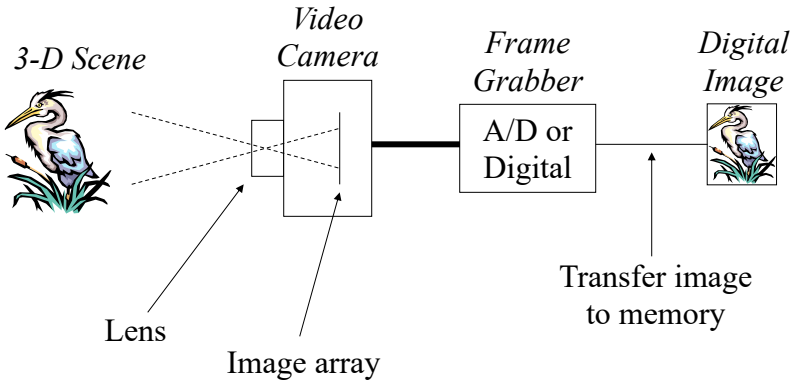
Computer Vision for HCI

Image Formation

1

Getting Images of the World



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2

CCD

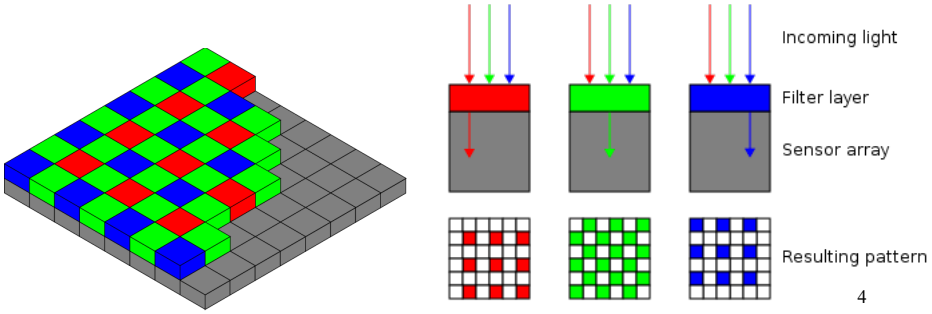
- Charged Coupled Device (CCD)
  - Tiny solid state cells convert light energy into electrical charge
  - All cells first cleared to 0, then integrate response to light energy falling on them
    - Shutter can control sensing time (SLOW and FAST shutters)
    - Typically, image sent every 1/60 second (interlaced to 30 fps)
  - Image plane acts as digital memory read row-by-row
  - Common chip sizes: 1/2", 1/3", 1/4"
  - Single chip (grayscale, color) or three-chip (R,G,B)
- Camera control
  - (Auto) focus and gain

3

3

Color on Single CCD

- Bayer filter
  - Filter pattern is 50% green, 25% red, and 25% blue (why 50% green?)
  - Interpolate to get pixel color



4

4

CMOS

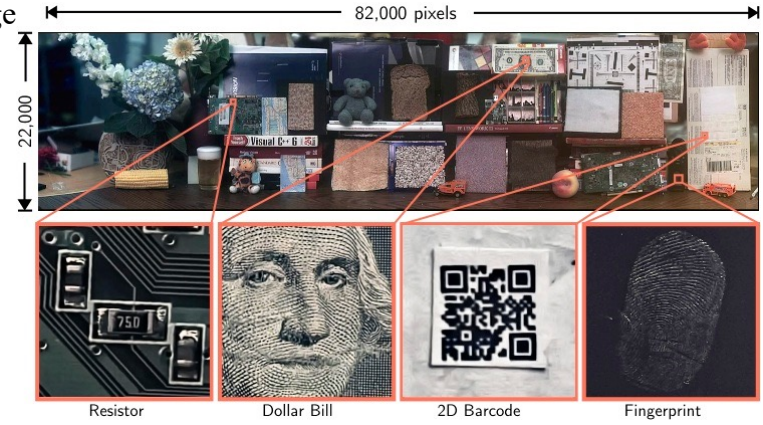
- More common today
- Complementary metal-oxide semiconductor (CMOS)
- Has transistors at each pixel to amplify and move the charge
  - More flexible as each pixel can be read individually
- "Rolling" shutter (exposes the frame from top to bottom)
  - CCD has "global" shutter (entire frame captured at once)
- Traditional manufacturing process
  - Has more noise
  - Lower light sensitivity
  - Consumes little power
- Cheaper!

