Imaging and Image Representation

- Sensing Process
- Typical Sensing Devices
- Problems with Digital Images
- Image Formats
- Relationship of 3D Scenes to 2D Images
- Other Types of Sensors

Images: 2D projections of 3D

- The 3D world has color, texture, surfaces, volumes, light sources, objects, motion, …
- A 2D image is a projection of a scene from a specific viewpoint.

Images as Functions

- A gray-tone image is a function:
  \[ g(x,y) = \text{val or } f(\text{row}, \text{col}) = \text{val} \]
- A color image is just three functions or a vector-valued function:
  \[ f(\text{row}, \text{col}) = (r(\text{row}, \text{col}), g(\text{row}, \text{col}), b(\text{row}, \text{col})) \]

Image vs Matrix

Digital images (or just "images") are typically stored in a matrix in different coordinate systems (x,y) vs. (i=row, j=column). It's helpful to use macros to convert when coding things up.
Gray-tone Image as 3D Function

Radiometry and Computer Vision*

- Radiometry is a branch of physics that deals with the measurement of the flow and transfer of radiant energy.
- Radiance is the power of light that is emitted from a unit surface area into some spatial angle; the corresponding photometric term is brightness.
- Irradiance is the amount of energy that an image-capturing device gets per unit of an efficient sensitive area of the camera. Quantizing it gives image gray tones.

What are radiance and irradiance?

Imaging Process

- Light reaches surfaces in 3D
- Surfaces reflect
- Sensor element receives light energy
- Intensity counts
- Angles count
- Material counts

CCD type camera: Commonly used in industrial applications

- Array of small fixed elements
- Can read faster than TV rates
- Can add refracting elements 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.

**Resolution**

- **resolution**: precision of the sensor
- **nominal resolution**: size of a single pixel in scene coordinates (i.e., meters, mm)
- **common use of resolution**: num_rows × num_cols (i.e., 515 x 480)
- **subpixel resolution**: measurement that goes into fractions of nominal resolution
- **field of view (FOV)**: size of the scene a sensor can sense
Resolution Examples

- Resolution decreases by one half in cases at left
- Human faces can be recognized at 64 x 64 pixels per face

Image Formats

- Portable gray map (PGM) older form
- GIF was early commercial version
- JPEG (JPG) is modern version
- Many others exist: header plus data
- Do they handle color?
- Do they provide for compression?
- Are there good packages that use them or at least convert between them?

PGM image with ASCII info.

- P2 means ASCII gray
- Comments
  - W=16; H=8
  - 192 is max intensity
  - Can be made with editor
  - Large images are usually not stored as ASCII

PBM/PGM/PPM Codes

- P1: ascii binary (PBM)
- P2: ascii grayscale (PGM)
- P3: ascii color (PPM)
- P4: byte binary (PBM)
- P5: byte grayscale (PGM)
- P6: byte color (PPM)
**JPG current popular form**

- Public standard
- Allows for image compression; often 10:1 or 30:1 are easily possible
- 8x8 intensity regions are fit with basis of cosines
- Error in cosine fit coded as well
- Parameters then compressed with Huffman coding
- Common for most digital cameras

**From 3D Scenes to 2D Images**

- **Object**
- **World**
- **Camera**
- **Real Image**
- **Pixel Image**

**Other Types of Sensors: Orbiting satellite scanner**

- View earth 1 pixel at a time (through a straw)
- Prism produces multispectral pixel
- Image row by scanning boresight
- All rows by motion of satellite in orbit
- Scanned area of earth is a parallelogram, not a rectangle

**Human eye as a spherical camera**

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

Magnetic Resonance Imaging

- Sense density of certain chemistry
- S slices x R rows x C columns
- Volume element (voxel) about 2mm per side
- At left is shaded image created by “volume rendering”

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
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)

Where do we go next?

So we’ve got an image, say a single gray-tone image.

**What can we do with it?**

The simplest types of analysis is **binary image analysis**.

Convert the gray-tone image to a binary image (0s and 1s) and perform analysis on the binary image, with possible reference back to the original gray tones in a region.