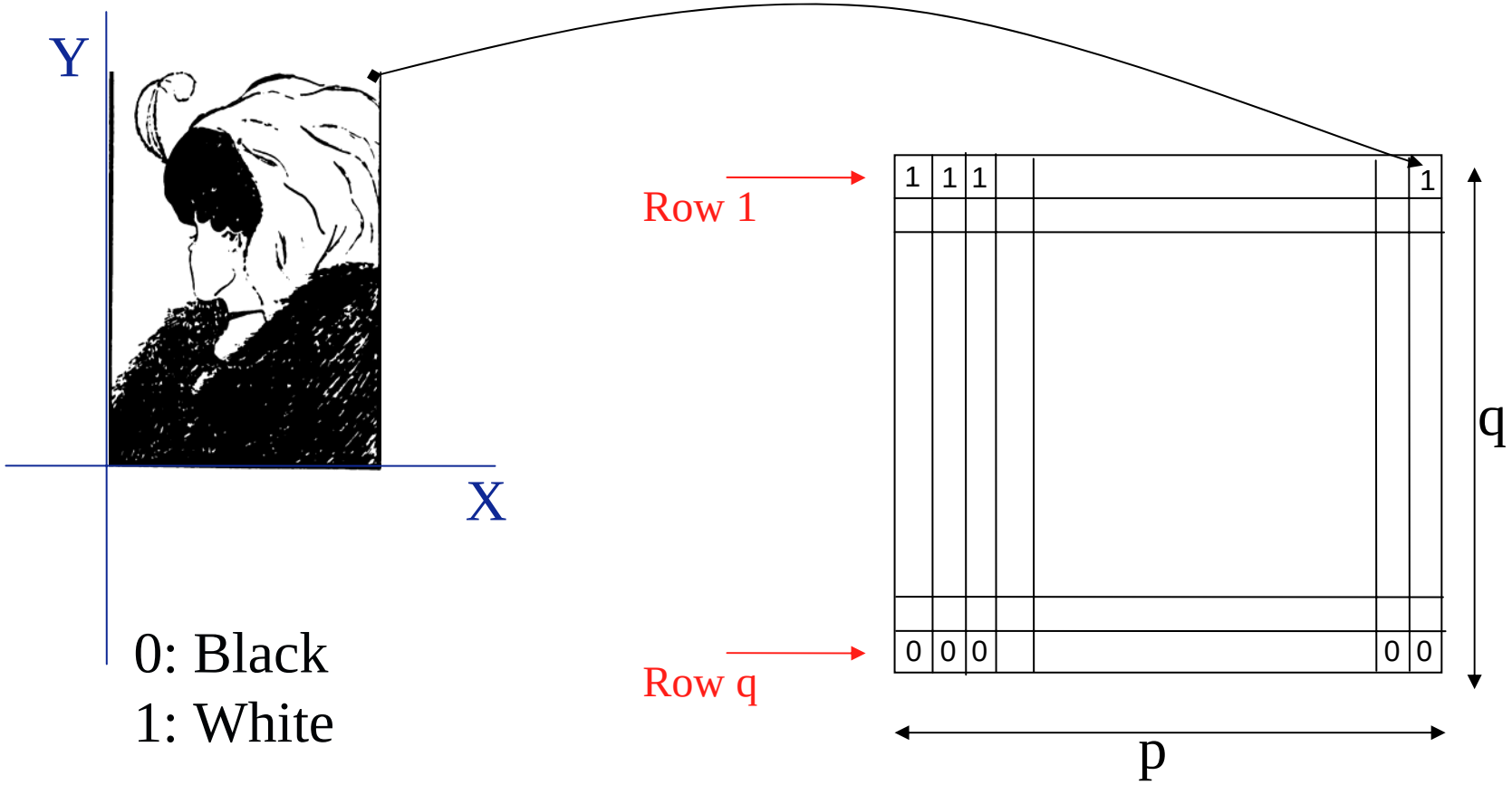


- Camera & Light
  - Geometry, Radiometry, Color
- Digital images
  - Filters, edges, texture, optical flow
- Shape (and motion) recovery
  - Multi-view geometry
  - Stereo, motion, photometric stereo, ...
- Segmentation
  - Clustering, model fitting, probalistic
- Tracking
  - Linear dynamics, non-linear dynamics
- Recognition
  - templates, relations between templates

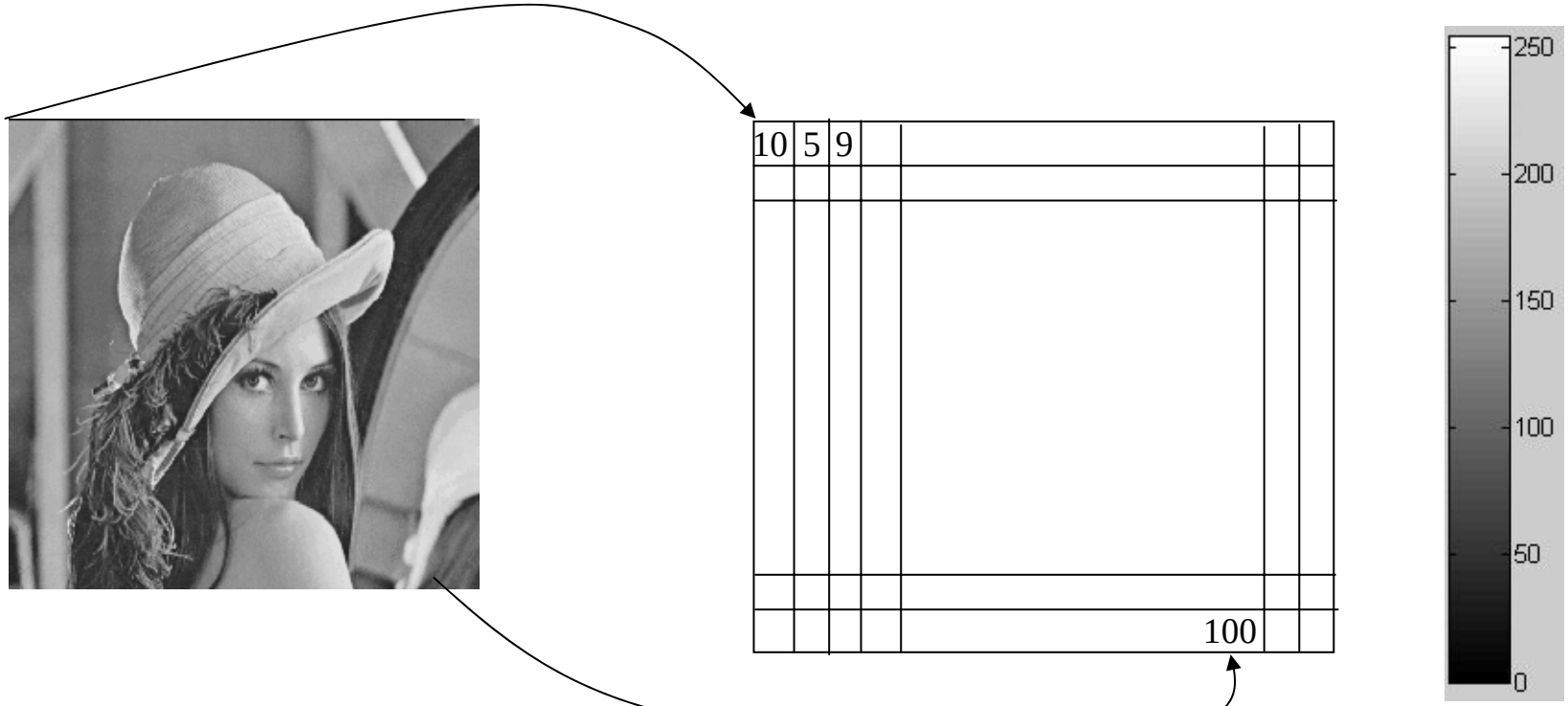
General

- Binary
- Gray Scale
- Color

Binary Images

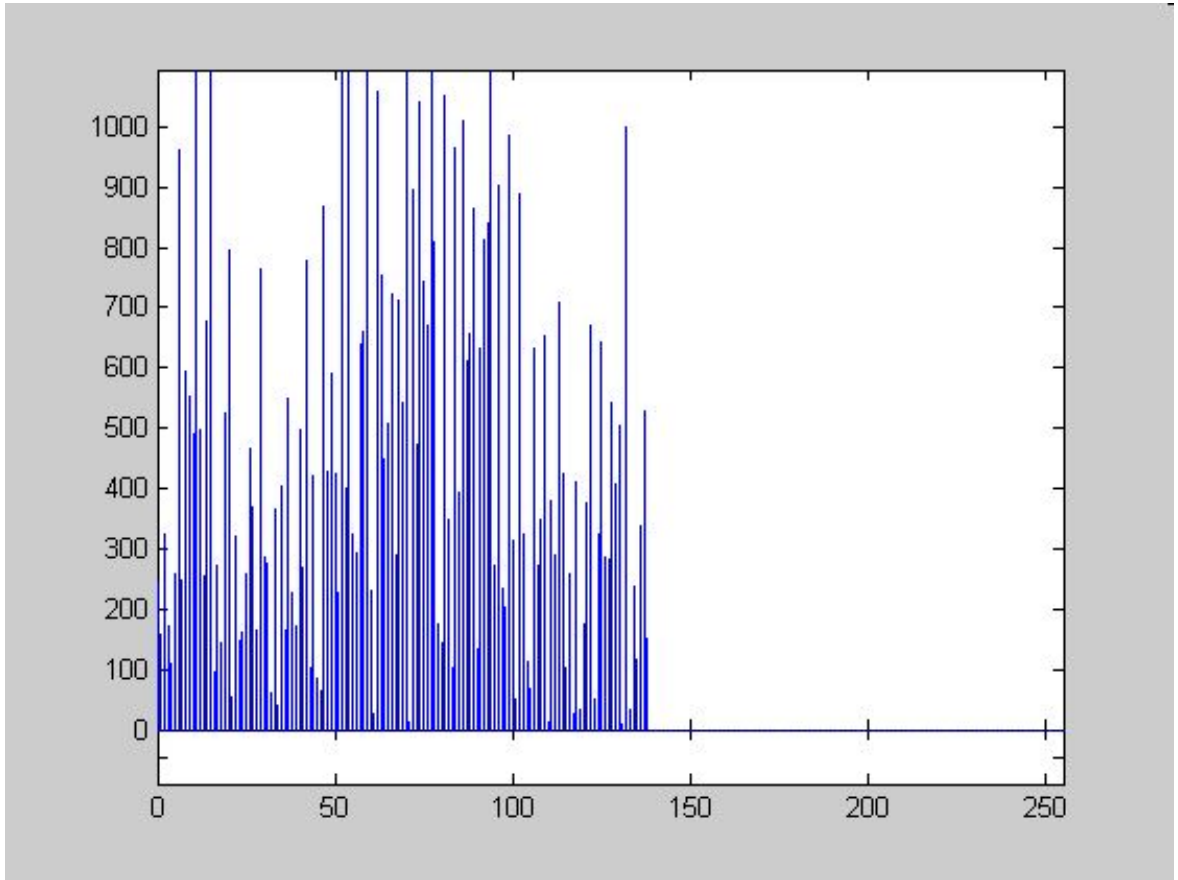


Gray Level Image



Color Image
Red, Green, Blue Channels

Image Histogram



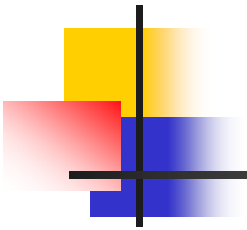


Image Noise

- Light Variations
- Camera Electronics
- Surface Reflectance
- Lens

Image Noise

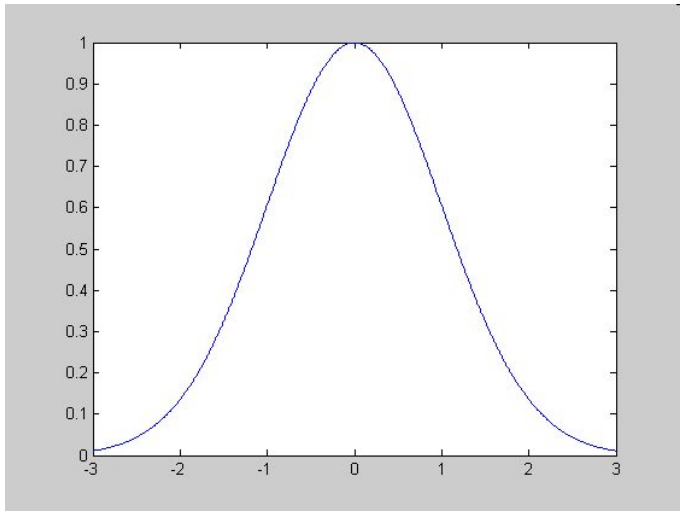
- $I(x,y)$: the true pixel values
- $n(x,y)$: the noise at pixel (x,y)