5

5

Shree Nayar @ Columbia

Gigapixel image



Eternal Camera

6

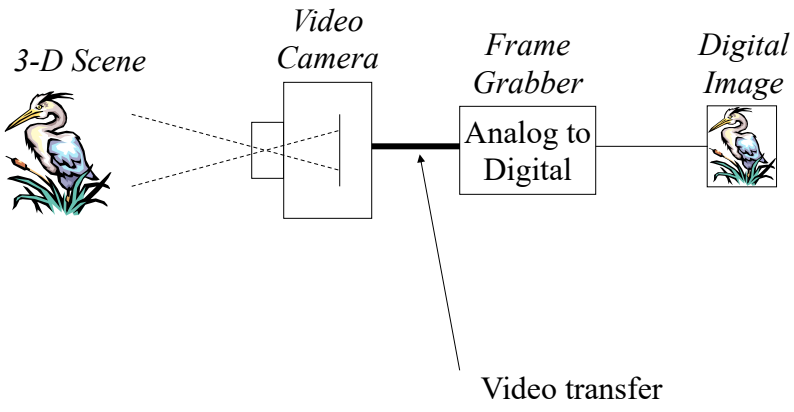
The Human Eye as a Camera

- Spherical camera with 20mm focal length lens
- Iris controls amount of light passed (auto-gain)
- Retina has 100,000,000 receptor cells
  - Large compared to CCD arrays
  - Unevenly populated
    - High concentration of cones (color receptors) in fovea
    - High concentration of rods (b/w intensity receptors) outside of fovea

7

7

Getting Images of the World



8

8

Connecting Cameras to Devices

Increasing quality (bandwidth)

- Composite cable (VHS)
  - RCA or BNC connectors
  - Combines color and brightness into one coax signal
- S-Video or Y/C cable (S-VHS)
  - Separate transmission of luminance (Y) and chrominance (C) information
  - Four-pin connector
- Component cables (DVD)
  - Three cables (RCA connectors): Y, R-Y, and B-Y

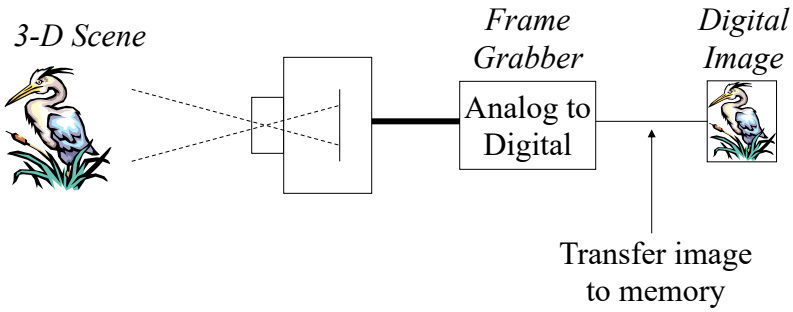
Quality depends on camera properties

- Digital or "firewire" (IEEE 1394) connection
  - Image already captured/digitized in camera
- USB
- HTTP IP cameras

9

9

Getting Images of the World



10

10

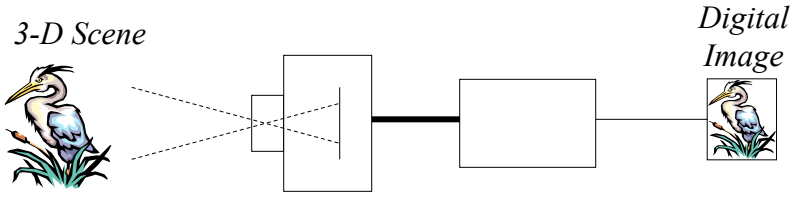
Frame Grabbers/Digitizers and Input

- Frame grabber contains memory for image
  - Real-time transfer to memory
  - Composite, S-video
- Software access (libraries)
- Analog input
  - Composite and S-video
- Direct digital input
  - Firewire/USB/Thunderbolt/HTTP/etc.

