

Introduction to Computer Vision

CS / ECE 181B

Thursday, April 1, 2004

Today

- Course Details
- HW #0 and HW #1 are available.

Course web site

- <http://www.ece.ucsb.edu/~manj/cs181b>
- Syllabus, schedule, lecture notes, assignments, links, etc.
- Visit it regularly!

Prereqs and background knowledge

- E.g., I assume you know:
 - Basic linear algebra
 - Basic probability
 - Basic calculus
 - Programming languages (C, C++) or MATLAB
 - ♦ First discussion session on MATLAB

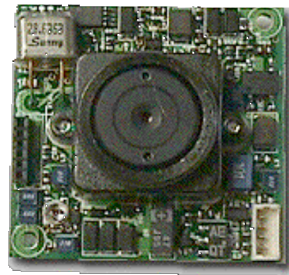
Your job

- You are expected to:
 - Attend the lectures and discussion sessions
 - ♦ You're responsible for everything that transpires in class and discussion session (not just what's on the slides)
 - Keep up with the reading
 - Prepare: Read the posted slides *before* coming to class
 - Ask questions in class – participate!
 - Do the homework assignments on time and with integrity
 - ♦ “Honest effort” will get you credit
 - Check course web site often
 - Give us feedback during the quarter

First part of course: Image Formation

- Chapters refer to the Forsyth's book
 - I will not be following the book closely.
- Geometry of image formation- Chapters 1-3
(Camera models and calibration)
 - Where?
- Radiometry of image formation- Chapter 4
 - How bright?

Cameras (real ones!)



Digital images

- We're interested in digital images, which may come from
 - An image originally recorded on film
 - ♦ Digitized from negative or from print
 - Analog video camera
 - ♦ Digitized by frame grabber
 - Digital still camera or video camera
 - Sonar, radar, ladar (laser radar)
 - Various kinds of spectral or multispectral sensors
 - ♦ Infrared, X-ray, Landsat...
- Normally, we'll assume a digital camera (or digitized analog camera) to be our source, and most generally a video camera (spatial and temporal sampling)

What is a Camera?

- A camera has many components
 - Optics: lens, filters, prisms, mirrors, aperture
 - Imager: array of sensing elements (1D or 2D)
 - Scanning electronics
 - Signal processing
 - ADC: sampling, quantizing, encoding, compression
 - ♦ May be done by external frame grabber (“digitizer”)
- And many descriptive features
 - Imager type: CCD or CMOS
 - Imager number
 - SNR
 - Lens mount
 - Color or B/W
 - Analog or digital (output)
 - Frame rate
 - Manual/automatic controls
 - Shutter speeds
 - Size, weight
 - Cost

Camera output: A raster image

- Raster scan – A series of horizontal scan lines, top to bottom
 - **Progressive scan** – Line 1, then line 2, then line 3, ...
 - **Interlaced scan** – Odd lines then even lines



Raster pattern
Progressive scan



Interlaced scan

Example: Sony CXC950



Scan Type	Interlaced area scan
Frame Rate	30 Hz ← Really 29.97 fps
Camera Resolution	640 X 480
Horizontal Frequency	15.734 kHz ← 525 lines * 29.97
Interface Type	Analog
Analog Interfaces	NTSC Composite; NTSC RGB; NTSC Y/C
Video Output Level	1 Vpp @ 75 Ohms
Binning?	No
Video Color	3-CCD Color
Sensor Type	CCD
CCD Sensor Size (in.)	1/2 in.
Maximum Effective Data Rate	27.6 Mbytes/sec = $640 * 480 * 3 * 29.97$
White Balance	Yes
Signal-to-noise ratio	60 dB ← 9-10 bits/color
Gain (user selectable)	18 dB
Spectral Sensitivity	Visible

Integration	Yes
Integration (Max Rate)	256 Frames
Exposure Time (Shutter speed)	10 μ s to 8.5 s
Antiblooming	No
Asynchronous Reset	No
Camera Control	Mechanical Switches; Serial Control
Dimensions	147 mm X 65 mm X 72 mm
Weight	670 g
Power Requirements	+12V DC
Operating Temperature	-5 C to 45 C
Storage Temperature	-20 C to 60 C
Length of Warranty	1 year(s)
Included Accessories	(1) Lens Mount Cap, (1) Operating Instructions

Example: Sony DFWV300

Highlights:

- IEEE1394-1995 Standard for a High Performance Serial Bus
- VGA (640 x 480) resolution Non-Compressed YUV Digital Output
- 30 fps Full Motion Picture
- DSP
- 200 Mbps, High Speed Data Transfers
- C Mount Optical Interface



Example: Sony XC999



Highlights:

- 1/2" IT Hyper HAD CCD mounted
- Ultra-compact and lightweight
- CCD iris function
- VBS and Y/C outputs
- Can be used for various applications without CCU
- External synchronization
- RGB output (with CMA-999)

Specifications

Pick up device:

1/2" IT Hyper HAD CCD

Color filter:

Complementary color mosaic

Effective picture elements:

768 (H) x 494 (V)

Lens mount:

NF mount (Can be converted into a C mount)

Synchronization:

Internal/ External (auto)

External sync. system:

HD/ VD (2 ~ 4Vp-p), VS

External sync. frequency:

± 50ppm

Horizontal resolution:

470 TV lines

Minimum illumination:

4.5 Lux (F1.2, AGC)

Sensitivity:

2,000 lux F5.6 (3,200K, 0dB)

Video output signals:

VBS, Y/ C selected with the switch

S/ N ratio:

48 dB or more

Electronic shutter speed:

1/ 1000 sec., CCD IRIS, FL

White balance:

ATW, 3200K, 5600K, Manual (R.B)

Gain control:

AGC, 0 dB

Power requirements:

DC 10.5 ~ 15V (typical 12V)

Power consumptions:

3.5W

Dimensions:

22 (W) x 22 (H) x 120 (D) mm
(excluding projecting parts)

Weight:

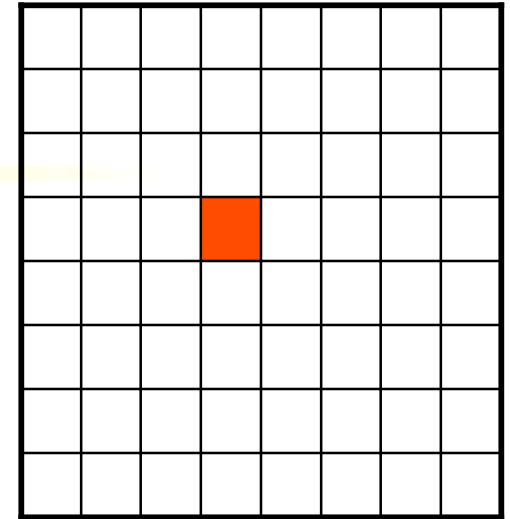
about 99g

MTBF:

34,800 Hrs.

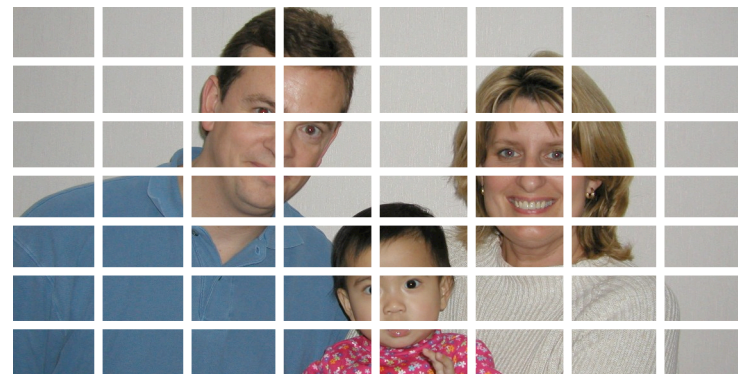
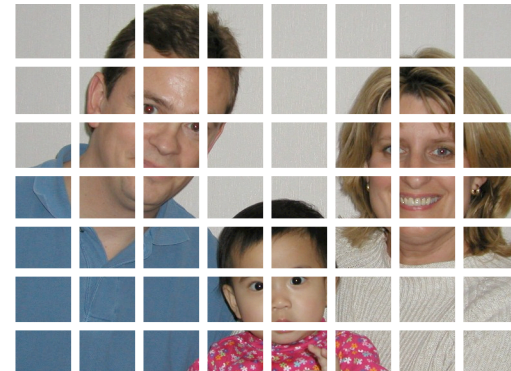
Pixels

- Each line of the image comprises many picture elements, or *pixels*
 - Typically 8-12 bits (grayscale) or 24 bits (color)
- A 640x480 image:
 - 480 rows and 640 columns
 - 480 lines each with 640 pixels
 - $640 \times 480 = 307,200$ pixels
- At 8 bits per pixel, 30 images per second
 - $640 \times 480 \times 8 \times 30 = 73.7$ Mbps or 9.2 MBs
- At 24 bits per pixel (color)
 - $640 \times 480 \times 24 \times 30 = 221$ Mbps or 27.6 MBs



Aspect ratio

- Image aspect ratio – width to height ratio of the raster
 - 4:3 for TV, 16:9 for HDTV, 1.85:1 to 2.35:1 for movies
 - We also care about *pixel aspect ratio* (not the same thing)
 - ♦ Square or non-square pixels