$$\hat{I}(x,y) = I(x,y) + n(x,y)$$

➔

Gaussian Noise

$$n(x,y) = e^{\frac{-n^2}{2\sigma^2}}$$



Salt & Pepper Noise

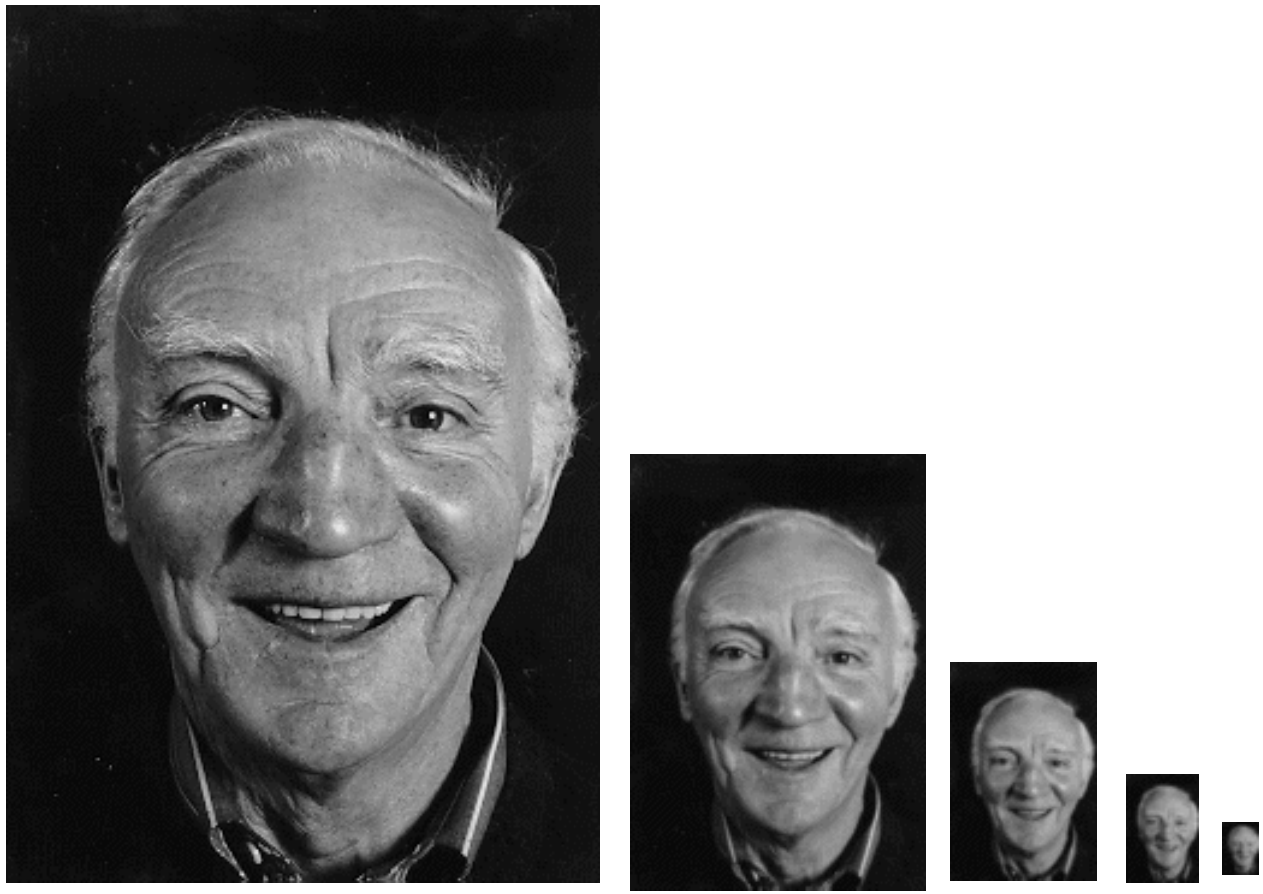
$$\hat{I}(x,y)=\begin{cases} I(x,y) & p<l \\ s_{\min}+r(s_{\max}-s_{\min}) & p\geq l \end{cases}$$

- p is uniformly distributed random variable
- l is threshold
- s_{min} and s_{min} are constant

Image Filtering and Enhancing

- Linear Filters and Convolution
- Image Smoothing
- Edge Detection
- Pyramids

Image Filtering and Enhancing



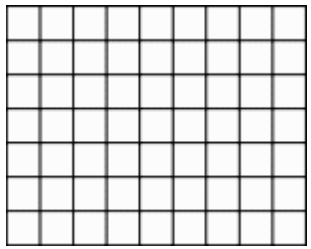
Blurring An Image

Sharpening An Image

Image Rotation

Image Scaling

Correcting Lens distortion



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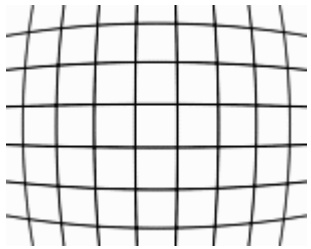
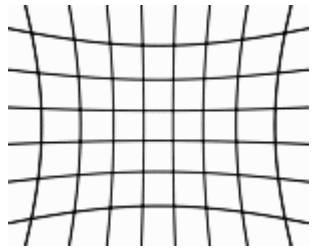


