Computer Vision Introduction
http://www.ugrad.cs.jhu.edu/~cs461

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Outline for Today

- Outline and Organization of the course
- What is Computer Vision
- Matlab Demo

Course Information

- Use the course WEB site
  - http://www.ugrad.cs.jhu.edu/~cs461
- What you need
  - access to Matlab + Image Processing Toolbox
    - CS computing lab
    - Your own PC and the student edition (purchase online at mathworks.com)
    - Any other matlab-capable computer
  - one of the two recommended texts

What is Computer Vision?

- **Trucco and Verri**
  - *computing properties of the 3D world from one or more digital images*
- **Stockman and Shapiro**
  - *To make useful decisions about real physical objects and scenes based on sensed images*
- **Ballard and Brown**
  - *The construction of explicit, meaningful description of physical objects from images*
- **Forsyth and Ponce**
  - ***...**extracting descriptions of the world from pictures or sequences of pictures*

Some Related Terms

- **Image Processing:** the study of the properties of operators that produce images from other images
  - we will touch on image filtering and related operators from image processing
- **Machine Vision:** a somewhat outdated term which now tends to refer to industrial vision applications where (usually) a single camera is used to solve a structured inspection task
  - the “reverse CAD” model
- **Pattern Recognition:** typically refers to the recognition of structures in 2D images (usually without reference to any underlying 3D information).
- **Photogrammetry:** the science of measurement though non-contact sensing, e.g. terrain maps from satellite images. Usually is more focused on accuracy issues than interpretation.

Why Is Vision Hard?

Why Is Vision Hard?

A Model for Vision

Geometry
Objects
Motion
Texture
Lighting
Movement
Activity....

? Vision Processing ?

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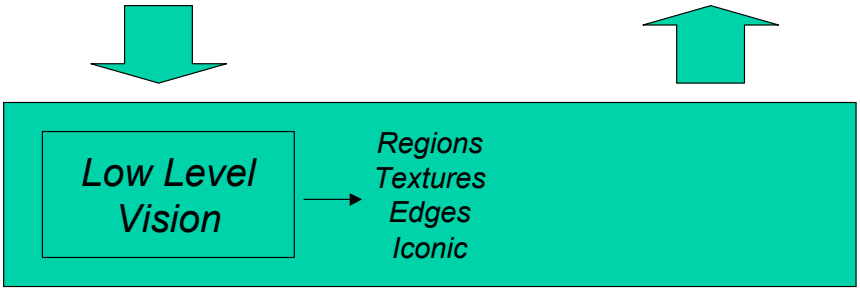
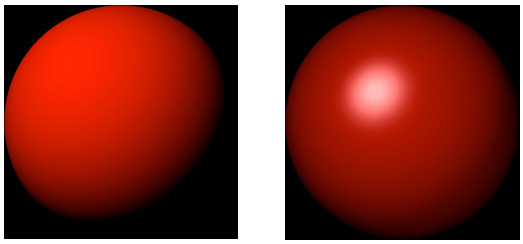
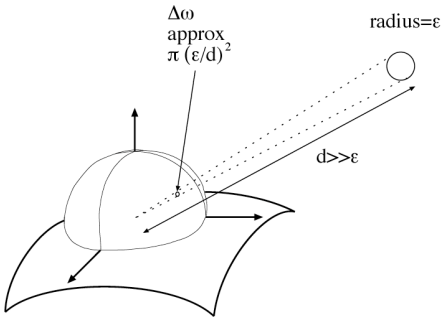
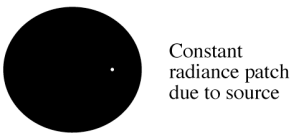


Problems of Computer Vision: Modeling

What are the physical and geometric processes that govern (digital) imaging?