11

11

Getting Images of the World



12

12

Digital Images

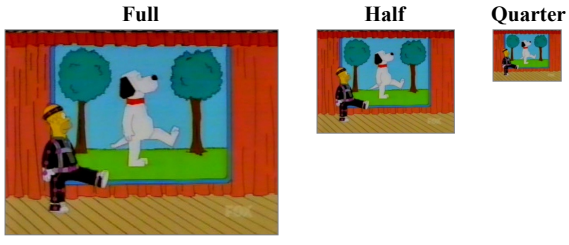
- Might represent cartoon, page of text, map of NYC, product from catalog, etc.
- An image is 2-D rectangular matrix of discrete intensity values (from CCD)
  - Space and intensity range are quantized
- Each "cell" in the matrix is called a Pixel
  - Picture element, sometimes called PEL (old school term)

13

13

Aspect Ratio

- Aspect ratio is ratio of width to height of image
- Typical "classic" video images have aspect ratio of 4:3 (1.33:1)
  - Full-resolution: 640 x 480
  - Half-resolution: 320 x 240
  - Quarter-resolution: 160 x 120



14

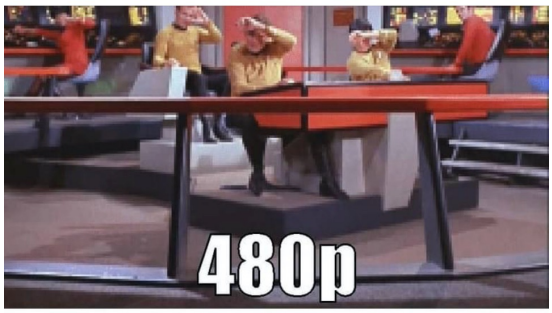
14

HD Video

- Common HD video sizes
  - 1280 x 720
  - 1920 x 1080
- HD aspect ratio of 16:9
  - Same as 1.78:1
- Ultra HD
  - 4K (3840 x 2160)
  - 8K (7680 x 4320)