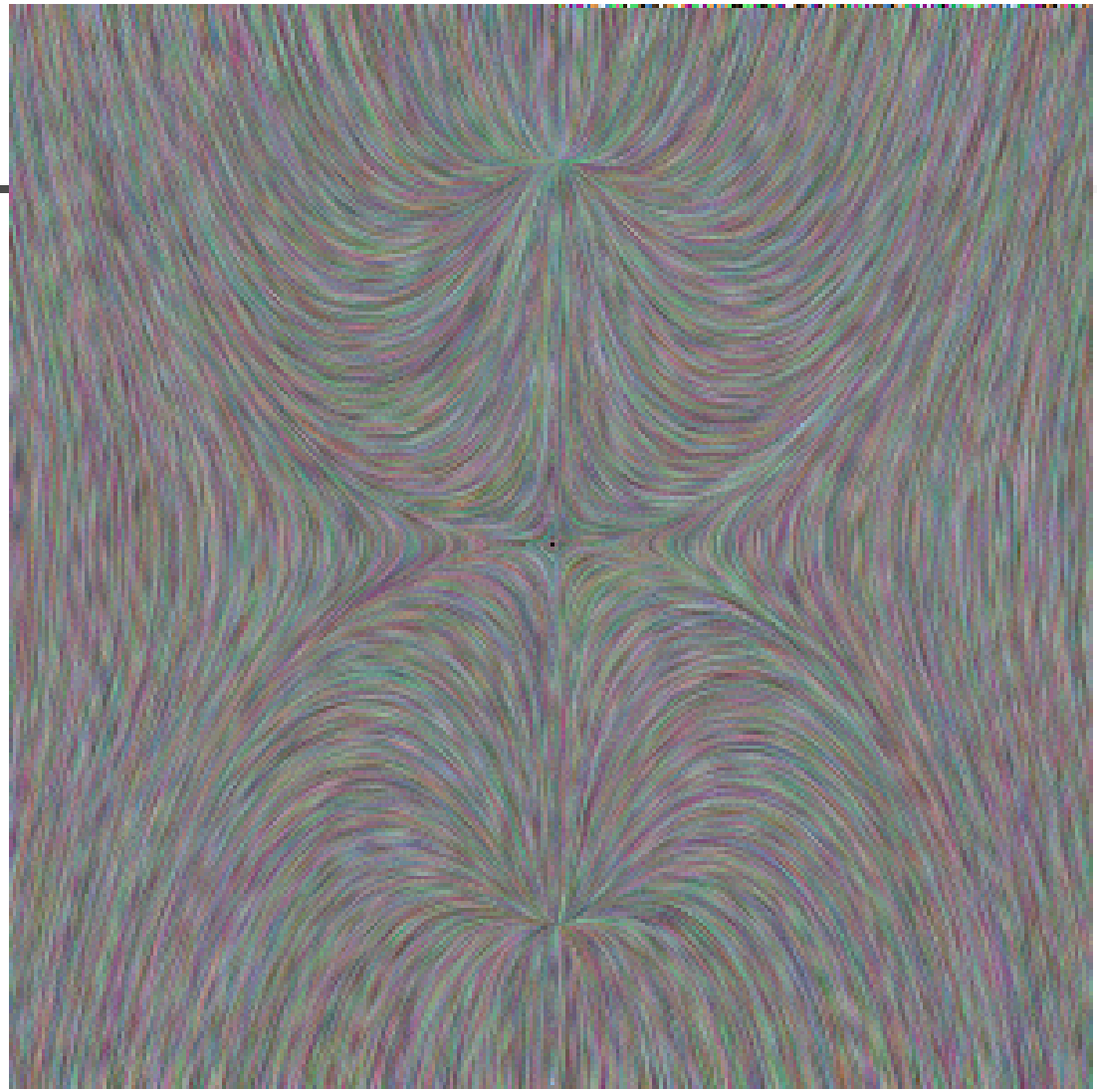
Barrel

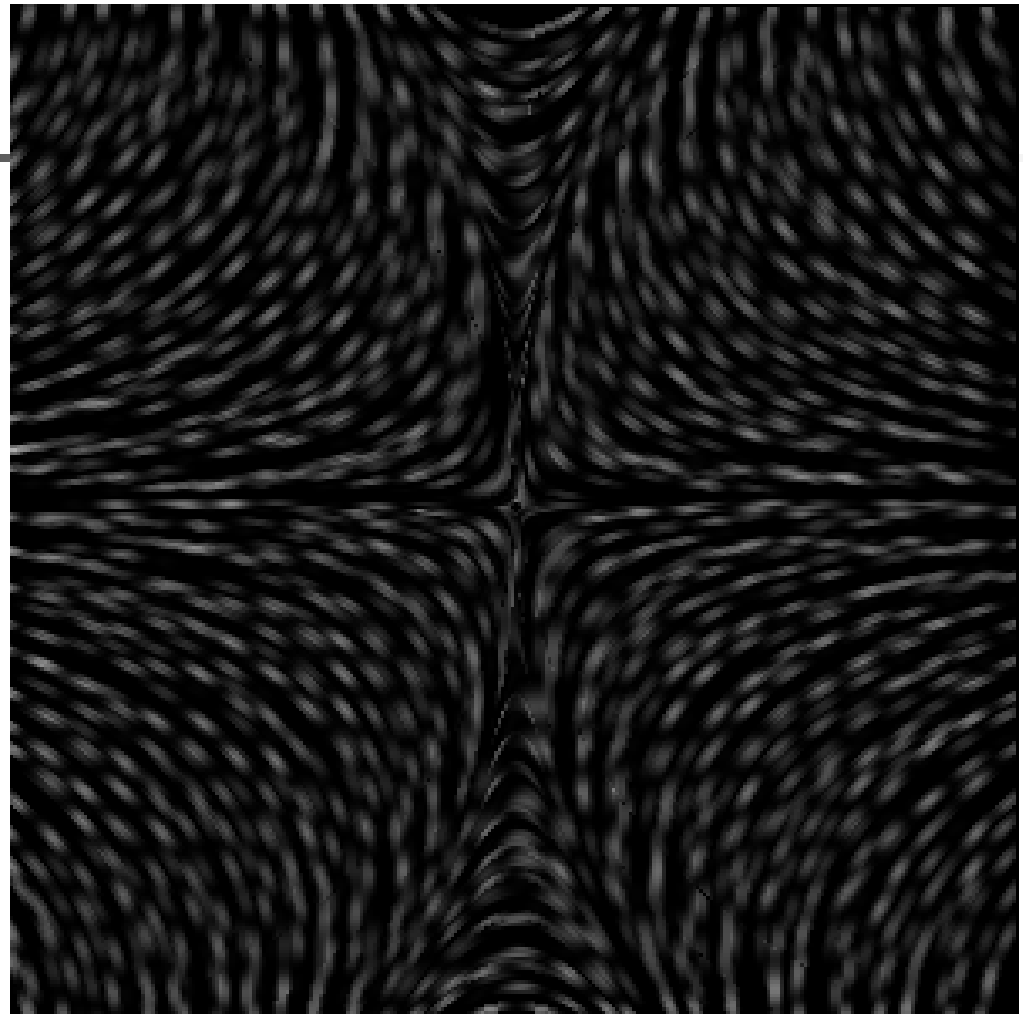


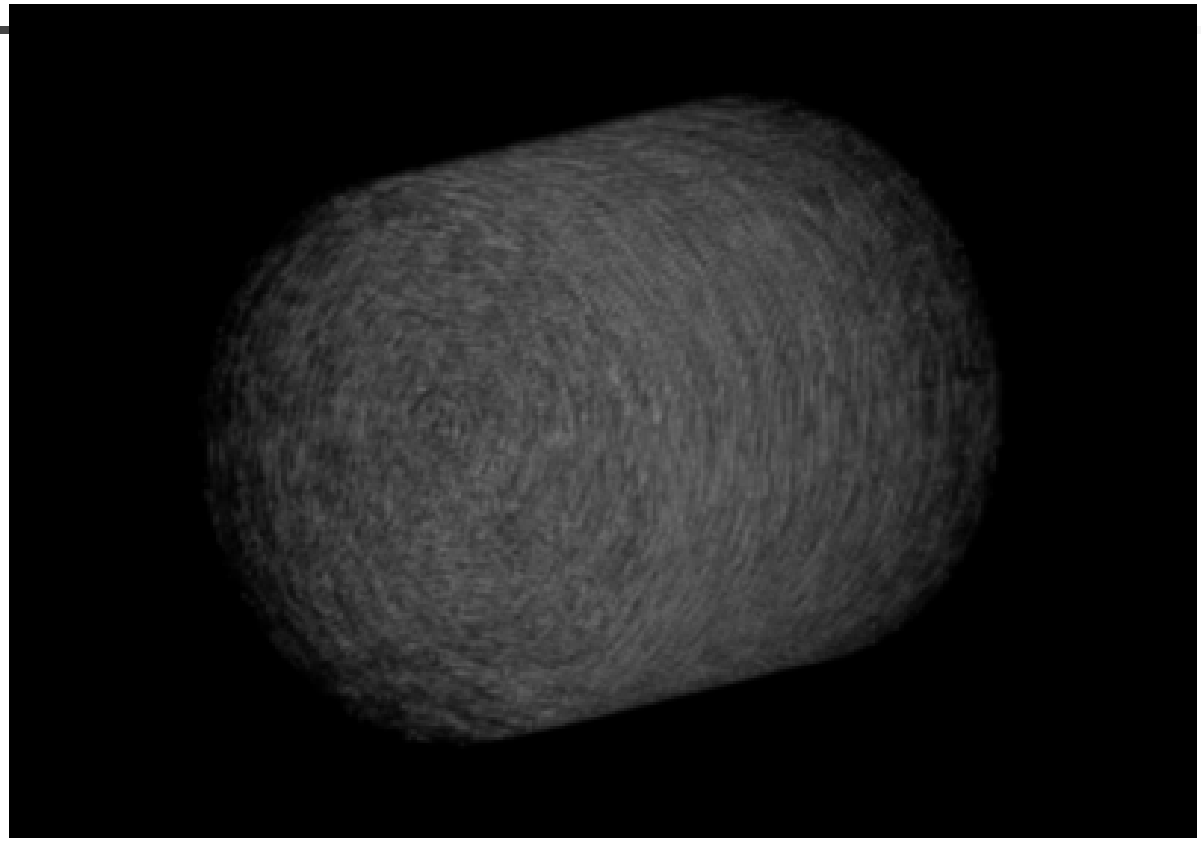
Pincushion

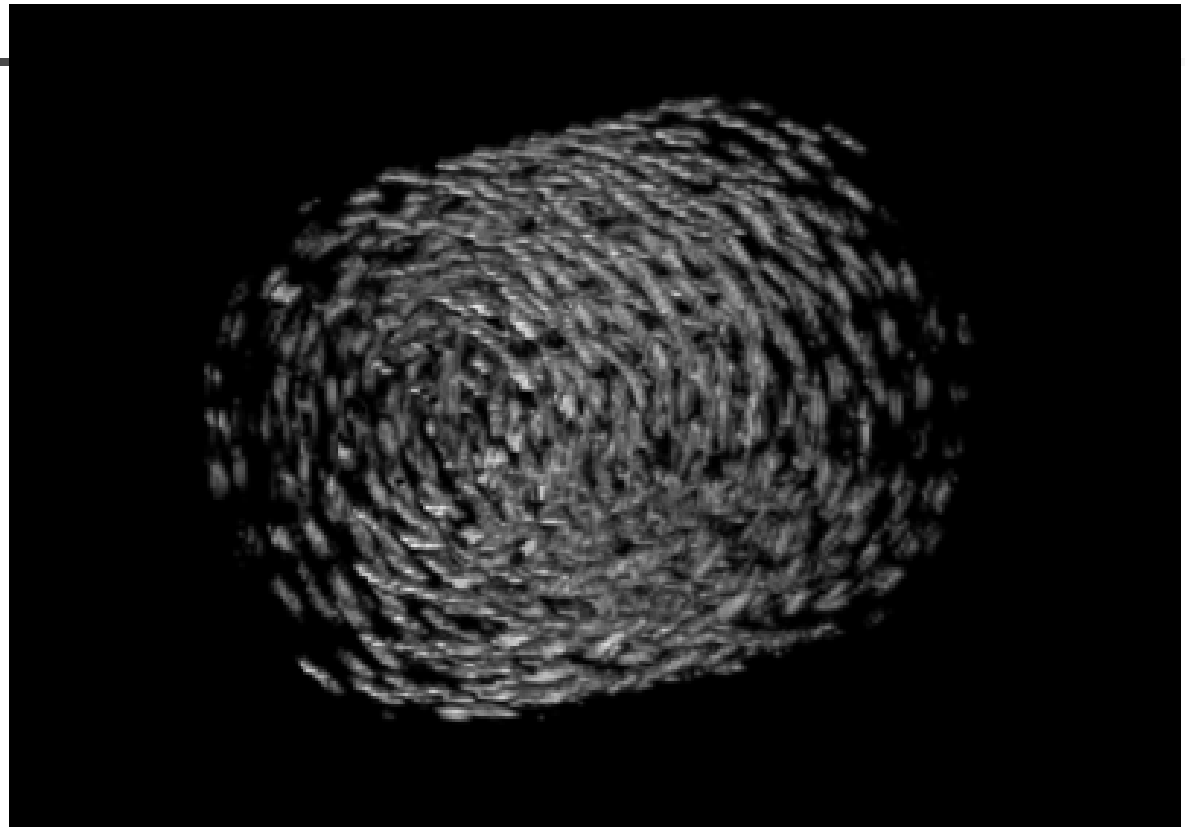
可视化

- 科学计算可视化
  - （CT）医学图象重建，流场、湍流、激波、气象、核爆模拟，有限元分析……。





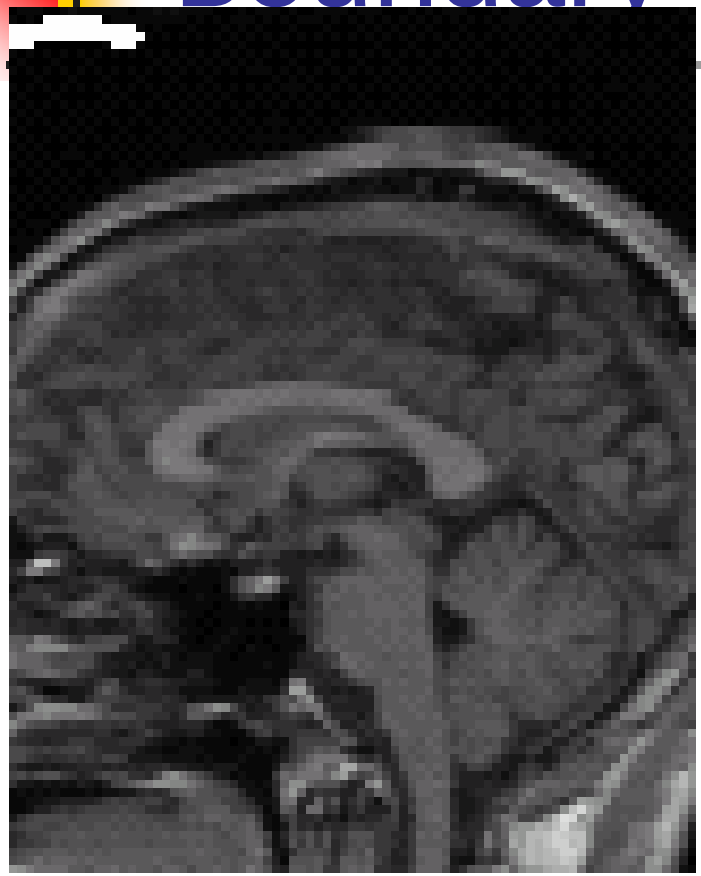


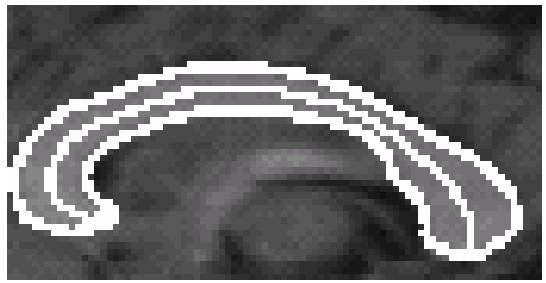


Boundary Detection

http://www.robots.ox.ac.uk/~vdg/dynamics.html

Boundary Detection

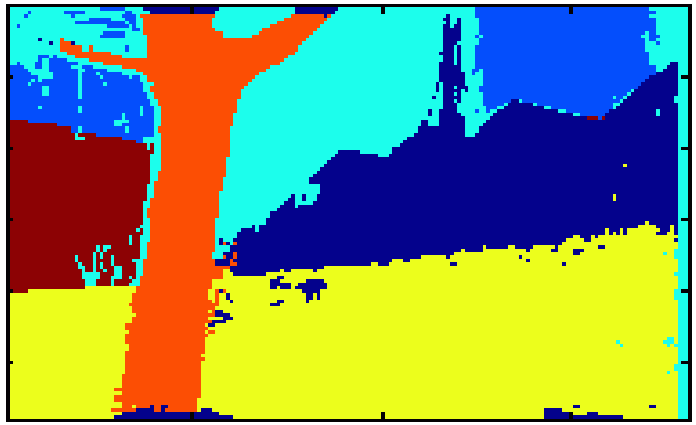


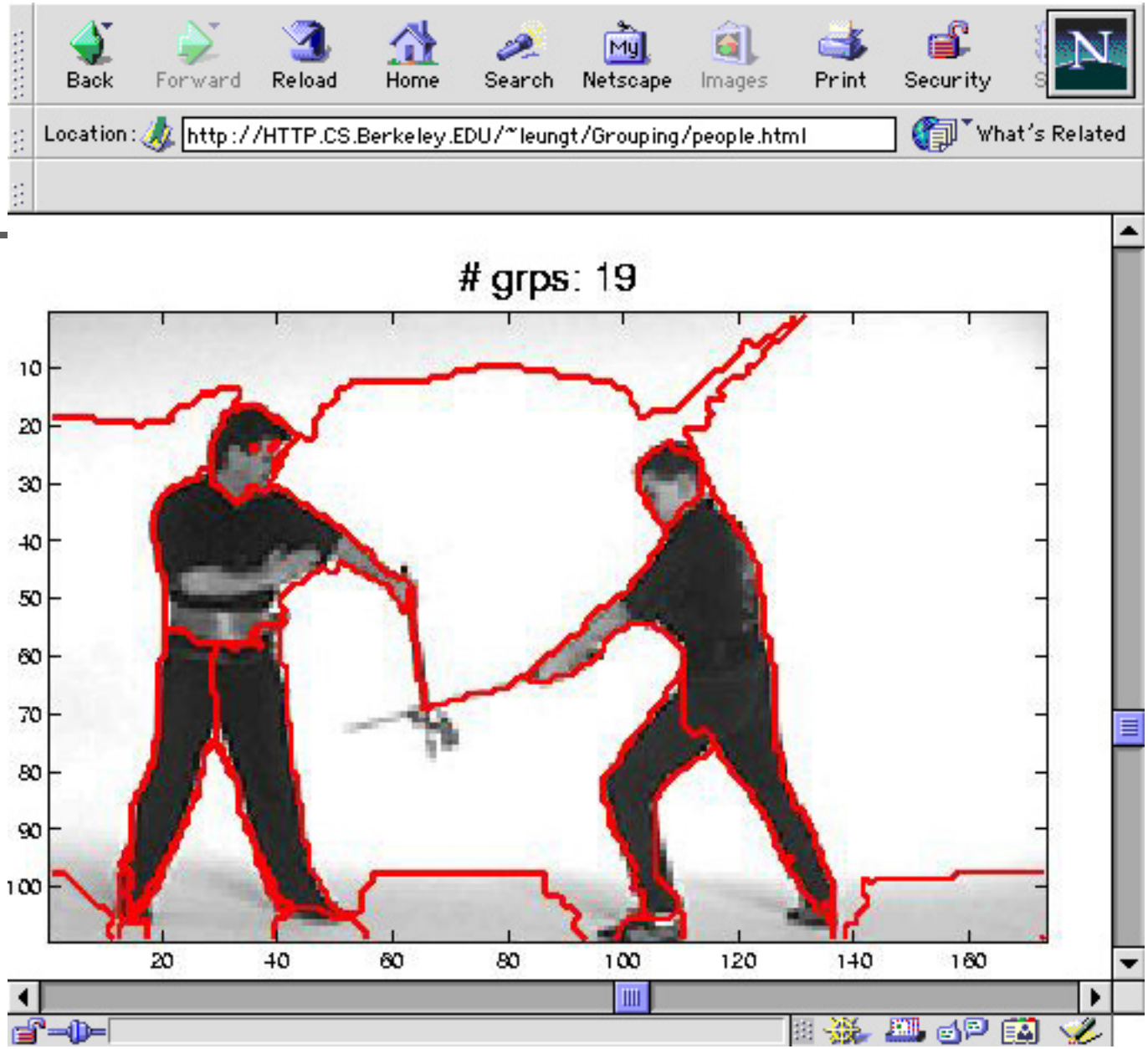


Finding the Corpus Callosum

(G. Hamarneh, T. McInerney, D. Terzopoulos)

Region Segmentation

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Security
Location :
http://HTTP.CS.Berkeley.EDU/~leungt/Grouping/people.html
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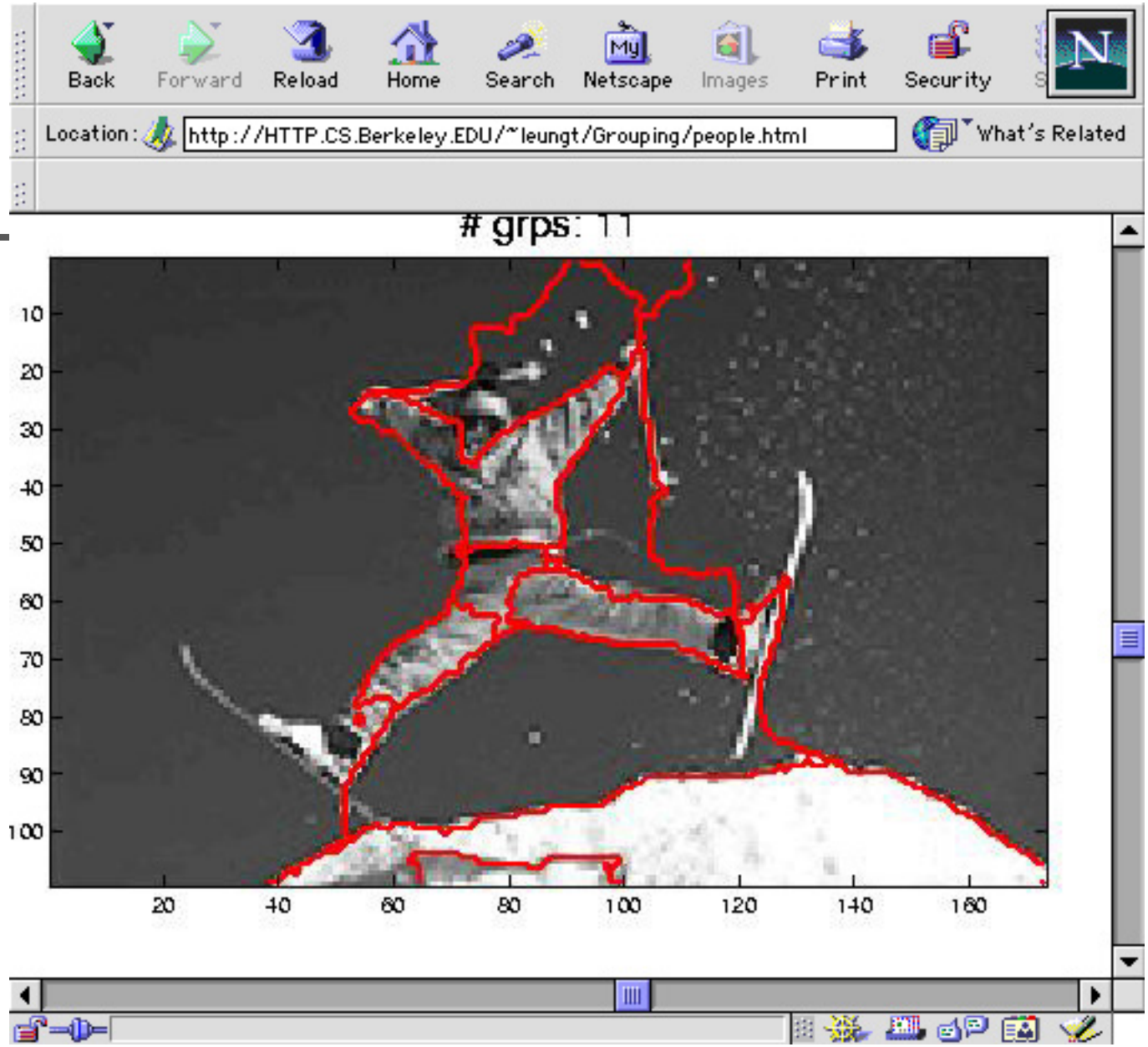
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Images
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Security
Location :
http://HTTP.CS.Berkeley.EDU/~leungt/Grouping/people.html
What's Related
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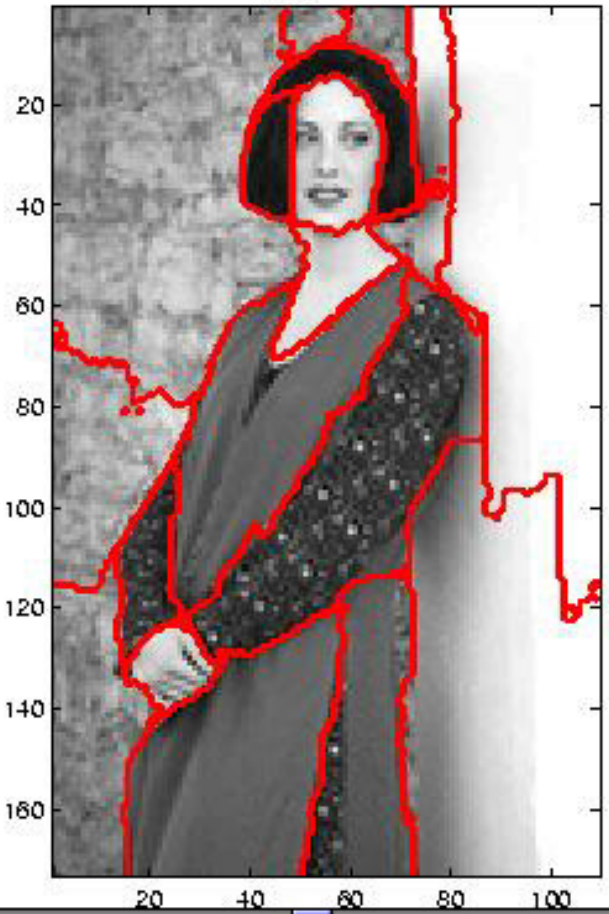
corel img # 181087