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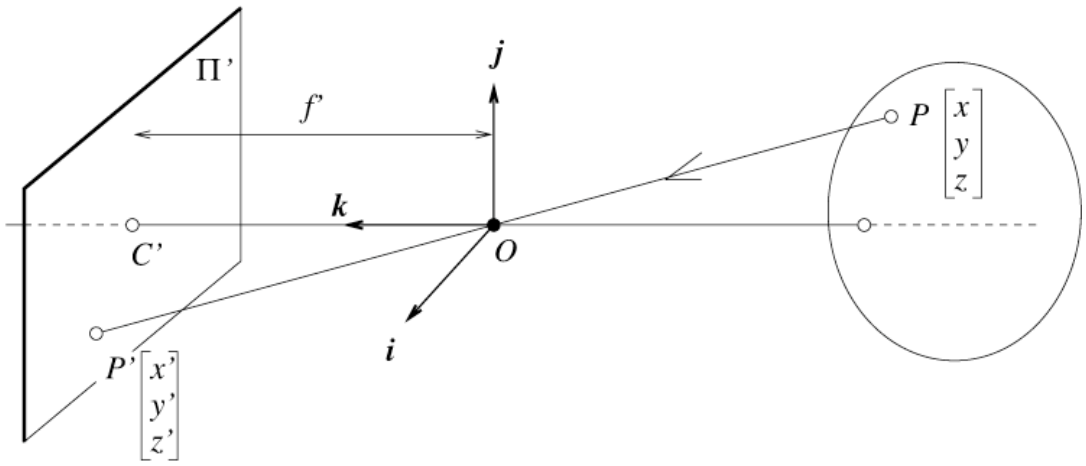


General Rules

If you can't understand (i.e. model) the forward process, you will have a hard time solving the inverse!

A related point: the best way to test vision algorithms is almost always to implement the forward model to test the (inverse) solution.

Computer Vision vs. Graphics

Is Vision the "Inverse" of Graphics?

- Computer Graphics
  - Produce "plausible" images
  - You choose the models, conditions, imaging parameters, etc.
- Computer Vision
  - Given real images with noise, sampling artifacts …
  - Estimate physically quantities
  - Ill-posed ---- what is the minimum world knowledge we need?

Problems of Computer Vision: Feature Extraction

What are the "informative" areas of an image and how do we detect them?

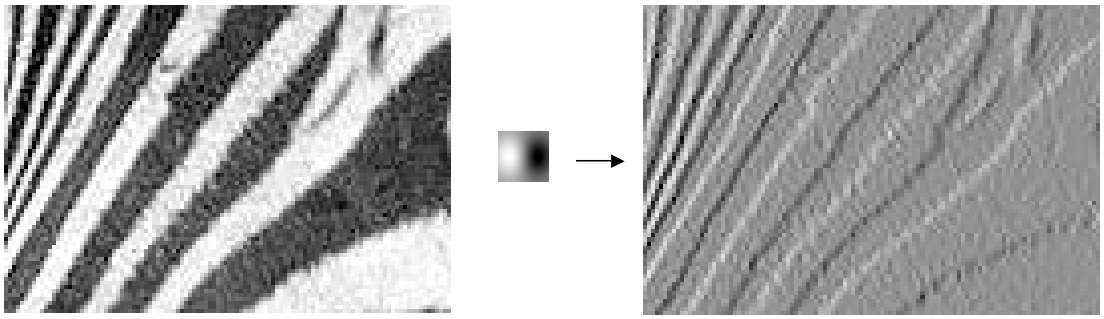
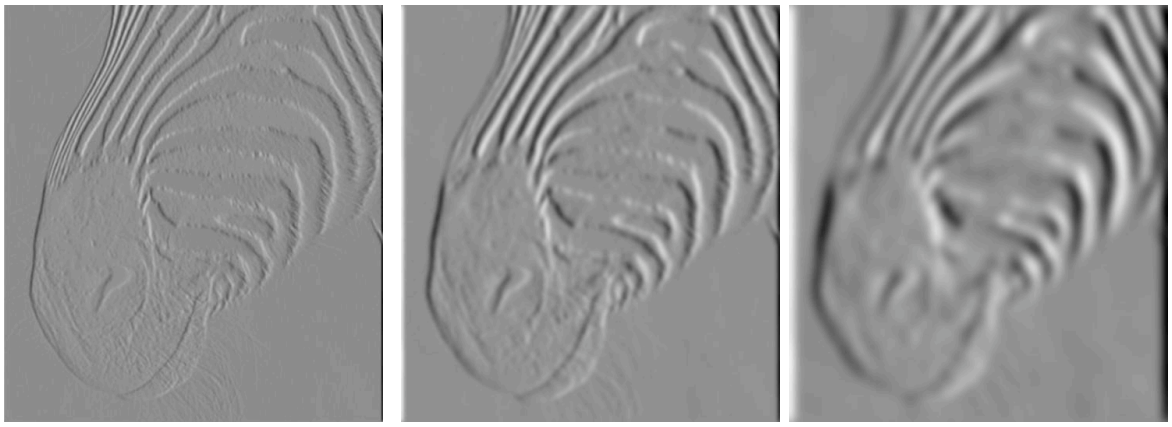