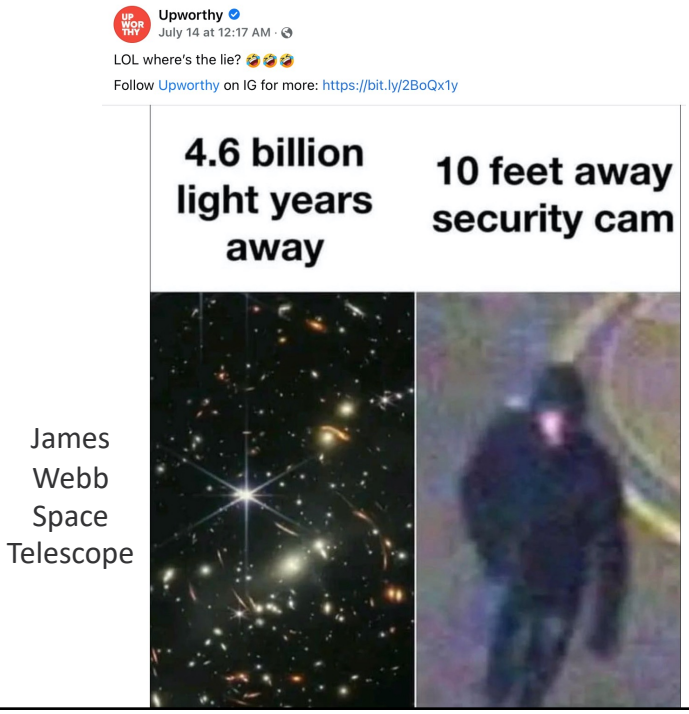
15

15



16

16



James Webb Space Telescope

17

17

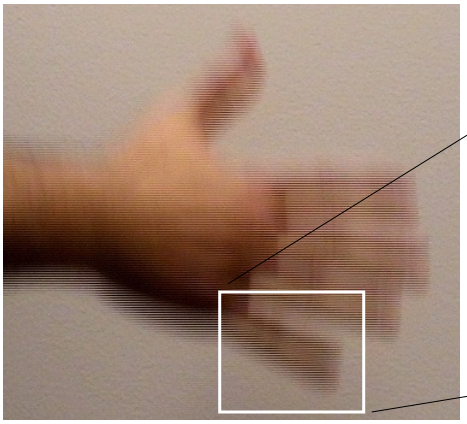
Image Fields and Interlacing

- "Interlaced" video cameras capture at rate of 60 fields-per-second
- For lower bandwidth and smooth human perception, 60 fields-per-second are interlaced to make 30 images-per-second
  - Fields vs. frame
- Frame at time T composed of
  - Odd(or Even) frame rows are from field taken at T
  - Even(or Odd) frame rows are from field taken at T-1/60
- Progressive cameras
  - No interlacing
- HDTV 1080p vs. 1080i

18

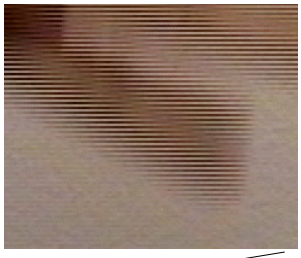
18

Image Fields and Interlacing



Hand motion (waving up-down)

Interlacing of frame grabber "zippers" two sequential fields (filmed at 60Hz) to produce a single image (for 30Hz rate)



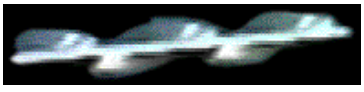
Can be problematic for motion analysis!

19

19

"Rods"

A lifeform from another dimension???



20

20

21

Rod (optics)

Wikipedia

- "Videos of rod-shaped objects moving quickly through the air were claimed by some ufologists and cryptozoologists to be alien life forms, 'extradimensional' creatures, or very small UFOs"
- "The fast passage before the camera of an insect flapping its wings has been shown to produce rodlike effects, due to motion blur, if the camera is shooting with relatively long exposure times"

22

22

Temporal Resolution

- 24, 30 frames-per-second (fps) movies
- 60, 120, 240 hertz display/tv refresh
  - 24 fps not evenly spread into 60 hz
  - But 120 and 240 hz ok!
  - At 120, can start to use 3D display alterations/shuttering
    - 24 or 30 fps movie in 3D ok on 240 hz display (120 hz each eye)

23

23

Sony's MotionFlow

http://itstillworks.com/sony-motionflow-17525.html

When you have a film that is filmed at 24 Hz, there are two different ways to put it on a 120-Hz television set. One is to show each frame five times. The other, which is what Sony MotionFlow does, is to create frames that represent averages of the two frames and show them in the intervals between the two original frames. Doing this creates a smoother and more natural appearance. However, because it looks very different from the slightly jittery motion you see at the movies or on traditionally filmed television, some feel that it looks unrealistic, referring to it as the "soap opera effect."

24

24

Thermal Video of UFO??