grps: 19



Netscape: Image Segmentation

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Location: http://HTTP.CS.Berkeley.EDU/~leungt/Gro What's Related

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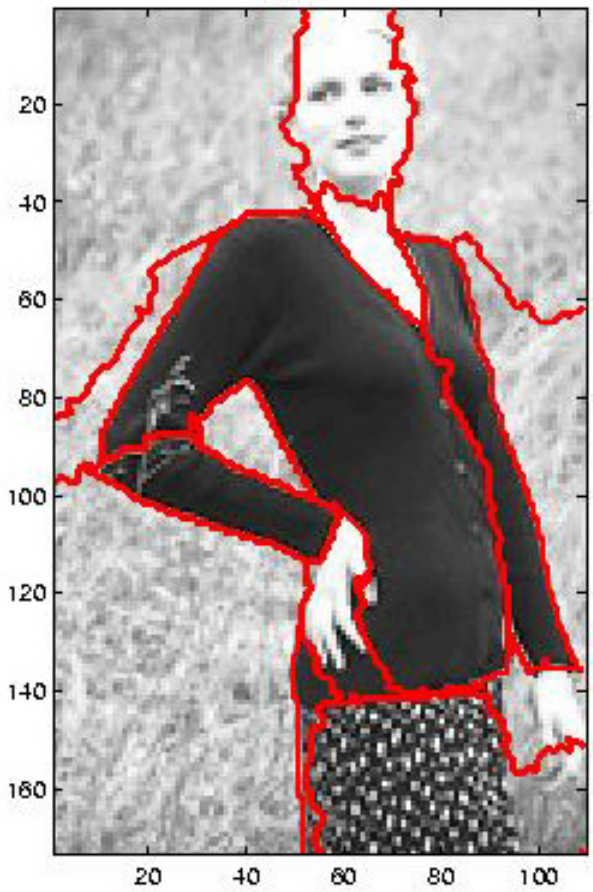
grps: 15



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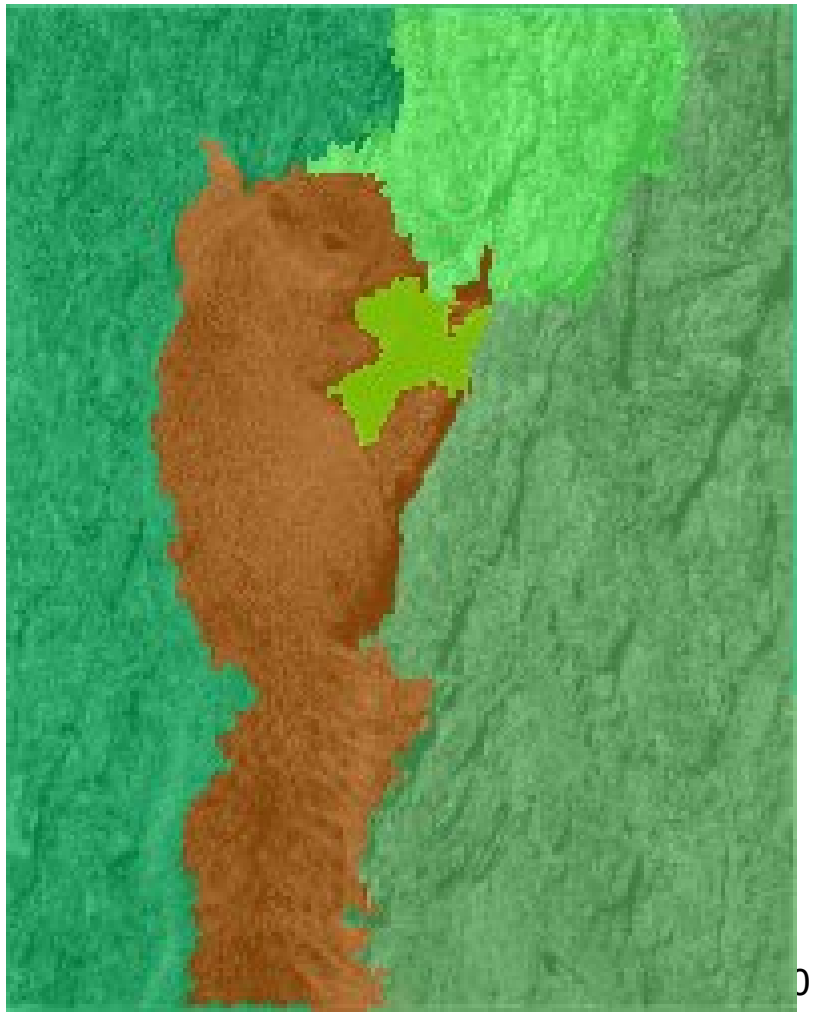
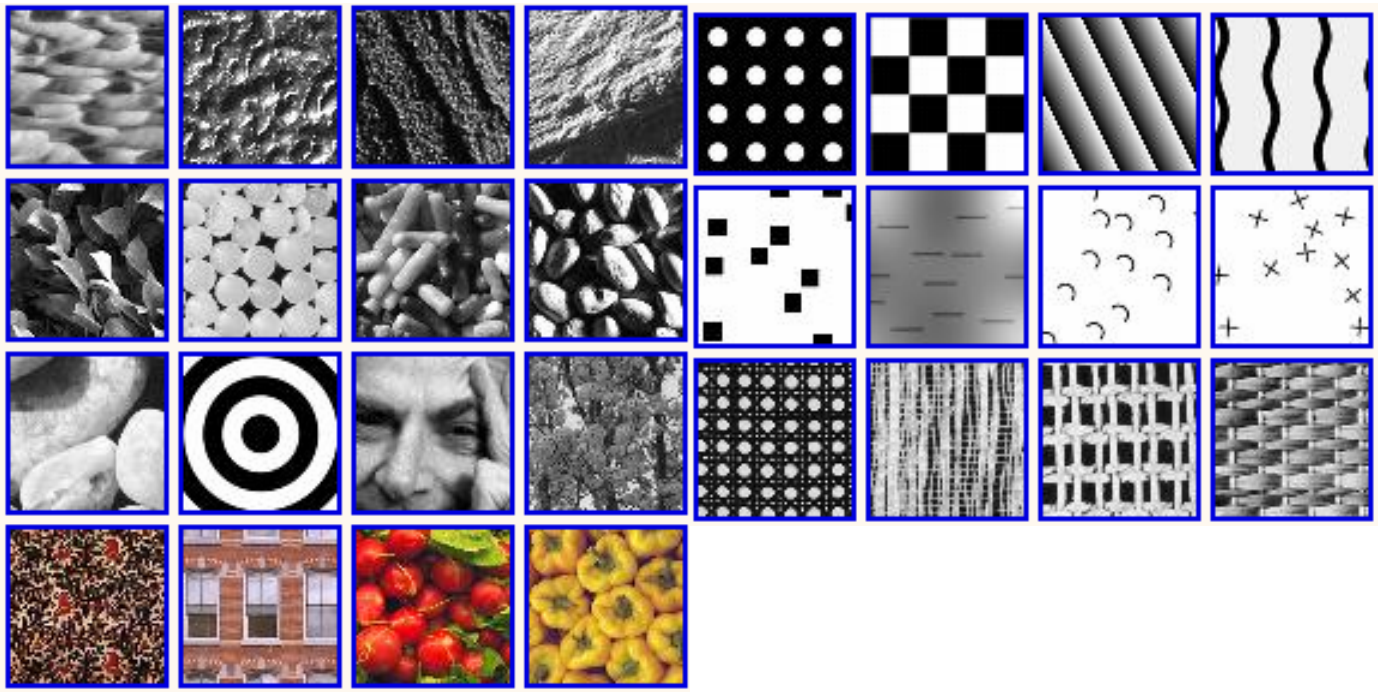
Region Segmentation



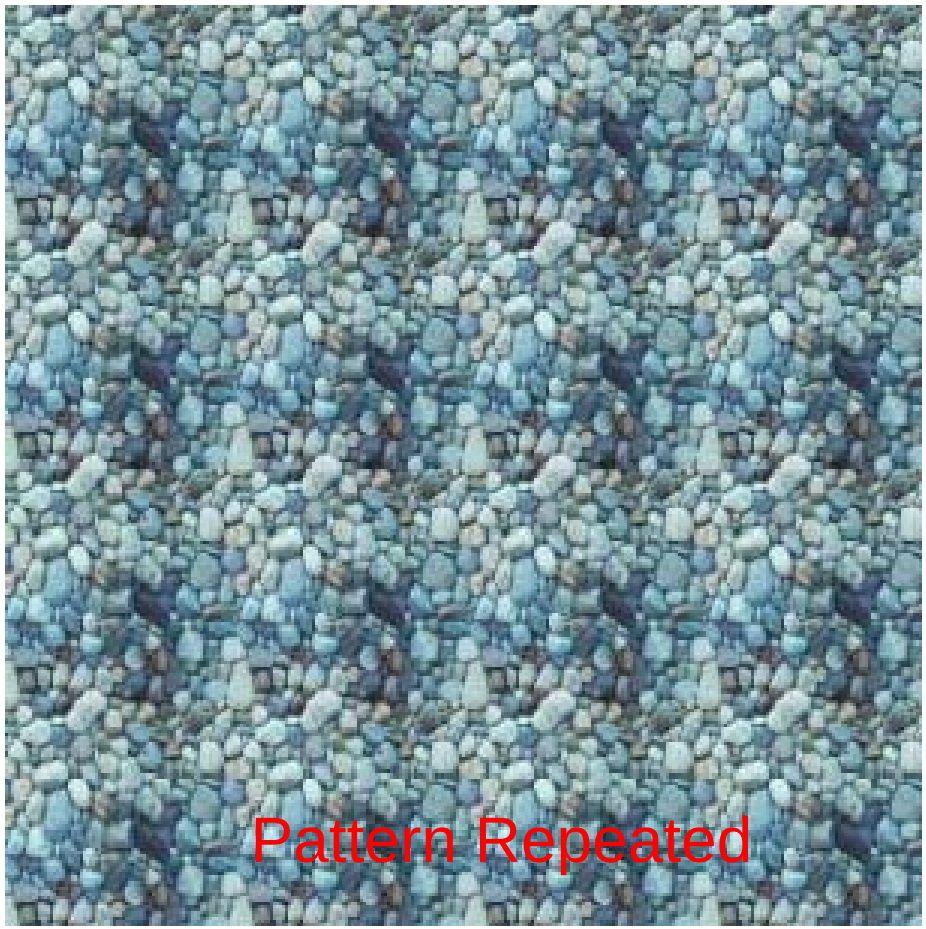
Texture



Textures

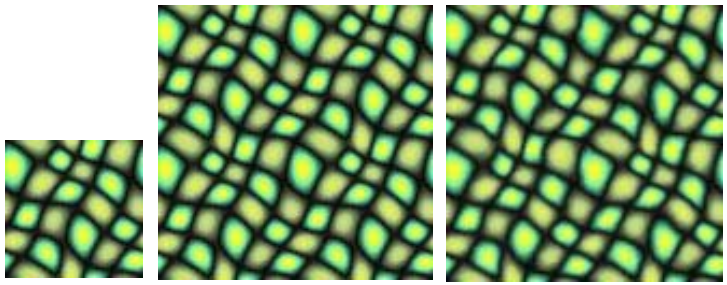
2D texture synthesis

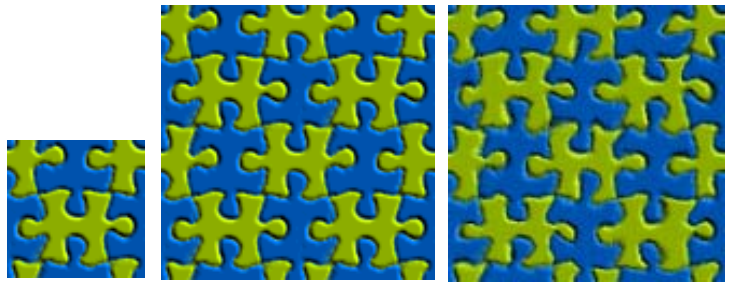
Photo

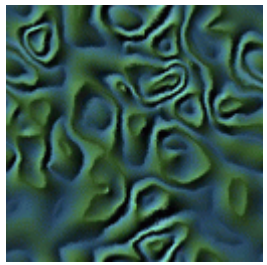


Textures

2D texture synthesis

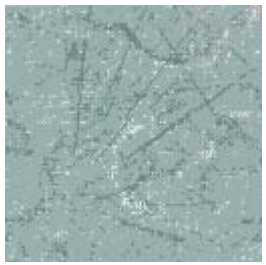


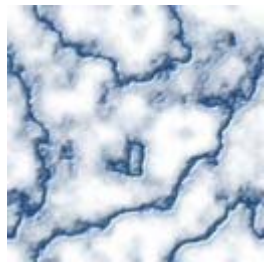




Textures

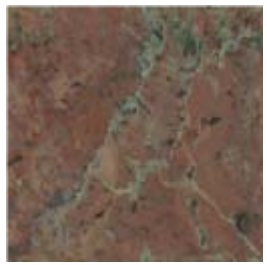
3D texture synthesis

Textures
3D texture synthesis

- Some animations
  - (Click on the target object to see the movie)