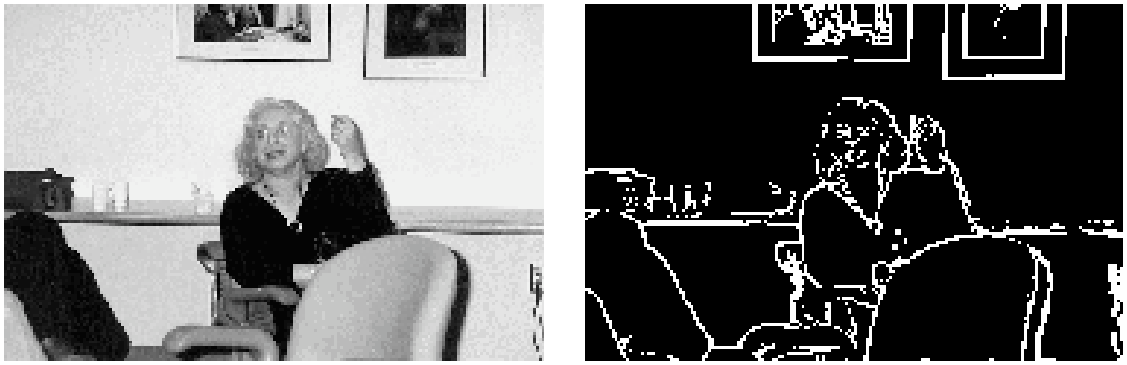
Image Filter Result

Problems of Computer Vision: Feature Extraction



Filter kernels that are larger see effects at coarser scales -- the filter on the left responds to the zebra's whiskers, that on the right to its stripes

Problems of Computer Vision: Feature Extraction



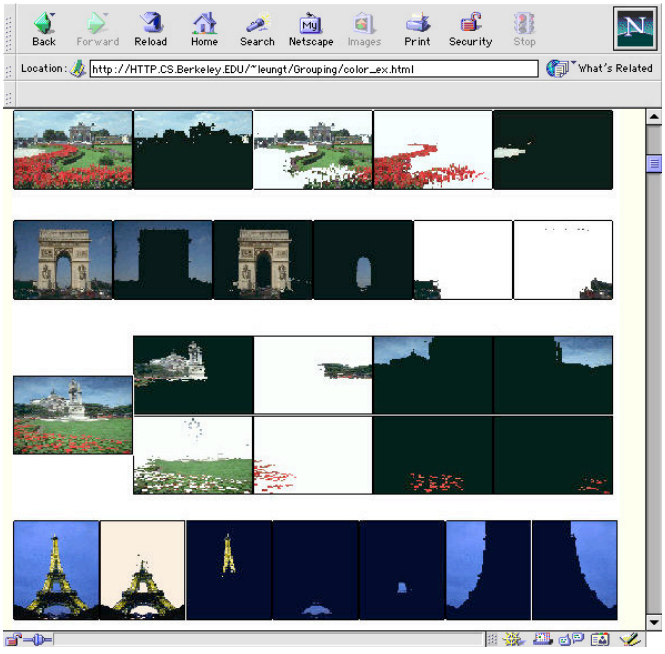
Thresholding suppresses "non-feature" areas of the image

Computer Vision vs. Image Processing

- Image Processing
  - Mostly concerned with *image-to-image* transformations
    - Filtering
    - Enhancement
    - Compression

- Computer Vision
  - Concerned with how images *reflect the 3D world*
    - Filtering *for feature extraction*
    - Enhancement *for recognition/detection*
    - Compression *that preserves geometric information in images*

Problems of Computer Vision: Segmentation and Grouping



What portions of an image pertain to one another and to relevant physical phenomena?