25

25

Types of Images

- Binary image
  - Simplest image type
  - Digital image with all pixel values 0 or 1
    - Usually, 0 is black and 1 is white in display
  - Useful for studying object shapes

	0	1	2	3
0	1	1	0	0
1	1	1	0	0
2	1	1	1	1

26

26

Types of Images

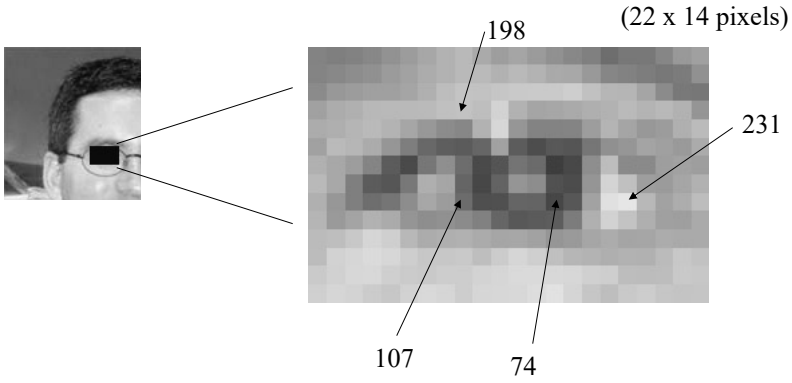
- Grayscale image
  - Monochrome digital image with one intensity value per pixel
  - Grayscale values for 8-bit pixels are 0-255
    - 0-darkest, 255-brightest

	0	1	2	3
0	133	128	0	0
1	112	104	255	234
2	90	32	12	9

27

27

Grayscale Pixels

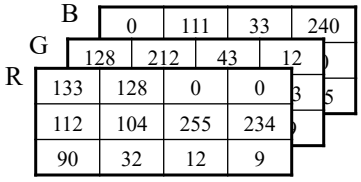


28

28

Types of Images

- RGB image (or multi-spectral)
  - Color digital image with three intensity values/bytes per pixel (24-bit color)
    - Red, Green, Blue
  - Some image formats use 8-bit colormap



29

29

30

30

Digital Image Formats

- Dozens of image formats in use (too many!)
- Mainly two components to digital image
- Image file header
  - Info on image dimensions, type, date of creation, title, etc.
- Pixel data
  - Stream of data in raster order (row-by-row)
  - Bytes, ASCII (decimal)
- May have compressed images

31

31

Digital Image Formats

- Data Compression
  - Many images have local pixel correlations
  - Compression may reduce image size considerably
  - Method is <u>lossless</u> if can recover image exactly
    - RLE 00000111100011111111000000000
      5(0)4(1)3(0)7(1)9(0) *or* (6,9)(13,19)
  - Method is <u>lossy</u> if ***cannot*** **reconstruct exactly**
    - JPEG

32

32

RGB to Grayscale

- A monochrome luminance signal (Y) can be created by combining RGB signals
- NTSC broadcast TV quantization formula:

$$Y = .299\ R + .587\ G + .114\ B$$

Most weight on Green channel

33

33

Pixel Storage

- Matlab (image as **matrix** of data)
  - Gray image: `grayIm = zeros(height,width);`
  - Color image: `rgbIm = zeros(height,width,3);`

3 image planes!

Python: `grayIm = numpy.zeros((height, width))`

34

34

Pixel Access

- Accessing pixel data at location (x, y)
- Matlab
  - Gray image: `gray_value = grayIm(y,x);`
  - Color image:
```
red_value = rgbIm(y,x,1);
green_value = rgbIm(y,x,2);
blue_value = rgbIm(y,x,3);
```

Be careful to check for valid (x,y) locations!
Matlab uses ROWS, COLUMNS (not x,y)!!!

Could use `gray_value = grayIm(r,c);`

Python: `gray_value = grayIm[y,x]`

IMPORTANT: Python is 0-(N-1), while Matlab is 1-N

35

35

Image Viewers

- Matlab display functions
  - image()
  - imagesc()
  - imshow()
- Python display functions
  - Can use matplotlib.pyplot
    - imshow()
  - Others…

36

36

Summary

- Imagers (CCD, CMOS)
- Cable quality
- Images
  - Sizes, interlacing, storage
- Color to gray conversion

37