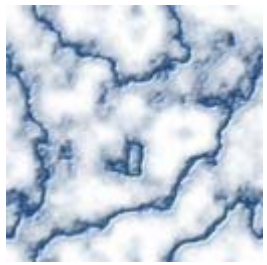


Image Coding
advanced techniques

SPIHT VS. JPEG

0.5bpp,

PSNR=37.12

1.0bpp,

PSNR=40.41

Image Watermarking

http://wapmail.ucd.ie/webmark/servlet/webmark

Original image

Watermarked Image

Difference

Imperceptible/Undeletable/Undetectable/Robustness/Unambiguous

Image Watermarking

Image Watermarking

Image Watermarking

Image Analogies

A

A’

B

B’

Artistic Filters

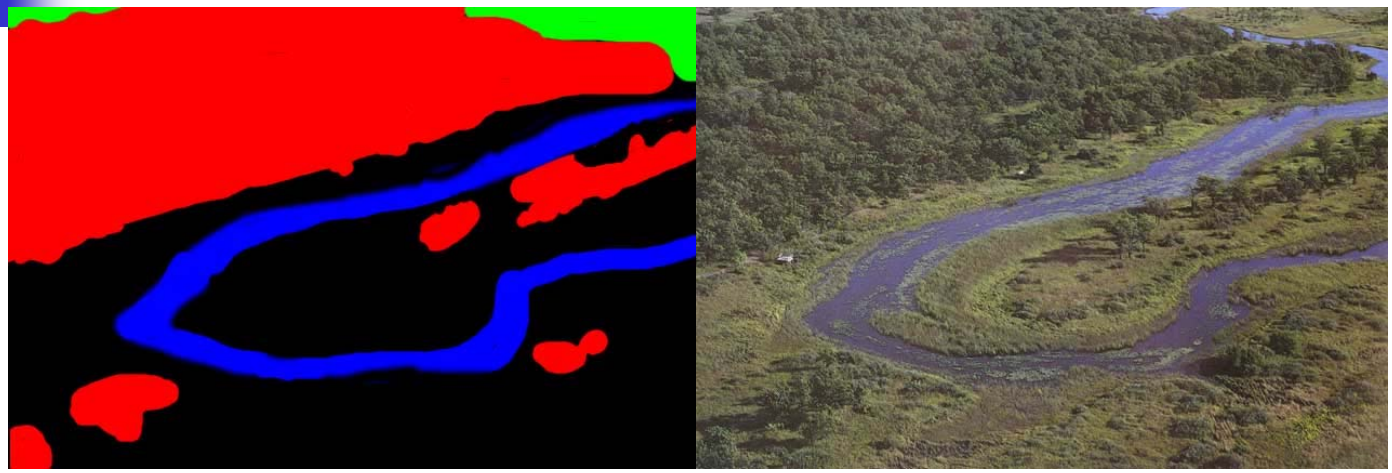
A

A’

B

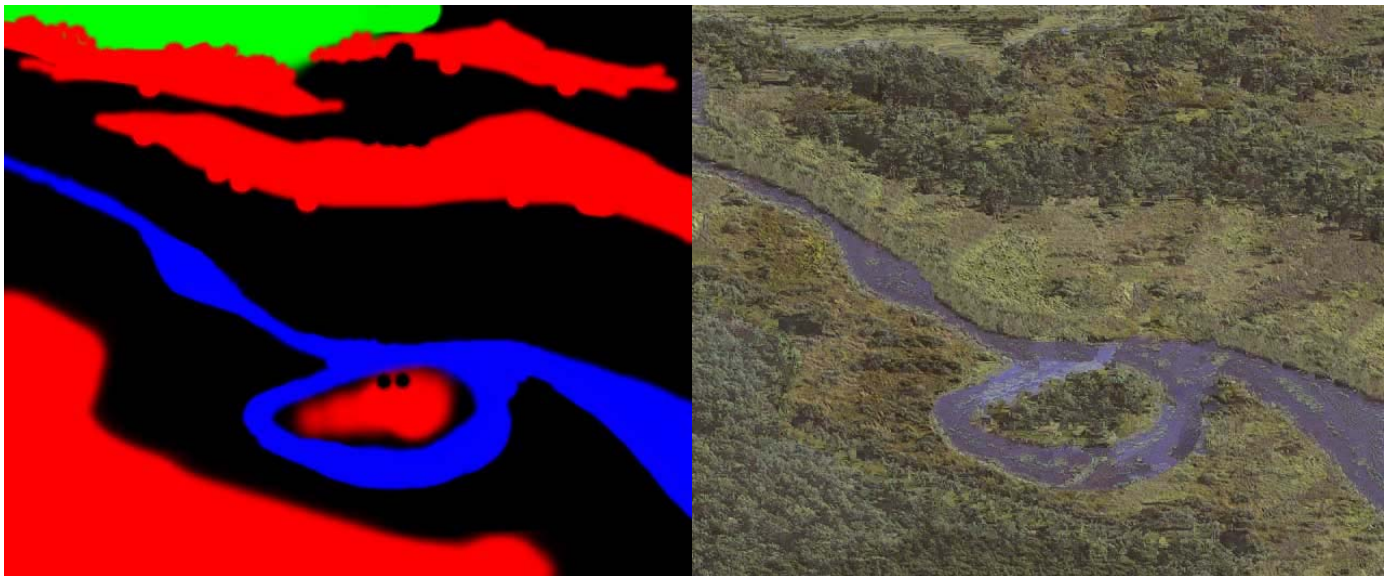
B’

Texture-by-numbers



A

A’



B

B’

Colorization

Unfiltered source (*A*)

Filtered source (*A'*)

Unfiltered target (*B*)

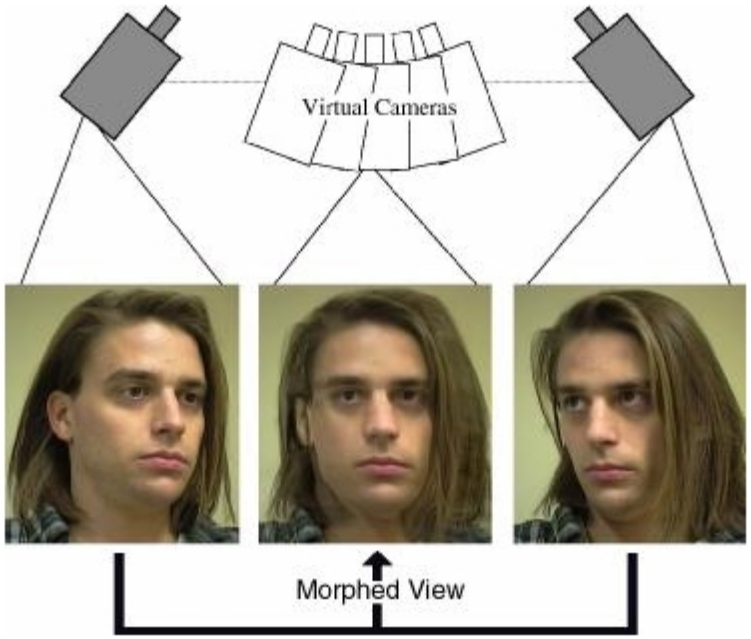
Filtered target (*B'*)

Image Morphing

Face morphing

Image Morphing
view morphing

- Morph between pair of images using epipolar geometry
  [Seitz & Dyer, SIGGRAPH'96] (Click on the target object to see the movie)



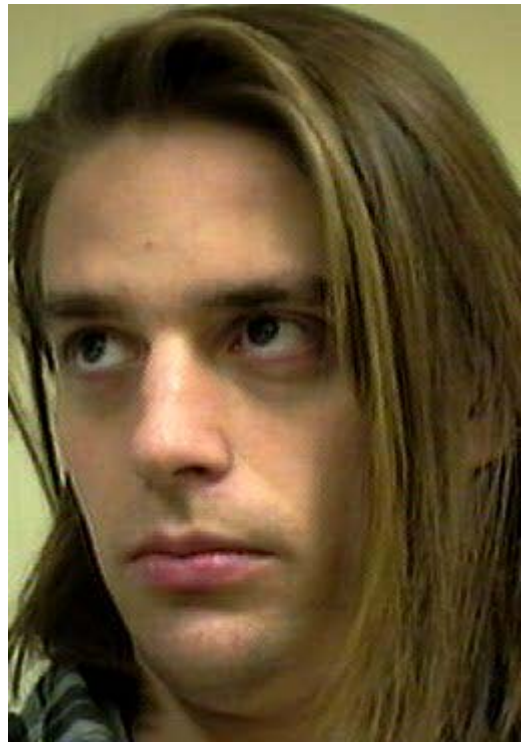


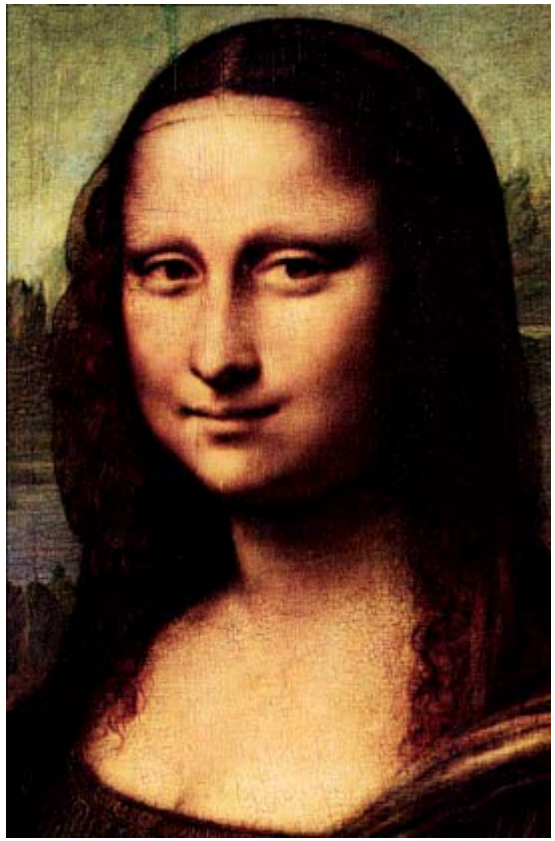
Image Morphing

view morphing + face morphing

(Click on the target object to see the movie)

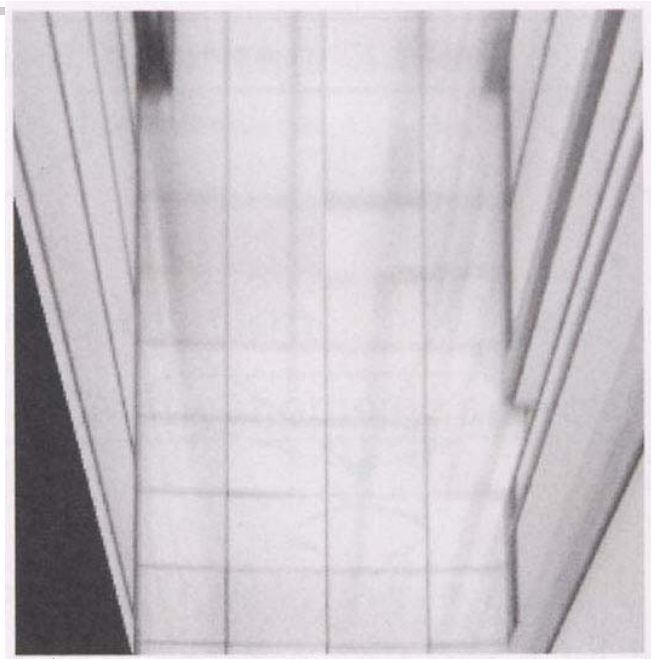
Image Morphing

More demos



(Click on the target object to see the movie)