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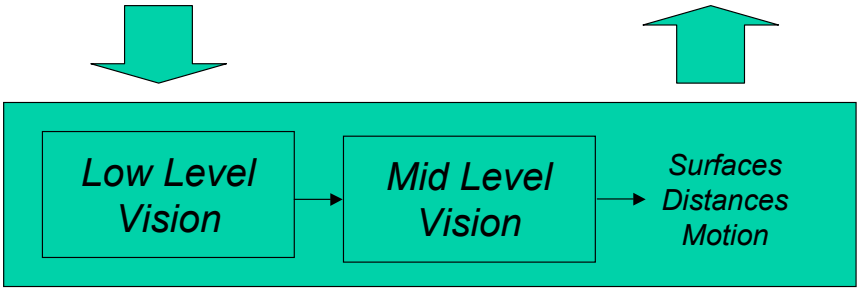
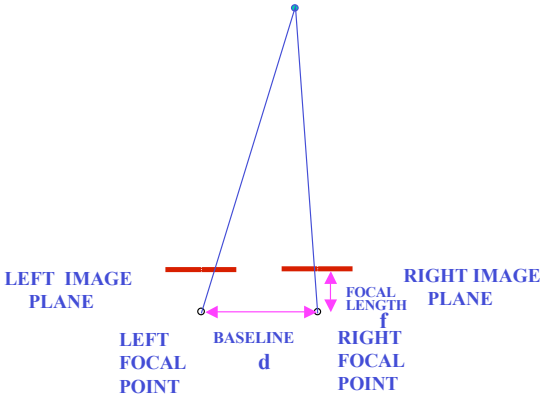
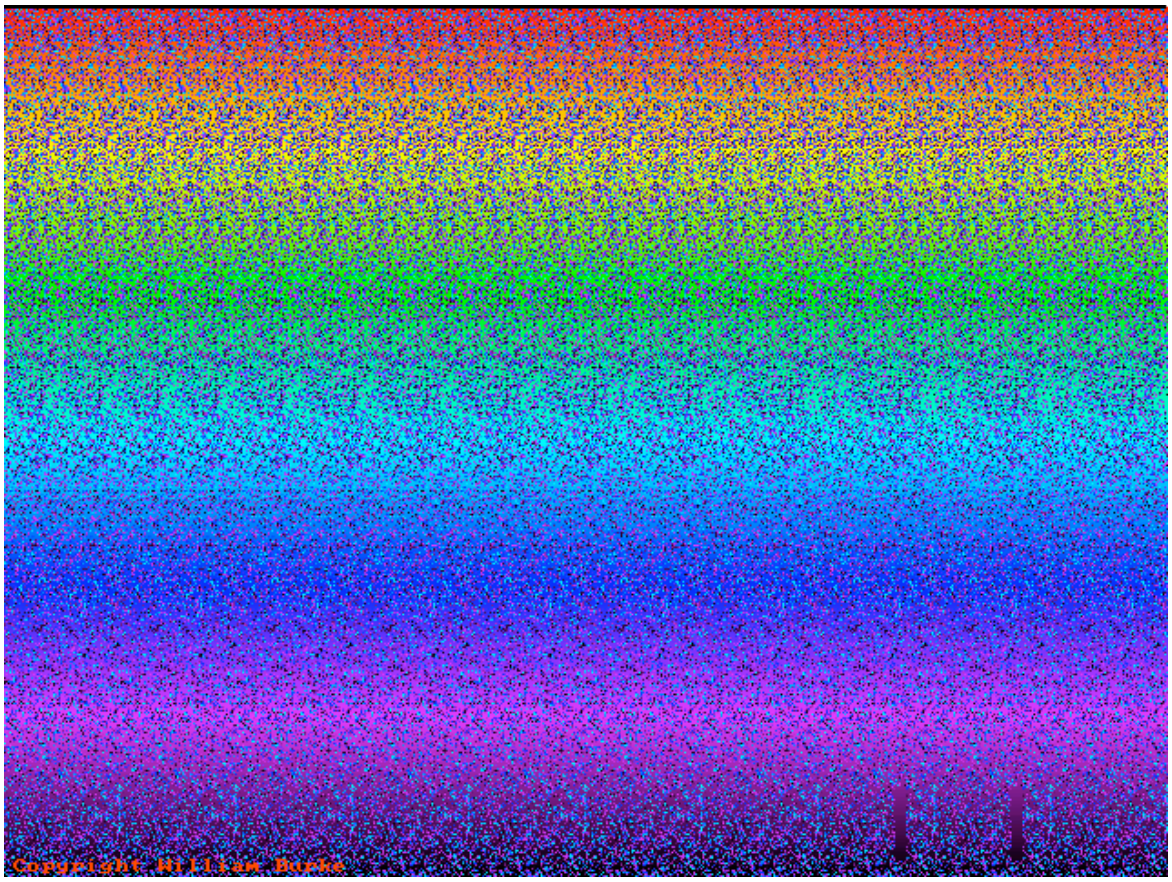