Sensor, Imager, Pixel

- An imager (sensor array) typically comprises $n \times m$ sensors
 - 320x240 to 7000x9000 or more (high end astronomy)
 - Sensor sizes range from 15x15 μm down to 3x3 μm or smaller
- Each sensor contains a photodetector and devices for readout
- Technically:
 - **Imager** – a rectangular array of sensors upon which the scene is focused (photosensor array)
 - **Sensor** (photosensor) – a single photosensitive element that generates and stores an electric charge when illuminated. Usually includes the circuitry that stores and transfers its charge to a shift register
 - **Pixel** (picture element) – atomic component of the image (technically not the sensor, but...)
- However, these are often intermingled

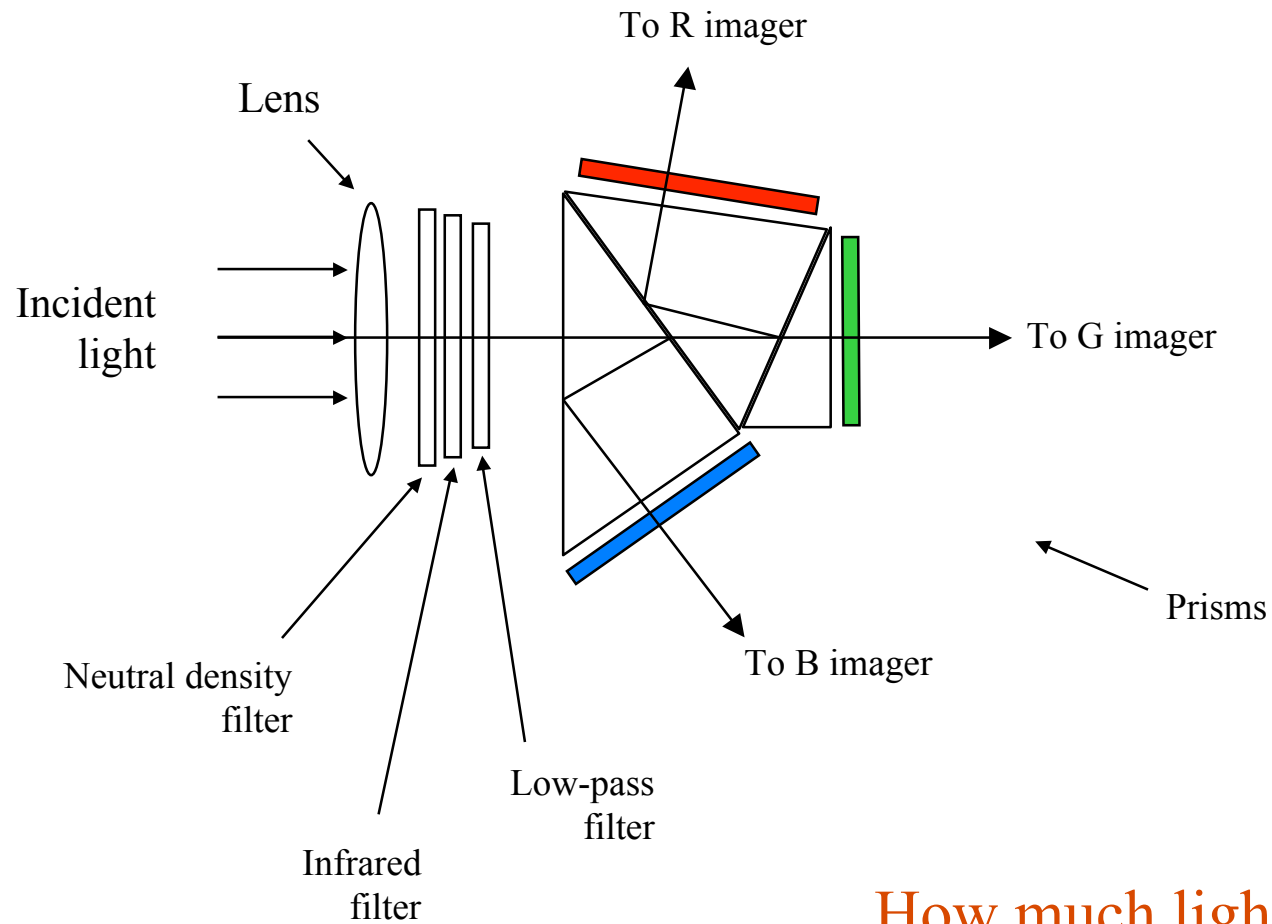
Imagers

- Some imager characteristics:
 - Scanning: Progressive or interlaced
 - Aspect ratio: Width to height ratio
 - Resolution: Spatial, color, depth
 - Signal-to-noise ratio (SNR) in dB
 - ♦ $\text{SNR} = 20 \log (S/N)$
 - Sensitivity
 - Dynamic range
 - Spectral response
 - Aliasing
 - Smear and other defects
 - Highlight control