Image warping with homographies



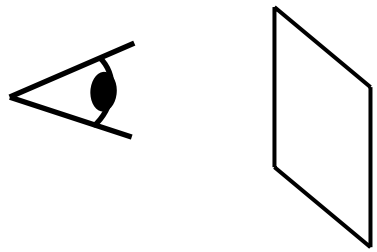


image plane in front

black area where no pixel maps to

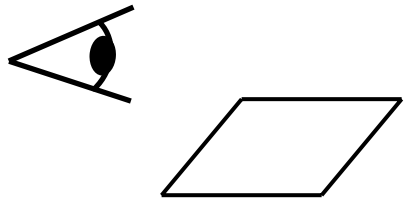


image plane below

Image Registration

Image Mosaics

+

=

Image Registration

Multiple Image Mosaics

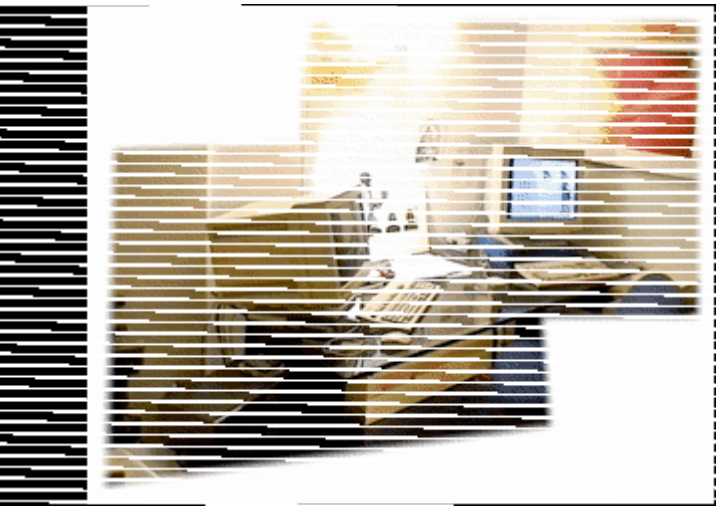


Image Registration

Panoramic Mosaics

Mosaics for Video Coding

Convert masked images into a background sprite for content-based coding

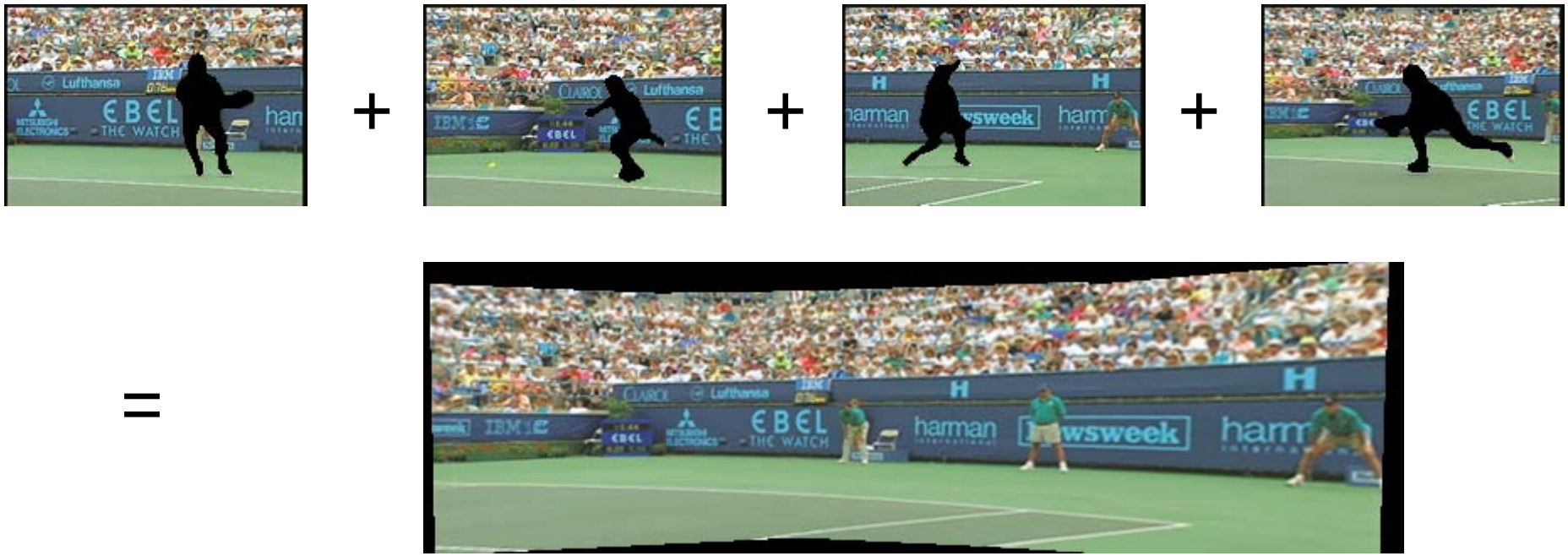
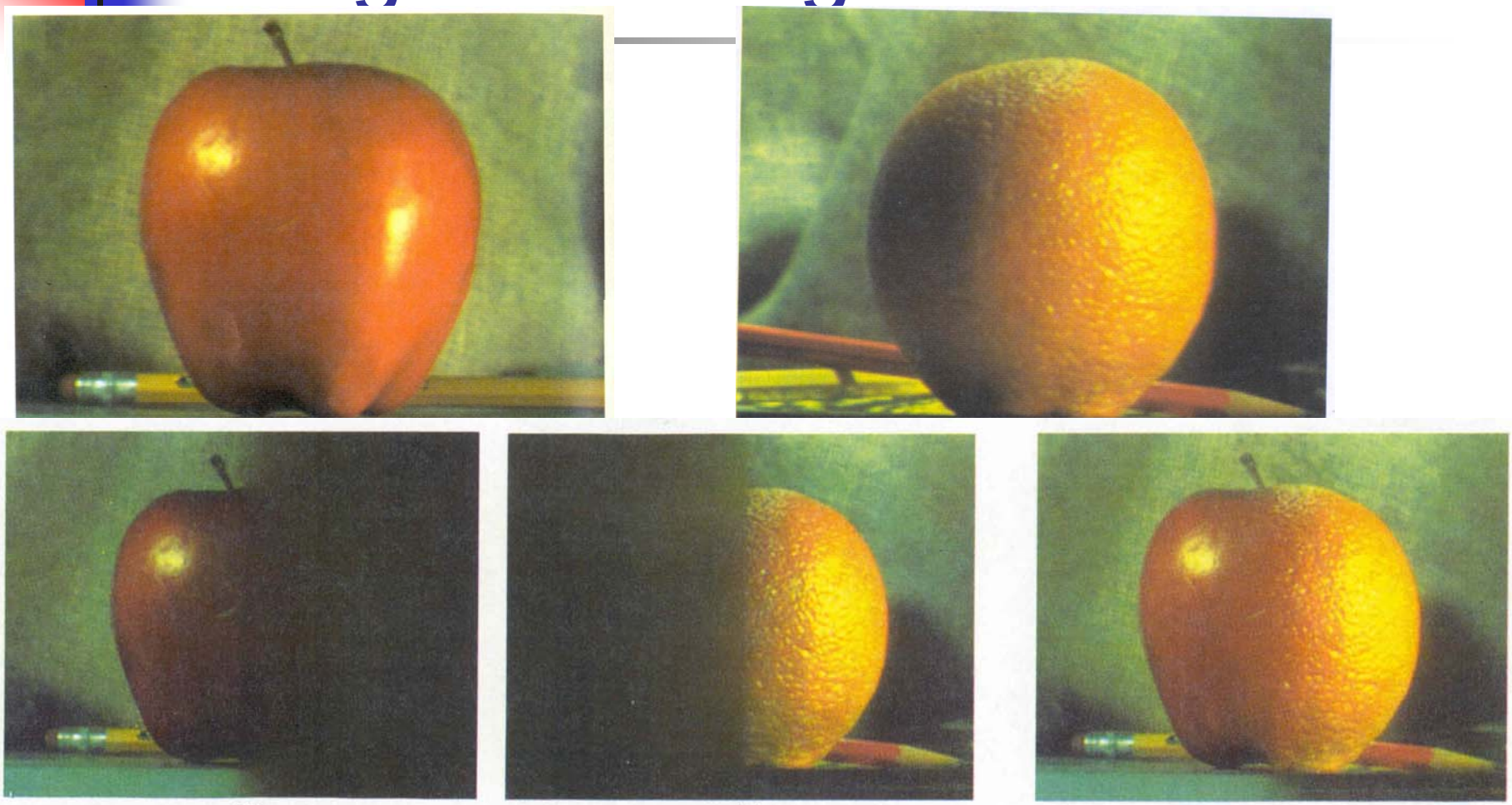
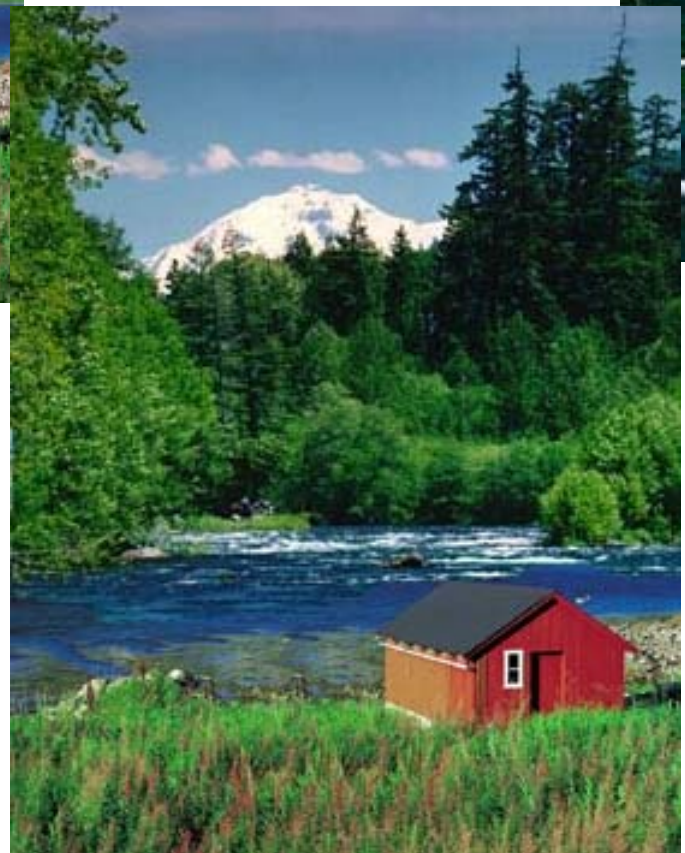


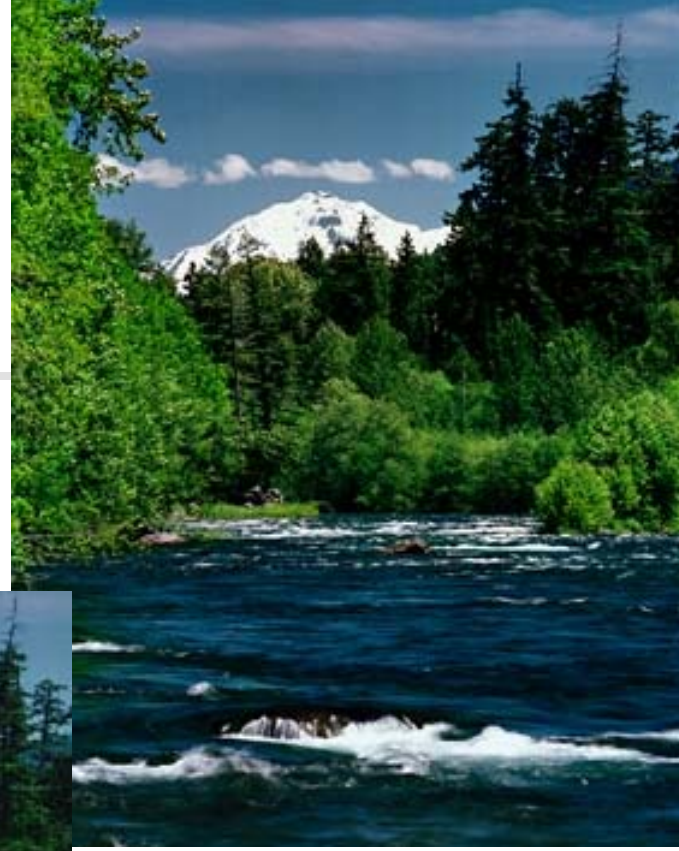
Image blending



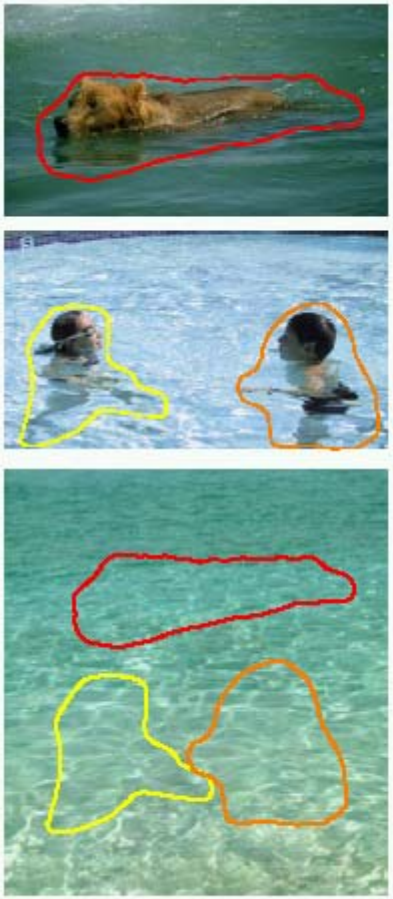
- Burt, P. J. and Adelson, E. H., A multiresolution spline with applications to image mosaics, ACM Transactions on Graphics, 42(4), October 1983, 217-236.