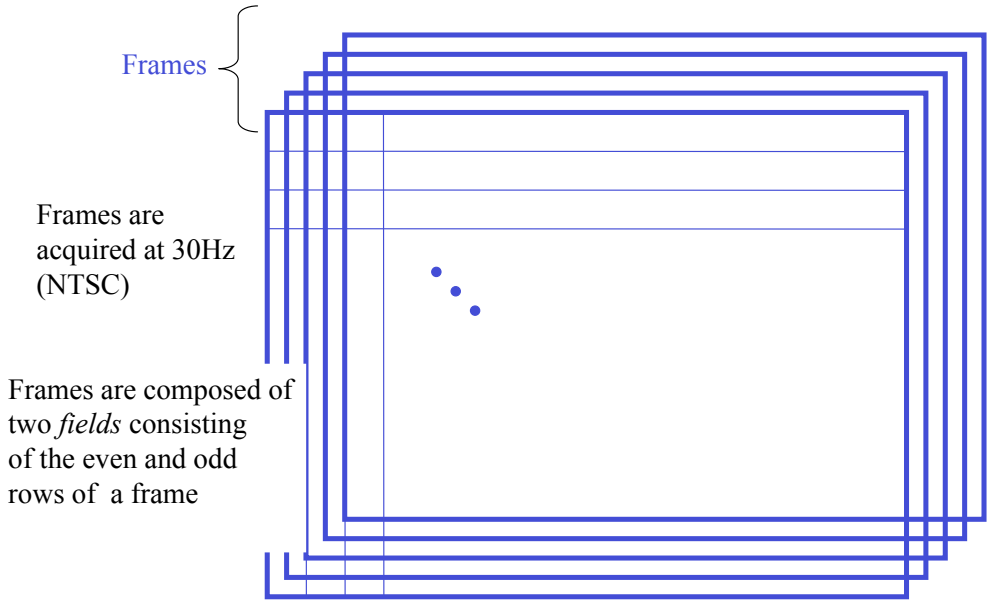
Problems of Computer Vision: Stereo Vision

From two (or more) images, determine the geometry of the scene by *matching* corresponding areas of the images



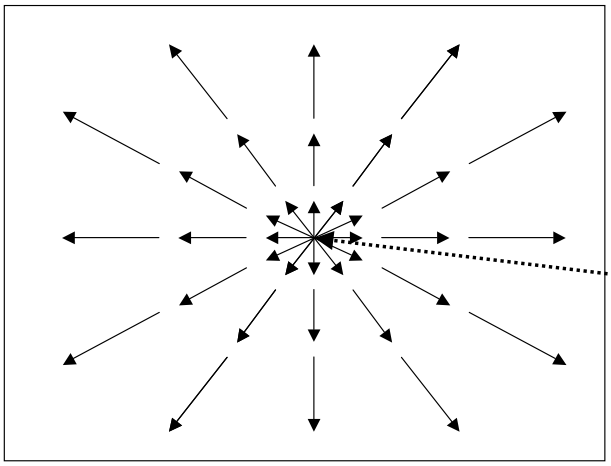


THE ORGANIZATION OF AN IMAGE SEQUENCE



THE MOTION FIELD

The "instantaneous" velocity of points in an image



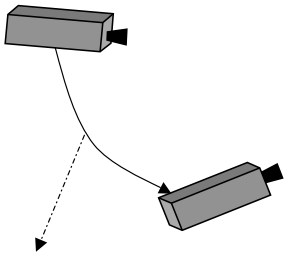
LOOMING

The *focus of expansion*

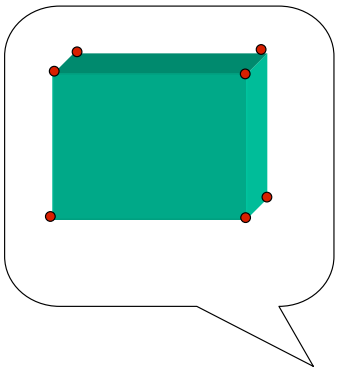
With just this information it is possible to calculate:

1. Direction of motion
2. Time to collision

MOVING CAMERAS ARE LIKE STEREO

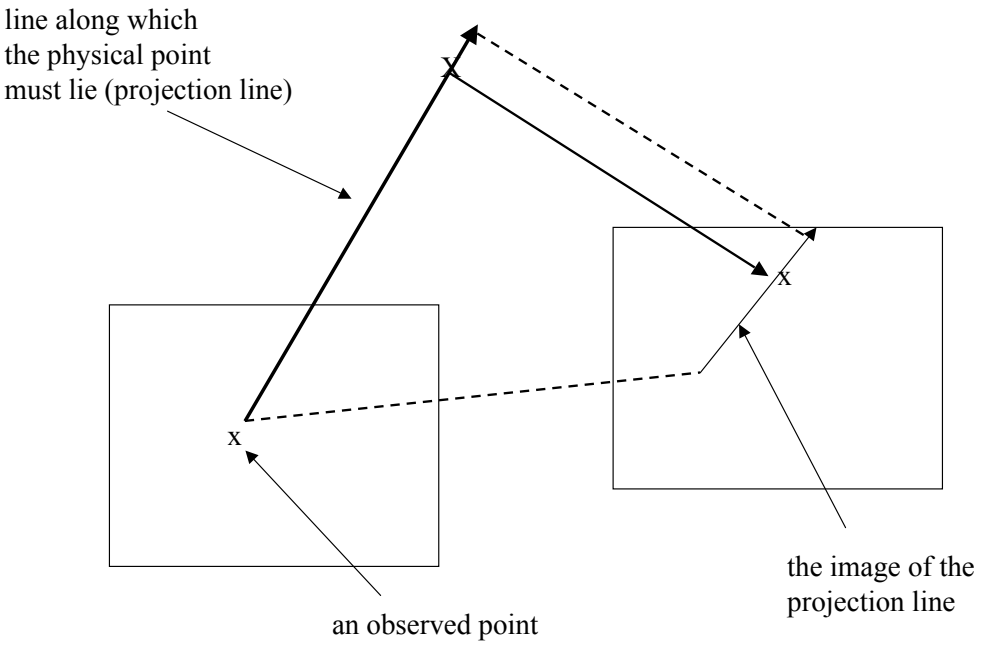


The change in spatial location between the two cameras (the "motion")



Locations of points on the object (the "structure")

THE EPIPOLAR CONSTRAINT



An Example

(Courtesy Carlo Tomasi)

A Model for Vision

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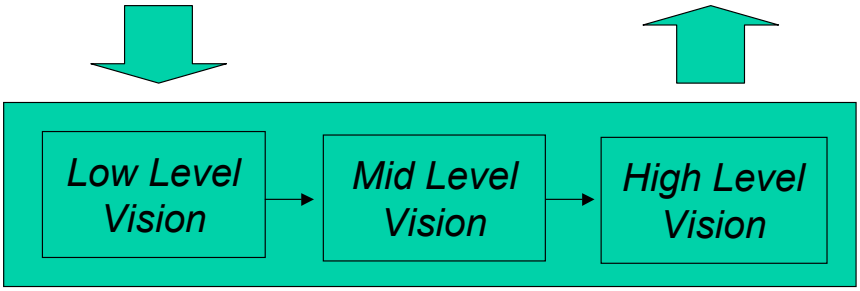
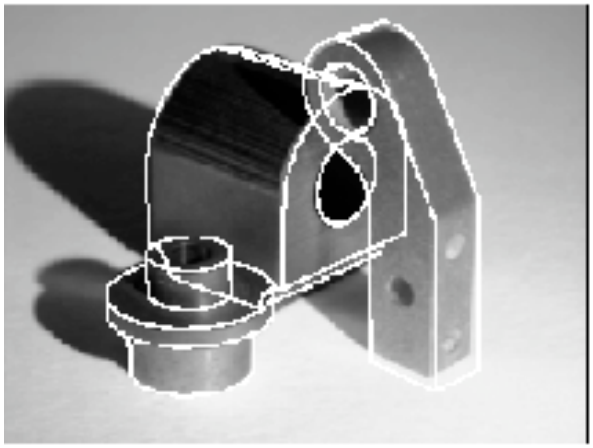
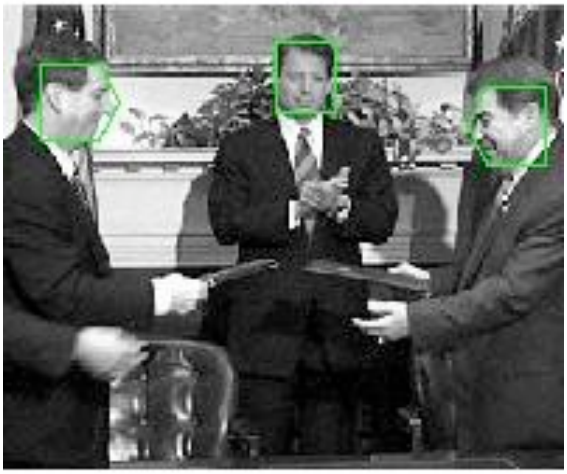


