Computer Vision: Imaging Devices

Summary of several common imaging devices covered in Chapter 2 of Shapiro and Stockman
Major issues

- What radiation is sensed?
- Is motion used to scan the scene or are all sensing elements static?
- How fast can sensing occur?
- What are the sensing elements?
- How is resolution determined?
  - in intensity
  - in space
CCD type camera

- Array of small fixed elements
- Can read faster than TV rates
- Can add refracting elts to get color in 2x2 neighborhoods
- 8-bit intensity common
Blooming Problem with Arrays

- Difficult to insulate adjacent sensing elements.
- Charge often leaks from hot cells to neighbors, making bright regions larger.
8-bit intensity can be clipped

- Dark grid intersections at left were actually brightest of scene.
- In A/D conversion the bright values were clipped to lower values.
Lens distortion distorts image

- “Barrel distortion” of rectangular grid is common for cheap lenses ($50)
- Precision lenses can cost $1000 or more.
- Zoom lenses often show severe distortion.
Human eye as a spherical camera

- 100M sensing elts in retina
- Rods sense intensity
- Cones sense color
- Fovea has tightly packed elts, more cones
- Periphery has more rods
- Focal length is about 20mm
- Pupil/iris controls light entry

- Eye scans, or saccades to image details on fovea
- 100M sensing cells funnel to 1M optic nerve connections to the brain
Surface data (2.5D) sensed by structured light sensor

- Projector projects plane of light on object
- Camera sees bright points along an imaging ray
- Compute 3D surface point via line-plane intersection
- REF: new Minolta Vivid 910 camera
2.5D face image from Minolta Vivid 910 scanner in the CSE PRIP Lab
Magnetic Resonance Imaging

- Sense density of certain chemistry
- \( S \) slices \( \times R \) rows \( \times C \) columns
- Volume element (voxel) about 2mm per side
- At left is shaded 2D image created by “volume rendering” a 3D volume: darkness codes depth
Single slice through human head

- MRIs are computed structures, computed from many views.
- At left is MRA (angiograph), which shows blood flow.
- CAT scans are computed in much the same manner from X-ray transmission data.
LIDAR also senses surfaces

Single sensing element scans scene

Laser light reflected off surface and returned

Phase shift codes distance

Brightness change codes albedo
Camera + Programs = Display

- Camera inputs to frame buffer
- Program can interpret data
- Program can add graphics
- Program can add imagery

Figure 2.3 Central role of the frame buffer in image processing.
Focus, Click, Print: ‘Film-Like Photography’

Light + 3D Scene:
- Illumination
- Shape
- Movement
- Surface BRDF, ...

Ray Bundles

2D Image:
- ‘Instantaneous’ Intensity Map
- ‘Center of Projection’ (P³ or P² Origin)

Position (x, y)

Angle (θ, φ)
Definitions

- **‘Film-like’ Photography:**
  - Static ‘instantaneous’ record of the 2D image formed by a lens
  - Display image \(\cong\) sensor image

- **‘Computational’ Photography:**
  - displayed image \(\neq\) sensor image
  - A more expressive, controllable displayed result, transformed, merged, decoded sensor data
What is Photography?

PHYSICAL

3D Scene
- light sources, BRDFs, shapes, positions, movements, ...

Eyepoint
- position, movement, projection, ...

Light & Optics

Exposure Control, tone map

Image
$I(x,y,\lambda,t)$

Display
$RGB(x,y,t_n)$

PERCEIVED

Scene
- light sources, BRDFs, shapes, positions, movements, ...

Eyepoint
- position, movement, projection, ...

Photo: A Tangible Record
Editable, storable as Film or Pixels
Ultimate Photographic Goals

PHYSICAL

3D Scene
- light sources,
- BRDFs,
- shapes,
- positions,
- movements,

Eyepoint
- position,
- movement,
- projection,

... Light & Optics

Sensor(s)

Computing

Visual Stimulus

3D Scene?
- light sources,
- BRDFs,
- shapes,
- positions,
- movements,

Eyepoint?
- position,
- movement,
- projection,

Photo: A Tangible Record

Meaning...
The Photographic Signal Path

Claim: Computing can improve every step
Computational Photography

Novel Cameras
- Generalized Sensor
- Processing
  - Ray Reconstruction
  - Upto 4D Ray Sampler
- Generalized Optics
- 4D Ray Bender
- 4D Ray Sampler
- 4D Light Field
- Display
- Recreate 4D Lightfield

Novel Illumination
- Light Sources
- Modulators
- Generalized Optics
- 4D Incident Lighting
- Scene: 8D Ray Modulator
Digital Refocusing using Light Field Camera

125μ square-sided microlenses
Refocused on Person
The Eye’s Lens

Varioptic Liquid Lens: Electrowetting
SICK sensor range image

Note human hands at the left and right and roll of tape at the center.

Used by NASA navigator and Axion Racing Team in DARPA autonomous navigation grand challenge.
Pulsed time-of-flight: time taken by a pulse of laser beam to travel from the scanner to the target point and back.
Other variations

- Microscopes, telescopes, endoscopes, ...
- X-rays: radiation passes through objects to sensor elements on the other side
- Fibers can carry image around curves; in bodies, in machine tools
- Pressure arrays create images (fingerprints, butts)
- Sonar, stereo, focus, etc can be used for range sensing (see Chapters 12 and 13)