Image blending





Poisson Image Editing



sources/destinations

cloning

seamless cloning

Image Inpainting

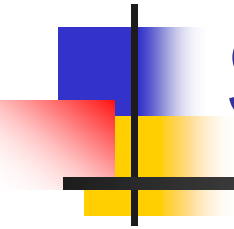
Photo repair

Image Inpainting Example

scene edit

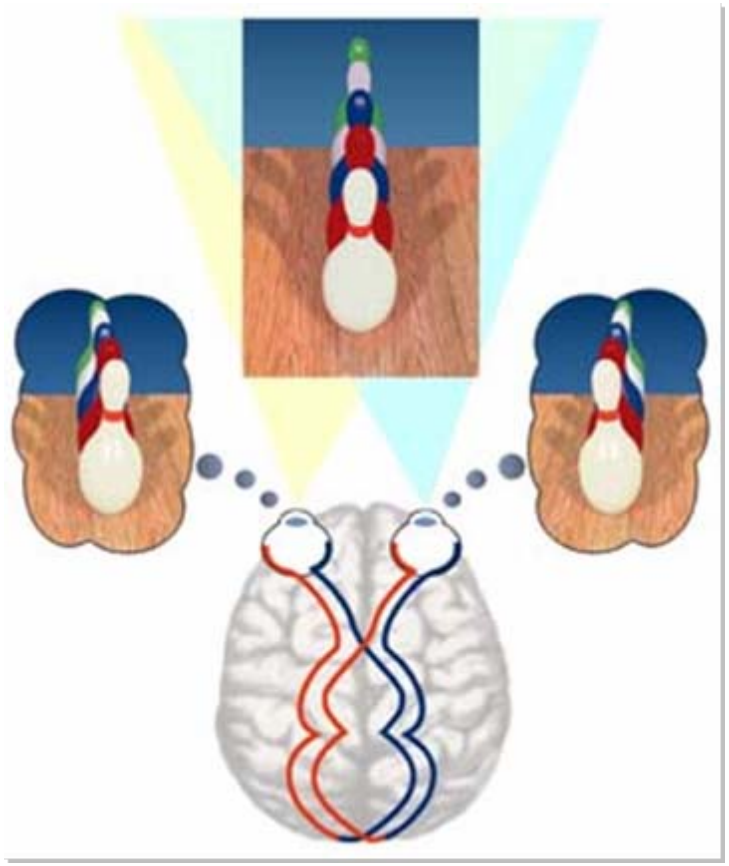
Image Inpainting

Original scene recovery

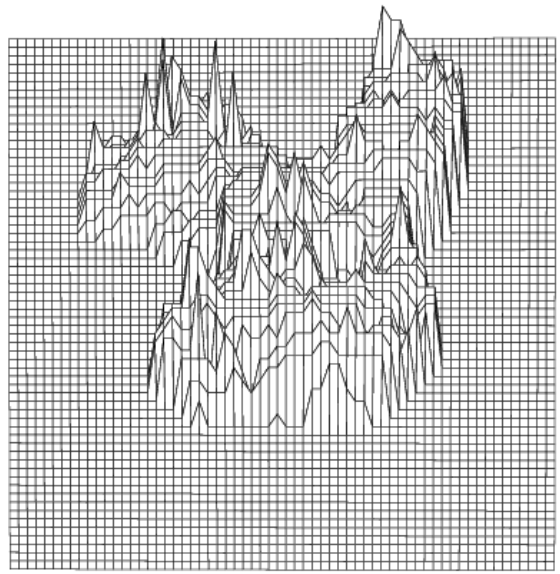


Stereo

http://www.vision3D.com/stereo.html

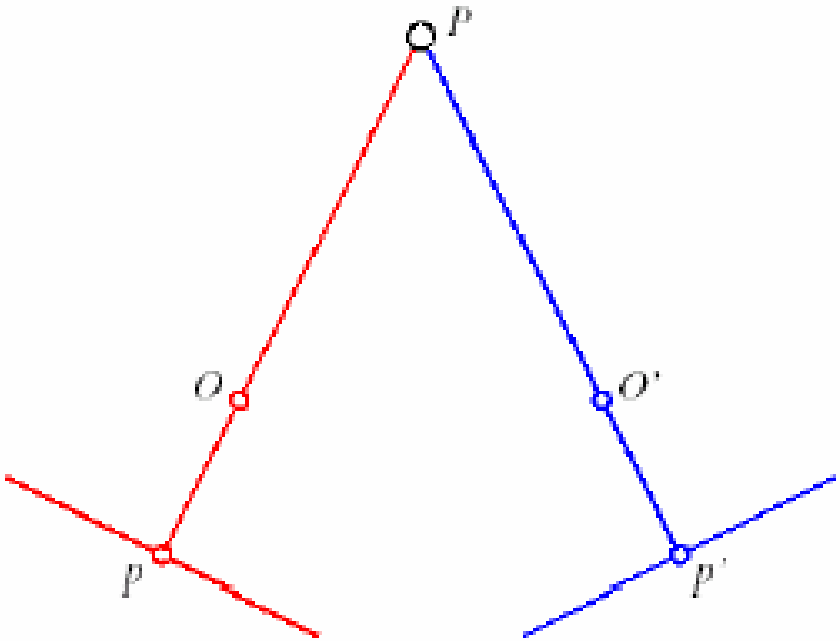


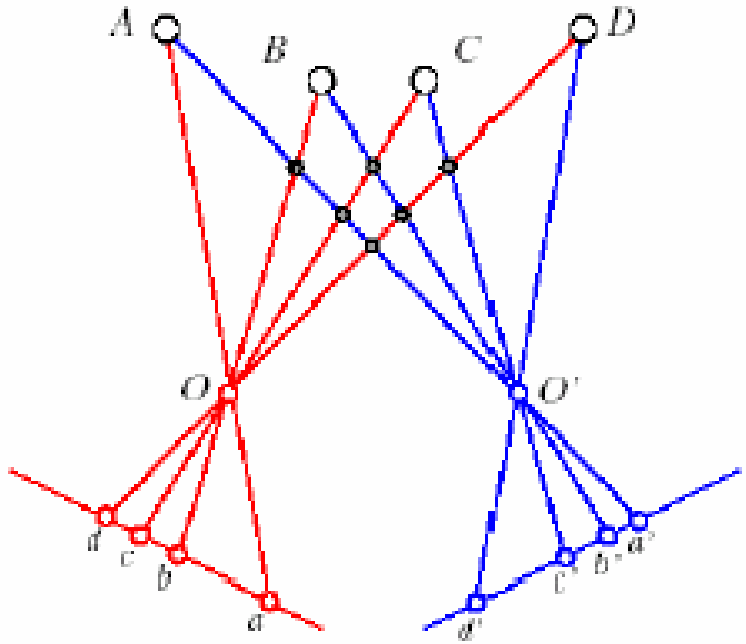
Example



Stereo Pair

Stereo





http://www.ai.mit.edu/courses/6.801/lect/lect01_darrell.pdf

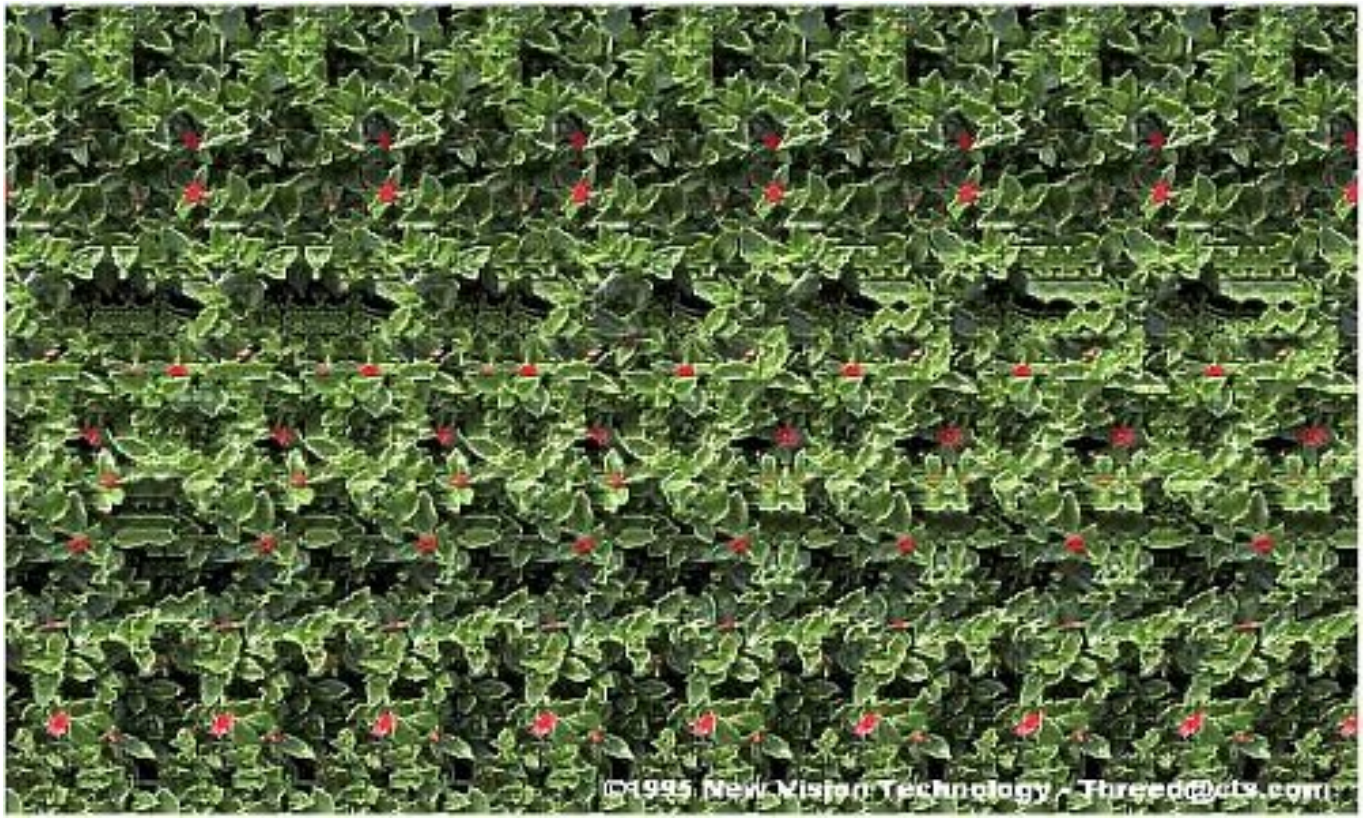
Stereo

http://www.magiceye.com/

Stereo

http://www.magiceye.com/

Stereo



Stereo results

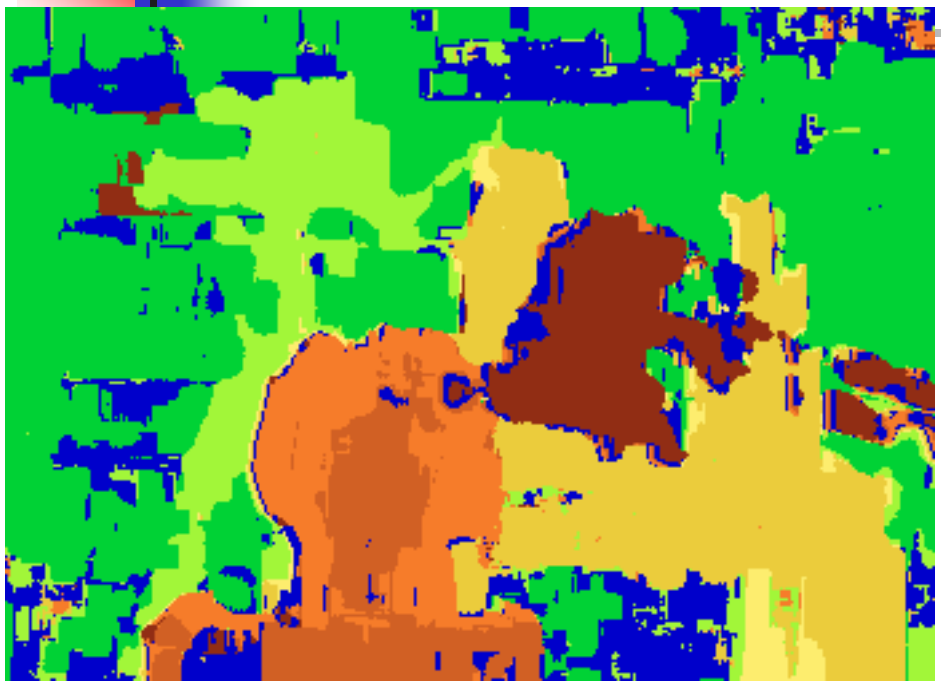
- Data from University of Tsukuba

Scene

Ground truth

(Seitz)

Results with window correlation



Window-based matching
(best window size)

Ground truth

(Seitz)

Results with better method

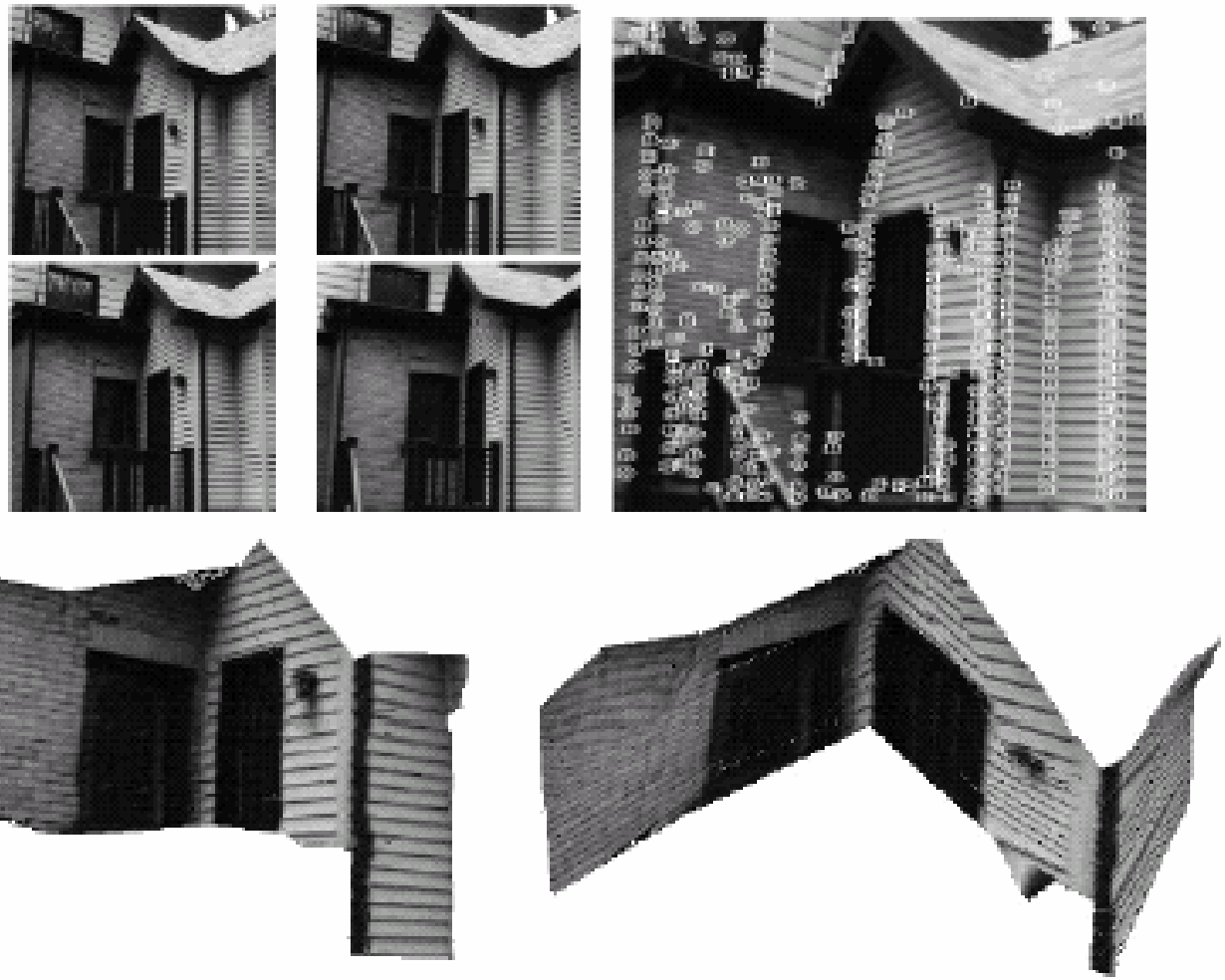
State of the art method

Ground truth

Boykov et al., Fast Approximate Energy Minimization via Graph Cuts, International Conference on Computer Vision, September 1999.