Problems of Computer Vision: Recognition



Given a database of objects and an image determine what, if any of the objects are present in the image.

Problems of Computer Vision: Recognition



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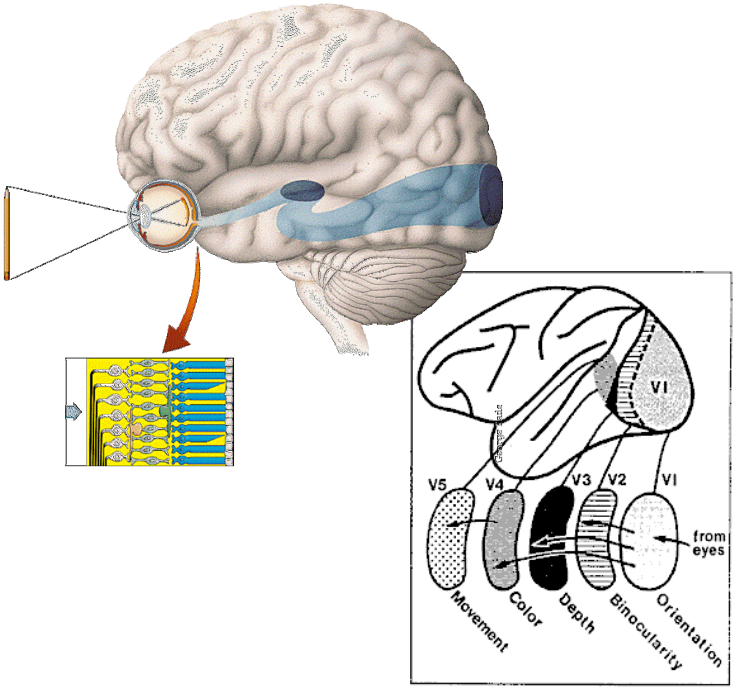
Can We Ever Make Vision Work?

Biology: We have eyes, as do many animals. Here is an extreme example:

Stomatopod eyes are unusual:
- they have stereo vision with just one eye;
- each eye is on a stalk, with a wide range of motion
- stomatopods have up to 16 visual pigments
- stomatopods can also see ultra-violet and infra-red light
- some can even see polarized light

Computer Vision vs. Human Vision

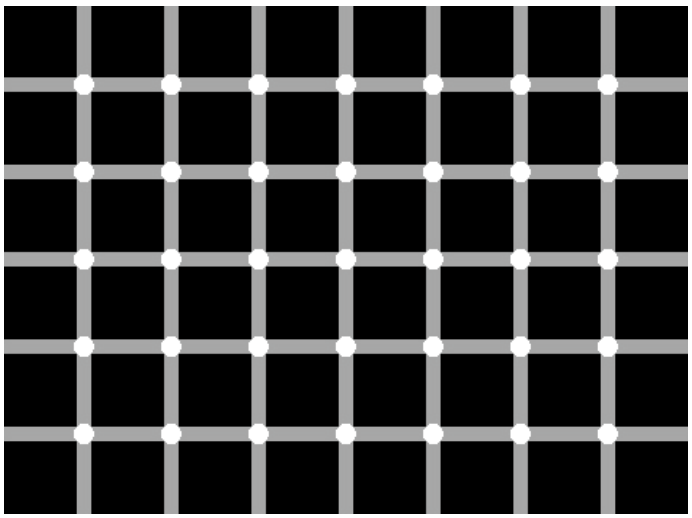


More than half the brain is devoted to visual processing.