Color sensors

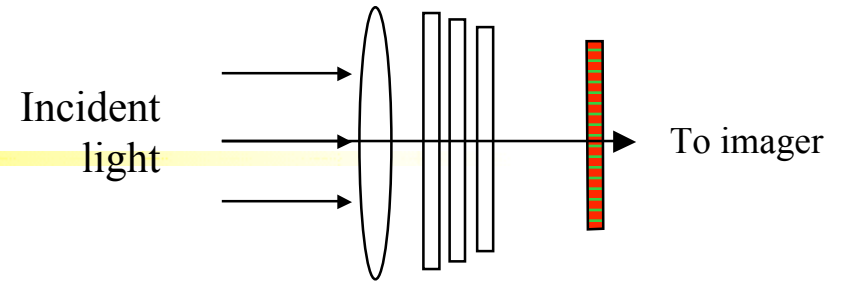
- CCD and CMOS chips do not have any inherent ability to discriminate color (i.e., photon wavelength/energy)
 - They sense “number of photons”, not wavelengths
 - Essentially grayscale sensors – need filters to discriminate colors!
- Approaches to sensing color
 - 3-chip color: Split the incident light into its primary colors (usually red, green and blue) by filters and prisms
 - ♦ Three separate imagers
 - Single-chip color: Use filters on the imager, then reconstruct color in the camera electronics
 - ♦ Filters absorb light (2/3 or more), so sensitivity is low

3-chip color

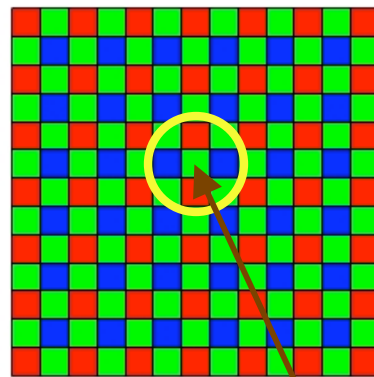


How much light energy reaches each sensor?

Single-chip color

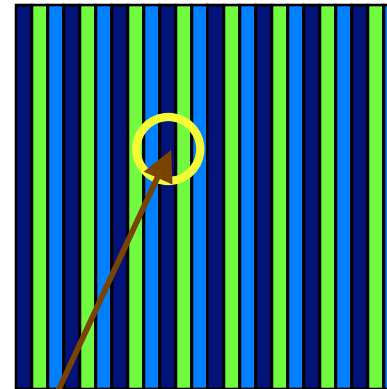


- Uses a mosaic color filter
 - Each photosensor is covered by a single filter
 - Must reconstruct (R, G, B) values via interpolation



Bayer filter

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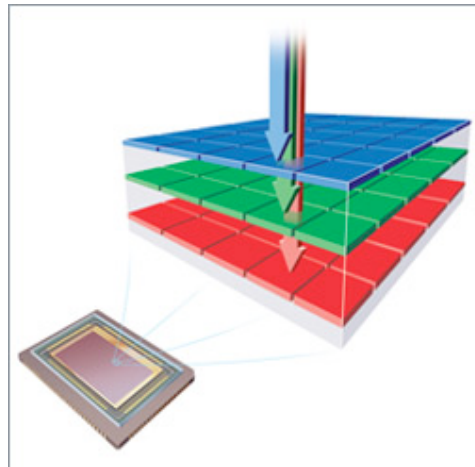
$$R(x, y) = f_R(I(x \pm dx, y \pm dy))$$

$$G(x, y) = f_G(I(x \pm dx, y \pm dy))$$

$$B(x, y) = f_B(I(x \pm dx, y \pm dy))$$

New X3 technology (www.foveon.com)

- Single chip, R, G, and B at every pixel
 - Uses three layers of photodetectors embedded in the silicon
 - ♦ First layer absorbs “blue” (and passes remaining light)
 - ♦ Second layer absorbs “green” (and passes remaining light)
 - ♦ Third layer absorbs “red”
 - No color mosaic filter and interpolation required



Reminders

- Peruse the course web site
- Get going on learning to use Matlab
- Review background areas
 - Linear algebra, PSTAT, Probability, ...
- Assignment #0 due **Tuesday, April 6.**
- First discussion session Friday 10am or Monday 3pm
 - Matlab overview