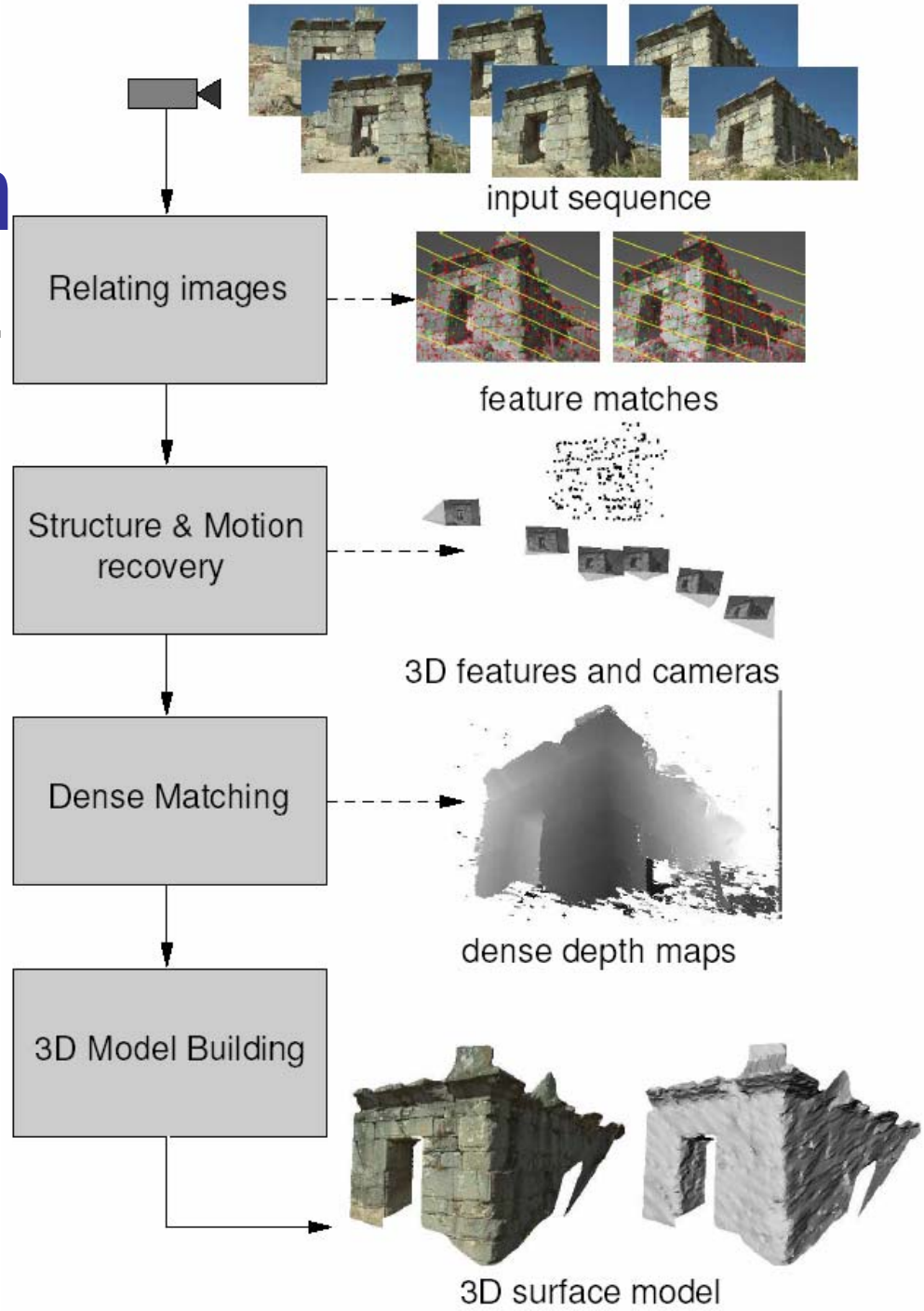
(Seitz)

Motion



http://www.ai.mit.edu/courses/6.801/lect/lect01_darrell.pdf

Structure from Motion



Structure from motion

Image Processing Example

Face detection

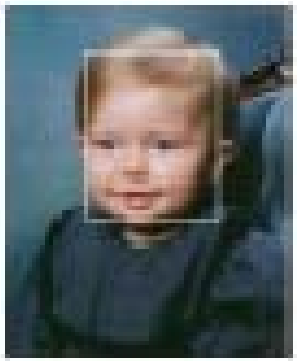
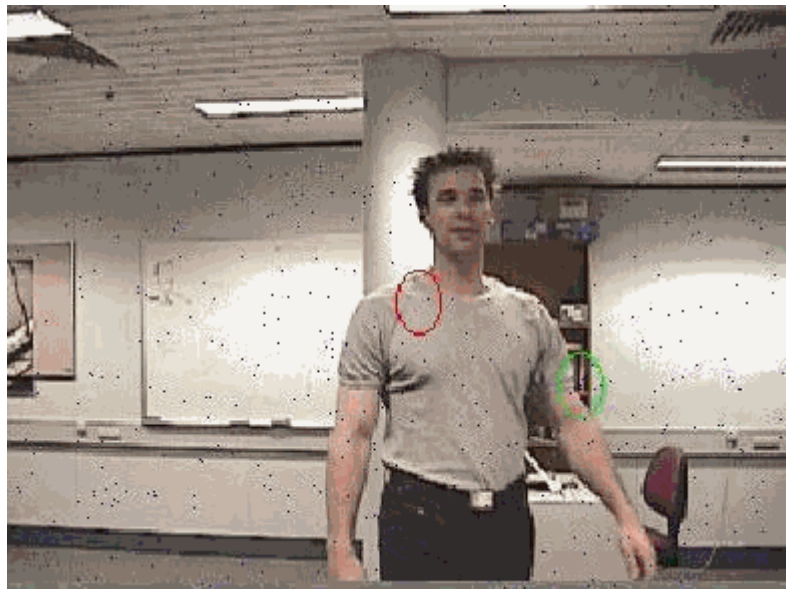


Image Processing Example

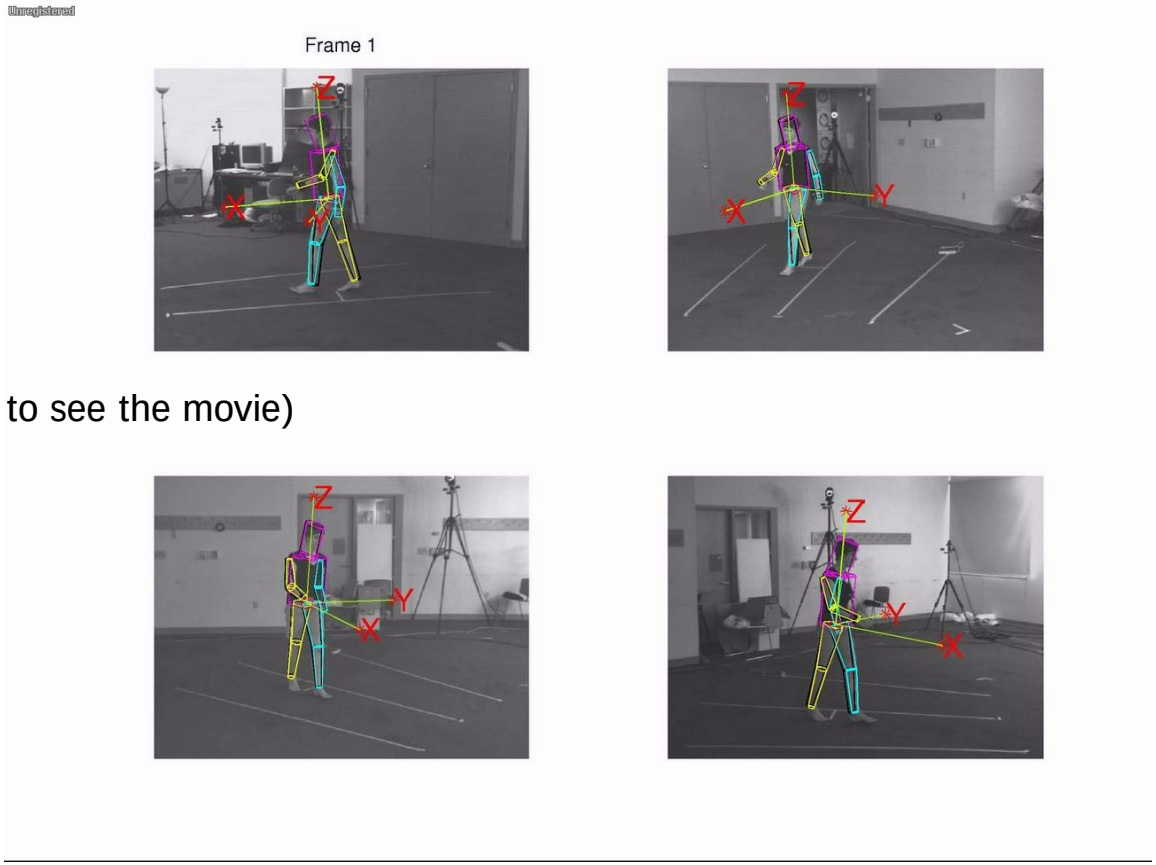
Face tracking

Tracking
2D Face detectiong and tracking



(Click on the target object to see the movie)

Tracking
3D Human tracking



(Click on the target object to see the movie)

Applications of projective

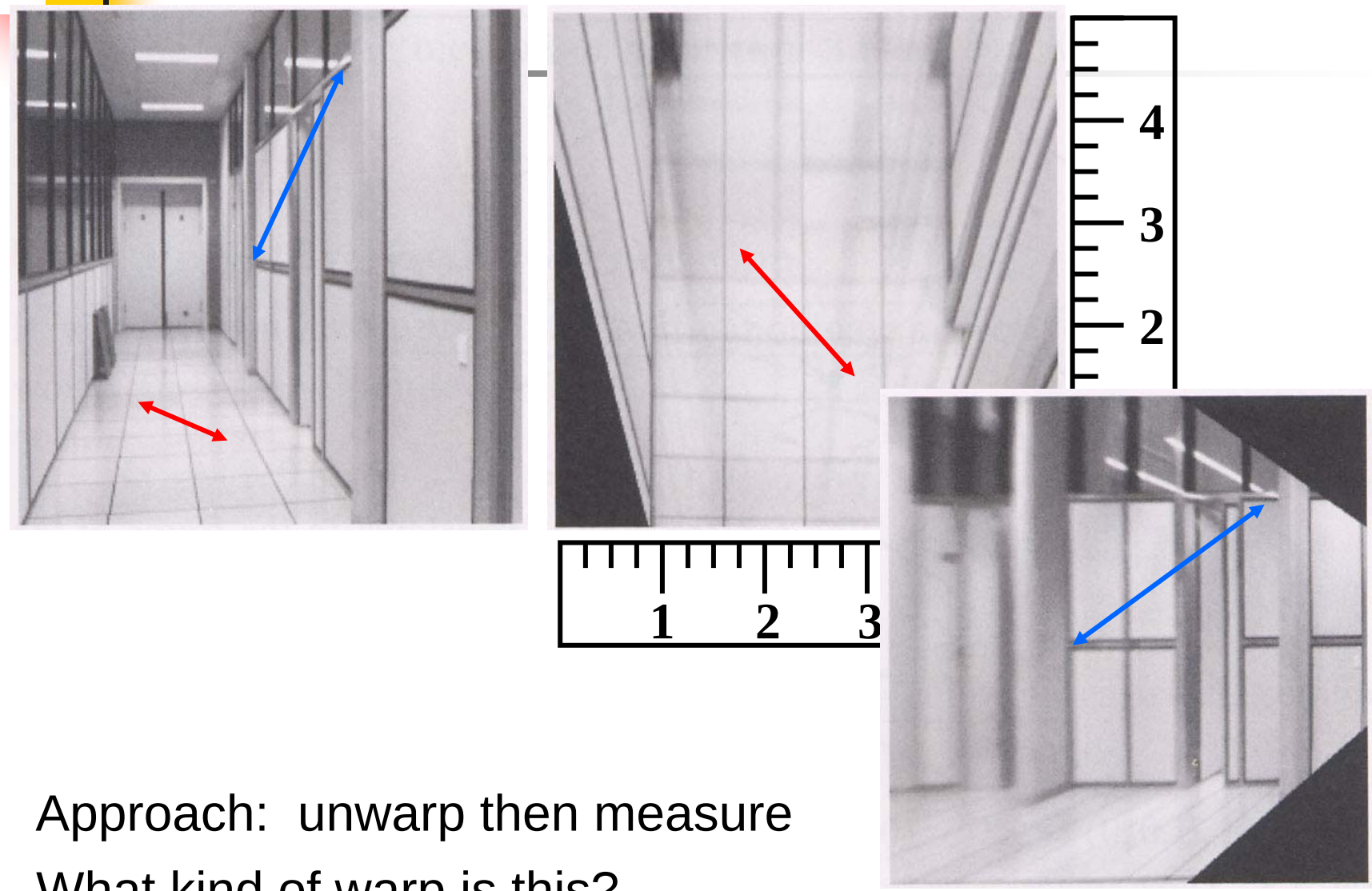
Vermeer's *Music Lesson*

Reconstructions by Criminisi et al.

3D Modeling from a Photograph

3D Modeling from a Photograph

Measurements on planes



Approach: unwarp then measure

What kind of warp is this?

Augemented Reality

adding virtual objects into real scenes

(Click on the target object to see the movie)

Augemented Reality

photorealistic augmented scene

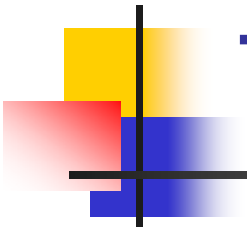
Addition of a virtual lamp which project virtual shadow on the real wall

Virtual lamp can be switched on

Augemented Reality

photorealistic augmented scene

Which table is the real one ?



Thank you

Any questions?