Processing is highly modularized

Oddly, we are better at subject rather than objective processing e.g. the right segmentation seems obvious to us

Illusions: What Do They Tell Us?



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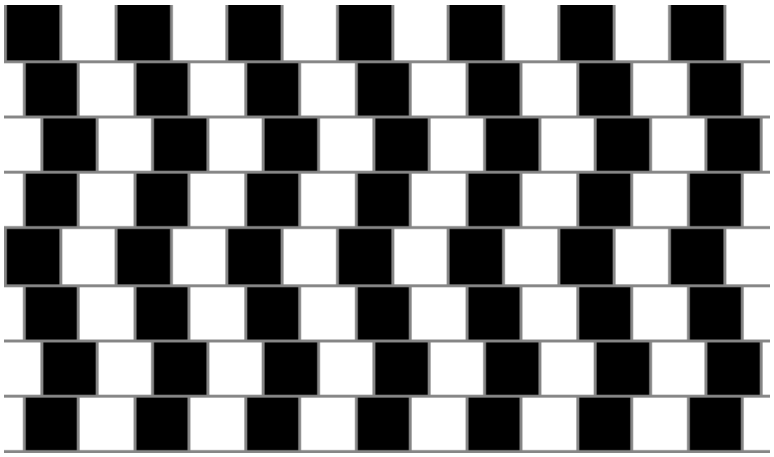

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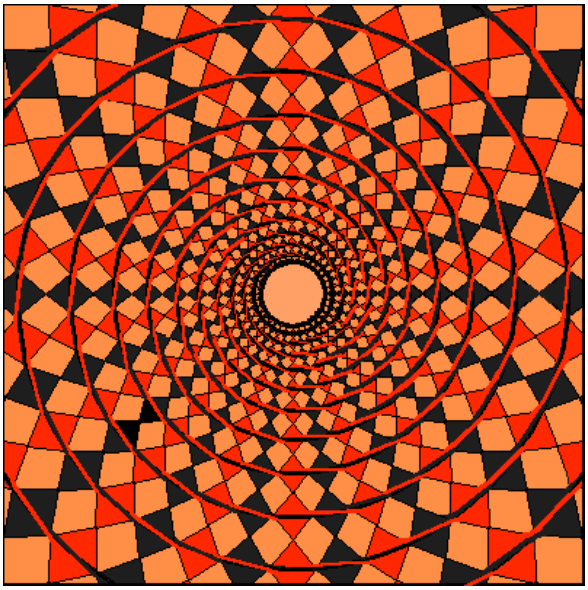

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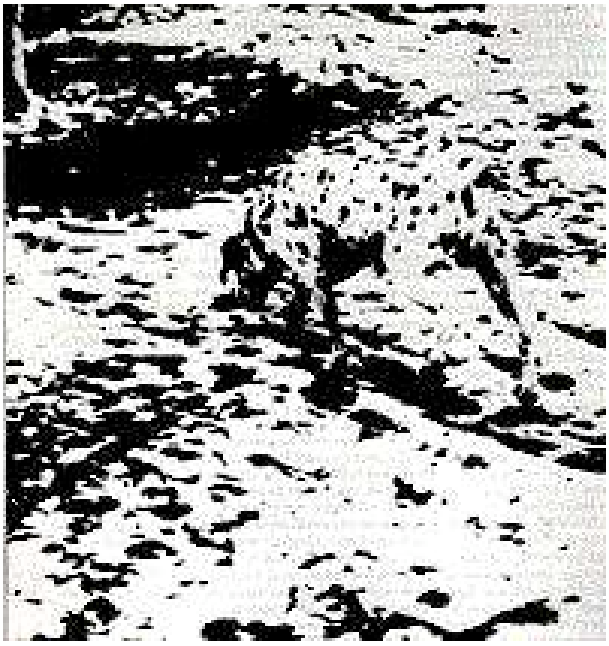

Illusions: What Do They Tell Us?

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Moving On ...

- Computer vision is still far from most biological systems, but ...
- After several decades of often highly experimental and anecdotal progress ...
- The previous decade saw huge advances in understanding geometric issues in vision, and ever more practical problems attacked....
- With the growth of computing power, it is possible to perform more and more complex processing on more and more images....
- Now, recent approaches/advances take advantage of heavily data-driven approaches
- We will touch on all of these points in more or less detail, starting from the bottom up ...